
# RELATÓRIO FINAL

**Relatório final com recomendações de proteção (RF)**

Ajuste Direto nº11/DRPM/2022 - Caracterização dos habitats de profundidade, com vista ao seu mapeamento até ao limite exterior da subárea dos Açores da Zona Económica Exclusiva Portuguesa.

# AZORES DEEP-SEA ECOSYSTEM: FINAL REPORT WITH PROTECTION RECOMMENDATIONS (RF)

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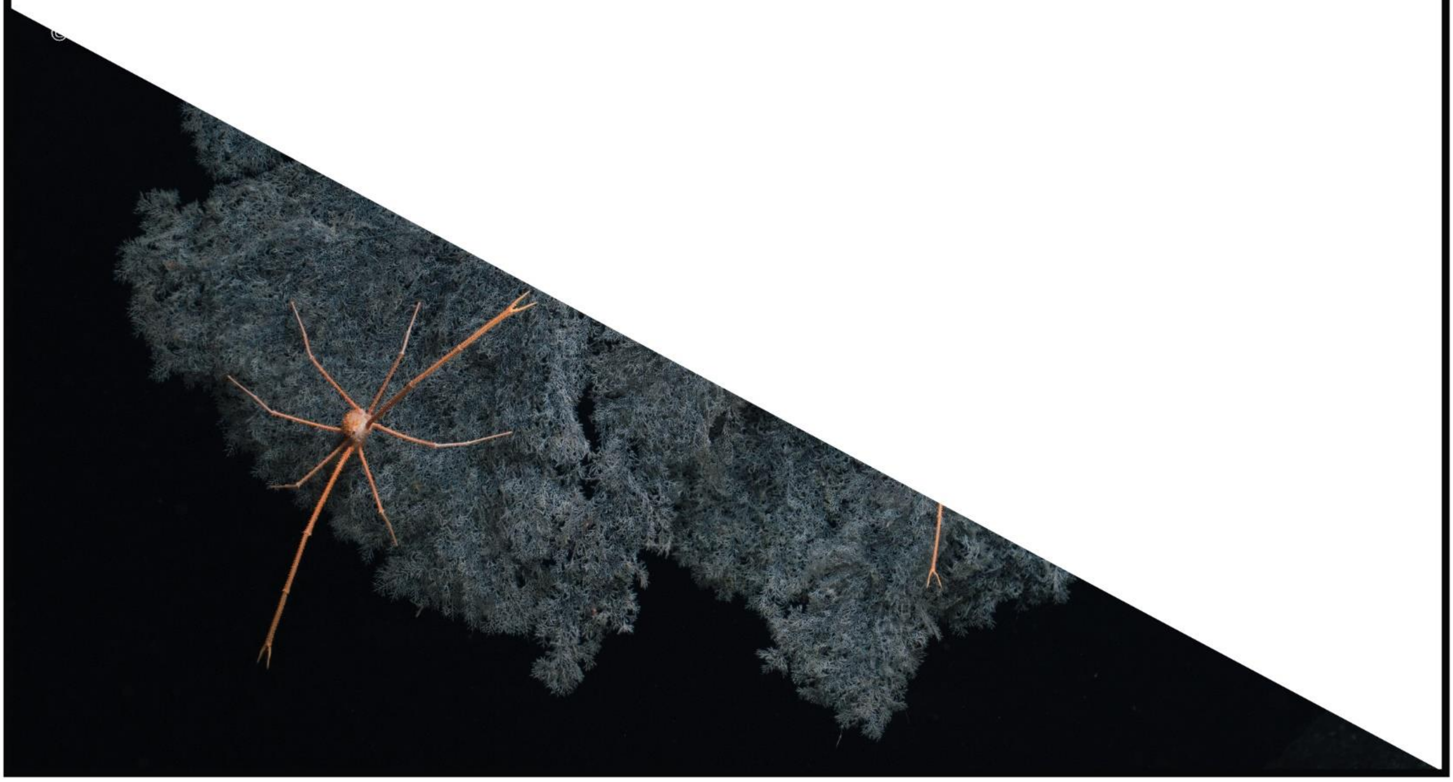


# SUMÁRIO EXECUTIVO

## Introdução

Após as primeiras expedições de exploração do oceano no final do século XIX e no início do século XX, lideradas pelo Príncipe Alberto I do Mónaco (Porteiro, 2009; Santos *et al.*, 2009) e por outras campanhas internacionais, uma extensa investigação científica baseada nos Açores, abriu uma janela para os grandes ecossistemas de águas profundas e para a determinação dos impactos das atividades humanas nesses ecossistemas. Os Açores têm, portanto, uma longa história de investigação do mar profundo, recentemente apoiada por muitos projetos de investigação, com financiamento regional, nacional e europeu, e com colaborações internacionais. Esta investigação consolidou o conhecimento, à escala global e regional, sobre montes submarinos, cordilheiras oceânicas e ecossistemas hidrotermais. O mar profundo dos Açores contém um número diversificado de habitats bentónicos, que albergam jardins e recifes de coral de águas frias, agregações de esponjas e hidrários, fontes hidrotermais, entre outros ecossistemas relevantes. Esses ambientes funcionam como berçário e refúgio para muitas espécies de peixes de profundidade, incluindo de importância socioeconómica (Pham *et al.*, 2015) e podem ser *hotspots* para predadores marinhos, constituindo-se assim como essenciais para a estabilidade e resiliência das cadeias alimentares marinhas.

Historicamente, o conhecimento atual sobre a diversidade e estrutura da fauna de invertebrados bentónicos do oceano profundo dos Açores, assenta em amostras recolhidas por técnicas remotas, como redes, trenós ou outras artes de amostragem engenhosas (Porteiro, 2009), mas também no estudo de espécimes recolhidos como captura acessória pela frota de pesca de fundo (p. ex., Sampaio *et al.*, 2012). Os avanços na robótica subaquática e na tecnologia de imagem (Durden *et al.*, 2015; Dominguez-Carrió *et al.*, 2021) permitiram a investigação visual de habitats de profundidade, melhorando exponencialmente a nossa compreensão sobre as associações e ecologia das espécies bentónicas, bem como sobre a extensão espacial dos seus povoamentos e das comunidades que elas integram. Durante a última década, o Grupo de Investigação em Ecologia do Mar Profundo dos Açores (ADSR) tem investido recursos avultados na exploração de múltiplas estruturas geomorfológicas do mar profundo que podem ser encontradas no interior da ZEE dos Açores.

Apesar de todos estes esforços, ainda existem lacunas substanciais no conhecimento científico sobre estes ecossistemas, que podem dificultar a implementação de políticas ambientais marinhas na região dos Açores, nomeadamente a Diretiva-Quadro Estratégia Marinha (DQEM) e a sua avaliação do estado ambiental, mas também das Diretivas Habitats, Aves e Água. Com efeito, a Direção Regional de Políticas Marítimas (DRPM), enquanto autoridade ambiental para o meio marinho da Região Autónoma dos Açores (RAA), considerou necessário colmatar as lacunas de conhecimento relativas à caracterização do mar profundo nos Açores, através do inventário e caracterização de habitats de águas profundas, em especial dos Ecossistemas Marinhos Vulneráveis (VMEs).

## Objetivos

O relatório final pretende resumir a informação sobre a distribuição das espécies, habitats de profundidade e unidades geomorfológicas identificadas. Pretende ainda apresentar recomendações para a proteção destes ecossistemas e a obtenção ou manutenção do seu bom estado ambiental, de acordo com os requisitos da

Diretiva-Quadro Estratégia Marinha. Tal como descrito no relatório R0, o relatório RF consiste numa atualização significativa do Relatório R1 das lacunas de informação e conhecimento pré-existentes, com uma secção adicional com recomendações para a proteção dos ecossistemas de profundidade nos Açores. Esta última secção contém sugestões sobre formas de avaliar o Descritor 6 da Diretiva-Quadro Estratégia Marinha para o mar profundo, incluindo propostas e sugestões sobre como identificar condições de referência para efeitos de elaboração de relatórios. Por último, realizará uma avaliação das pressões e ameaças das atividades humanas no mar profundo com potencial para afetar estes ecossistemas.

Com base na descrição da prestação de serviços e na descrição dos trabalhos apresentados no relatório R0, este relatório deverá conter uma compilação detalhada da melhor informação existente sobre a biodiversidade do mar profundo dos Açores e a sua distribuição espacial até aos 1.000 m profundidade, nomeadamente no que diz respeito a:

1) Espécies indicadoras de VME;
2) Localização de comunidades biológicas conhecidas;
3) Inventário e descrição dos habitats identificados nos Açores;
4) Distribuição espacial conhecida dos habitats até ao limite exterior da subzona dos Açores da ZEE portuguesa.

Assim, o objectivo deste relatório é descrever a informação existente sobre a biodiversidade marinha bentónica no mar profundo (>200 m) até ao limite exterior da subzona dos Açores da ZEE portuguesa até aos 1.000 m de profundidade. A compilação incluirá, simultaneamente, dados dos programas de observação de capturas acessórias das pescas açorianas e dados de vídeo recolhidos durante os vários projetos de investigação. Também identificará lacunas de conhecimento e áreas que necessitam de recolha de novas informações e assim será utilizado para apoiar o planeamento de missões de campo para recolha de novos dados, com ênfase nos dados de vídeo e amostras biológicas para confirmação taxonómica.

## Definições

Após uma leitura atenta da descrição da prestação de serviços, verificou-se o uso frequente dos termos comunidades biológicas e habitats, com o mesmo significado. Assim, considerou-se fundamental clarificar o significado desta terminologia, para o desenvolvimento futuro dos trabalhos: **Comunidades biológicas,** grupo ou associação de diferentes espécies que ocupam o mesmo ambiente físico (habitat) e área geográfica, no mesmo período de mesmo tempo. Tal como a descrição da prestação de serviços refere, **espécies indicadoras de VME** são as que podem ser vulneráveis aos impactos das atividades pesqueiras e que podem indicar a presença de um VME. Todavia, a descrição da prestação de serviços parece ter usado tanto o termo VME como habitat para designar as áreas que se enquadram nos critérios da FAO que definem VMEs. No entanto, não é claro se o texto quando refere habitats, pretende de facto indicar o ambiente físico, as comunidades biológicas ou um VME. Devido a essas inconsistências, adota-se a designação **VME** e **habitats** com o seguinte significado: conjunto de áreas espaciais que se enquadram nos critérios da FAO para descrever um ecossistema marinho vulnerável.

## Área de estudo

A área de estudo abrange o mar profundo, entre a costa das ilhas e o limite externo da subárea dos Açores da ZEE portuguesa, dos 200 aos 1 000 m de profundidade. O mar profundo é um conceito difuso, tradicionalmente usado para denominar áreas do oceano com mais de 200 m de profundidade, onde a luz solar começa a desaparecer e a tornar-se monocromática. Esta definição aplica-se aos objetivos deste projeto e, portanto, é usada para definir o limite batimétrico superior da área de estudo. Para efeitos deste projeto, o mar profundo dos Açores, até aos 1 000 m de profundidade, está organizado em 7 grandes áreas (Nível 1, N1), 20 áreas de estudo (Nível 2, N2) e 139 áreas de amostragem (Nível 3, N3).

## Conjuntos de dados existentes

Após a compilação exaustiva de dados sobre a biodiversidade do fundo do mar dos Açores até aos 1.000 m de profundidade produzimos uma base de dados georreferenciada com os respetivos metadados, seguindo as recomendações de interoperabilidade das autoridades regionais, bem como as normas internacionais de harmonização. A base de dados compilada até à data contém 60,877 (taxa) mais 1,683 (comunidades) registos de biodiversidade marinha no mar profundo dos Açores com destaque para taxas que indicam a presença de VME. Tal como descrito em R0, para além da compilação exaustiva sobre a biodiversidade do fundo do mar dos Açores até aos 1.000 m de profundidade, apresentada sob a forma de BD0, a versão revista da base de dados (BD1), e a versão final dos dados (BD2) baseou-se em 5 grupos principais de fontes de informação: 1) a base de dados georreferenciada (BD0) de informação pré-existente, 2) dados resultantes da anotação das imagens do mar profundo dos Açores recolhidas entre 2018 e 2022 (incluídas em videoAnnotationDB), dados resultantes da anotação das imagens de profundidade dos Açores recolhidas durante os cruzeiros de investigação realizados em 2023 (incluídos no videoAnnotationDB), dados resultantes da atualização da base de dados da Coleção de Referência da Biodiversidade Marinha dos Açores (COLETA) com informação recolhida entre 2019 e 2022 e as novas amostras recolhidas em 2023 (incluídas na coleçãoDB), e dados de ocorrências de comunidades biológicas (communitiesDB) no mar profundo dos Açores.

Os dados contidos na versão atualizada do coletaDB contém, além das informações pré-existentes, a catalogação dos exemplares recolhidos durante o período de 2019 e 2022, bem como os registos recolhidos e catalogados em 2023. O banco de dados atualizado do coletaDB contém 6,796 registos de ocorrências, 23% a mais que o reportado em BD0 e 6% a mais que o reportado em BD1. De referir que todos os registos já foram incorporados na base de dados, mesmo os recolhidos muito recentemente. Consideramos, portanto, que o CollectionDB está atualizado, conforme descrito na Seção 2.6 do relatório R0. A base de dados contém ainda novos registos de ocorrência resultantes da anotação de 145 vídeos recolhidos durante os levantamentos realizados entre 2019 e 2023. A base de dados atualizada da biodiversidade do fundo do mar dos Açores observada nos vídeos recolhidos até aos 1.000 m de profundidade (videoAnnotationDB) contém dados de 606 transectos de vídeo, 460 a mais que em BD0. As novas análises resultaram em 37.980 novos registos de ocorrência na ZEE dos Açores. Em 1 de novembro de julho de 2023, videoAnnotationDB continha um total de 52.698 registos, cerca de 3,5 vezes mais do que o relatado em BD0 (16.838) e 28% mais do que o relatado em BD1 (41.271). As bases de dados globais permaneceram inalteradas em relação às reportadas em BD0 e BD1 com 1,383 registos, incluindo 1,131 registos de corais de águas frias e 252 registos de esponjas de águas profundas. Na versão final da base de dados georreferenciada sobre a biodiversidade do mar profundo dos Açores (BD2), foi mantida a base de dados estruturada e organizada em BD0 e BD1, permitindo a compilação sistematizada desta informação. Por último, o CommunitiesDB contém 1,683 registos de ocorrência de comunidades biológicas no mar profundo dos Açores, incluindo 1,389 registos de jardins de corais, 189 de agregações de esponjas de águas profundas, 89 de Xenophyophores e 16 registos de outras comunidades.

### Abordagem taxonómica integrativa

Utilizando uma abordagem taxonómica integrativa, examinámos 52 espécimes de 18 taxa de corais de águas frias. Este trabalho gerou 94 novas sequências de DNA *consensus* (tamanho médio de 700 pb) e uma base de dados de *genome skimming* com 9 milhões de sequências PE por espécime. Pela primeira vez, foi realizado um estudo genómico que combinou dados de sequenciação de alto rendimento de corais de águas frias amostrados em diferentes locais do Atlântico Norte e dos Açores, tendo-se usado uma abordagem filogenómica que incluiu um total de 445 taxa. Utilizando esta base de dados, em conjunto com caracteres morfológicos diagnosticantes, atribuímos nomes a sete morfotipos (pertencentes às famílias Paramuriceidae, Keratoisididae, Alcyoniidae) e identificámos quatro possíveis novas espécies (*Alcyonium* sp. nov*., Aquaumbra* sp. nov., e membros das famílias Aquaumbridae e Cerveridae).

Relativamente a alguns problemas de identificação não resolvidos por imagens de vídeo, foi possível avaliar a variabilidade de coloração de determinados morfotipos (e.g. *Viminella flagellum* e *Alcyonium* sp.), concluindo que pertencem à mesma espécie. Conseguimos também resolver problemas de complexos de espécies (por exemplo, *Paramuricea/Placogorgia*). Para outras espécies decidimos utilizar uma abordagem mais conservadora para serem utilizadas como OTUs para as imagens de vídeo, uma vez que apresentam os mesmos caracteres externos, mas são espécies diferentes (e.g. *Muriceides paucituberculata vs Dacrygorgia modesta; clados de Keratoisididae; Pseudoanthomastus* spp.). Também foi possível confirmar espécies que anteriormente eram consideradas identificações "duvidosas" a partir de registos de vídeo (por exemplo, *Errina atlantica, Leptopsammia formosa*).

A avaliação taxonómica dos espécimes de Porifera da COLETA aumentou consideravelmente o nosso conhecimento sobre a diversidade de esponjas da Região dos Açores, que até à data representava um grupo pouco estudado. De um total de 52 espécimes analisados, foram classificadas 36 espécies. Foram identificadas quatro potenciais novas espécies (*Hertwigia* sp. nov., *Geodia* sp. nov., *Regadrella* sp. nov. e *Farreidae* gen. a confirmar sp. nov.) e um género (*Euretidae* new. gen. sp. nov). Três espécies (*Siphonodictyon viridicens*, *Petrosia* (*Strongylophora*) *vansoesti* e *Haliclona* (*Halichoclona*) *magna*) e um género *(Neoschrammeniella* sp.) são novos registos nos Açores. Para além disso, foi possível resolver problemas de identificação relacionados com complexos de espécies (*Characella* spp.; *Haliclona* spp.). Além disso, tivemos a oportunidade de recolher e examinar catorze espécies que até agora eram maioritariamente conhecidas da literatura, ou pouco recolhidas, mas que são espécies que podem ser raras ou endémicas na região dos Açores (para citar algumas: *Farrea laminaris, Chonelasma ijimae, Raspailia falcifera, Lissodendoryx (Ectyodoryx) foliata, Echynostylinos reticulatus, Xestospongia friabilis*).

Atribuímos nomes de espécie a 17 morfotipos, mas também pudemos retificar oito morfotipos OTUS que tinham sido erradamente atribuídos com base na imagem (ou seja, caracteres morfológicos externos). Por exemplo, pudemos reconhecer que algumas espécies partilham as mesmas morfologias externas mas são diferentes: a *Characella connectens* vs *Nethea amygdaloides*; a esponja massiva *Haliclona magna* vs *Xestospongia friabilis*; a lamelar *Pachastrella monilifera* vs *Poecillastra compressa*; a *Phakellia* spp. vs *Lissodendoryx (Ectyodoryx) foliata*. Outros, apresentaram variação de cor mas correspondem à mesma espécie, e.g. o morfotipo *Haliclona implexa* amarelo e branco*, Exsuperantia archipelagus* e Porifera digitate amarelo.

Também pudemos compreender melhor a presença de complexos de espécies crípticas (e.g. *Characella* spp., *Asconema* spp.), ou polifiléticas (e.g. família Chanilinidae), onde os caracteres taxonómicos baseados nas espículas não são suficientes para distinguir as espécies. Assim é necessário mais trabalho, incluindo uma abordagem genómica, para confirmar as potenciais novas espécies aqui apresentadas. O trabalho de colaboração com investigadores reconhecidos em taxonomia e filogenética de corais e esponjas de águas frias apoiará o trabalho continuado de revisões taxonómicas que serão úteis na reconstrução de histórias evolutivas. Finalmente, este trabalho irá melhorar a nossa compreensão da relação biogeográfica entre as comunidades de corais de águas frias e de esponjas dos Açores no contexto do Atlântico.

### Espécies indicadoras de VME

A ocorrência de corais de águas frias nos Açores foi documentada pela primeira vez durante grandes expedições oceanográficas no final do século XIX. Resultados de investigações históricas e recentes, incluindo a informação gerada nesta prestação de serviços, têm contribuído para a identificação dos Açores como um *hotspot* de corais de águas frias no Atlântico Norte, incluindo espécies da subclasse de antozoários Octocorallia, ordens Antipatharia e Scleractinia e da família de hidrozoários Stylasteridae. A reavaliação da diversidade total de corais de águas frias nos Açores com base na nova informação gerada nesta prestação de serviços contabiliza 191 espécies, com mais 4 novas espécies putativas para a ciência. É provável que a lista cresça no futuro com o aumento do esforço de amostragem do mar profundo. A diversidade de esponjas nos Açores é elevada (cerca de 460 espécies, Van Soest, 2012), onde mais de 330 espécies são batiais e abissais (World Porifera Database, Neele *et al.*, 2015). No entanto, as esponjas que habitam áreas remotas da Dorsal Médio-Atlântica, montes submarinos adjacentes, e encostas da plataforma batial insular, incluída na ZEE dos Açores, são pouco estudadas.

Uma grande proporção de CWCs nos Açores pertence a Octocorallia, incluindo gorgónias, corais moles e penas marinhas, com 101 espécies identificadas (24 famílias) (Braga-Henriques *et al.*, 2013; Sampaio *et al.*, 2019b. Destes, 27 espécies estão listadas como espécies indicadoras de VME (Tabela 13; ICES, 2020a), sendo as espécies mais comuns registadas nos Açores *Viminella flagellum*, *Callogorgia verticillata*, *Dentomuricea* aff. *meteor*, *Acanthogorgia* spp. com base em registos históricos e COLETA (Braga-Henriques *et al.*, 2013). Os Scleractinia nos Açores são compostos por 58 espécies (10 famílias) de corais solitários (corais cálice) e coloniais (corais duros) (ver Apêndice A em Braga-Henriques *et al.*, 2013). Do total de espécies registadas, nove espécies são listadas como espécies indicadoras de VME, sendo as espécies mais comuns registadas nos Açores representadas pelo coral cálice *Caryophyllia* spp., e pelos corais duros *Madrepora oculata* e *Lophelia pertusa*. A diversidade dos corais negros (Antipatharia) nos Açores compreende 18 espécies (5 famílias) com base no inventário de espécies fornecido por Braga-Henriques *et al.*, (2013), mas várias espécies ainda necessitam de revisão taxonómica. Seis dessas espécies estão listadas como indicadores VME pelo ICES (2020) (Tabela 13). Os corais negros são componentes importantes das comunidades de águas frias nos Açores a profundidades inferiores a 600 m, com as espécies *Stichopathes gravieri*, *Bathypathes* spp. e *Parantipathes* spp., muitas vezes formando comunidades mistas com octocorais e esponjas. Os estilasterídeos, comummente conhecidos como corais renda, são hidrozoários coloniais da família Stylasteridae (ordem Anthoathecata) que podem produzir um esqueleto de carbonato de cálcio, semelhante aos escleractínios (Cairns, 2011). Nos Açores, existem nove espécies de estilasterídeos com base no registo histórico e COLETA (Braga-Henriques *et al.* 2013), das quais três espécies são listadas como indicadores de VME. Treze espécies de esponjas nos Açores estão listadas como indicadores VME, uma vez que se enquadram na maioria dos critérios VME. A maioria dessas espécies é grande em tamanho e forma agregações de esponjas estruturalmente complexas. Embora haja um conhecimento limitado sobre o papel ecológico das esponjas nos Açores, a evidência de outras regiões sugere que as esponjas servem de habitat para variadas espécies de invertebrados e peixes (e.g., Hawkes *et al.*, 2019), desempenhando também inúmeras funções em sistemas bento-pelágicos de acoplamento e reciclagem de nutrientes (Cathalot *et al.*, 2015; Maldonado *et al.*, 2019; Rooks *et al.*, 2020).

### Comunidades biológicas indicadoras de VME

A presença isolada de espécies indicadoras de VME não deve ser considerada suficiente para classificar estruturas geomorfológicas em VMEs, e dados sobre a abundância e as associações de espécies observadas também deveriam estar incluídas nas avaliações. Por esta razão, o conjunto de comunidades bentónicas de profundidade presente nos Açores, entendido como grupos de populações de espécies que interagem entre si no espaço, deve ser primeiro identificado e descrito, e posteriormente avaliado de forma a determinar a sua vulnerabilidade face às atividades humanas. Aqueles que constituem VMCommunities (VMCs) deixam o termo VME como uma referência a uma série de comunidades funcionalmente inter-relacionadas e espacialmente sobrepostas que compõem o ecossistema. A avaliação para a determinação dos VMCs deve ainda seguir os cinco critérios para definição do que constitui um VME fornecidos pela FAO (2009), especificamente adaptados para a avaliação das comunidades bentónicas dos Açores.

O conjunto de imagens de vídeo subaquáticas, disponíveis para a equipa do ADSR, cobrem montes/cordilheiras ao longo da Dorsal Médio-Atlântica e encostas insulares dos grupos centro/leste até aos ~1 000 m de profundidade, fornece evidências da complexidade dos ecossistemas bentónicos do mar profundo dos Açores. Através de avaliações visuais, 39 associações de espécies bentónicas conspícuas já foram identificadas e catalogadas, fornecendo em cada caso os principais táxons estruturantes da comunidade (isto é, espécies indicadoras). A grande maioria das comunidades bentónicas identificadas até o momento pode ser incluída na categoria de jardins de corais (n= 23), sem subestimar aquelas classificadas como agregações de esponjas (n= 9), recifes de corais (n= 2), agregações de foraminíferos (n= 1) e aquelas formadas por outros táxons (n= 4). As principais espécies que conferem estrutura tridimensional ao fundo marinho dos Açores correspondem a grandes gorgónias, que geram comunidades conspícuas amplamente distribuídas ao longo das diferentes estruturas geomorfológicas avaliadas. Áreas mais profundas tendem a abrigar uma variedade maior de corais de águas frias de grandes dimensões e estruturantes para além de Octocorallia, como corais negros, corais de bambu e corais duros formadores de recifes. Agregações de esponjas também foram amplamente observadas, especialmente aquelas formados por grandes esponjas litistídeas em áreas menos profundas e agregações de esponjas hexactinelídeos abaixo de 600-700 m. Das 39 comunidades bentónicas identificadas a partir das imagens de vídeo, 25 enquadram-se nos critérios de VMC com base na presença e densidade de espécies bioconstructoras estruturalmente complexas, a singularidade dos seus componentes e/ou a vulnerabilidade intrínseca da comunidade a impactos, e também a sua capacidade de recuperação. A base de dados de comunidades biológicas gerada a partir da avaliação das imagens contém 1683 registos de ocorrência de comunidades biológicas do mar profundo dos Açores, nomeadamente 1389 registos de Coral gardens, 189 de Deep-sea sponge aggregations, 89 de agregações de foraminíferos e 16 registos de outras comunidades.

### Distribuição espacial da diversidade biológica do mar profundo nas estruturas geomorfológicas

Várias expedições científicas utilizando diferentes tipos de plataformas de vídeo visitaram os Açores e recolheram quantidades importantes de dados de vídeo. Apresentamos um resumo dos diferentes levantamentos científicos realizados entre 2009 e 2023 que forneceram dados imagéticos que permitiram avaliar a composição e distribuição da fauna e comunidades bentónicas de profundidade no interior da ZEE dos Açores, e pelos quais a equipa ADSR é integralmente responsável ou atualmente tem acesso ao material de vídeo. As imagens recolhidas derivam de mais de 1 155 transectos de vídeo subaquáticos gravados por ROVs, sistemas de câmaras rebocadas, submersíveis e a câmara de deriva Azor, o que equivale a uma distância linear sobre o fundo do mar de mais de 1 577 quilómetros. Os transectos de vídeo subaquáticos existentes até 1.000 m abrangem toda a ZEE (Figura 10), com 69 no Grupo Ocidental dos Açores, 49 na Dorsal Médio-Atlântica Norte, 103 na Dorsal Médio-Atlântica Central, 47 na Dorsal Médio-Sul. -Crista Atlântica, 295 no Grupo Centro-Norte dos Açores, 392 no Grupo Centro-Sul dos Açores, e 193 no Grupo Oriental dos Açores, e 34 fora da ZEE mas em áreas de interesse. Visitámos todas as áreas identificadas no relatório R1, nomeadamente 39 áreas inexploradas na ZEE dos Açores. Visitámos também duas áreas que não estavam listadas no relatório R1, nomeadamente o monte submarino Gaillard e uma área a oeste dos Picos S do Princesa Alice. Por fim, também revisitamos outras estruturas geomorfológicas que necessitavam de esforços complementares de amostragem.

Até o momento, foram processados 606 mergulhos subaquáticos no nível 1 e no nível 2 de anotação, atribuindo um valor da escala SACFOR a cada OTU observada nos segmentos de 100 m de comprimento. Imagens de vídeo e anotações foram obtidas de todas as 140 áreas L3. A 1 de Novembro de 2023, a base de dados gerada a partir da anotação da megafauna bentónica contém 52.697 registos dentro da ZEE dos Açores. Cada um destes registos corresponde à ocorrência de uma OTU em segmentos de 100 m ao longo de cada mergulho, fornecendo um valor de densidade estimado utilizando a codificação da escala SACFOR. Esta base de dados é hoje uma ferramenta fundamental para mapear a distribuição da biodiversidade e dos táxons indicadores de VME dentro dos limites da ZEE dos Açores. Após um processo de verificação realizado para verificar inconsistências e uma determinação cuidadosa de identificações taxonómicas incertas, os dados contidos na base de dados de vídeos foram incluídos em “BD2: Base de dados georreferenciada de espécies e habitats de profundidade”. As distribuições dos registos são apresentadas no relatório.

### Distribuição espacial da diversidade biológica do mar profundo nas estruturas geomorfológicas

Para avaliar as áreas geográficas com informação pré-existente suficiente e com lacunas de conhecimento substanciais, usamos a compilação de dados aqui descrita, principalmente no que diz respeito à localização dos levantamentos de vídeos recolhidos em projetos de investigação anteriores. As imagens recolhidas provêm de mais de 1 155 transectos de vídeo obtidos através de ROVs, sistemas de câmaras rebocadas, submersíveis tripulados e pela câmara de deriva Azor drift-cam, o que equivale a uma distância linear sobre o fundo marinho de mais de 1 577 quilómetros. Os transectos de vídeo existentes até 1.000 m abrangem toda a ZEE, com 69 mergulhos no Grupo Ocidental dos Açores, 49 na Dorsal Médio-atlântica Norte, 103 na Dorsal Médio-atlântica Central, 47 na Dorsal Médio-atlântica Sul, 295 no Grupo Central Norte, 392 no Grupo Central Sul e 193 no Grupo Oriental, e 34 fora da ZEE mas em áreas de interesse. Visitámos todas as áreas identificadas no relatório R1, nomeadamente 39 áreas inexploradas na ZEE dos Açores. Também visitámos duas áreas que não estavam listadas no relatório R1, nomeadamente o monte submarino Gaillard e uma área a oeste dos Picos S do Princesa Alice. Finalmente, revisitámos também outras estruturas geomorfológicas que necessitavam de esforços de amostragem complementares.

Até à data, tem sido obtidas imagens de vídeo e anotações para as 140 áreas L3. Um total de 606 mergulhos tem sido processados ao nível 1 e nível 2 de anotação, que atribuí um valor da escala SACFOR para cada OTU em segmentos de 100 m de comprimento. Em data de 1 de novembro de 2023, a base de dados gerada a partir da anotação da megafauna bentónica contém 52.697 registos dentro da ZEE dos Açores. Cada um destes registos corresponde à ocorrência de uma OTU em segmentos de 100 m ao longo de cada mergulho, dando um valor estimado de densidade na escala SACFOR. Esta base de dados constitui atualmente uma ferramenta fundamental para o mapeamento da distribuição dos taxa indicadores de biodiversidade e VME dentro dos limites da ZEE dos Açores. Após um processo de verificação de inconsistências e de uma determinação cuidadosa das identificações taxonómicas incertas, os dados contidos na base de dados vídeo foram incluídos na "BD2: Base de dados georreferenciada de espécies e habitats de profundidade". As distribuições dos registos são apresentadas no relatório.

### Ecossistemas marinhos vulneráveis

Foram avaliadas as 140 estruturas geomorfológicas do mar profundo dos Açores em relação a cada um dos cinco critérios da FAO que definem o que constitui um VME, com base na informação compilada, recolhida e analisada durante esta prestação de serviços. A avaliação baseou-se nas espécies e comunidades encontradas em cada uma das estruturas geomorfológicas, bem como a sua abundância em base os dados georreferenciados incluídos no BD2, que contém informação sobre espécies e habitats (ver secção 6). A avaliação das características das estruturas geomorfológicas em função dos critérios VME permitiu identificar 41 das 140 áreas como VMEs: Hard-Rock Café, Flores NE, Chaucer S, Estrela, Kurchatov N, Isolado, Kurchatov SE, Kurchatov S, Kurchatov SW, Agulhas Corvo-Graciosa, Óscar, Gigante N, Gigante, Gigante Agulhas NW, Gigante Agulhas SW, Cavala, Beta, Sardinha, Voador, Farpas, Espadarte, Sedlo W, Gaillard, Graciosa S, Ilha Azul SE, São Jorge W Rosais, Álvaro Martins, Dom João de Castro, Ferraria Norte, Ferraria Mar, Girard, Pico S Lajes, Faial W Capelinhos, Condor, Ponta da Ilha N, Ponta da Ilha S, Albatroz do Meio, Açor S, Princesa Alice Picos S, Sauerwein, e Formigas.

### Avaliação do Descritor 6

Para dar apoio as avaliações dos critérios do Descritor 6 (D6C3 e D6C5), procedeu-se a uma avaliação do grau de pressão e ameaça relacionado com as atividades humanas. Para o efeito, adotámos uma metodologia padrão que parte da caraterização e mapeamento dos valores de conservação e das pressões decorrentes das atividades e usos potenciais. Foram também desenvolvidas matrizes de pressões e ameaças que permitem uma avaliação objetiva dos impactos e contribuem para a avaliação dos D6C3 e D6C5. A aplicação das categorias de portfólio de VME e esforço de pesca identificou 22 áreas classificadas como VME que se enquadram na categoria de portfólio alto VME - baixo VMS, 14 que se enquadram na categoria de portfólio alto VME - alto VMS e 3 na outra categoria. As áreas onde o esforço de pesca elevado se sobrepõe ao índice VME elevado podem ser áreas de impactos adversos potencialmente significativos em ecossistemas marinhos vulneráveis.

Foram avaliadas metodologias de análise dos dados recolhidos ao longo do projeto para definir metodologias de avaliação D6C3 que dizem respeito à "Extensão espacial de cada tipo de habitat que é negativamente afetado por perturbações físicas, através da alteração da sua estrutura biótica e abiótica e das suas funções", e D6C5 "A extensão dos efeitos negativos das pressões antropogénicas sobre a condição do tipo de habitat, incluindo a alteração da sua estrutura e funções bióticas e abióticas, não excede uma proporção especificada da extensão natural do tipo de habitat na zona de avaliação." A recente recolha de imagens do fundo do mar permitiu identificar que uma grande parte das comunidades bentónicas, incluindo corais e esponjas, observadas nas principais áreas de pesca de fundo nos Açores se encontram ainda em bom estado ambiental e têm um elevado valor natural e ecológico. No entanto, foram observadas algumas colónias de coral de vida longa com impactos visíveis da pesca. Uma vez que não foram detetadas diferenças entre as quatro diferentes classes de intensidade de pesca e as condições do coral *V. flagellum* e da sua epibiose, pode especular-se que as áreas avaliadas podem ainda estar em bom estado e que estes valores podem ser utilizados como condição de referência. Os dados recolhidos permitiram identificar que grande parte das comunidades bentónicas, incluindo corais e esponjas, observadas nas principais zonas de pesca demersal dos Açores (como a Princesa Alice, as encostas das ilhas Terceira e São Miguel e o Banco D João de Castro) ainda se encontram em bom estado ambiental e têm um elevado valor natural e ecológico. No entanto, foram observadas algumas colónias de corais de longa duração com impactos visíveis da pesca. Estas observações *in situ* corroboram as conclusões de estudos anteriores que sugerem que uma pesca de profundidade bem regulamentada, baseada em artes de anzol e linha (preferencialmente linha de mão), poderá contribuir para uma explotação sustentável do mar profundo.

# EXECUTIVE SUMMARY

## Introduction

After the first expeditions to the deep sea in the late 19th and early 20th centuries lead by Prince Albert I of Monaco (Porteiro, 2009; Santos *et al.*, 2009), extensive scientific research based in the Azores has opened a window on the functioning of large deep-sea ecosystems and the impacts of human activities in such ecosystem. The Azores have, therefore, a long history of deep-sea research, recently supported by various regional, national, and European funded research projects and international collaborations. This research consolidated the knowledge about seamounts, ridges, and hydrothermal vent ecosystems at the global and local scales. The Azores deep sea harbour a diverse number of benthic habitats, which are home to several coral gardens, cold-water coral reefs, sponge grounds and hydrothermal vents, among other relevant ecosystems. Such environments provide nursery and refuge areas for socio-economically important deep-sea fish species (Pham *et al.*, 2015) and can be hotspots for marine predators, vital to the stability and resilience of marine food webs.

Historically, our knowledge about the diversity and structure of the benthic invertebrate fauna of the Azores relied on samples collected using remote techniques, such as nets or sleds (Porteiro, 2009), or on the evaluation of specimens provided by the fishing fleet as bycatch (e.g., Sampaio *et al.*, 2012). Advances in underwater robotics and imaging technology (Durden *et al.*, 2015; Dominguez-Carrió *et al.*, 2021) have enabled the visual investigation of deep-sea habitats, exponentially improving our understanding about the ecology of benthic species, as well as the spatial extent of the communities they form. During the past decade, the Azores Deep-Sea ecology Research group (ADSR), has assigned a great deal of resources into the exploration of the various deep-sea geomorphological features that can be found inside the Azores EEZ.

Despite all these efforts, substantial gaps in scientific knowledge still exist that may hamper the implementation of marine environmental policies in the Region, namely the Marine Strategy Framework Directive (MSFD) and its assessment of the environmental status, but also the Habitats, Birds, and Water Directives. Indeed, the Regional Directorate for Maritime Policies (DRPM), as the environmental authority for the marine environment in the Autonomous Region of the Azores (RAA), considered necessary to fill the knowledge gaps regarding the characterization of the deep sea in the Azores through the inventory and characterization of deep-sea habitats as well as vulnerable marine ecosystems (VMEs).

## Objectives

The final report aims to summarize the information on the distribution of species, deep-sea habitats and geomorphological units identified. It also aims to present recommendations for the protection of these ecosystems and obtaining or maintaining their good environmental status, in accordance with the requirements of the Marine Strategy Framework Directive. As described in the report R0, the report RF consist of a significant update of the R1 Report of pre-existing information and knowledge gaps, with an additional section with recommendations for the protection of deep-sea ecosystems in the Azores. This last section contains suggestions on ways to assess Descriptor 6 of the Marine Strategy Framework Directive for the deep sea, including proposals and suggestions on how to identify reference conditions for reporting purposes. Finally, it will perform an assessment of the pressures and threats from human activities in the deep-sea at sea with the potential to affect these ecosystems.

Based on the description of the provision of services and the description of work presented in the R0 report, this report should contain a detailed compilation of the best existing information on the biodiversity of the deep sea of the Azores and its spatial distribution down to 1,000 m depth, namely in what regards to:

1) VME indicator species;
2) Location of known biological communities;
3) Inventory and description of habitats identified in the Azores;
4) Known spatial distribution of habitats up to the outer limit of the Azores subarea of the Portuguese EEZ.

Therefore, the objective of this report is to describe the existing information regarding the benthic marine biodiversity in the deep sea (>200 m) to the outer limit of the Azores sub-area of the Portuguese EEZ down to 1,000 m depth. The compilation will include, at the same time, data from the bycatch observer programs of the Azorean fisheries and video data collected during the various research projects. It will also identify knowledge gaps and areas in need of gathering new information and thus be used to support the planning of field missions to collect new data, with emphasis on the video data and biological samples for taxonomic confirmation.

## Definitions

After a careful read of the description of the provision of services we believe that the text referred interchangeably to biological communities and habitats. Therefore, here we adopted that "biological communities" and" habitats" in the provision of services refer to: ***Biological communities*** as a group or association of different species occupying the same physical environment and geographical area at the same time. The description of the provision of services referred to ***VME indicator species*** in the correct term, i.e., species that may be vulnerable to impacts from fisheries activities and that may indicate the presence of a VME. In what concerns to the use of VME, the description of the provision of services seems to have used the term VMEs and, sometimes, habitat to describe those areas that fit the FAO criteria. However, it was not apparent that the text referring to habitats meant to describe the physical environmental, the biological communities, or a VME. Because of these inconsistencies, we adopted that ***VME*** and ***habitats*** meant: those spatial areas that fit the FAO criteria to describe a vulnerable marine ecosystem.

## Study area

The study area encompasses the deep sea of the Azores sub-area of the Portuguese EEZ down to 1,000 m depth. The deep sea is a fuzzy concept traditionally used to name areas of the ocean deeper than 200 m depth, where sunlight begins to fade away. This definition applies well to the objectives of this project, and it is therefore used to define the upper bathymetric limit of the study area. For the purposes of this project, the deep sea of the Azores up to 1,000 m depth will be organized into 7 large areas (level 1) and 20 study areas (level 2), where 139 sampling areas were identified (level 3).

### Existing datasets

After the exhaustive compilation of data on the deep-sea biodiversity of the Azores down to 1,000 m depth we produced georeferenced database with the respective metadata, following the interoperability recommendations of regional authorities, as well as international harmonization standards. The database compiled to date contain 60,877 (taxa) plus 1,683 (communities) records of marine biodiversity in the deep sea of the Azores with an emphasis on rates that indicate the presence of VME. As described in R0, in addition to the exhaustive compilation on the deep-sea biodiversity of the Azores down to 1,000 m depth, presented in the form of BD0, the revised version of the database (BD1), and the final version of the data (BD2) was based on 5 main groups of information sources: 1) the georeferenced database (BD0) of pre-existing information, 2) data resulting from the annotation of the deep sea images of the Azores collected between 2018 and 2022 (included in videoAnnotationDB), data resulting from the annotation of the deep sea images of the Azores collected during the research cruises carried out in 2023 (included in videoAnnotationDB), data resulting from updating the Azores Marine Biodiversity Reference Collection (COLETA) database with information collected between 2019 and 2022 and the new samples collected in 2023 (included in colectionDB), and data on the occurrences of biological communities (communitiesDB) in the deep sea of the Azores.

The information contained in the updated version of the collectionDB contains, in addition to the pre-existing information, the cataloguing of the specimens collected during the period 2019 and 2022, as well as the records collected and catalogued in 2023. The updated coletaDB database contains 6,796 occurrence records, 23% more than reported in BD0 and 6% more than reported in BD1. It should be noted that all records have already been incorporated into the database, even those collected very recently. We therefore consider that the collectionDB is up to date, as described in Section 2.6 of the R0 report. The database also contains new occurrence records resulting from the annotation of 145 videos collected during the surveys carried out between 2019 and 2023. The updated database of deep-sea biodiversity in the Azores observed in the videos collected down to 1,000 m depth (videoAnnotationDB) contains data from 606 video transects, 460 more than in BD0. The new analyses resulted in 37,980 new records of occurrence within the Azores EEZ. On November 1, July 2023, videoAnnotationDB contained a total of 52 698 records, about 3.5 times more than reported in BD0 (16 838), and 28% more than reported in BD1 (41 271). The global databases remained unchanged from that reported in BD0 and BD1 with 1,383 records, including 1,131 records of cold-water corals and 252 records of deep-sea sponges. In the final version of the georeferenced database on the biodiversity of the deep sea of the Azores (BD2), the structured and organized database in BD0 and BD1 was maintained, allowing for the systematized compilation of this information. Finally, communitiesDB contains 1,683 records of the occurrence of biological communities in the deep sea of the Azores, including 1,389 records of Coral gardens, 189 of Deep-sea sponge aggregations, 89 of Xenophyophores and 16 records of other communities.

### Integrative taxonomic approach

Using an integrative taxonomic approach, we have examined 52 specimens across 18 taxa of cold-water corals. This work generated 94 new DNA barcoding consensus sequences (average length 700 bp), and a genome skimming dataset with 9M PE reads per specimen. For the first time a genomic study that combined high-throughput sequencing data from cold-water corals sampled on different sites of the North Atlantic and the

Azores was conducted, applying a phylogenomic approach that included 445 taxa. Using this dataset together with diagnosing morphological characters, we have attributed names to seven morphotypes (corals belonging to Paramuriceidae, Keratoisididae, Alcyoniidae), and identified four putative new species (*Alcyonium* sp. nov., *Aquaumbra* sp. nov., and species of the families Aquaumbridae and Cerveridae).

Regarding identification problems sorted out by video imagery, we could assess the colour variation of several morphotypes (e.g. *Viminella flagellum* and *Alcyonium sp.*), concluding they belong to the same species. We could also disentangle species complexes problems (e.g. Paramuricea/Placogorgia). For other species we have decided to use a more conservative approach to be used as OTUs for the video imagery, once they present the same external characters, but are different species (e.g. *Muriceides paucituberculata* vs *Dacrygorgia modesta;* Keratoisididae clades; *Pseudoanthomastus spp.*). We could also confirm species that previously were considered “doubtful” identifications from video records (e.g. *Errina atlantica, Leptopsammia formosa*).

The taxonomic examination of Porifera specimens from COLETA greatly increased the knowledge of the sponge diversity of the Azorean Region, which to date represented a poorly studied group. From a total of 52 analised specimens, 36 species were assigned. Four putative new species (*Hertwigia sp*. nov., *Geodia sp*. nov., *Regadrella sp*. nov. and Farreidae gen. to be confirmed sp. nov.) and one genus (Euretidae new. gen. sp. nov) were identified. Three species (*Siphonodictyon viridicens*, *Petrosia (Strongylophora) vansoesti* and *Haliclona (Halichoclona) magna*) and one genus (*Neoschrammeniella sp*.) are new records in the Azores. Additionally, we could resolve identification problems related to species complexes (see *Characella spp*.; *Haliclona spp*.). Furthermore, we had the opportunity to collect and examine fourteen species that were so far mostly know from the literature, or scarcely collected, but are species that may be rare or endemic in the Azores region (to name a few: *Farrea laminaris, Chonelasma ijimae, Raspailia falcifera, Lissodendoryx (Ectyodoryx) foliata, Echynostylinos reticulatus, Xestospongia friabilis)*.

We have attributed names to 17 morphotypes names to species, we could also rectify eight OTUS morphotypes that were erroneously attributed based on image (i. e. external morphological characters). For instance, we could recognize that some species share the same external morphologies but are different: the papillate *Characella connectens* vs *Nethea amygdaloides*; the massive *Haliclona magna* vs *Xestospongia friabilis*; the lamellar *Pachastrella monilifera* vs *Poecillastra compressa*; the flabellate *Phakellia spp.* vs *Lissodendoryx (Ectyodoryx) foliata.* Others, presented colour variation but corresponded to the same species, e.g. the *Haliclona implexa* morphotype yellow and white*, Exsuperantia archipelagus* and Porifera digitate yellow.

We could also better understand the presence of cryptic species complexes (e.g. *Characella spp., Asconema spp.*), or polyphyletic (e.g. family Chanilinidae), where the taxonomic characters based on spicules are not enough to distinguish between species. Therefore, further work including a genomic approach is necessary to confirm the putative species put forward here. The collaborative work with highly renowned researchers on cold-water coral and sponge taxonomy and phylogenetics, will support continued work on taxonomic revisions that will be useful in reconstructing evolutionary histories. Finally, this will improve our understanding of the biogeographic relationship between the Azorean cold-water corals and sponge communities within the wide Atlantic context.

### VME indicator species

The occurrence of cold-water corals in the Azores was first documented during major oceanographic expeditions during the late nineteenth century and throughout the 1900s. Results of historical and recent research have contributed to the identification of the Azores as a cold-water coral hotspot in the NE Atlantic, comprising species of the anthozoan subclass Octocorallia, orders Antipatharia and Scleractinia and of the hydrozoan family Stylasteridae. The reassessment of the total diversity of cold-water corals in the Azores based on the new information generated in this provision of services accounts for 191 species, with further 4 new putative new species to science. This list is likely to grow in the future with increasing deep-sea sampling effort from ROV expeditions. The diversity of sponges in the Azores is reported to be high (about 458 species, Van Soest, 2012), where more than 330 species are bathyal and abyssal (World Porifera Database, Neele *et al.*, 2015). However, the sponges that inhabit remote areas of the Mid-Atlantic Ridge, adjacent seamounts as well as the slopes of the island bathyal platform, included in the Azores EEZ, are little studied.

A large proportion of CWCs in the Azores belong to Octocorallia, including gorgonians, soft corals, and sea-pens, with 101 species identified (24 families) (Braga-Henriques *et al.*, 2013; Sampaio *et al.*, 2019b). From these, 27 taxa are listed as VME indicator species (ICES, 2020a), with the most commonly recorded in the Azores being *Viminella flagellum*, *Callogorgia verticillata*, *Dentomuricea* aff. *meteor*, *Acanthogorgia* spp. based on historical and COLETA records (Braga-Henriques *et al.*, 2013). The Scleractinia in the Azores are composed of 58 species (10 families) of solitary (cup corals) and colonial scleractinians (stony corals) (see Appendix A in Braga-Henriques *et al.*, 2013). From the total species recorded, nine taxa are listed VME indicator species, with the most commonly recorded in the Azores being represented by the cup coral *Caryophyllia* spp., and the stony corals *Madrepora oculata* and *Lophelia pertusa*. The diversity of black corals (Antipatharia) in the Azores comprises 18 species (5 families) based on the inventory provided by Braga-Henriques *et al.*, (2013), although several still require taxonomic revision. Six of these taxa are listed as VME indicator species by ICES (2020). Black corals are important components of cold-water communities in the Azores at depths below 600 m, with *Leiopathes* sp., *Stichopathes gravieri*, *Bathypathes* spp. and *Parantipathes* spp., often forming mixed communities with octocorals and sponges. Stylasterids, commonly known as lace corals, are colonial hydrozoans of the Family Stylasteridae (Order Anthoathecata) that can produce a calcium carbonate skeleton, similar to scleractinians (Cairns, 2011). In the Azores, there are nine species of sylasterids based on historical record and COLETA (Braga-Henriques *et al.* 2013), of which three taxa are listed as VME indicators. Thirteen sponge taxa in the Azores are listed as VME indicators as they fit most of the VME criteria. Most of these species are large in size and form structurally complex sponge aggregations. Although there is limited knowledge on the ecological role of sponges in the Azores, evidence form other regions suggests that sponges serve as habitat for numerous invertebrate and fish species (e.g., Hawkes *et al.*, 2019), also performing numerous functions in bentho-pelagic coupling and nutrient recycling (Cathalot *et al.*, 2015; Maldonado *et al.*, 2019; Rooks *et al.*, 2020).

### VME indicator biological communities

The sole presence of VME indicator species is not considered sufficient to classify geomorphological features into VMEs, and data on the abundance and observed species associations should also be included in the assessments. For this reason, the set of deep-sea benthic communities present in the Azores, understood as groups of populations of species that interact together in space, should be first identified and described, and then evaluated in order to determine their vulnerability against human activities Identifying those that constitute VMCommunities (VMCs) leaves the term VME as a reference to a series of functionally interrelated and spatially overlapping communities that make up the ecosystem. The assessment to determine VMCs should also follow the 5 criteria for defining what constitutes a VME provided by FAO (2009), specifically adapted for the evaluation of benthic communities in the Azores.

The set of underwater video images available to the ADSR team, which cover seamounts/ridges along the Mid-Atlantic Ridge and island slopes of the central/eastern groups down to ~1,000 m depth, has provided evidence of the complexity of Azores deep-sea benthic ecosystem. Through visual assessments, 39 associations of conspicuous benthic species have now been identified and catalogued, providing in each case the main structuring taxa (i.e., indicator species). The vast majority of benthic communities identified so far can be included under the category of coral gardens (n= 23), not undervaluing those classified as sponge grounds (n= 9), coral reefs (n= 2), Xenophyophore aggregations (n= 1) and those formed by other taxa (n= 4). The main species providing tridimensional structure to the seabed of the Azores correspond to large gorgonian corals, which generate conspicuous communities widely distributed along the different geomorphological features evaluated. Deeper areas tend to host a wider variety of large and structuring cold-water corals besides Octocorallia, such as black corals, bamboo corals and reef-forming stony corals. Sponge grounds have also been widely observed, especially those formed by large lithistid sponges in shallower areas and aggregations of hexactinellid sponges below 600-700 m. From the 39 benthic communities identified from the video images, 25 were considered to fit the criteria for VMCs based on the presence and density of structurally complex bioengineering species, the uniqueness of their components and/or the intrinsic vulnerability of the community to disturbances, as well as their capacity of recovery. The database of biological communities generated from the evaluation of the images contains 1 683 records of occurrence of biological communities in the deep sea of the Azores, namely 1 389 records of Coral gardens, 189 of Deep-sea sponge aggregations, 89 of foraminifera aggregations and 16 records of other communities.

### Spatial distributions of deep-sea biological diversity on geomorphological features

Several scientific expeditions using different types of video platforms have visited the Azores and collected important amounts of video data. We present a summary of the different scientific surveys carried out from 2009 to 2023 that provided imagery data that to evaluate the composition and distribution of deep-sea benthic fauna and communities inside the Azores EEZ, and for which the ADSR team is fully responsible for or currently has access to the video material. The collected footage derives from over 1 155 underwater video transects recorded by ROVs, towed-camera systems, submersible and the Azor drift-cam, equalling to a linear distance over the seabed of more than 1 577 kilometres. The existing underwater video transects down to 1,000 m span the whole EEZ, with 69 in Western Group of the Azores, 49 in the Northern Mid-Atlantic Ridge, 103 in the central Mid-Atlantic Ridge, 47 in the Southern Mid-Atlantic Ridge, 295 in the Northern Central Group of the Azores, 392 in the Southern Central Group of the Azores, and 193 in the Eastern Group of the Azores, and 34 outside the EEZ but in areas of interest. We visited all areas identified in the R1 report, namely 39 unexplored areas in the Azores EEZ. We also visited two areas that were not listed in the R1 report, namely the Gaillard seamount and an area west of Picos S do Princesa Alice. Finally, we also revisited other geomorphological structures that needed complementary sampling efforts.

To date, video footage and annotations have been obtained for all 140 L3 areas. A total of 606 underwater dives have been processed at the level 1 and level 2 of annotation, assigning a value of the SACFOR scale to each OTU observed in segments of 100 m in length. As of 1st November 2023, the database generated from the annotation of the benthic megafauna contains 52,697 records inside of the Azores EEZ. Each of these records corresponds to the occurrence of one OTU in segments of 100 m along each dive, providing an estimated density value using the coding of the SACFOR scale. This database is now a fundamental tool for mapping the distribution of biodiversity and VME indicator taxa within the limits of the Azores EEZ. After a verification process carried out to check for inconsistencies and a careful determination of uncertain taxonomical identifications, the data contained in the video database was included in "BD2: Georeferenced database of deep-sea species and habitats". The distributions of the records are presented thought the report.

### Vulnerable Marine Ecosystems

We evaluated the 140 geomorphological structures of the Azores in relation to each of the five FAO criteria to define what constitutes a VME, based on the information compiled, collected and analysed during this project. The evaluation was based on the species and communities found in each geomorphological structure as well as a measure of their abundance in the BD2 Georeferenced database containing information of species and habitats (see section 6). The assessment of underwater features against the VME criteria identified 41 out of the 140 areas that could fit the criteria that defines a VME: Hard-Rock Café, Flores NE, Chaucer S, Estrela, Kurchatov N, Isolado, Kurchatov SE, Kurchatov S, Kurchatov SW, Agulhas Corvo-Graciosa, Óscar, Gigante N, Gigante, Gigante Agulhas NW, Gigante Agulhas SW, Cavala, Beta, Sardinha, Voador, Farpas, Espadarte, Sedlo W, Gaillard, Graciosa S, Ilha Azul SE, São Jorge W Rosais, Álvaro Martins, Dom João de Castro, Ferraria Norte, Ferraria Mar, Girard, Pico S Lajes, Faial W Capelinhos, Condor, Ponta da Ilha N, Ponta da Ilha S, Albatroz do Meio, Açor S, Princesa Alice Picos S, Sauerwein, and Formigas.

### Evaluating of Descriptor 6

To support the assessments of the Descriptor 6 criteria (D6C3 and D6C5), we carried out an assessment of the degree of pressure and threat relating to human activities. We adopted a standard methodology for this purpose which starts from the characterization and mapping of conservation values and pressures arising from activities and potential uses. We also developed matrices of pressures and threats that allow an objective assessment of impacts and contribute to the assessment of D6C3 and D6C5. The application of the VME and fishing effort portfolio categories identified 22 areas classified as VME that fall in the portfolio category high VME – low VMS, 14 falling in the portfolio category high VME – high VMS, and 3 in the other category. The areas where high fishing effort overlaps with high VME index may be areas of potentially significant adverse impacts in vulnerable marine ecosystems.

We evaluated methodologies to analyze the data collected throughout the project to define D6C3 assessment methodologies that concern the "Spatial extent of each type of habitat that is negatively affected by physical disturbances, through the alteration of its biotic and abiotic structure and of its functions", and D6C5 "The extent of the negative effects of anthropogenic pressures on the condition of the habitat type, including alteration of its biotic and abiotic structure and functions, does not exceed a specified proportion of the natural extent of the habitat type in evaluation zone." The recent collection of seafloor imagery made it possible to identify that a large part of the benthic communities, including corals and sponges, observed in the main bottom fishing grounds in the Azores are still in good environmental condition and have a high natural and ecological value. However, some long-lived coral colonies with visible impacts from fishing were observed. Since no differences were detected between the four different fishing intensity classes and the V. flagellum conditions and epibiosis, one might speculate that the areas evaluated may still be in good condition and that these values may be used a baseline condition. The research cruises made it possible to identify that a large part of the benthic communities, including corals and sponges, observed in the main demersal fishing grounds of the Azores (such as Princesa Alice, the slopes of Terceira and São Miguel Islands and Banco D João de Castro) are still in good environmental condition and have a high natural and ecological value. However, some long-lived coral colonies with visible impacts from fishing were observed. These in-situ observations corroborate the conclusion of previous studies that suggest that well-regulated deep-sea fishing based on hook and line gear (preferably hand line) could contribute to the sustainable exploration of the deep sea.

## ACRONYMS

ADSR – Azores Deep-Sea ecology Research group

CITES – Convention on International Trade in Endangered Species of Wild Fauna and Flora

COLETA – Marine Biological Reference Collection of the University of the Azores

CoML – Census of Marine Life

CWCs – Cold-Water Corals

DRPM – Regional Directorate for Maritime Policies

EEZ – Exclusive Economic Zone

FAO – Food and Agricultural Organization

FRN – Fundação Rebikoff-Niggeler

ICES – International Council for the Exploration of the Sea

IMAR – Marine Research Institute

IUCN – International Union for Conservation of Nature

MAR – Mid Atlantic Ridge

MSFD – Marine Strategy Framework Direction

NAFO – Northwest Atlantic Fisheries Organization

NOAA – National Oceanic and Atmospheric Administration

OBIS – Ocean Biogeographic Information System

OTU – Operational Taxonomic Unit

PAM – Prince Albert I of Monaco

PUs – Planning units

RAA – Autonomous Region of the Azores

ROVs – Remotely Operated Vehicles

SACFOR – Superabundant, Abundant, Common, Frequent, Occasional, Rare

UAç – University of the Azores

UN – United Nations

VME – Vulnerable Marine Ecosystem

VMC – Vulnerable Marine Community

WGDEC – Working Group on Deep Water Ecology

WKVME – ICES Workshop on VME

WoRMS – World Register of Marine Species

# FINAL REPORT WITH PROTECTION RECOMMENDATIONS

## 1. Introduction

The present report was prepared for the Regional Government of Azores to under the provision of services 11/DRPM/2022 - Characterization of deep-depth habitats, with a view to their mapping to the outer limit of the Aazores sub-area of the Portuguese Exclusive Economic Zone. The final report (RF) aims to summarize the information on the distribution of species, deep-sea habitats and geomorphological units identified. It also aims to present recommendations for the protection of these ecosystems and obtaining or maintaining their good environmental status, in accordance with the requirements of the Marine Strategy Framework Directive. As described in the R0 report, the **RF report consist of a significant update of the R1 Report of pre-existing information and knowledge gaps, with an additional section with recommendations for the protection of deep-sea ecosystems in the Azores**.

### *1.1 General setting of the Azores deep-sea*

The Azores is an oceanic archipelago in the mid-North Atlantic Ocean, spreading along a NW–SE-trending strip of 600-km long, with the Mid-Atlantic Ridge (MAR) separating the islands of Flores and Corvo, to the west, from the remaining islands' groups (Figure 1). Portugal's marine jurisdiction around the islands encompasses an Exclusive Economic Zone of almost 1 million km$^2$ of which about 99% is deep sea (>200 m), and a claimed continental shelf extension that expands Portuguese sovereignty to approximately twice this value. The islands of recent origin (Feraud *et al.*, 1980) rise from volcanic edifices sitting on an elevation roughly delineated by the 2,000 depth contour and named the Azores Plateau, laying above the tectonically active Azores triple junction between the North American, Eurasian and African plates (Searle, 1980; Lourenço *et al.*, 1998). The main tectonic features in the region are (i) the Mid-Atlantic Ridge (MAR), which crosses the Azores Plateau in a path approximately North-South and (ii) the Terceira Rift which crosses WNW-ESE to NW-SE direction and defines the NE margin of the plateau (Lourenço *et al.*, 1998; Vogt & Jung, 2004). The Azorean section of the MAR is a spreading centre that separates the North American plate from the Eurasian and African plates (Searle, 1980). Terceira Rift is an ultra-slow spreading ridge, which is thought to operate as the present Eurasian and African plate boundary along much of its extent (Vogt & Jung, 2004). The seafloor surrounding the islands is characterized by a diverse topography comprising island slopes, seamounts, deep fracture zones, trenches, a considerable extension of the MAR and abyssal plains exceeding 5,000 m depth. Seamounts are prominent topographic features in the Azores, with 460 seamount-like features that may occupy 37% of the EEZ (Morato *et al.*, 2008; 2013). The physical characteristics of the seafloor surrounding the Azores Archipelago has been compiled in Perán *et al.* (2016).

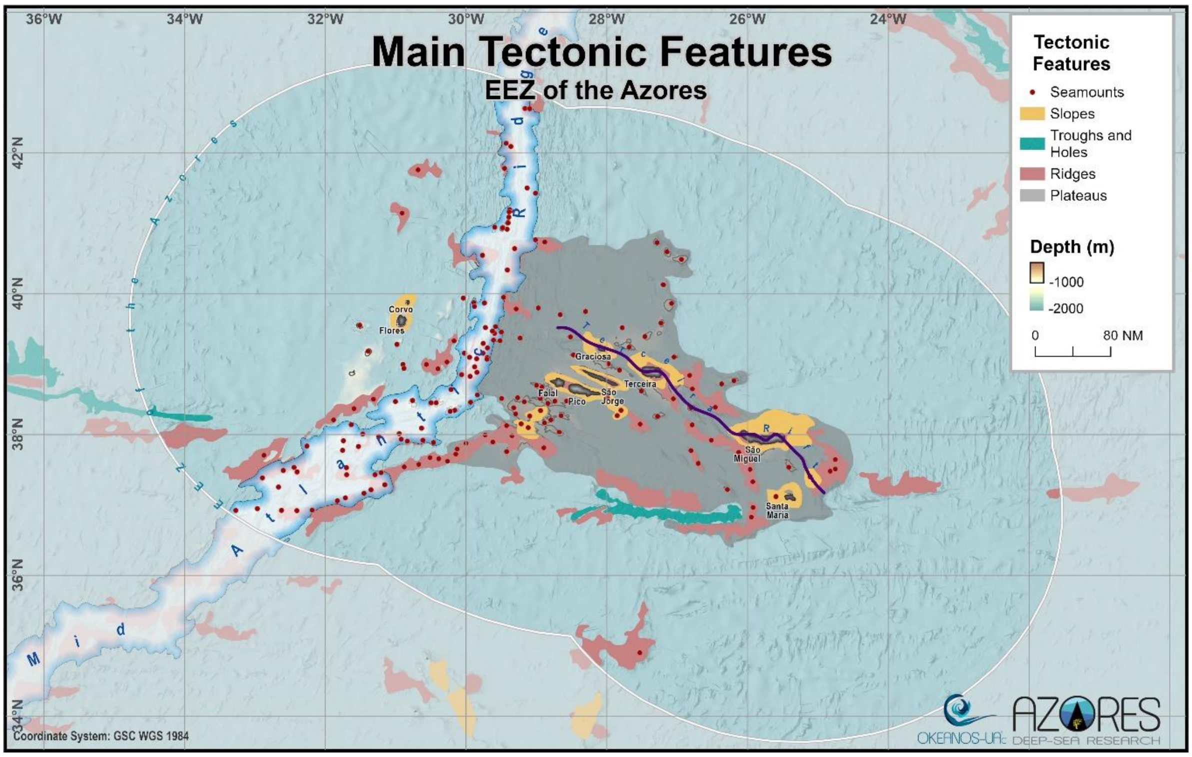



**Figure 1** Map of the Azores showing the main tectonic features in the region, the Mid-Atlantic Ridge and Terceira Rift, and other geomorphologic structures of the seafloor (e.g., seamounts, slopes, plateaus, ridges, throughs and holes).

## *1.2 Brief physical and oceanography description*

The archipelago is located on the inter-gyre region of the eastern North Atlantic between 34º and 50ºN, which shapes the complex oceanographic environment of the Azores (Maillard, 1986; Amorim *et al.*, 2017). Large-scale circulation is influenced by two eastward currents branching from the Gulf Stream: the cold North Atlantic Current in the north, crossing the Mid-Atlantic Ridge between 45-48 48ºN (Bower *et al.*, 2002), and the warm Azores Current to the south, which crosses the MAR between 34-36ºN (Alves & Verdière, 1999; Bashmachnikov *et al.*, 2004; Martins *et al.*, 2008). Almost permanent complex mesoscale eddies with meanders and resurface circulation pattern related topographical features are also important oceanographic features in the region (Reverdin *et al.*, 2003; Caldeira & Reis, 2017). In deeper waters, numerous water masses can be located: the North Atlantic Central Water from ca. 150 to 500 m depth; the Northern Sub-Polar Water at ca. 500-700 m depths, the Mediterranean Outflow Water at ca. 700-1,300 m and the North Atlantic Deep Water below 2,000 m depth (Johnson & Stevens, 2000; Bashmachnikov *et al.*, 2009). The eastward-flowing Azores Current is considered as the northern limit of the North Atlantic Subtropical Gyre (Juliano & Alves, 2007).

The Azores geographic region is a transitional zone between subtropical and temperate climate, experiencing large scale spatial and seasonal variation of oceanographic conditions (Lafon *et al.*, 2004). The sea temperature is characterized by horizontal gradients enhanced by the cold North Atlantic Current and the Azores Current flows (Bashmashnikov *et al.*, 2004). Average sea surface temperature ranges from 15ºC in the winter to 27ºC in the summer (Martins *et al.*, 2008; Amorim *et al.*, 2017). A deep mixed layer is present at ∼150 m depth during the winter, while a seasonal thermocline usually develops between 40 and 100 m depth in the summer (Santos *et al.*, 1995). In general, productivity is low, but localized upwelling associated with island slopes and seamounts can enhance local production (Bashmachnikov *et al.*, 2004; Morato *et al.*, 2009), with maximum values in the winter and spring and minimum values in the summer (Santos *et al.*, 2013). Datasets of environmental data for the Azores region from remote sensing and in situ data (e.g., temperature, salinity, chlorophyll-a, organic and inorganic carbon) have been compiled in Amorim *et al.* (2017).

### *1.3 Deep-sea exploration in the Azores*

After the first expeditions to the deep sea in the late 19th and early 20th centuries lead by Prince Albert I of Monaco (Porteiro, 2009; Santos *et al.*, 2009), extensive scientific research-based in the Azores has opened a window on the functioning of large deep-sea ecosystems and the impacts of human activities in such ecosystems. The Azores have, therefore, a long history of deep-sea research, recently supported by various regional (e.g., DRCT 2020, MapGES, DeepWalls, PlastDeep, Impactor, RECO), national (e.g., DeepData, Ecomining JPIOceans), and European funded research projects and international collaborations (e.g., OASIS, HERMIONE, CoralFISH, DiscardLess, ATLAS, MERCES, SponGES, iAtlantic, EMSODEV). This research, carried out at IMAR and Okeanos of the University of the Azores, consolidated the knowledge about seamounts, ridges and hydrothermal vent ecosystems at the global and local scales. Over the last decades, new deep-sea species, biotopes, hydrothermal vent fields, and ecological associations were discovered (e.g., Carreiro-Silva *et al.*, 2017; de Matos *et al.*, 2014a, b; Tempera *et al.*, 2015; Gomes-Pereira *et al.*, 2017; Pham *et al.*, 2015), and even new genes with potential for biotechnology (Martins *et al.*, 2014; Bettencourt *et al.*, 2017).

The Azores deep sea harbour a diverse number of benthic habitats, which are home to several coral gardens, cold-water coral reefs, sponge grounds and hydrothermal vents, among other relevant ecosystems (Tempera *et al.*, 2013). Such environments provide nursery and refuge areas for socio-economically important deep-sea fish species (Pham *et al.*, 2015) and can be hotspots for marine predators, vital to the stability and resilience of marine food webs. More than 450 seamount-like features have been identified inside the Azores EEZ (Morato *et al.*, 2008), which implies that the efforts required to obtain a detailed characterization of the benthic communities found in the region are enormous. Historically, our knowledge about the diversity and structure of the benthic invertebrate fauna of the Azores relied on samples collected using remote techniques, such as nets or sleds (Porteiro, 2009), or on the evaluation of specimens provided by the fishing fleet as bycatch (e.g., Sampaio *et al.*, 2012). Advances in underwater robotics and imaging technology (Durden *et al.*, 2015; Dominguez-Carrió *et al.*, 2021) have enabled the visual investigation of deep-sea habitats, exponentially improving our understanding about the ecology of benthic species, as well as the spatial extent of the communities they form.

During the past decade, the Azores Deep-Sea ecology Research group (ADSR), from the IMAR and Okeanos of the University of the Azores, has assigned a great deal of resources into the exploration of the various deep-sea geomorphological features that can be found inside the Azores EEZ, including several seamounts, ridges, slopes and hydrothermal vents. Since video platforms can descend hundreds to thousands of meters through the water column, images collected using these methods are the most powerful tool currently at our disposal to generate information about the distribution of marine ecosystems along latitudinal, longitudinal and bathymetrical gradients. Therefore, video images should be regarded as the most versatile sampling strategy to generate large censuses of species and communities without damaging the organisms focus of study. For this reason, since 2010 IMAR/U. Azores has led or participated in over twenty oceanographic surveys that make use of imaging technology with the final objective of improving our understanding about the diversity and distribution of deep-sea benthic fauna. Some of these cruises have been performed in collaboration with other international institutions (e.g., NIOZ, IFREMER, GEOMAR, IEO) and supported by multiple national and international projects (e.g., Hermione, CoralFISH, MIDAS, ATLAS, BIOMETORE, iATLANTIC, and MapGES, among others).

Despite all these efforts, substantial gaps in scientific knowledge still exist that may hamper the implementation of marine environmental policies in the Region, namely the Marine Strategy Framework Direction (MSFD) and its assessment of the environmental status, but also the Habitats, Birds, and Water Directives. Indeed, the Regional Directorate for Maritime Policies (DRPM), as the environmental authority for the marine environment in the Autonomous Region of the Azores (RAA), considered necessary to fill the knowledge gaps regarding the characterization of the deep-sea in the Azores, through the inventory and characterization of deep-sea habitats as well as vulnerable marine ecosystems (VMEs).

### *1.4 Objectives*

The final report aims to summarize the information on the distribution of species, deep-sea habitats and geomorphological units identified. It also aims to present recommendations for the protection of these ecosystems and obtaining or maintaining their good environmental status, in accordance with the requirements of the Marine Strategy Framework Directive. As described in the report R0, the report RF consist of a significant update of the R1 Report of pre-existing information and knowledge gaps, with an additional section with recommendations for the protection of deep-sea ecosystems in the Azores. This last section contains suggestions on ways to assess Descriptor 6 of the Marine Strategy Framework Directive for the deep sea, including proposals and suggestions on how to identify reference conditions for reporting purposes. Finally, it will perform an assessment of the pressures and threats from human activities in the deep-sea at sea with the potential to affect these ecosystems.

Based on the description of the provision of services and the description of work presented in the R0 report, this report should contain a detailed compilation of the best existing information on the biodiversity of the deep sea of the Azores and its spatial distribution down to 1,000 m depth, namely in what regards to:

5) VME indicator species;
6) Location of known biological communities;
7) Inventory and description of habitats identified in the Azores;
8) Known spatial distribution of habitats up to the outer limit of the Azores subarea of the Portuguese EEZ.

Therefore, the objective of this report is to describe the existing information regarding the benthic marine biodiversity in the deep sea (>200 m) to the outer limit of the Azores sub-area of the Portuguese EEZ down to 1,000 m depth. The compilation will include, at the same time, data from the bycatch observer programs of the Azorean fisheries and video data collected during the various research projects. It will also identify knowledge gaps and areas in need of gathering new information and thus be used to support the planning of field missions to collect new data, with emphasis on the video data and biological samples for taxonomic confirmation.

## *1.5 Definitions*

### Biological communities and habitats

In the area of Ecology, the concept of 'biological community' or 'biocenosis' has been used for decades to define characteristic associations of fauna. Specifically, the concept of community refers to a "group of populations of species that interact together in space", considering not only the space-time element, but the interactions between species (direct or indirect) as a fundamental component of the community (Stroud *et al.*, 2015). Studies carried out on the composition of marine benthic communities have demonstrated the key role played by environmental factors in the composition of observed species groups. The term "habitat" in ecology refers to the variety of resources (e.g., physical environment and biotic elements that exist in a region) necessary for a specific species to survive and reproduce. Therefore, "habitat" refers to a specific species and is fundamentally distinct from the concepts of environment, which is better described by "habitat-type." Therefore, modern classifications tend to combine the physical environment (habitat) with the conspicuous species that characterize the community in a higher-level entity, originally defined as a 'biotope', but which for practical reasons of interpretation of the terms used in directives and conventions, in some documents it is sometimes synonymous with 'habitat' (Olenin & Ducrotoy, 2006).

After a careful read of the description of the provision of services we believe that the text referred interchangeably to biological communities and habitats. Therefore, here we adopted that "biological communities" and" habitats" in the provision of services refer to:

- Biological communities as a group or association of different species occupying the same physical environment and geographical area at the same time.

### Vulnerable Marine Ecosystems (VME)

The description of the provision of services also refers to the need to contribute to a better definition of VMEs in the Azores and to the identification of areas that fit the adopted definitions of VMEs. The concept of a "vulnerable marine ecosystem" (VME) was included in United Nations (UN) General Assembly Resolution 61/105 as part of an international effort to minimize the effects of deep-sea fishing. However, despite the fact that over the last few years great efforts have been made to operationalize the VME concept, there are still some doubts about how to apply it to dwellings or communities (Watling & Auster, 2021), such as those found in the Azores. VMEs have been defined as groups of species (e.g., *Lophelia pertusa*), communities (e.g., coral garden composed of a certain type of species), or habitats (e.g., hydrothermal vents) that may be vulnerable to impacts from fisheries activities. During the operationalization of this concept, various categories of organisms, communities or habitats were considered VME indicators, suggesting that areas with these species would be considered VMEs with subsequent management measures implemented to protect these ecosystem attributes.

The Food and Agricultural Organization (FAO) of the United Nations (UN) subsequently developed criteria for defining what constitutes a VME (FAO, 2009; 2016):

***Uniqueness or rarity:*** an area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include habitats containing endemic species, habitats of rare, threatened or endangered species that occur only in discrete areas;

***Functional significance of the habitat:*** discrete areas or habitats that are necessary for the survival, function, spawning/reproduction or recovery of fish stocks, particular life-history stages (e.g., nursery grounds or rearing areas), or of rare, threatened or endangered marine species.

***Fragility:*** an ecosystem that is highly susceptible to degradation by anthropogenic activities.

***Life-history traits of component species that makes recovery difficult:*** ecosystems that are characterised by populations or assemblages of species with one or more of the following characteristics: slow growth rates, late age of maturity, low or unpredictable recruitment, and/or longlived.

***Structural complexity:*** an ecosystem that is characterised by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which is dependent on the structuring organisms.

These criteria may apply to a wide variety of species, communities, habitats, or ecosystems of the deep-sea. VMEs have been identified based on the occurrence of indicator taxa such as stony or gorgonian corals, or sponges, and are therefore best identified using high-quality underwater imagery, allowing an accurate and quantitative description of community composition and associated fauna (e.g., ICES, 2016; 2017). The Joint ICES/NAFO Working Group on Deep Water Ecology (WGDEC) has adopted specific terminology related to the concept of VME in the deep-sea areas:

- 'VME habitat' records are generally those from visual survey data (e.g., remotely operated vehicle (ROV) or towed/drop camera seabed imagery) that demonstrates the presence and location of a VME with a high degree of confidence and spatial accuracy. VME habitats = VME (ICES, 2016). The list of VME habitats to be considered by WGDEC was re-viewed and revised in 2020 (ICES, 2020a)
- 'VME indicator' refers to records of VME indicator species from data sources for which there is a degree of uncertainty that a VME is, or was, present. Typical examples are trawl-survey or static longline bycatch records (ICES, 2016). Representative taxa of VME habitats, which are recognised as VME indicators, were reviewed and revised by WGDEC in 2020 and 2021 (ICES, 2020a; 2021).
- 'VME element' refers to seabed topographic features, readily identified using high resolution multibeam data, and with which VMEs are often associated. Examples include seamounts, ridges, canyons (ICES, 2013).

After a careful interpretation of the description of the provision of services we believe that the text referred to ***VME indicator species*** in the correct term, i.e., species that may be vulnerable to impacts from fisheries activities and that may indicate the presence of a VME. In what concerns to the use of VME, the description of the provision of services seems to have used the term VMEs and, sometimes, habitat to describe those areas that fit the FAO criteria. However, it was not apparent that the text referring to habitats meant to describe the physical environmental, the biological communities, or a VME. Because of these inconsistencies, we adopted that ***VME*** and, sometimes, ***habitats*** meant:

- those spatial areas that fit the FAO criteria to describe a vulnerable marine ecosystem.

#### Considerations

Therefore, in this report and for the rest of the provision of services we will compile 1) the best available information, 2) an inventory, 3) a description, and 4) the known spatial distribution of:

- the megabenthic ***species*** (i.e., >3 cm), including those that are considered ***VME indicators***;
- the ***biological communities***, including those that can be considered ***VME biological communities***;
- and the spatial areas that fit FAO criteria to describe a ***vulnerable marine ecosystem***;

in the deep sea (>200 m) to the outer limit of the Azores sub-area of the Portuguese EEZ down to 1,000 m depth.

## 2. Study area

In accordance with Technical Specifications of the provision of services, the study area encompasses the deep sea of the Azores sub-area of the Portuguese EEZ down to 1,000 m depth (Figure 2). The deep sea is a fuzzy concept traditionally used to name areas of the ocean deeper than 200 m depth, where sunlight begins to fade away. This definition applies well to the objectives of this project, and it is therefore used to define the upper bathymetric limit of the study area. For the purposes of this provision of services, the deep sea of the Azores up to 1,000 m deep was organized into:

- Large areas (Level 1) - Seven large areas, including: (1) the Western Group, (2) Northern Mid-Atlantic Ridge, (3) Central Mid-Atlantic Ridge, (4) Southern Mid-Atlantic Ridge, (5) Northern Central Group, (6) Southern Central Group, and (7) Eastern Group (Figure 3).
- Study areas (Level 2) - The large areas were subdivided into 20 study areas, namely: (1) Hard Rock-café and Flores/Corvo, (2) Southern Chaucer and Kurchatov, (3) Gigante, Cavala and Picos SE Flores , (4) Alberto do Mónaco, Farpas, and Sarda, (5) Sedlo, Graciosa/S. Jorge, Terceira, and Dom João de Castro (6) Faial/Pico and Princesa Alice, and (7) São Miguel, Mar da Prata, Formigas, and Santa Maria (Figure 3).
- Sampling areas (Level 3): The study areas were then divided in to 140 geomorphological units or sampling areas (Table 1; Figure 4). These areas informed the compilation of existing information, the identification of gaps in information, the collection of new data, and the policy recommendations.

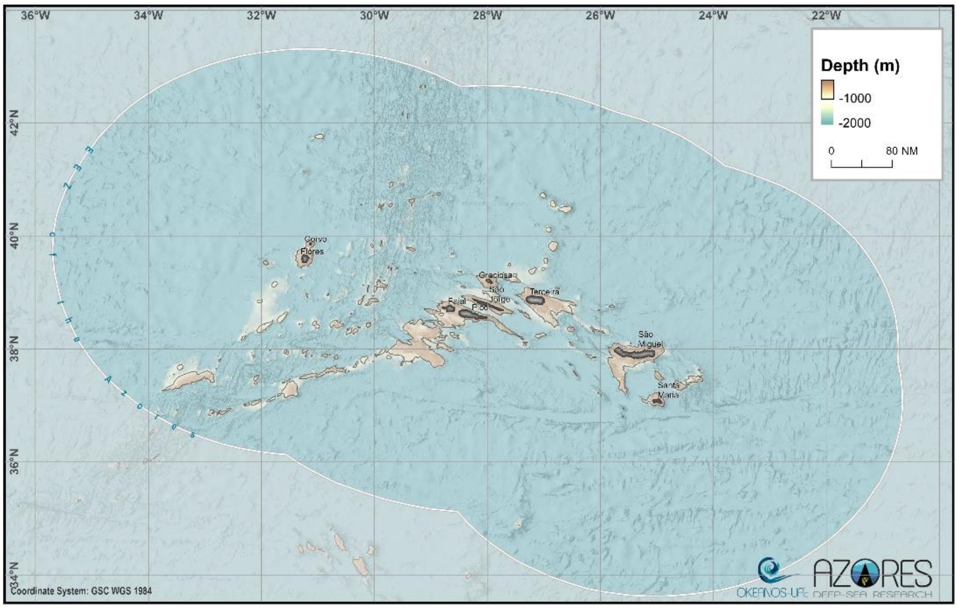



Figure 2 Deep sea of the Azores sub-area of the Portuguese EEZ down to 1,000 m a depth, as defined in Part II – Technical Specifications.

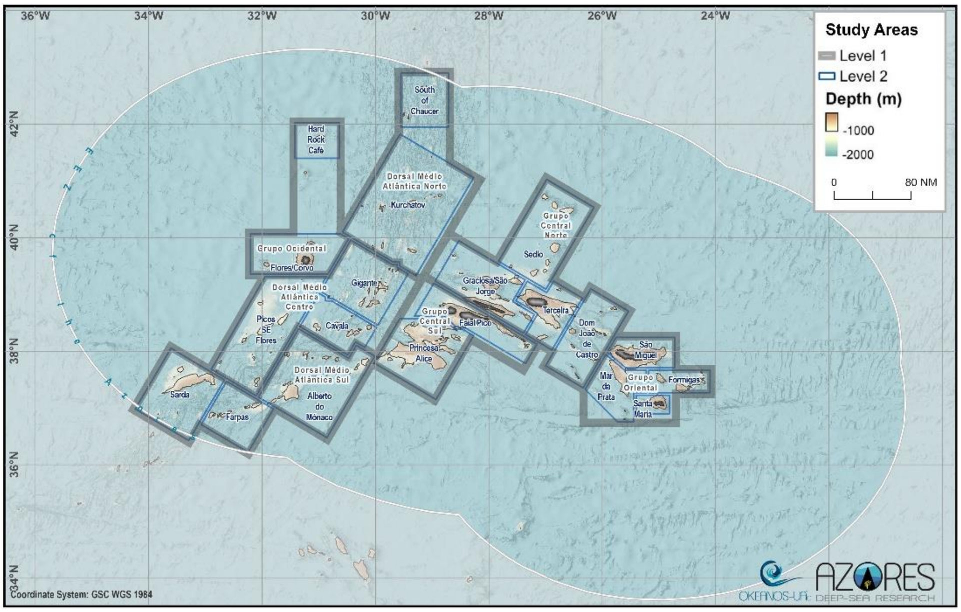



Figure 3 For the purposes of compiling existing information and identifying information gaps, the deep sea of the Azores up to 1,000 m depth is divided into 7 large areas (level 1) and 20 study areas (level 2).

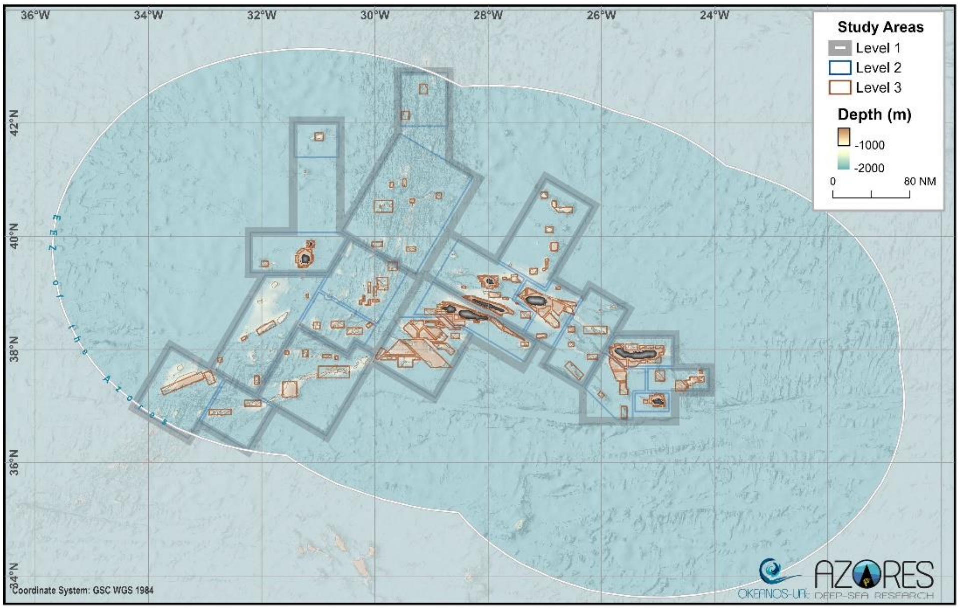



**Figure 4** In the 20 study areas (level 2), 140 sampling areas were identified (level 3) that will serve to inform the compilation of existing information, the identification of knowledge gaps, the collection of new data, and the policy recommendations.

**Table 1** For the purpose of this provision of services, the deep sea of the Azores up to 1,000 m deep were organized into: 7 large areas (level 1), 20 study areas (level 2), and 140 sampling areas (level 3). These areas served to inform the compilation of existing information, the identification of knowledge gaps, the collection of new data, and the development of policy recommendations.

| L1 | Level 2 | Level 3 |
|---|---|---|
| Western Group | Hard-rock café | Hard-rock café |
| | Flores/Corvo | Corvo NW |
| | | Corvo NE |
| | | Corvo SE |
| | | Corvo SW |
| | | Flores NW |
| | | Flores NE |
| | | Flores E |
| | | Flores S |
| | | Flores W |
| | | Cachalote |
| Northern Mid-Atlantic Ridge | Chaucer Sul | Chaucer S |
| | | Estrela |
| | Kurchatov | Kurchatov N |
| | | Isolado |
| | | Kurchatov SE |
| | | Kurchatov S |
| | | Kurchatov SW |
| | | Agulhas Corvo-Graciosa |
| | | Óscar |
| Central Mid-Atlantic Ridge | Gigante | Gigante N |
| | | Gigante |
| | | Gigante Agulhas NE |
| | | Gigante Agulhas NW |
| | | Gigante 127 |
| | | Gigante Agulhas S |
| | | Gigante Agulhas SW |
| | Cavala | Ferradura E |
| | | Ferradura |
| | | Cavala |
| | | Beta |
| | Picos SE Flores | Diogo Teive |
| | | Buchanan |
| | | Cabeçote |
| | | Sardinha |
| | | Lucky Strike E |
| Southern Mid-Atlantic Ridge | Alberto do Mónaco | Menez Gwen |
| | | Picoto |
| | | Alfa |
| | | Alfa E |
| | | Voador |
| | | Monte Alto |
| | Farpas | Farpas |
| | | Espadarte |
| | Sarda | Sarda East |
| | | Sarda |
| N Central | Sedlo | Sedlo W |
| | | Sedlo |
| | | Gaillard |
| | | Borda |
| | | João Leonardes |
| | | Serreta Mar |
| | Graciosa/ S Jorge | Mar da Fortuna |
| | | Graciosa NW |
| | | Graciosa NE |
| | | Graciosa SE |
| | | Graciosa S |
| | | Graciosa SW |
| | | Perestrelo |
| | | Bartolomeu |
| | | Ilha Azul |
| | | Ilha Azul E |
| | | Ilha Azul SE |
| | | São Jorge NW |
| | | São Jorge NE |
| | | São Jorge E Topo |
| | | São Jorge SE |
| | | São Jorge S Urzelina |
| | | São Jorge SW Velas |
| | | São Jorge W Rosais |
| | | João de Melo |
| | Terceira | Terceira N |
| | | Terceira NE |
| | | Terceira E |
| | | Terceira S |
| | | Terceira SW Angra |
| | | Terceira W Serreta |
| | | Álvaro Martins |
| | | Beirada de Fora |
| | | Gastromar |
| | | Maçarico |
| | | Albatroz do Norte |
| | Dom João de Castro | Alcatraz |
| | | Dom João de Castro |
| | | Ferraria Norte |
| | | Ferraria Mar |
| | | Girard Ridge |
| Southern Central Group | Faial/Pico | Faial NW |
| | | Faial N |
| | | Faial-Pico N |
| | | Pico NW |
| | | Pico NE |
| | | Pico S Lajes |
| | | Pico SW Espartel |
| | | Faial-Pico S |
| | | Faial S |
| | | Faial Filhas do Condor |
| | | Faial W Capelinhos |
| | | Condor |
| | | Baixo de São Mateus |
| | | Ponta da Ilha N |
| | | Ponta da Ilha S |
| | | Albatroz do Meio |
| | Princesa Alice | Agulhas 12 Milhas |
| | | Condor de Fora |
| | | Agulhas 18 Milhas |
| | | Bourée NE |
| | | Bourée E |
| | | Açor |
| | | Açor S |
| | | De Guerne N |
| | | De Guerne |
| | | São Mateus de Fora |
| | | Princesa Alice |
| | | Princesa Alice W |
| | | Princesa Alice Picos S |
| | | Henry Carr |
| | | Princesa Alice SW |
| Eastern Group | São Miguel | São Miguel NW |
| | | São Miguel N |
| | | São Miguel NE |
| | | São Miguel E |
| | | São Miguel SE |
| | | São Miguel S |
| | | São Miguel SW |
| | | São Miguel W |
| | Mar da Prata | Mar da Prata N |
| | | Mar da Prata |
| | | Mar da Prata S |
| | | Maria Celeste |
| | | Sauerwein |
| | Formigas | Grande Norte |
| | | Formigas |
| | | Margrette |
| | | Margrette E |
| | | Margrette NE |
| | Santa Maria | Santa Maria N |
| | | Santa Maria E |
| | | Santa Maria SW |
| | | Santa Maria W |
| | | Santa Maria Pico W |

## 3. Tasks developed during the project

The service provision stated that in order to achieve the expected results, the co-contractor will carry out tasks that will make it possible to fill existing gaps in the knowledge of marine biodiversity in the deep sea of the Azores, namely compilation of pre-existing information (Task 1), tasks of collecting new information (Task 2) and will produce lists of species, habitats, catalogues, and spatial distribution maps (Task 3) and provide compiled data and policy advice to the authorities of the Autonomous Region of the Azores regarding the need and design of specific conservation measures (Task 4). Here, we provide a short summary of the tasks developed during the contract with a list of the products delivered.

### *3.1 Pre-existing information and identification of gaps in information (Task 1)*

During the provision of services and the description of work presented in the R0 report, we have **produced the report R1**, entitled: *Azores deep-sea ecosystem: Pre-existing information and knowledge gaps (R1) - Report containing the description of existing information and identification of knowledge gaps and needs for gathering new information*. The report contained a detailed compilation of the best existing information on the biodiversity of the deep sea of the Azores and its spatial distribution down to 1,000 m depth, namely in what regards to 1) VME indicator species; 2) location of known biological communities; 3) inventory and description of habitats identified in the Azores; 4) known spatial distribution of habitats up to the outer limit of the Azores subarea of the Portuguese EEZ. The compilation included data from the Marine Biological Reference Collection (COLETA), video data collected during various research projects, and data from publicly available datasets. The R1 report also identified 100 areas with sufficient information and 39 areas with knowledge gaps and, therefore, in need of new data. Thus, it was used to support the planning of field missions to collect new video data and biological samples for taxonomic confirmation. A short summary of the pre-existing data is presented in Section 4.

#### Delivered products of Task 1

Morato, T., C. Dominguez-Carrió, L. Rodrigues, M. Ramos, G. Gonçalves, I. Carneiro, M. Carreiro-Silva (2023). Azores deep-sea ecosystem: Pre-existing information and knowledge gaps (R1) - Report containing the description of existing information and identification of knowledge gaps and needs for gathering new information. Direct Adjustment no 11/DRPM/2022 - Characterization of deep-sea habitats, with a view to mapping them up to the outer limit of the Azores sub-area of the Portuguese exclusive economic zone. Instituto de Investigação em Ciências do Mar - Okeanos, Universidade dos Açores, Horta, Portugal. 195pp.

### *3.2 New data on deep-sea marine biodiversity down to 1,000 m depth (Task 2)*

Assembly of new Azor drift-cam

The research cruises carried out on board medium and small ships used the low-cost deep sea image collection system called Azor drift-cam. This system was developed by the IMAR & Okeanos-UAç Deep Sea Research Group (ADSR) and aimed to carry out rapid assessments of deep-sea benthic habitats (Dominguez-Carrió et al., 2021). In order to conduct all the proposed surveys, we have built **6 units of the Azor drift-cam** (Figure 5), three more than what was proposed in the R0 report. The increased number of cameras systems built was related to the need of having multiple vessels operating at the same time.

**Figure 5** Six units of the Azor drift-cam used during the 2023 deep-sea surveys on board RV Arquipélago and MT Physeter.

Research expeditions

During the provision of services to the Regional Government of the Azores, several research cruises were carried out in the locations identified in the report R1 Report as containing knowledge gaps regarding the deep-sea benthic faunal composition. These cruises aimed to collect new data on deep-sea marine biodiversity down to 1,000 m depth. Altogether, it was possible to conduct five research cruises that lasted approximately **119** days at sea, corresponding to **551** people at sea, where a total of **376** dives were performed, covering about **227** km of seafloor and producing almost **437** hours of seafloor video footage. **We visited all areas identified in the R1 report**, namely **39** unexplored areas in the Azores EEZ. We also visited **two** areas that were not listed in the R1 report, namely the Gaillard seamount and an area west of Picos S do Princesa Alice. Finally, we also revisited other geomorphological structures that needed complementary sampling efforts.

The ADSR group made a great effort to bring the Portuguese Research Vessel (RV) Mário Ruivo to the Azores to continue exploring the deep-sea benthic habitats of this region. Unfortunately, after a long period of negotiations, the vessel's owner informed that it was not possible to carry out such a scientific campaign. The lack of legal certifications combined with logistical problems made this plan unfeasible. To overcome this problem, we decided to send the RV Arquipélago to explore the areas that had been allocated to be visited with the RV Mário Ruivo (e.g., Sedlo seamounts and Hard Rock Café), send MT Physeter to explore the slopes of Terceira and São Miguel Island, and to contact several other institution that could have the technological means to perform deep-sea exploration with tools that allowed the collection of biological samples of unknown species. After, several contacts we had the opportunity to build a true partnership with the North American philanthropic entity, Dalio Philanthropies, owner of the RV OceanXplorer. This RV is equipped with the best and most advanced ocean exploration technology, including two submarines capable of diving down to 1,000 m deep and an ROV down to 6,000 m, high-definition probes and sensors, sophisticated laboratories, several support vessels, and a diving centre. The expedition was the result of a partnership between OKEANOS – Institute for Research in Marine Sciences, OceanX, the Regional Government of the Azores and aimed to complement the information that has been collected with the Azor drift-cam, taking advantage of the capabilities from the ship to collect biological samples of deep-sea specimens for taxonomic identification.

#### Annotation of deep-sea images of the Azores collected between 2018 and 2022

A large majority of videos that have been collected between 2018 and 2022 were not previously annotated and translated into species occurrence lists. Therefore, during this provision of service we performed a detailed annotation of the deep-sea video transects that have been collected in the Azores EZZ between 2018 and 2022. The annotation was performed to evaluate the type of substrate observed and the biological diversity. In what relates to the biodiversity, this effort resulted in the annotation, at the level 1 and level 2, of 454 underwater dives (2018-2022), resulting in 40 726 records of deep-sea benthic megafauna in the Azores. These statistics demonstrate a significant advance in the massive task of annotating past videos. When compared to the expected results described in the R0 report (550 videos, 50 000 records), the statistics were slightly lower but within the expected range. These records were added to those collected and analysed in 2023 (see section 3.3) to produce the video component of the BD2 – Georeferenced database containing information of species and habitats, composed of the pre-existing information (BD0), updated with new information acquired (BD1, BD2) on the spatial distribution of habitat indicator species, known communities, and identified habitats".

#### Azores Marine Biodiversity Reference Collection (COLETA) database

During this provision of service, we update the Azores Marine Biodiversity Reference Collection (COLETA) database with information collected between 2019 and 2022 by sampling programs ARQDAÇO, CONDOR and the oceanographic surveys M128 and ExploSea2. We also added the new data collected during the ARQDAÇO 2023 surveys and with data collected during the provision of services flagship research cruise OceanXplorer 2023. A total of **1 277** new records, representing a **23%** increase in the pre-existing dataset, were included in the COLETA database. The dataset was expanded from the 5 519 records reported in the report R0 and BD0 to **6 796** reported here and in BD2.

Delivered products of task 2

Morato, T., C. Dominguez-Carrió, L. Rodrigues, I. Areosa, J. Balsa, I. Bruno, I. Carneiro, L. Fauconnet, S. Gomes, G. Gonçalves, M. Ramos, G.H. Taranto, M.P. Vilavendrell, M. Carreiro-Silva (2023). Relatório das campanhas realizadas durante o primeiro período de missões de campo (RM1). Produzido no âmbito do Ajuste Direto n.º 11/DRPM/2022 - Caracterização dos habitats de profundidade, com vista ao seu mapeamento até ao limite exterior da subárea dos Açores da zona económica exclusiva portuguesa. Instituto de Investigação em Ciências do Mar - Okeanos, Universidade dos Açores, Horta, Portugal. 106pp.

Morato, T., C. Dominguez-Carrió, L. Rodrigues, G.H. Taranto, L. Fauconnet, G. Gonçalves, J. Balsa, I. Carneiro, I. Areosa, I. Bruno, D. Catarino, T. Cerqueira, N. Collazo, G. Edery, A. Godinho, S. Gomes, M. Ramos, A. Rosa, M. Pladevall, F. Porteiro, M. Carreiro-Silva. (2023). Relatório das campanhas realizadas durante o segundo período de missões de campo (RM2). Produzido no âmbito do Ajuste Direto n.º 11/DRPM/2022 - Caracterização dos habitats de profundidade, com vista ao seu mapeamento até ao limite exterior da subárea dos Açores da zona económica exclusiva portuguesa. Instituto de Investigação em Ciências do Mar - Okeanos, Universidade dos Açores, Horta, Portugal. 172pp.

## *3.3 Analysis of data, images, samples and production of lists and catalogues of species and habitats (Task 3)*

Analysis of images to characterize the deep-sea biodiversity and habitats in the Azores

During this provision of service, we not only analysed the video images collected in previous years (section 3.2), but have also analysed about 145 new dives collected in 2023 that resulted in 11 972 new records of deep-sea biodiversity in the Azores. Altogether, a total of 606 underwater dives from all the 140 L3 areas have been processed at the level 1 and level 2 of annotation, resulting in 52,698 records of deep-sea benthic megafauna inside the Azores EEZ. The video dataset was expanded by 3.5 times when compared to the 16 799 records reported in R1. The analysis of the images collected in the deep-sea of the Azores also allowed for the main benthic communities of the invertebrate megafauna to be identified, resulting in a list that includes 39 biological communities including coral gardens (23), cold-water coral reefs (2), sponge aggregations (9), xenophoyphore aggregations (1) and other fauna types (4). Those communities have been identified in the video images and a specific database containing their spatial distribution has been created.

Catalogues of the Azores deep-sea biodiversity

During this provision of service, the first Digital Catalogue of Deep-Sea Species and Habitats of the Azores (CD2) was developed, a digital tool that incorporates information on the diversity of species and biological communities found in the deep sea of the Azores. The catalogue is composed of a large database of still images extracted from the video footage collected in the Azores in recent years that include sessile (or low mobility) benthic invertebrate species and benthopelagic (bottom-associated) fish, as well as invertebrate communities identified down to 1,000 m depth. All taxa observed in the video footage were classified into taxonomic categories named OTUs (Operational Taxonomic Units), which are associated to a specific and unique reference number based on existing knowledge of the species given for the Azores. At the current stage of development, the catalogue contains **410** OTUs, all of them with selected images and associated metadata. More than 60% of the OTUs have now been identified down to genus or species level. The catalogue of biological communities compiles images and information regarding the benthic communities that are identified from the underwater images based on their characteristic species. At the present stage of development, the digital catalogue includes **39** biological communities, the vast majority being coral gardens (23) and sponge aggregations (9).

ATLAS of the Azores geomorphological units

The information obtained during the provision of services was used to produce digital technical sheets for each geomorphological unit with the aim of facilitating spatial understanding of the Azores deep-sea and summarizing existing information to support the spatial management of human activities and the organization and planning of future exploration work. The final aversion of ATLAS of the Azores geomorphological units (FTD2) contain the description of around **all 140 areas** that have been identified in the Azores sub-area of the Portuguese exclusive economic zone (EEZ). The ATLAS was structured according to the contents compiled for each geomorphological unit and include a brief description of the location of the unit, the main characteristics of its geomorphology, the oceanographic conditions, and the biological communities observed. Each digital technical sheet is divided into four main sections.

Delivered products

Dominguez-Carrió C, Morato T, Ramos M, Medeiros V, Edery G, Carneiro I, Gonçalves G, Carreiro-Silva M (2023). Catálogo digital de espécies e habitats do mar profundo dos açores (CD0). Produzido no âmbito do Ajuste Direto n.º 11/DRPM/2022 - Caracterização dos habitats de profundidade, com vista ao seu mapeamento até ao limite exterior da subárea dos Açores da zona económica exclusiva portuguesa. Instituto de Investigação em Ciências do Mar - Okeanos, Universidade dos Açores, Horta, Portugal. 32 pp.

Dominguez-Carrió C, Morato T, Ramos M, Medeiros V, Edery G, Carneiro I, Gonçalves G, Carreiro-Silva M (2023). Catálogo digital de espécies e habitats do mar profundo dos açores (CD1). Produzido no âmbito do Ajuste Direto n.º 11/DRPM/2022 - Caracterização dos habitats de profundidade, com vista ao seu mapeamento até ao limite exterior da subárea dos Açores da zona económica exclusiva portuguesa. Instituto de Investigação em Ciências do Mar - Okeanos, Universidade dos Açores, Horta, Portugal. 110 pp.

Dominguez-Carrió C, Morato T, Ramos M, Edery G, Pladevall M, Porteiro F, Carneiro I, Gonçalves G, Medeiros V, Carreiro-Silva M (2023). Catálogo digital de espécies e habitats do mar profundo dos açores (CD2). Produzido no âmbito do Ajuste Direto n.º 11/DRPM/2022 - Caracterização dos habitats de profundidade, com vista ao seu mapeamento até ao limite exterior da subárea dos Açores da zona económica exclusiva portuguesa. Instituto de Investigação em Ciências do Mar - Okeanos, Universidade dos Açores, Horta, Portugal. 30 pp.

Morato, T., C. Dominguez-Carrió, L. Fauconnet, G.H. Taranto, L. Rodrigues, G. Gonçalves, I. Carneiro, M. Ramos, J. Balsa, M.P. Vilavendrell, V. Medeiros, M. Carreiro-Silva (2023). Fichas técnicas digitais das unidades geomorfológicas do mar profundo dos Açores (FTD0). Produzido no âmbito do Ajuste Direto n.º 11/DRPM/2022 - Caracterização dos habitats de profundidade, com vista ao seu mapeamento até ao limite exterior da subárea dos Açores da zona económica exclusiva portuguesa. Instituto de Investigação em Ciências do Mar - Okeanos, Universidade dos Açores, Horta, Portugal. 11pp

Morato, T., C. Dominguez-Carrió, L. Fauconnet, G.H. Taranto, L. Rodrigues, G. Gonçalves, I. Carneiro, M. Ramos, J. Balsa, M.P. Vilavendrell, V. Medeiros, M. Carreiro-Silva (2023). Fichas técnicas digitais das unidades geomorfológicas do mar profundo dos Açores (FTD1). Produzido no âmbito do Ajuste Direto n.º 11/DRPM/2022 - Caracterização dos habitats de profundidade, com vista ao seu mapeamento até ao limite exterior da subárea dos Açores da zona económica exclusiva portuguesa. Instituto de Investigação em Ciências do Mar - Okeanos, Universidade dos Açores, Horta, Portugal. 15pp.

Morato, T., C. Dominguez-Carrió, L. Fauconnet, G.H. Taranto, L. Rodrigues, M. Ramos, G. Gonçalves, I. Carneiro, J. Balsa, T. Cerqueira, G. Edery, I. Bruno, M. Pladevall, A. Godinho, S. Gomes, V. Medeiros, M. Carreiro-Silva (2023). Fichas técnicas digitais das unidades geomorfológicas do mar profundo dos Açores (FTD2). Produzido no âmbito do Ajuste Direto n.º 11/DRPM/2022 - Caracterização dos habitats de profundidade, com vista ao seu mapeamento até ao limite exterior da subárea dos Açores da zona económica exclusiva portuguesa. Instituto de Investigação em Ciências do Mar - Okeanos, Universidade dos Açores, Horta, Portugal. 17 pp.

## *3.4 Integration of data in the Azores Marine Geographic Information System (SIGMAR-Azores), distribution maps and advice on conservation needs (Task 4)*

Integration of the databases BD2 in SIGMAR–Azores

After the exhaustive compilation of data on the deep-sea biodiversity of the Azores down to 1,000 m depth (see section 6), we produced georeferenced database with the respective metadata, following the interoperability recommendations of regional authorities, as well as international harmonization standards. The database compiled to date contain 60,733 records of marine biodiversity in the deep sea of the Azores with an emphasis on rates that indicate the presence of VME. Here, we present a brief description of the final version of the georeferenced database on the biodiversity of the deep sea of the Azores (BD2) containing the pre-existing information updated with the new information acquired, on the spatial distribution of VME indicator species and biological communities. As described in R0, in addition to the exhaustive compilation on the deep-sea biodiversity of the Azores down to 1,000 m depth, presented in the form of BD0, the revised version of the database (BD1), and the final version of the data (BD2) was based on 5 main groups of information sources:

- The georeferenced database (BD0) of pre-existing information, as described in section 1.2 of the R0 report, presented in the form of:
    - species occurrence data resulting from analyzes of pre-existing videos (videoAnnotationDB)
    - data from the Marine Biological Reference Collection of the University of the Azores (COLETA), as well as the respective database (coletaDB)
    - public global data contained in the Ocean Biogeographic Information System portal (obisDB), the NOAA Deep Sea Coral Data Portal (noaaDB), and the ICES Vulnerable Marine Ecosystems data portal (icesDB).
- Data resulting from the annotation of the deep sea images of the Azores collected between 2018 and 2022 (included in videoAnnotationDB), as described in section 2.5 of the R0 report.
- Data resulting from the annotation of the deep sea images of the Azores collected during the research cruises carried out in 2023 (included in videoAnnotationDB), as described in section 3.1 of the R0 report.
- Data resulting from updating the Azores Marine Biodiversity Reference Collection (COLETA) database with information collected between 2019 and 2022 and the new samples collected in 2023 (included in colectionDB), as described in section 2.6 of the R0 report.
- Data on the occurrences of biological communities (communitiesDB) in the deep sea of the Azores, described in the R1 report, as described in section 3.2 of the R0 report.

The information contained in the updated version of the collectionDB contains, in addition to the pre-existing information, the cataloguing of the specimens collected during the period 2019 and 2022, as well as the records collected and catalogued in 2023. The updated coletaDB database contains 6,796 occurrence records, 23% more than reported in BD0 and 6% more than reported in BD1. It should be noted that all records have already been incorporated into the database, even those collected very recently. We therefore consider that the collectionDB is up to date, as described in Section 2.6 of the R0 report. The database also contains new occurrence records resulting from the annotation of 145 videos collected during the surveys carried out between 2019 and 2023. The updated database of deep-sea biodiversity in the Azores observed in the videos collected down to 1,000 m depth (videoAnnotationDB) contains data from 606 video transects, 460 more than in BD0. The new analyses resulted in 37,980 new records of occurrence within the Azores EEZ. On November 1, July 2023, videoAnnotationDB contained a total of 52 697 records, about 3.5 times more than reported in BD0 (16 838), and 28% more than reported in BD1 (41 271). The global databases remained unchanged from that reported in BD0 and BD1 with 1240 records, including 1,079 records of cold-water corals and 161 records of deep-sea sponges. In the final version of the georeferenced database on the biodiversity of the deep sea of the Azores (BD2), the structured and organized database in BD0 and BD1 was maintained, allowing for the systematized compilation of this information.

Finally, communitiesDB contains 246 records of the occurrence of biological communities in the deep sea of the Azores, including 139 records of Coral gardens, 66 of Deep-sea sponge aggregations, 28 of Cold-water coral reefs and 13 records of other communities.

The structure and metadata of the Azores deep sea biodiversity occurrence databases have not undergone significant changes in relation to what was reported in BD0 and BD1. It should be noted that the suggestions and comments offered by technicians from the Regional Administration of the Azores, regarding the presentation of metadata in GeMA format, were considered and all necessary changes were introduced. All databases produced were converted and integrated into a GIS environment and produced output formats compatible with the needs of SIGMAR Açores, namely .csv files. No output data was produced in shapefile format, as it was considered inappropriate by regional administration technicians. The geographic database integrates the respective metadata in the formats and standards defined by the Azores Metadata Manager (GeMA). The metadata was created on the GEMA platform in accordance with the Azores Metadata Manager User Manual (GeMA) and the METADATA Filling Manual in its Versions #6, of June 2021 (INSPIRE AÇORES, 2021a,b) and exported in .xml format.

These databases were made available for viewing on a web portal created for this purpose (see section 3.3). The portal continues to be developed and is a dynamic tool, in digital format, where the databases will be continuously updated as new records are produced. The portal is hosted on the ADSR Group website.

#### Detailed maps of the distribution of deep-sea biodiversity the Azores

The occurrence and distribution data of deep-sea species compiled and transferred to SIGMAR-Açores was used to produce a set of species distribution maps, which are included in sections 6, 7 and 8 of this report. For its construction, a standardized map model was developed and applied to all the results.

#### Advice on conservation needs

The final report also aims to present recommendations for the protection of these ecosystems and obtaining or maintaining their good environmental status, in accordance with the requirements of the Marine Strategy Framework Directive. This section contains suggestions to 1) identify aiming to Protec deep sea ecosystems, 2) to assess Descriptor 6 of the Marine Strategy Framework Directive for the deep sea, including proposals and suggestions on how to identify reference conditions for reporting purposes, and 3) to assess the pressures and threats from human activities in the deep-sea at sea with the potential to affect these ecosystems.

For these purposes, we evaluated the 140 geomorphological structures of the Azores in relation to each of the five FAO criteria to define what constitutes a VME, based on the information compiled, collected and analysed during this project. The evaluation was based on the species and communities found in each geomorphological structure as well as a measure of their abundance in the BD2 Georeferenced database containing information of species and habitats (see section 7). In order to support the assessments of the Descriptor 6 criteria (D6C3 and D6C5), we carried out an assessment of the degree of pressure and threat relating to human activities. We adopted a standard methodology for this purpose, such as that described in Fernandes et al. (2020) which starts from the characterization and mapping of conservation values (section 10) and pressures arising from activities and potential uses. For this purpose, we compiled the human activities that affect the deep sea of the Azores up to 1,000 m deep, through the analysis of existing Vessel Monitoring System data in the region. We also developed matrices of pressures and threats that allow an objective assessment of impacts and contribute to the assessment of D6C3 and D6C5. Over the past years, the Regional Directorate for Maritime Policies (DRPM) of the Regional Government of the Azores have produced several documents to support the implementation of the strategy. In particular, an update to the Initial Marine Strategies Report for the Azores subdivision was written, which included, in Part D, a reassessment of the environmental status and the definition of environmental targets for the 11 qualitative descriptors, including descriptor 6, seabed integrity (D6). In this context, we evaluated methodologies to analyze the data collected throughout the project to define D6C3 assessment methodologies that concern the "Spatial extent of each type of habitat that is negatively affected by physical disturbances, through the alteration of its biotic and abiotic structure and of its functions", and D6C5 "The extent of the negative effects of anthropogenic pressures on the condition of the habitat type, including alteration of its biotic and abiotic structure and functions, does not exceed a specified proportion of the natural extent of the habitat type in evaluation zone."

Delivered products

Morato, T., C. Dominguez-Carrió, L. Rodrigues, M. Ramos, G. Gonçalves, I. Carneiro, G.H. Taranto, J. Balsa, M.P. Vilavendrell, L. Fauconnet, V. Medeiros, M. Carreiro-Silva (2023). Base de dados georreferenciada da informação pré-existente (BD0) sobre a biodiversidade do mar profundo dos Açores (R0). Produzido no âmbito do Ajuste Direto n.º 11/DRPM/2022 - Caracterização dos habitats de profundidade, com vista ao seu mapeamento até ao limite exterior da subárea dos Açores da zona económica exclusiva portuguesa. Instituto de Investigação em Ciências do Mar - Okeanos, Universidade dos Açores, Horta, Portugal. 28pp.

Morato, T., C. Dominguez-Carrió, L. Rodrigues, M. Ramos, G. Gonçalves, I. Carneiro, J. Balsa, M.P. Vilavendrell, G.H. Taranto, L. Fauconnet, E. Gal·la, I. Bruno, V. Medeiros, M. Carreiro-Silva (2023). Base de dados georreferenciada contendo informação pré-existente e a nova informação compilada e analisada sobre a biodiversidade do mar profundo dos Açores (BD1). Produzido no âmbito do Ajuste Direto n.º 11/DRPM/2022 - Caracterização dos habitats de profundidade, com vista ao seu mapeamento até ao limite exterior da subárea

dos Açores da zona económica exclusiva portuguesa. Instituto de Investigação em Ciências do Mar - Okeanos, Universidade dos Açores, Horta, Portugal. 36pp.

Morato, T., C. Dominguez-Carrió, L. Rodrigues, M. Ramos, G. Gonçalves, I. Carneiro, J. Balsa, L. Fauconnet, G.H. Taranto, T. Cerqueira, G. Edery, I. Bruno, M. Pladevall, A. Godinho, S. Gomes, M. Carreiro-Silva (2023). Base de dados georreferenciada sobre a biodiversidade dos mar profundo dos Açores (BD2): versão final contendo a informação pré-existente atualizada com a nova informação adquirida. Produzido no âmbito do Ajuste Direto n.º 11/DRPM/2022 - Caracterização dos habitats de profundidade, com vista ao seu mapeamento até ao limite exterior da subárea dos Açores da zona económica exclusiva portuguesa. Instituto de Investigação em Ciências do Mar - Okeanos, Universidade dos Açores, Horta, Portugal. 38pp.

Morato, T., C. Dominguez-Carrió, L. Rodrigues, M. Ramos, G.H. Taranto, G. Gonçalves, I. Carneiro, L. Fauconnet, J. Balsa, T. Cerqueira, G. Edery, I. Bruno, M. Pladevall, A. Godinho, S. Gomes, I. Areosa, F. Porteiro, M. Carreiro-Silva (2023). Azores deep-sea ecosystem: final report with protection recommendations (RF). Direct Adjustment no 11/DRPM/2022 - Characterization of deep-sea habitats, with a view to mapping them up to the outer limit of the Azores sub-area of the Portuguese exclusive economic zone. Instituto de Investigação em Ciências do Mar - Okeanos, Universidade dos Açores, Horta, Portugal. 596.

## 4. Pre-existing information

Historically, the scientific knowledge about the diversity and structure of the benthic invertebrate fauna of the Azores relied on samples collected using nets or sleds (Porteiro, 2009), or on the evaluation of specimens provided by local fishers as bycatch (e.g., Sampaio et al., 2012). Advances in underwater robotics and imaging technology (Durden et al., 2015; Dominguez-Carrió et al., 2021) have enabled the visual investigation of deep-sea habitats, exponentially improving our understanding about the ecology of benthic species, as well as the spatial extent of the communities they form. During the past decade, the Azores Deep-Sea ecology Research group (ADSR), has assigned a great deal of resources into the exploration of the various deep-sea geomorphological features that can be found inside the Azores EEZ. Despite all these efforts, substantial gaps in scientific knowledge still existed (in January 2023) that could hamper the implementation of marine environmental policies in the Region, namely the Marine Strategy Framework Directive (MSFD) and its assessment of the environmental status, but also the Habitats, Birds, and Water Directives. Indeed, the Regional Directorate for Maritime Policies (DRPM), as the environmental authority for the marine environment in the Autonomous Region of the Azores (RAA), considered necessary to fill the knowledge gaps regarding the characterization of the deep sea in the Azores through the inventory and characterization of deep-sea habitats as well as vulnerable marine ecosystems (VMEs).

### *4.1 Pre-existing datasets*

Over the last 15 years, several scientific expeditions using different types of video platforms have visited the Azores and collected important amounts of video data. The collected footage derived from over 700 underwater video transects recorded by ROVs, towed-camera systems and the Azor drift-cam (among others), equalling (in January 2023) to a linear distance over the seabed of more than 700 kilometres. The set of video transects was obtained from more than 25 scientific cruises carried out in the Azores within the scope of national and international projects on board of different research vessels equipped with underwater video platforms. The existing underwater video transects down to 1,000 m span the whole EEZ, with 61 in Western Group of the Azores, 33 in the Northern Mid-Atlantic Ridge, 103 in the central Mid-Atlantic Ridge, 47 in the Southern Mid-Atlantic Ridge, 142 in the Northern Central Group of the Azores, 263 in the Southern Central Group of the Azores, and 76 in the Eastern Group of the Azores.

The Marine Biological Reference Collection (COLETA) contained, in January 2023, more than 11,481 records, of which about 5,500 refer to deep sea fauna such as Actinaria, Antipatharia, Hydrozoa, Octocorallia, Scleractinia, and Stylasteridae. In what concerns sponges, most of the records contained in the COLETA database were unidentified species but also spanned the whole Azores EZZ. As reported in R1, the data existing in the COLETA database was extracted and verified, in particular, considering atypical, suspicious or missing values, for example latitude, longitude or depth, and corrected whenever necessary.

With the aim of exhausting all potential sources of information, the information contained in public global databases, such as the ICES Vulnerable Marine Ecosystems data portal, the NOAA Deep Sea Coral Data Portal, and the Ocean Biogeographic Information System (OBIS), were also assessed but revealed to be of limited use.

### *4.2 Pre-existing information on VME indicator species*

The occurrence of cold-water corals in the Azores was first documented during major oceanographic expeditions during the late nineteenth century and throughout the 1900s. Results of historical research have contributed to the identification of the Azores as a cold-water coral hotspot in the NE Atlantic, with 186 species identified to date comprising species of the anthozoan subclass Octocorallia, orders Antipatharia and Scleractinia and of the hydrozoan family Stylasteridae (Braga-Henriques *et al.*, 2013; Sampaio *et al.*, 2019b). Thus, the list is likely to grow with increasing deep-sea sampling effort from ROV expeditions. The diversity of sponges in the Azores is reported to be high (about 458 species, Van Soest, 2012), where more than 330 species are bathyal and abyssal (World Porifera Database, Neele *et al.*, 2015). However, the sponges that inhabit remote areas of the Mid-Atlantic Ridge, adjacent seamounts as well as the slopes of the island bathyal platform, included in the Azores EEZ, were found to be little studied.

A large proportion of CWCs in the Azores belong to Octocorallia, including gorgonians, soft corals, and sea-pens, with 101 species identified (24 families) (Braga-Henriques *et al.*, 2013; Sampaio *et al.*, 2019b). From these, 27 taxa are listed as VME indicator species (ICES, 2020a), with the most recorded in the Azores being *Viminella flagellum*, *Callogorgia verticillata*, *Dentomuricea* aff. *meteor*, *Acanthogorgia* spp. based on historical and COLETA records (Braga-Henriques *et al.*, 2013). The Scleractinia in the Azores are composed of 58 species (10 families) of solitary (cup corals) and colonial scleractinians (stony corals) (see Appendix A in Braga-Henriques *et al.*, 2013). From the total species recorded, nine taxa are listed VME indicator species, with the most commonly recorded in the Azores being represented by the cup coral *Caryophyllia* spp., and the stony corals *Madrepora oculata* and *Lophelia pertusa*. The diversity of black corals (Antipatharia) in the Azores comprises 18 species (5 families) based on the inventory provided by Braga-Henriques *et al.*, (2013), although several still require taxonomic revision. Six of these taxa are listed as VME indicator species by ICES (2020). Black corals are important components of cold-water communities in the Azores at depths below 600 m, with *Leiopathes* sp., *Stichopathes gravieri*, *Bathypathes* spp. and *Parantipathes* spp., often forming mixed communities with octocorals and sponges. Stylasterids, commonly known as lace corals, are colonial hydrozoans of the Family Stylasteridae (Order Anthoathecata) that can produce a calcium carbonate skeleton, similar to scleractinians (Cairns, 2011). In the Azores, there are nine species of sylasterids based on historical record and COLETA (Braga-Henriques *et al.* 2013), of which three taxa are listed as VME indicators. Thirteen sponge taxa in the Azores are listed as VME indicators as they fit most of the VME criteria. Most of these species are large in size and form structurally complex sponge aggregations. Although there is limited knowledge on the ecological role of sponges in the Azores, evidence form other regions suggests that sponges serve as habitat for numerous invertebrate and fish species (e.g., Hawkes *et al.*, 2019), also performing numerous functions in bentho-pelagic coupling and nutrient recycling (Cathalot *et al.*, 2015; Maldonado *et al.*, 2019; Rooks *et al.*, 2020).

### *4.3 Pre-existing information on VME indicator biological communities*

The sole presence of VME indicator species is not considered sufficient to classify geomorphological features into VMEs, and data on the abundance and observed species associations should also be included in the assessments. For this reason, the set of deep-sea benthic communities present in the Azores, understood as groups of populations of species that interact together in space, should be first identified and described, and then evaluated in order to determine their vulnerability against human activities Identifying those that constitute VMCommunities (VMCs) leaves the term VME as a reference to a series of functionally interrelated and spatially overlapping communities that make up the ecosystem. The assessment to determine VMCs should also follow the 5 criteria for defining what constitutes a VME provided by FAO (2009), specifically adapted for the evaluation of benthic communities in the Azores.

The set of underwater video images available to the ADSR team, which cover seamounts/ridges along the Mid-Atlantic Ridge and island slopes of the central/eastern groups down to ~1,000 m depth, has provided evidence of the complexity of Azores deep-sea benthic ecosystem. Through visual assessments, 31 associations of conspicuous benthic species have now been identified and catalogued, providing in each case the main structuring taxa (i.e., indicator species). The vast majority of benthic communities identified so far can be included under the category of coral gardens (n=17), not undervaluing those classified as sponge grounds (n=8), and those formed by other taxa (n=4). The main species providing three-dimensional structure to the seabed of the Azores correspond to large gorgonian corals, which generate conspicuous communities widely distributed along the different geomorphological features evaluated. Deeper areas tend to host a wider variety of large and structuring cold-water corals besides Octocorallia, such as black corals, bamboo corals and reef-forming stony corals. Sponge grounds have also been widely observed, especially those formed by large lithistid sponges in shallower areas and aggregations of hexactinellid sponges below 600-700 m. From the 31 benthic communities identified from the video images, 20 were considered to fit the criteria for VMCs based on the presence and density of structurally complex bioengineering species, the uniqueness of their components and/or the intrinsic vulnerability of the community to disturbances, as well as their capacity of recovery. The processing of biological samples coupled with the and analysis of a large set of underwater video images during the provision of services will significantly improve our knowledge on the biological diversity of the Azores deep sea and our capacity to accurately identify and describe the composition of benthic communities and their spatial distribution.

### *4.4 Pre-existing spatial distributions of deep-sea biological diversity on geomorphological features*

The compilation of the existing information identified a total of 146 dives that have currently been annotated by the ADSR team to report the occurrence of megabenthic (morpho)species (or OTUs) in the deep sea of the Azores. These dives have been processed with annotations of level 1 (spatial scale of approximately 1,000) and level 2 (spatial scale of 100 with SACFOR), and are distributed throughout 27 sampling areas. All areas with annotation at level 2 are located along the Mid-Atlantic Ridge inside the EEZ of the Azores, covering a large latitudinal gradient that ranges from 36.8º N to 42.45º N.

The annotation of the underwater video transects has produced over 16,000 records of megabenthic (morpho)species (OTUs) for the deep-sea of the Azores. A summary of the occurrence data in the large areas explored, shown in high taxonomic levels, is provided. A large percentage of the occurrences relate to OTUs that belong to the to the phylum Cnidaria (38%; mostly cold-water corals) or Porifera (49%; sponges), with the remaining phyla much less represented. Regarding Cnidaria, the highest number of occurrences belong to the Subclass Octocorallia (n=3 889 occurrences), followed by Antipatharia (n=1,027) and Scleractinia (n=856). The study areas of Cavala, Gigante & Agulhas NE and Voador currently hold the highest number of records, although such values should be taken with caution since dissimilarities can derive from differences in sampling effort. Almost 200 OTUs belonging to the phyla Cnidaria and Porifera have currently been identified in the sampling areas. Octocorallia (n=60 OTUs) was by far the most diverse Subclass of the phylum Cnidaria, followed by Antipatharia (n=19) and Scleractinia (n=16). The sampling areas of Cavala and Gigante & Agulhas NE hosted the highest number of OTUs identified from the images, in both cases with more than 100 OTUs of Cnidaria and Porifera combined.

The taxonomic work that will be developed during the provision of services will significantly increase our capacity to detect and identify the megabenthic OTUs that appear in the video images of the Azores deep sea, which will improve the quality of the annotations shown here. Hence, changes to the identification and number of OTUs to be provided in the Video Database, and summarized in this report, should be expected by the end of the provision of services.

### *4.5 Pre-existing information on Vulnerable Marine Ecosystems*

The assessment of underwater features described against the VME criteria resulted only from a qualitative evaluation of the occurrence of VME indicator species and VME indicator communities of 27 sampling areas. A more careful evaluation of all the sampling areas will be performed during the project, after all areas have been surveyed and the data extracted and analysed. It should also be highlighted that many knowledge gaps still exist hampering a proper evaluation of the some VME criteria. This preliminary evaluation identified 12 geomorphologic features out of the 27 features that have a high probability of being considered VMEs. These included 2 sampling areas along the MAR (Gigante Agulhas SW and Cavalo), eight seamounts (Oscar, Gigante, Cavala, Beta, Voador, Condor, Dom João de Castro, and Formigas), and two areas on the slopes of Faial and Pico Islands (Faial Capelinhos and Pico Ponta Ilha N).

### *4.6 Preliminary evaluation of areas with sufficient pre-existing information and with substantial knowledge gaps*

To evaluate the geographic areas with sufficient pre-existing information and with substantial knowledge gaps we used the data compilation described in R1, mostly in what regards to the location of the video surveys collected during previous research projects. The compilation of the existing video data, identified a total of 727 video surveys (i.e., dives) for 906 km of seafloor in the deep sea (>200 m) spreading the whole Azores sub-area of the Portuguese EEZ down to 1,000 m depth: 61 in the western group, 33 in the northern MAR, 103 in the central MAR, 47 in the southern MAR, 141 in the northern central group, 262 in the southern central group, and 76 in the eastern group. From these videos, only about 143 have been annotated for substrate typology and the benthic megafauna, with the remaining 582 still to be analysed. After the assessment of each sampling area against the sampling statistics we concluded that there are 100 areas with sufficient video data and 39 areas in need of scientific exploration: 39; Hard-rock café, Southeast Kurchatov Europe, Sedlo W, Sedlo, Borda, João Leonardes, Ilha Azul E, São NE, São W Topo, Álvaro Martins, Terceira N, Terceira S, TE Terceira R E, Maçarico, Gastromar, Albatroz Norte, Heitor Alvares, Ferraria Norte, Ferraria Mar, Agulhas 18 milhas, São Mateus de Fora, Açor NW, Açor SE, Princesa Alice, Princesa Alice E, Princesa Alice SE, Alberto do Mónaco, São Miguel NE, São Miguel N, São Miguel NW, São Miguel W, São Miguel SW, São Miguel S, São Miguel SE, São Miguel E, Mar da Prata North, Mar da Prata, Sauerwein, Grande Norte. We also found that a major effort has to be done in order to translate the existing videos into useful information, since from the 725 video transects only 146 have been annotated, with 579 still to be analysed.

## 5. New surveys

In the context of the provision of services for the Regional Government of the Azores, we embraced the titanic challenge of finishing up visit all geomorphological features in the Azores EEZ, between 200 m and 1,000 m depth, with existing gaps in knowledge identified in the R1 report. The compilation of the existing video data described in the R1 report, identified a total of 39 areas in need of scientific exploration.

### *5.1 Summary of the new surveys*

During 2023, we were able to conduct five major research cruises to complement the existing information related to the deep-sea benthic biodiversity in the Azores down to 1,000m. These cruises were conducted on board the RV Arquipélago, the Maritime Tourist vessel (MT) Physeter, and the RV OceanXplorer. The five MapGES 2023 cruises were the continuation of the long-term strategy to map deep-sea biodiversity and identify

Vulnerable Marine Ecosystems (VMEs) in the Azores using the Azor drift-cam imagery system. As in other MapGES cruises, the objectives were to "(i) map benthic communities inhabiting unexplored seamounts, ridges, and island slopes, (ii) identify new areas that fit the FAO Vulnerable Marine Ecosystem definition; and (iii) determine distribution patterns of deep-sea benthic biodiversity in the Azores". The results of this cruise added to the previous contributions to identify the environmental drivers that determine the spatial distribution of deep-sea benthic biodiversity in the Azores. It also provides valuable information in the context of Good Environmental Status (GES), Marine Spatial Planning (MSP) and new insights on how to sustainably manage deep-sea ecosystems.

We performed several underwater video transects along the seafloor with the Azor drift-cam, the submersibles Neptune and Nadir and with the ROV Chimaera. It allows the recording of high-quality underwater video images of the seabed down to 1,000 m depth. The Azor drift-cam system was deployed from the RV Arquipélago, owned by the Government of the Azores, while the submarines and ROV were deployed from the RV OceanX. In each of the areas or geomorphological structures to be explored, a representative number of dives (or transects) were carried out with the video camera systems from a depth of about 1,000 m to the shallowest depth of each structure. The objective is to obtain underwater images to characterize the biodiversity along the entire bathymetric gradient and substrate types of each structure. The video transects were planned according to the best bathymetry available, so that the camera systems move from deeper to shallower areas. This methodology allowed the collected images to always have the best possible quality, maximizing the area of incidence of light and avoiding its dissipation in the water column (in the case of descending transects). The transects carried out with the Azor drift-cam were planned to last approximately 60 min in the seafloor, with the system drifting over the benthic habitats at an approximate speed of 0.5 to 1 knot. Under normal oceanographic conditions, each working day allowed for 5 to 6 dives, corresponding to around 5 km of bottom explored per day. The surveys carried out with the submersibles Neptune and Nadir and with the ROV Chimaera lasted approximately 4-6 hours in the seafloor, with the vehicles moving at an approximate speed of 0.2 to 0.4 knot. Each working day allowed for 1 dive with both subs and 1 dive with the ROV, covering similar areas, corresponding to around 1-2 km of bottom explored per day.

Altogether, the five research cruises lasted approximately **119** days at sea (74 in the MT Physeter, 29 in the RV Archipelago, and 16 in RVNI OceanXplorer), corresponding to **551** people at sea. We performed a total of **376** dives, covering about **227** km of seafloor and producing almost **437** hours of seafloor video footage We visited **41** unexplored areas in the Azores EEZ (Figure 6; Table 2):

- Hard Rock Café (north of Corvo Island) in the Western group of the Azores (n= 1);
- Kurchatov SE (previously called Southeast Kurchatov Europe) in the northern Mid-Atlantic Ridge (n= 1);
- The Sedlo W, Sedlo, Borda, João Leonardes, São Jorge NE, São Jorge E Topo (wrongly called São Jorge W Topo), Álvaro Martins seamount, Terceira N, Terceira S, Terceira E, Maçarico, Beirada de fora (previously included in Maçarico), Gastromar, Albatroz Norte, Ferraria Norte, and Ferraria Mar in the Northern part of the central group of the Azores (n= 16);
- Agulhas 18 Milhas, São Mateus de Fora, Boureé NE and Boureé NE (both previously known as Açor NW), de Guerne N (previously known as Açor SE), Princesa Alice peak, Princesa Alice W (previously included

in the Princesa Alice), Princesa Alice SW (previously known as Alberto do Mónaco), Picos S do Princesa Alice, Açor, and De Guerne (previously included in the Açor SE area) in the Southern part of the central group of the Azores (n= 11);

- São Miguel NE, São Miguel N, São Miguel NW, São Miguel W, São Miguel SW, São Miguel S, São Miguel S, São Miguel SE, Mar da Prata N, Mar da Prata, Sauerwein, and Grande Norte (n= 12).

We also visited **two** areas that were not listed in the R1 report, namely the Gaillard seamount and an area west of Picos S do Princesa Alice. Finally, we also revisited other geomorphological structures that needed complementary sampling efforts, namely:

- Isolado, Kurchatov N, Kurchatov SW, São Jorge SE, São Jorge S Urzelina, São Jorge NW, Faial W Capelinhos, Pico S Lajes, Pico NE, Agulhas das 12 Milhas, Mar da Fortuna, Serreta Mar, Terceira NE, Dom João de Castro, and Mar da Prata S.

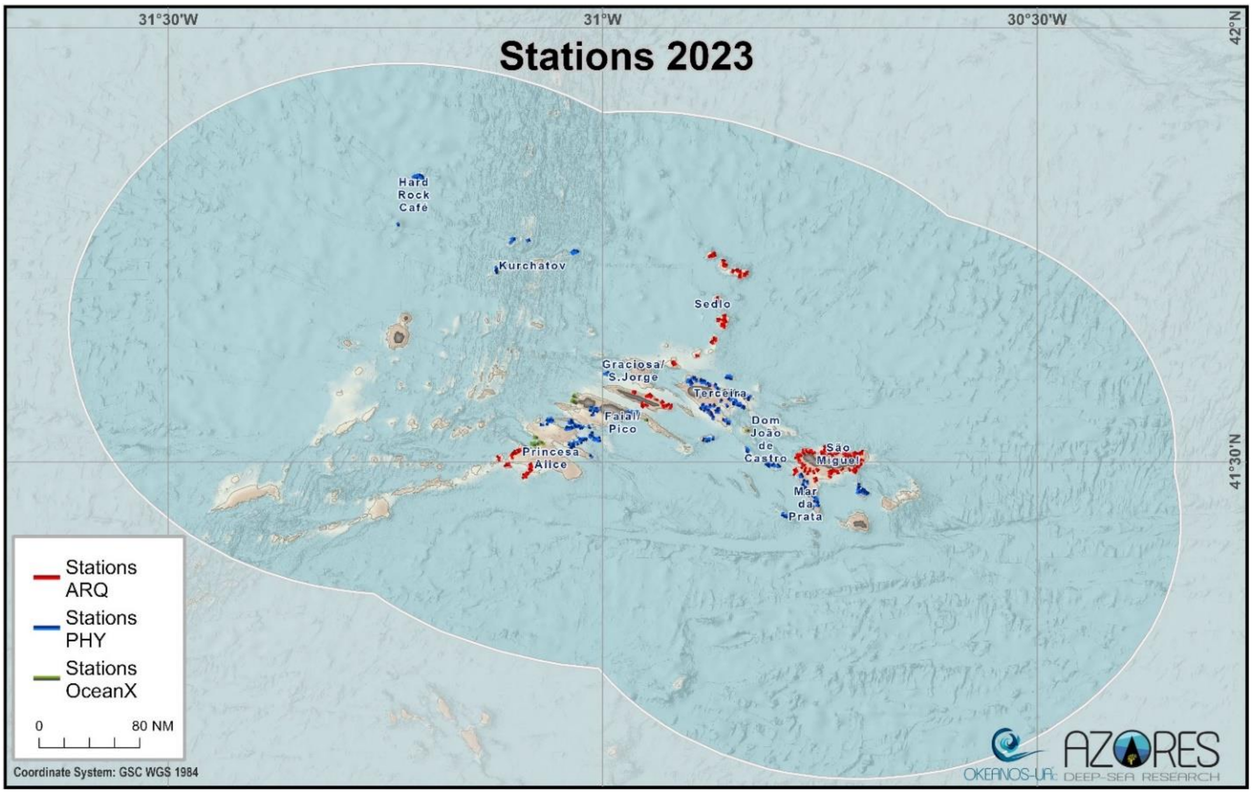



**Figure 6** Location of the 376 dives carried out during the 2023 field season.

**Table 2.** Research cruises conducted during the 2023 field season, with information about the number of dives, the total distance of seafloor covered, and the number of hours spent collecting video footage on the seafloor.

| Leg | Dates | Areas explored | Dives | Dist. (m) | Bottom time (h) |
|---|---|---|---|---|---|
| MT Physeter 1 | 15/05/2023-21/05/2023 | Banks south of Faial and Pico Island slopes: Faial S, São Mateus de Fora, Boureé NE, Pico NE | 27 | 15,920 | 27:26 |
| MT Physeter 2 | 30/05/2023-11/06/2023 | Banks south of Faial: De Guerne N, Boureé NE, Agulhas 12 Milhas, Agulhas 18 Milhas, and Açor bank | 25 | 14,410 | 20:58 |
| RV Arquipélago 1a | 08/07/2023-11/07/2023 | Geomorphological structures south of Princesa Alice bank | 23 | 9,100 | 21:52 |

| | | | | | |
|---|---|---|---|---|---|
| RV Arquipélago 1b | 14/07/2023-21/07/2023 | Sedlo, Borda, João Leonardes, Gaillard and Mar da Fortuna seamounts and the northern slopes of São Jorge Island | 41 | 26,900 | 40:21 |
| MT Physeter 3 | 14/07/2023-30/07/2023 | Terceira Island slopes: Terceira N, NE, E and S, Gastromar, Maçarico, and Álvaro Martins seamount | 67 | 38,260 | 71:31 |
| MT Physeter 4 | 31/07/2023 - 04/08/2023 | São Jorge Island slopes and banks: E Topo, NE, SE and S Urzelina | 12 | 10,380 | 12:48 |
| RV Arquipélago 2a | 19/08/2023 - 25/08/2023 | Perestrelo Bartolomeu, Kurchatov SE, Hard Rock Café, Petrov, Isolado, Kurchatov N, Kurchatov SW | 28 | 21,090 | 26:08 |
| RV Arquipélago 2b | 29/08/2023 - 09/09/2023 | Albatroz N, Ferraria N, Ferraria Mar, Sauerwein, Mar da Prata S, Mar da Prata, Mar da Prata N, Grande Norte | 51 | 25,710 | 50:23 |
| RV Arquipélago 2c | 14/09/2023 - 16/09/2023 | De Guerne | 2 | 1,660 | 02:47 |
| MT Physeter 5 | 15/08/2023 - 15/09/2023 | São Miguel Island slopes, banks and seamounts: São Miguel N, NW, W, SW, S, SE, E, NE and Mar da Prata N | 81 | 44,450 | 77:56 |
| RV OceanX 1 | 24/08/2023-08/09/2023 | Dom João de Castro seamount and Princesa Alice bank (Princesa Alice, Princesa Alice W, Bourée E) and South slopes of Faial and Pico islands | 19 | 19,040 | 84:30 |

## *5.2 Main achievements of the new surveys*

- We finally managed to explore the Sedlo seamount with the Azor drift-cam. From 2002 to 2005, Sedlo was the focus of an EU multidisciplinary research project, OASIS (Oceanic Seamounts: An Integrated Study), which showed highly complex hydrographic patterns with anticyclonic circulation around its three summits, driven mainly by the formation of the Taylor column. It is speculated that this seamount hosts one of the most important spawning grounds in the Azores for certain species of fish (e.g., orange roughy and alfonsinos).
- The Hard Rock Café seamount was finally explored with the Azor drift-cam. The hydrographic Institute have mapped this seamount in 2020 but given its location 210 nautical miles from the natural starting point of the MapGES cruises (Horta) and given its position to the north of the Azores archipelago (normally more affected by adverse weather conditions), the visit to this seamount was being postponed a few years ago. After all conditions were met, the Hard Rock Café was visited. It is a geomorphological structure that, due to its characteristics, was from the first moment on the list of the first options for the expansion of the Azores Marine Park, hence the doubled importance of this visit.
- It was also the first time that an extensive scientific survey was specifically designed to explore, map, and describe the deep-sea benthic communities that inhabit the banks, ridges, seamounts, and slopes located around São Miguel Island
- We also visited a seamount named Petrov. This area does not yet have high-resolution bathymetry data, so we tried to prospect the area looking for a peak between 300 m and 1,000 m depth. However, after launching the Azor drift-cam in search of a shallower peak we were unable to reach the bottom. All sonars on board indicated depths between 1,900 m and 2,500 m deep, indicating that this area is much deeper than current nautical charts demonstrate and highlighting, once again, the importance of carrying out multibeam bathymetry surveys in the Azores.
- Our explorations have added supporting evidence to consider the Sedlo seamount as an essential fish habitat. We found areas that are home to the orange roughy (*Hoplostethus atlanticus*) and discovered

that Sedlo, and other neighbouring seamounts, are home to a high number of deep-sea shark species, some of which are rarely seen in the Azores. We also discovered aggregations of the black coral *Leiopathes expansa* on the summit of Sedlo W, with most specimens being relatively small in size. This area appears to be a good candidate to be considered a Vulnerable Marine Ecosystem and should be kept on the list of priority areas for conservation in the Azores.

- Deep-sea explorations with the Azor drift-cam also added supporting evidence to consider Hard Rock Café and Isolado, Essential Fish Habitats. We found that these areas were both home to the highly endangered deep-sea fish orange roughy (*Hoplostethus atlanticus*) and both exhibited large schools of the wreckfish (*Polyprion americanus*). These areas also showed a high number of deep-sea shark species, some of which rarely observed in the Azores. Although these areas showed low abundances in terms of benthic megafauna, we detected some frequent colonies of the slow-growing black corals *Antipathes dichotoma* and *Leiopathes expansa*.
- We also explored the Borda, João Leonardes, and Gaillard seamounts, north of Graciosa Island. Together with Sedlo, these seamounts appear to host unique deep-sea benthic communities when compared to other areas of the Azores EEZ explored so far with the black corals *Leiopathes expansa* and *Parantipathes hirondelle*, the bamboo coral *Acanella arbuscula*, stylasterids of the genus *Errina*, the sea urchin sea bream *Cidaris cidaris* and lamellated sponges of the genus *Phakellia*, among others.
- The abundance, diversity, and condition in which the several benthic communities observed were found thriving on the Terceira island's slopes was particularly special. Despite these previously unexplored areas being subjected to considerable degrees of fishing effort, most of the benthic fauna observed was visually healthy and harboured many associated fish species as well. The main highlights of Terceira island's slopes surveys were the sighting of uncommonly large specimens of the coral *Dentomuricea* aff. *meteor* in Terceira N, quite possibly the largest specimens we have recorded so far in the Azores region, the detection of areas with the display of black coral aggregations such as *Leiopathes glaberrima* and *L. expansa*, and the observation of what we believe are small primnoid corals yet to be identified in at least two different seamounts in Terceira E area.
- Most seamounts on the way to and around São Miguel Island, such as Albatroz N, Ferraria N, Ferraria Mar, Mar da Prata and Grande Norte host interesting deep-sea benthic communities with the deeper areas demonstrating abundant coral gardens of both *Narella versluysi* and *Narella bellissima,* sometimes, in aggregation with *Callogorgia verticillata, Acanthogorgia* sp. or *Leiopathes expansa*. Shallower areas were mainly characterized by large gardens of *Viminella flagellum,* sometimes associated with *Callogorgia verticillata* and other times with frequent and large *Dentomuricea.*
- The Sauerwein ridge, between the islands of São Miguel and Santa Maria, had a surprisingly low biodiversity, highlighting once again the need to better understand the reasons that explain the spatial distribution patterns of benthic communities to better inform management and conservation of these vulnerable ecosystems.
- Although the Grande Norte seamount was clearly the area with the highest intensity of bottom fishing, where we observed several lost bottom longlines, the benthic communities observed appeared to be in good environmental condition, displaying large aggregations of *Callogorgia verticillata*. These

observations add to the evidence that hook-and-line fishing produces much smaller impacts when compared to other fishing gear.

- Also noteworthy is the observation, around the island of São Miguel, of some coral aggregations that seem to be particularly rare to observe in the Azores archipelago. These include (i) a vast area completely covered by a reef of the hard coral *Eguchipsammia cornucopia*; (ii) an extraordinarily dense coral garden that includes, among other species, the coral *Paragorgia johnsoni* (a species that does not appear to be very common on the islands' slopes), and particularly high densities of the primnoid species *Narella bellissima* and *N. versluysi*; iii) a vast area dominated by an unidentified species from the Stylasteridae family (i.e. lacy corals); and iv) an area dominated by a rare purplish coral, possibly belonging to the genus *Paramuricea*.
- Large colonies of black corals (*Leiopathes* sp.), possibly more than 1,000 years old, which are "hanging" on steep walls of the Princesa Alice bank. It is possible that before demersal fishing exploited this bank, these arborescent black corals, vulnerable to fishing, were much more abundant and larger and older. These corals are very slow growing and can live for thousands of years.
- One of the largest and densest gorgonian forests *Callogorgia verticillata* found in the Azores. This gorgonian forest, found on the Dom João de Castro seamount, is characterized by fan-shaped colonies whose feathery branches resemble palm leaves.
- Dense aggregations of the largest species of sponges that inhabit the deep sea of the Azores (e.g., *Characella pachastrelloides*, *Haliclona magna*), on the Princesa Alice bank. Sponges play a structuring role in the deep sea, increasing ecosystem productivity and creating habitat for other species.
- One of the few (and small) cold-water coral reefs of *Lophelia pertusa* and *Madrepora oculata* known in the Azores, found at around 850 m depth in the Capelinhos area, west of Faial. Hard cold-water coral reefs play an important role in deep-sea biogeochemical cycles but are very vulnerable to ocean acidification. Better understanding of their distribution and susceptibility to climate change are priority lines of research for the future.
- In one of the areas explored with multibeam, an unknown canyon (or gorge) was found, approximately 15 km long, 340 m wide and with cliffs approximately 100 m high. The canyons of the Azores are quite unknown habitats and where unique ecosystems can be found.
- The invasive alga *Rugulopteryx okamurae*, which in recent years has had an increasingly frequent presence along the Azorean coast, has been repeatedly observed in large patches up to depths of around 900 m, suggesting that the impact of this species on resident communities may not only limited to coastal areas, but also extends to the deep sea of the Azores. Therefore, in order to fully understand how *Rugulopteryx okamurae* alters the distribution and niche dynamics of native species and the extent of its impacts, there is a need to investigate how it affects low- to high-depth communities.

These research cruises made it possible to identify that a large part of the benthic communities, including corals and sponges, observed in the main demersal fishing grounds of the Azores (such as Princesa Alice, the slopes of Terceira and São Miguel Islands and Banco D. João de Castro) are still in good environmental condition and have a high natural and ecological value. However, some long-lived coral colonies with visible impacts from fishing were observed. These *in-situ* observations corroborate the conclusion of previous studies that suggest that well-regulated deep-sea fishing based on hook and line gear (preferably hand line) could contribute to the sustainable exploration of the deep sea.

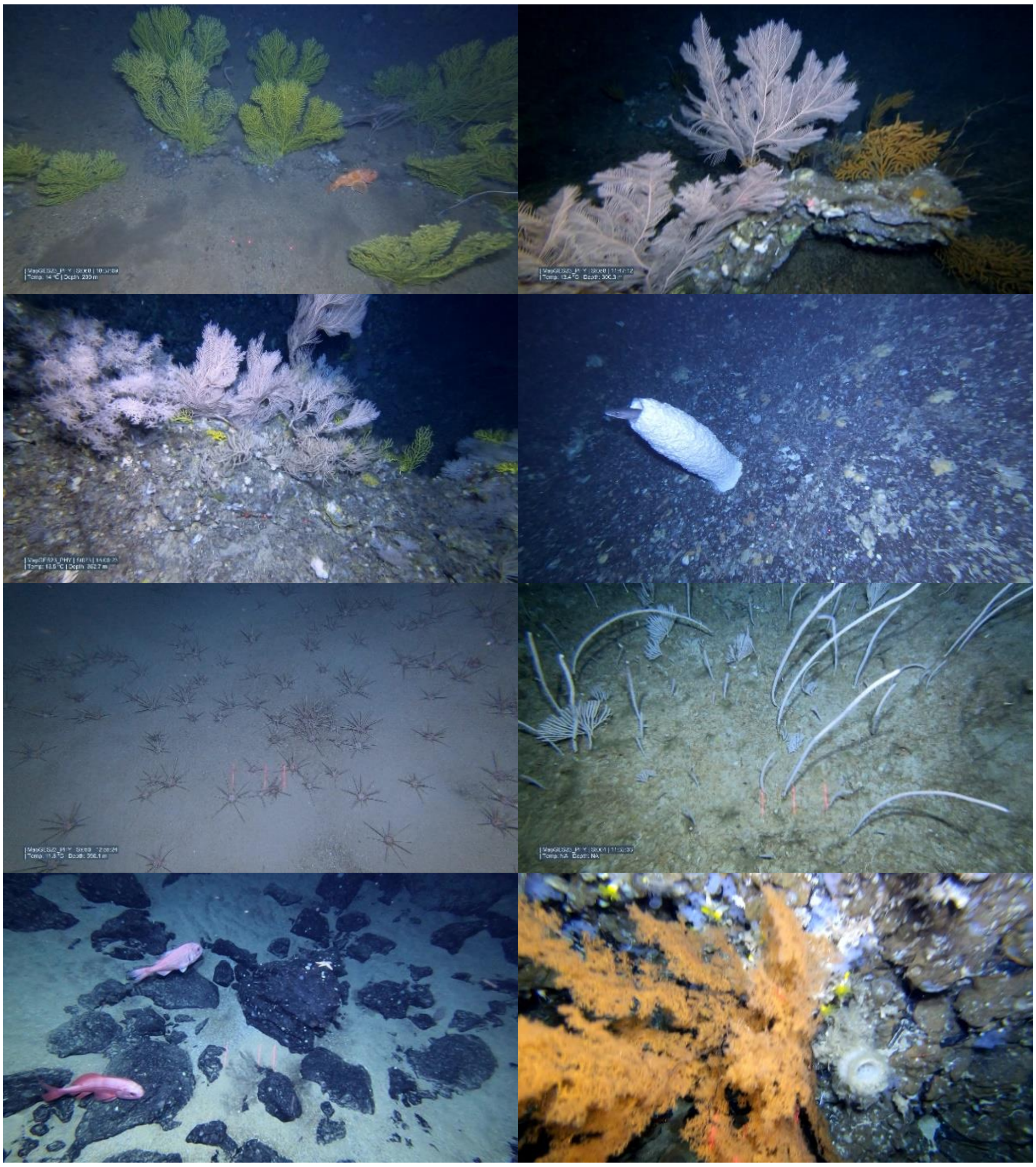


**Figure 7** Underwater images collected during the first season of the MapGES 2023 field activities onboard the RV Arquipélago and MT Physeter.

**Figure 8** Underwater images collected during the second season of the MapGES 2023 field activities onboard the RV Arquipélago, MT Physeter, and RV OceanX.

## *5.3 Biological samples obtained*

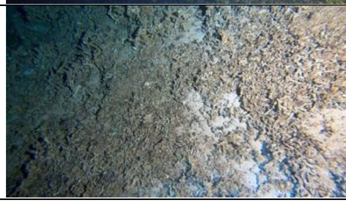
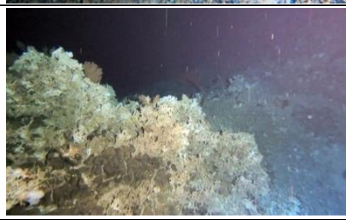
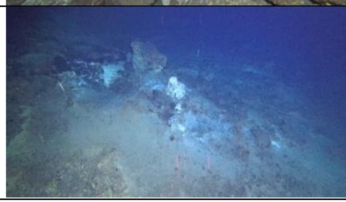
With the development of the Azor drift-cam and partnerships with the international scientific community, the amount of information regarding the composition and spatial distribution of benthic communities in the Azores was significantly enlarged over the last four years. However, the catalogue of the deep-sea benthic species of the Azores has been produced mostly based on the Azor drift-cam videos, and contains a large number of unidentified species, some of which could be new to science. In order to fill this knowledge gap, there was a need to collect biological samples of cold water-corals and sponges to make species identification from videos possible and, thus, better understand the biodiversity of the Azores deep sea. Having the possibility to build a true partnership with OceanX to continue deep-sea exploration in the Azores and to collect biological samples of unknown species has significantly contributed to the ongoing efforts to improve the understanding of deep-sea biodiversity in the Azores. During the OceanX 2023 cruise, we were able to collect 268 biological samples belonging to approximately 197 different morphotypes. It is likely that this sampling effort will help solving about 100 taxonomic questions.

## 6. Updated deep-sea biodiversity datasets

### *6.1 Video analysis*

The ADSR team analysed the images of the deep seabed collected during the scientific cruises following a standardized methodology to extract three levels of information from each dive: substrate type, composition of the benthic megafauna, and biological communities. The type of substrate was visually evaluated along the whole length of the transect, annotating the sections where each substrate is dominant. The selected substrate types are based on bottom composition and sediment grain size and correspond to categories recurrently used in ecological studies of the deep sea: Mud, Sand, Gravels, Cobbles and pebbles, Boulders, Flat rock, Outcropping rock, Vertical walls, Coral rubble, Coral framework, Lava flows, and Mineral deposits (Table 3). Considering that substrate type can vary at very small scales, and combinations of different substrate types commonly exist, and the annotation protocol followed allows for the selection of a primary (higher cover) and secondary substrate (lower cover) at any given time.

**Table 3.** List of substrate categories considered for the annotation of images collected in the deep sea of the Azores region, with an illustrative image of each.

| Susbtrate type | Example | Susbtrate type | Example |
|---|---|---|---|
| Mud |  | Outcropping rock |  |
| Sand |  | Vertical walls |  |
| Gravels |  | Coral rubble |  |
| Cobbles and pebbles |  | Coral framework |  |
| Boulders |  | Lava flows |  |
| Flat rock |  | Mineral deposits |  |

The assessment of the biological diversity that characterizes each of the areas explored was accomplished through the annotation of the benthic megafauna observed in the images. Benthic megafauna is defined as those sessile (or low mobility) invertebrate species of a size greater than 3 cm that can be identified from underwater images. Each (morpho)species observed was classified and given an Operational Taxonomic Unit (OTU) number, which allows the discrimination of the different (morpho)species at different levels of taxonomic identification. The annotation was done at two levels of detail according to two spatial scales (1,000 m and 100 m) to obtain information with sufficient resolution to analyse the data at the scale of the Azores EEZ (level 1) and at the scale of the geomorphological structures (level 2).

- Level 1 of annotation consisted on the registration of each OTU observed in each of the underwater dives. This rapid analysis generates a database of benthic megafauna occurrences at a spatial scale of approximately 1,000 m, permitting species distribution maps to be rapidly constructed, and the data can be used in other large-scale studies, as for example, the development of predictive models of species distributions.
- Level 2 of the annotation consisted on the registration of each OTU in segments of 100 meters in length along the whole underwater dive, providing at the same time a value of abundance based on the semi-quantitative SACFOR scale (Figure 9) (Connor & Hiscock, 1996). The abundance values of the SACFOR scale (Superabundant, Abundant, Common, Frequent, Occasional, Rare) are relative to the maximum size of each OTU, and divided into 4 categories: <1 cm, 1-3 cm, 3-15 cm and >15 cm (Table 4). Once the SACFOR values were assigned to the different OTUs in the 100 m segments, data regarding the environmental parameters available was added to the table, together with the geographical position of the sampling unit.

**Table 4.** SACFOR scale to quantify the abundance of OTUs that appeared in the images recorded in deep sea of the Azores. S: superabundant, A: abundant, C: common, F: frequent, O: occasional, R: rare.

| | Maximum size of the OTU | | | |
|---|---|---|---|---|
| Observed density | < 1 cm | 1-3 cm | 3-15 cm | > 15 cm |
| > 10 000·$m^{-2}$ | S | - | - | - |
| 1,000-9 999·$m^{-2}$ | A | S | - | - |
| 100-999·$m^{-2}$ | C | A | S | - |
| 10-99·$m^{-2}$ | F | C | A | S |
| 1-9·$m^{-2}$ | O | F | C | A |
| 1-9·10 $m^{-2}$ | R | O | F | C |
| 1-9·100 $m^{-2}$ | - | R | O | F |
| 1-9 ·1,000 $m^{-2}$ | - | - | R | O |
| <1·1,000 $m^{-2}$ | - | - | - | R |

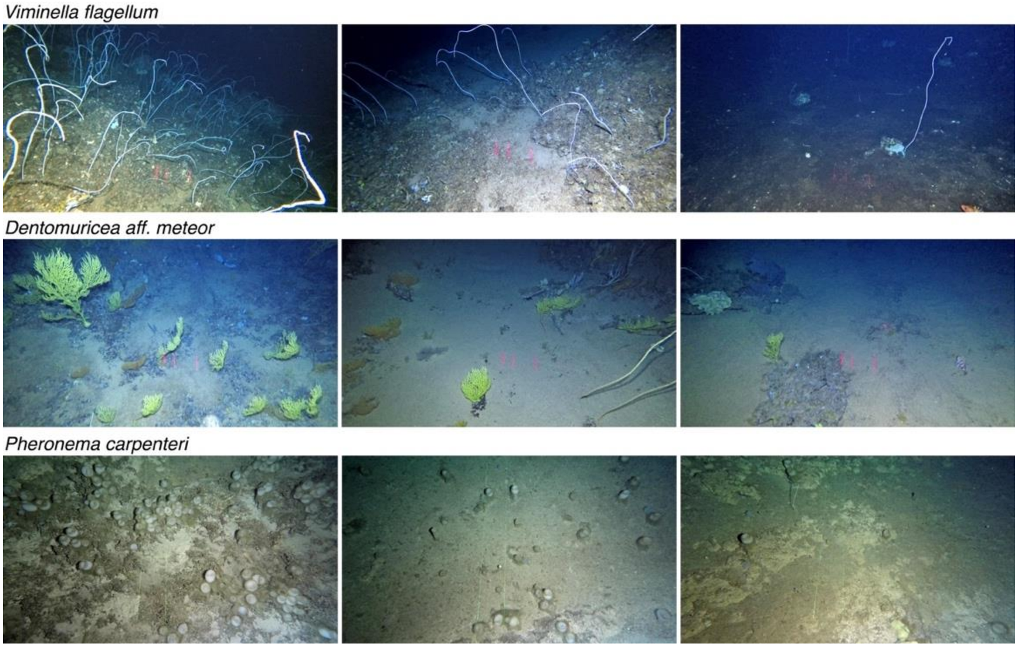
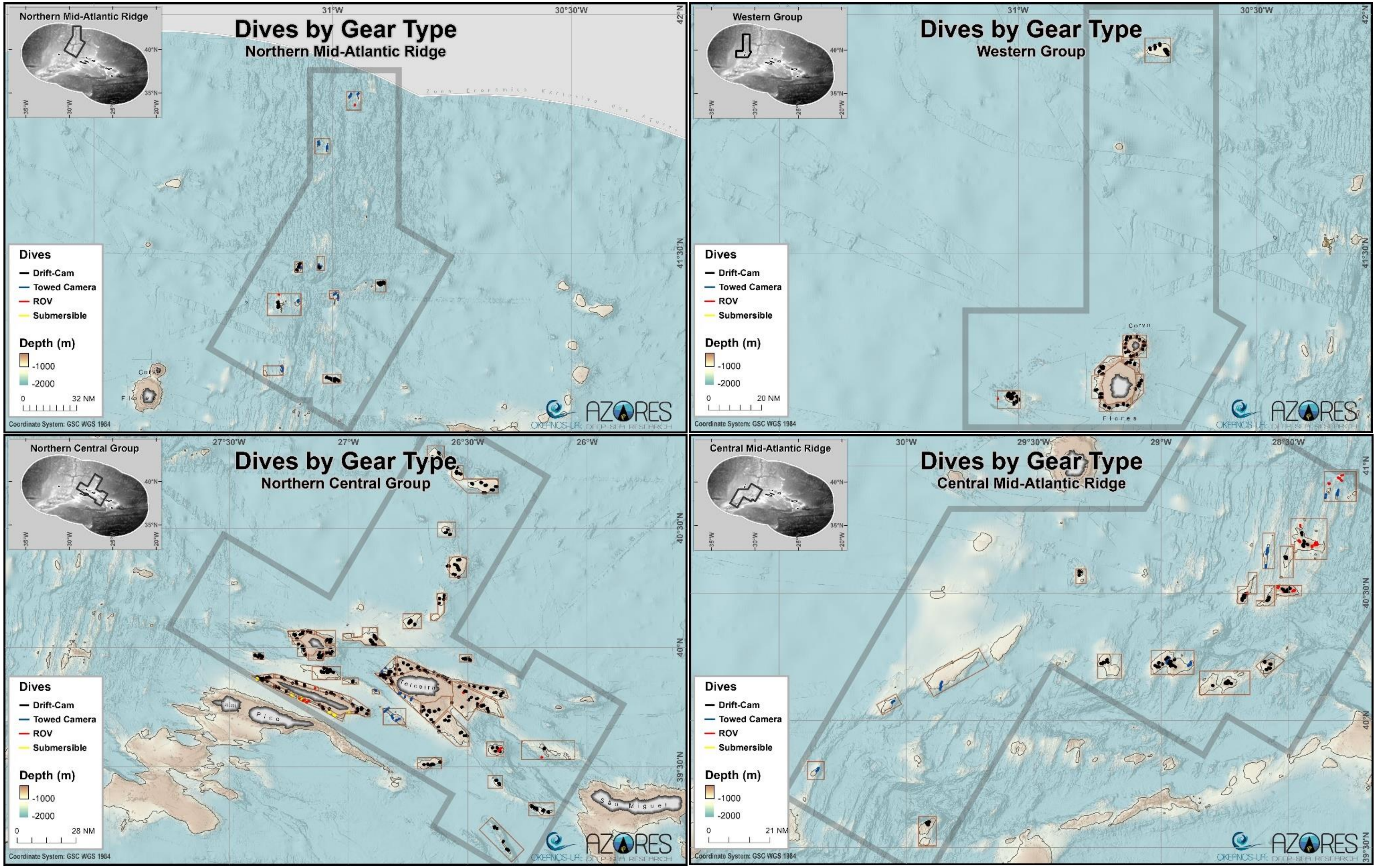



Figure 9 Examples of three VME indicator species (> 15 cm) common in the deep sea of the Azores (two corals and one sponge) reaching different density values on seamounts found in the region. Image credits: IMAR-UAç, Azor drift-cam.

### *6.2 Deep-sea Video database*

Over the last years, the ADSR team has made important efforts to develop, establish and implement a long-term plan for the collection of new images of the deep seafloor within the limits of the Azores EEZ. This strategy included the participation in large international scientific consortium and the attraction of large funding (e.g., ATAS, MERCES, and iAtlantic projects), the implementation of real partnerships with the international scientific community (e.g., NIOZ, IFREMER, IEO, OceanXplorer), allowing to take advantage of their resources towards our research agenda, and, more importantly, the development of cost-effective video collection tools (e.g., the Azor drift-cam). The present provision of services to the Regional Government of the Azores, allowed to significantly increase the spatial coverage of the rapid assessments of the deep-sea biodiversity in the Azores and to compile the "BD2 – Georeferenced database containing information of species and habitats, composed of the pre-existing information updated with new information acquired on the spatial distribution of habitat indicator species, known communities, and identified habitats".

Several scientific expeditions using different types of video platforms have visited the Azores and collected important amounts of video data. Table 5 summarizes the different scientific surveys carried out from 2009 to 2023 that provided imagery data that to evaluate the composition and distribution of deep-sea benthic fauna and communities inside the Azores EEZ, and for which the ADSR team is fully responsible for or currently has access to the video material. In this table, we also show the research cruises that visited areas of interest outside the Azores EEZ (areas coded as L09), namely around the Rainbow hydrothermal vent area and the Great Meteor seamount complex. The collected footage derives from over 1 155 underwater video transects recorded by ROVs, towed-camera systems, submersible and the Azor drift-cam, equalling to a linear distance over the seabed of more than 1 577 kilometres. The set of video transects was obtained from 30 scientific cruises carried out in the Azores within the scope of national and international projects on board of different research vessels equipped with underwater video platforms, such as NRP Gago Coutinho with ROV Luso (e.g., EMEPC/Luso/Açores/2009, CoralFISH, Blue Azores 2018), RV Sarmiento de Gamboa with ROV Liropus (e.g., ATLAS/MedWaves), RV Pelagia with its towed-camera frame (e.g., MIDAS, iMAR/Eurofleets+ 2021, 2022, Nico Leg12), RV Arquipélago with the Azor drift-cam (MapGES 2018, 2019, 2020, 2021, 2022, 2023), and the RV OceanXplorer with the ROV Chimaera and the Submersibles Nadir and Neptune (e.g., OceanX 2023) among others. The existing underwater video transects down to 1,000 m span the whole EEZ (Figure 10), with 69 in Western Group of the Azores, 49 in the Northern Mid-Atlantic Ridge, 103 in the central Mid-Atlantic Ridge, 47 in the Southern Mid-Atlantic Ridge, 295 in the Northern Central Group of the Azores, 392 in the Southern Central Group of the Azores, and 193 in the Eastern Group of the Azores, and 34 outside the EEZ but in areas of interest.


Northern Mid-Atlantic Ridge
Dives by Gear Type
Northern Mid-Atlantic Ridge
31°W
30°30'W
42°N
41°30'N
Dives
Drift-Cam
Towed Camera
ROV
Submersible
Depth (m)
-1000
-2000
0
32 NM
Coordinate System: GSC WGS 1984
AZORES
Western Group
Dives by Gear Type
Western Group
31°W
30°30'W
42°N
41°30'N
Corvo
Flores
Dives
Drift-Cam
Towed Camera
ROV
Submersible
Depth (m)
-1000
-2000
0
20 NM
Coordinate System: GSC WGS 1984
AZORES
Northern Central Group
Dives by Gear Type
Northern Central Group
27°30'W
27°W
26°30'W
26°W
40°30'N
40°N
39°30'N
Terceira
Pico
São Miguel
Dives
Drift-Cam
Towed Camera
ROV
Submersible
Depth (m)
-1000
-2000
0
28 NM
Coordinate System: GSC WGS 1984
AZORES
Central Mid-Atlantic Ridge
Dives by Gear Type
Central Mid-Atlantic Ridge
30°W
29°30'W
29°W
28°30'W
41°N
40°30'N
40°N
39°30'N
Dives
Drift-Cam
Towed Camera
ROV
Submersible
Depth (m)
-1000
-2000
0
21 NM
Coordinate System: GSC WGS 1984
AZORES

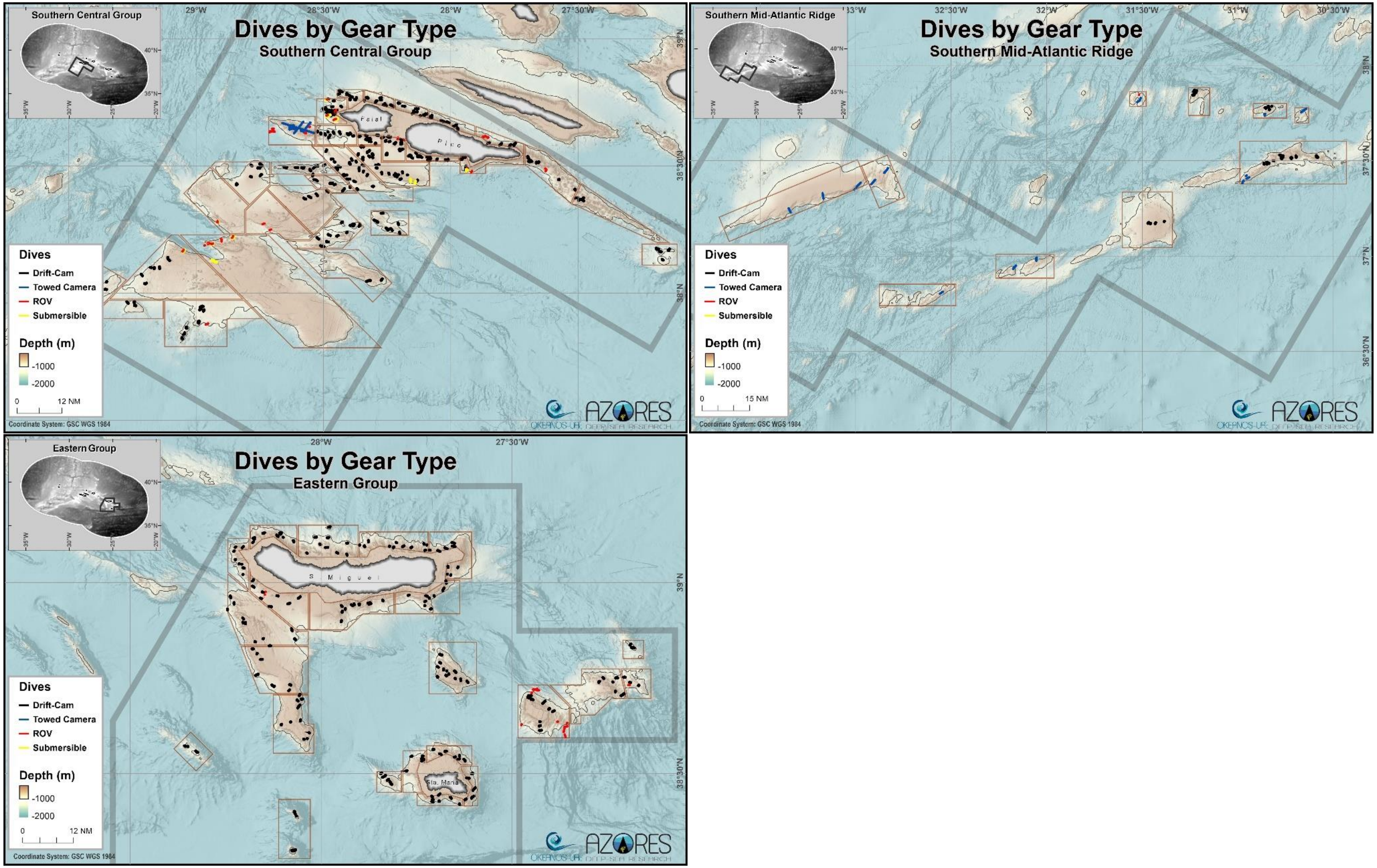



Figure 10 Location of the video transects in the EEZ of the Azores compiled to evaluate the deep-sea benthic fauna down to 1,000 m depth. Dives are colour coded by platform used to collect the videos.

Table 5. Scientific surveys that provided imagery data, that area available to ADSR team, to evaluate the deep-sea benthic fauna in the Azores EEZ, with reference to the platform used and the area explored. Other scientific expeditions with video platforms visited the Azores, but their data is not publicly available or accessible. In this table we also show research cruises that visited areas of interest but outside the Azores EEZ (L09).

| Survey Name | Year | Vessel | Gear | Areas L3 number | N Dives | Surveyed (m) | Reference |
|---|---|---|---|---|---|---|---|
| EMEPC/Luso/Açores/2009 | 2009 | NRP Gago Coutinho | ROV LUSO | L040102, L050214, L050218, L050303, L050403, L070107 | 11 | 3 789 | EMEPC, n.a. |
| CoralFISH 2010 LUSO | 2010 | NRP Gago Coutinho | ROV LUSO | L060112, L060207, L060211 | 7 | 5 500 | Tempera *et al.* (2011) |
| Treasure_2014 | 2014 | RV Pelagia | NIOZ towed camera | L090101, L090102 | 9 | 28 935 | |
| Treasure_2015 | 2015 | RV Pelagia | NIOZ towed camera | L090101, L090102 | 6 | 13 741 | |
| Treasure_2016 | 2016 | RV Pelagia | NIOZ towed camera | L090101, L090102, L090103 | 16 | 29 671 | Duineveld, G. (2017) |
| MedWaves 2016 | 2016 | RV Sarmiento de Gamboa | ROV Liropus | L070302 | 10 | 8 669 | Orejas *et al.* (2017) |
| MIDAS 64PE413 | 2016 | RV Pelagia | NIOZ towed camera ROV Cougar | L060112 | 37 | 44 428 | Not available |
| Blue Azores 2018 | 2018 | NRP Gago Coutinho | ROV | L030102, L030106, L030108, L050218, L060105, L060106 | 13 | 16 489 | Morato *et al.* (2019b) |
| TRANSECT L'Atalante 2018 | 2018 | RV L'Atalante | ROV Victor 6 000 | L030102 | 1 | 122 | Carreiro-Silva *et al.* (2019a) |
| MapGES 2018 | 2018 | RV Arquipélago | Azor drift-cam | L050402, L050403, L070203 | 11 | 8 010 | Morato *et al.* (2019d) |
| Nico L12 64PE441 | 2018 | RV Pelagia | NIOZ towed camera | L040202, L050221, L050305, L090102 | 7 | 15 907 | Dominguez-Carrió *et al.* (2019b) |
| ExploSea2 2019 | 2019 | RV Sarmiento de Gamboa | ROV LUSO | L030101, L030102, L060111, L060215 | 11 | 7 761 | Somoza *et al.*, (2020) |
| MapGES 2019 | 2019 | RV Arquipélago | Azor drift-cam | L020208, L030102, L030103, L030106, L030107, L030108, L030202, L030203, L030204, L030205, L030310, L040103, L040105, L040108, L040110, L060102, L060103, L060104, L060111, L060114, L060115 | 163 | 135 929 | Morato *et al.* (2020a) |
| Terceira 2019 64PE456 | 2019 | RV Pelagia | NIOZ towed camera | L050221, L050305 | 2 | 6 400 | Morato & Taranto (2019) |
| Rainbow 2019 64PE454 | 2019 | RV Pelagia | NIOZ towed camera | L040302, L040303, L090102 | 6 | 17 217 | Dominguez-Carrió *et al.* (2019a) |
| Blue Azores 2019 | 2019 | DSV Ada Rebikoff | Submersible LULA 1000 | L060113 | 2 | 3 600 | |
| Greenpeace Pole-to-Pole 2019 | 2019 | MV Esperanza | ROV Seaeye Cougar-XT | L030204, L030205 | 6 | 980 | Carreiro- Silva et al. (2019b) |
| Deep Walls 2020 – LULA 1000 | 2020 | DSV Ada Rebikoff | Submersible LULA 1000 | L050216, L050217, L050218, L060106 | 6 | ~2 400 | Carreiro-Silva *et al.* (2021) |
| MapGES 2020 | 2020 | RV Arquipélago | Azor drift-cam | L050105, L050106, L050203, L050204, L050205, L050206, L050207, L050208, L050211, L050212, L050302, L050306, L060108, L060113, L060202 | 100 | 78 613 | Morato *et al.*, (2020b) |
| Terceira 2020 64PE479 | 2020 | RV Pelagia | NIOZ towed camera | L050213, L050305 | 1 | 2 755 | Dominguez-Carrió *et al.* (2021b) |

| Survey Name | Year | Vessel | Gear | Areas L3 number | N Dives | Surveyed (m) | Reference |
|---|---|---|---|---|---|---|---|
| iMAR / Eurofleets+ 2021 | 2021 | RV Pelagia | NIOZ towed camera | L020101, L020102, L020202, L020203, L020205, L020206, L020207, L030101, L030104, L030204 | 22 | 52 610 | Morato *et al.* (2021) |
| MapGES 2021 | 2021 | RV Arquipélago | Azor drift-cam | L010201, L010202, L010203, L010204, L050220, L060101, L060102, L060103, L060104, L060106, L060107, L060108, L060109, L060110, L060111, L060113, L060201 | 155 | 138 994 | Not available |
| Terceira 2021 64PE488 | 2021 | RV Pelagia | NIOZ towed camera | L050306 | 1 | 1 029 | Ramos *et al.* (2021) |
| iMAR / Eurofleets+ 2022 | 2022 | RV Pelagia | NIOZ towed camera | L030305, L030306, L030309, L040102, L040105, L040106, L040108, L040201, L040302 | 12 | 32 489 | Not available |
| MapGES 2022 | 2022 | RV Arquipélago | Azor drift-cam | L010205, L010206, L010207, L010208, L010209, L010210, L030302, L050209, L050214, L050219, L050406, L060103, L060116, L070204, L070302, L070303, L070304, L070305, L070401, L070402, L070403, L070404, L070405 | 135 | 202 427 | Morato *et al.* (2022) |
| NOAA EX2205, EX2206 | 2022 | RV Okeanos Explorer | ROV Deep explorer | L020101, L020206, L010210, L050402, L070304 | 5 | 2 401 | NOAA Ocean Exploration, n.d. |
| MapGES 2023 ARQ | 2023 | RV Arquipélago | Azor drift-cam | L010101, L020202, L020203, L020204, L020206, L050101, L050102, L050103, L050104, L050105, L050106, L050203, L050209, L050214, L050215, L050311, L050404, L050405, L060209, L060213, L060215, L060216, L060217, L070201, L070202, L070203, L070205, L070301 | 148 | 249 720 | Morato *et al.* (2023a,b) |
| MapGES 2023 PHY | 2023 | MT Physeter | Azor drift-cam | L050215, L050216, L050217, L050218, L050301, L050302, L050303, L050304, L050306, L050307, L050308, L050309, L050310, L060105, L060108, L060109, L060201, L060202, L060203, L060204, L060206, L060208, L060210, L070101, L070102, L070103, L070104, L070105, L070106, L070107, L070108, L070201 | 206 | 258 466 | Morato *et al.* (2023a,b) |
| OceanX 2023 | 2023 | RV OceanXplorer | ROV Chimarea, Submersibles Nadir and Neptune | L050403, L060106, L060111, L060114, L060205, L060211, L060213 | 20 | 71 952 | Morato *et al.* (2023b) |

To date, **606** underwater dives have been processed at the level 1 and level 2 of annotation, assigning a value of the SACFOR scale to each OTU observed in the segments of 100 m in length (section 6.1). Video footages and annotations were obtained from all the **140** L3 areas (Figure 11). As of 1st November 2023, the database generated from the annotation of the benthic megafauna contains **52,698** records inside of the Azores EEZ (Table 6). Each of these records corresponds to the occurrence of one OTU in segments of 100 m along each dive, providing an estimated density value using the coding of the SACFOR scale. This database is now a fundamental tool for mapping the distribution of biodiversity and VME indicator taxa within the limits of the Azores EEZ. After a verification process carried out to check for inconsistencies and a careful determination of uncertain taxonomical identifications, the data contained in the video database was included in "BD2: Georeferenced database of deep-sea species and habitats".

The distribution of the records regarding cold-water corals and sponges is given in Figure 12. Broken down into lower taxonomic levels (Table 6), the database contains 855 occurrences of Actinaria (Figure 13), 2179 of Antipatharia (Figure 14), 955 of Hydrozoa (Order Lepthotheca) (Figure 15), 9777 of Octocorallia (Figure 16), 2499 of Scleractinia (Figure 17), and 1037 of hydrozoan family Stylasteridae (Figure 18). In what concerns sponges, from the total of 27 915 records, a large percentage are still classified as undetermined Porifera, which relates to morphospecies for which identification from video images results complicated and no physical specimens have yet been collected (Figure 19). Additionally, the database contains 458 records of the VME indicator taxa Xenophyophores (Figure 20) and 6 989 records of other taxonomic groups.

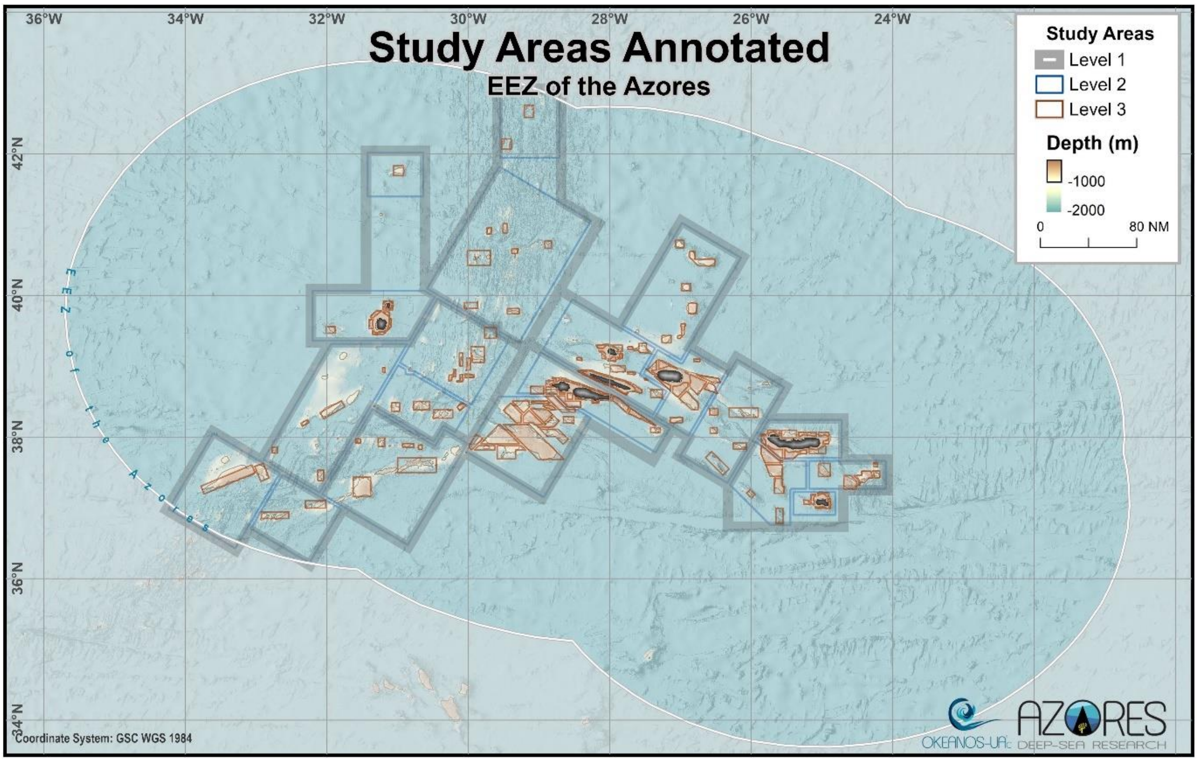



**Figure 11** Location of the Level 3 sampling (marked in red in the map) that have the megafauna observed in the video transects annotated using the SACFOR scale at intervals of 100 m in length.

**Table 6.** Summary of occurrences of megabenthic (morpho)species or OTUs, inside the Azores EEZ, derived from the analysis of the video images. Occurrence data was collected in intervals of 100 m in length for each dive, attributing to each identified OTU an abundance value following the scale SACFOR scale. Data as of November 1st, 2023.

| Phylum | Grouping | N |
|---|---|---|
| Cnidaria (incl. cold-water corals) | | 17 336 |
| | Actinaria | 855 |
| | Antipatharia | 2 179 |
| | Hydrozoa | 955 |
| | Octocorallia | 9 777 |
| | Scleractinia | 2 499 |
| | Stylasteridae | 1 037 |
| | Indet. | 34 |
| Porifera | | 27 915 |
| | Demospongiae | 12 552 |
| | Hexactinellida | 4 692 |
| | Indet. | 10 671 |
| Foraminifera | Xenophyophores | 458 |
| Bryozoa | | 363 |
| Mollusca | | 213 |
| Arthropoda | | 3 128 |
| Echinodermata | | 3 270 |
| Brachiopoda | | 15 |
| Total | | 52 698 |

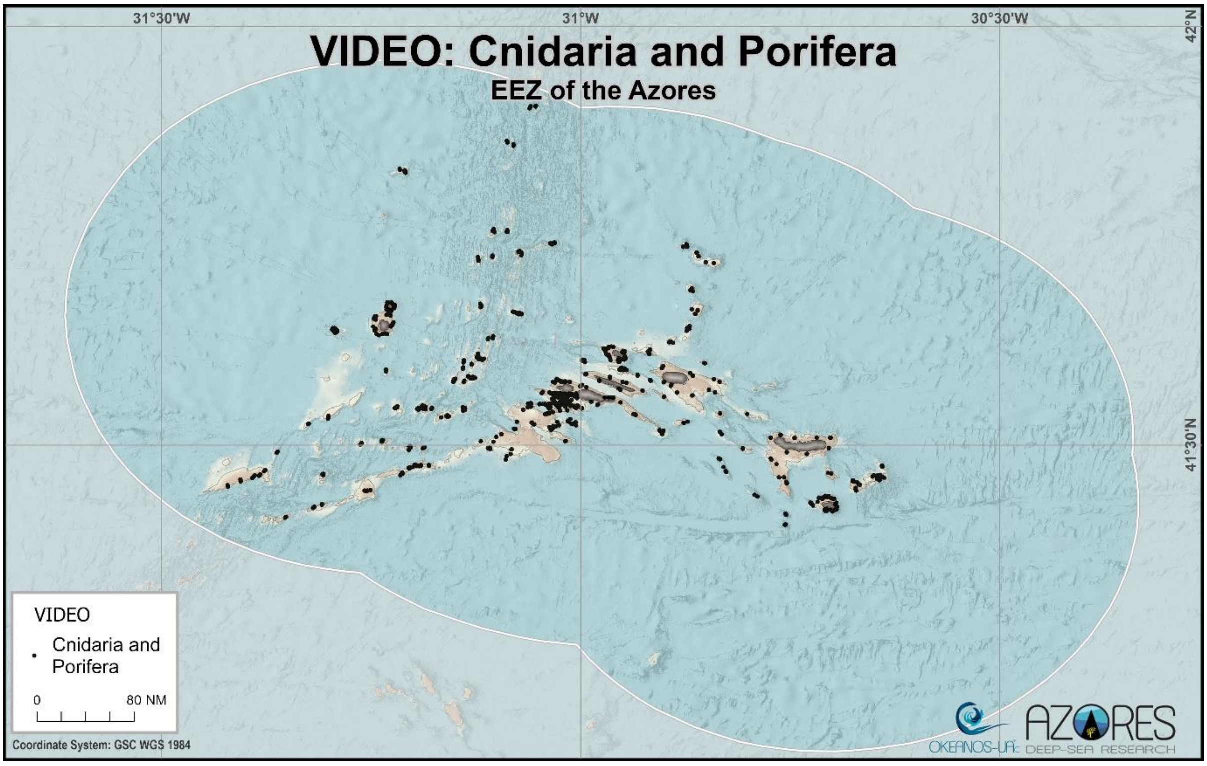



**Figure 12.** Geographical distribution of the 45 250 records of Cnidaria and Porifera, inside the Azores EEZ, contained in the video annotation database, as of November 1st, 2023.

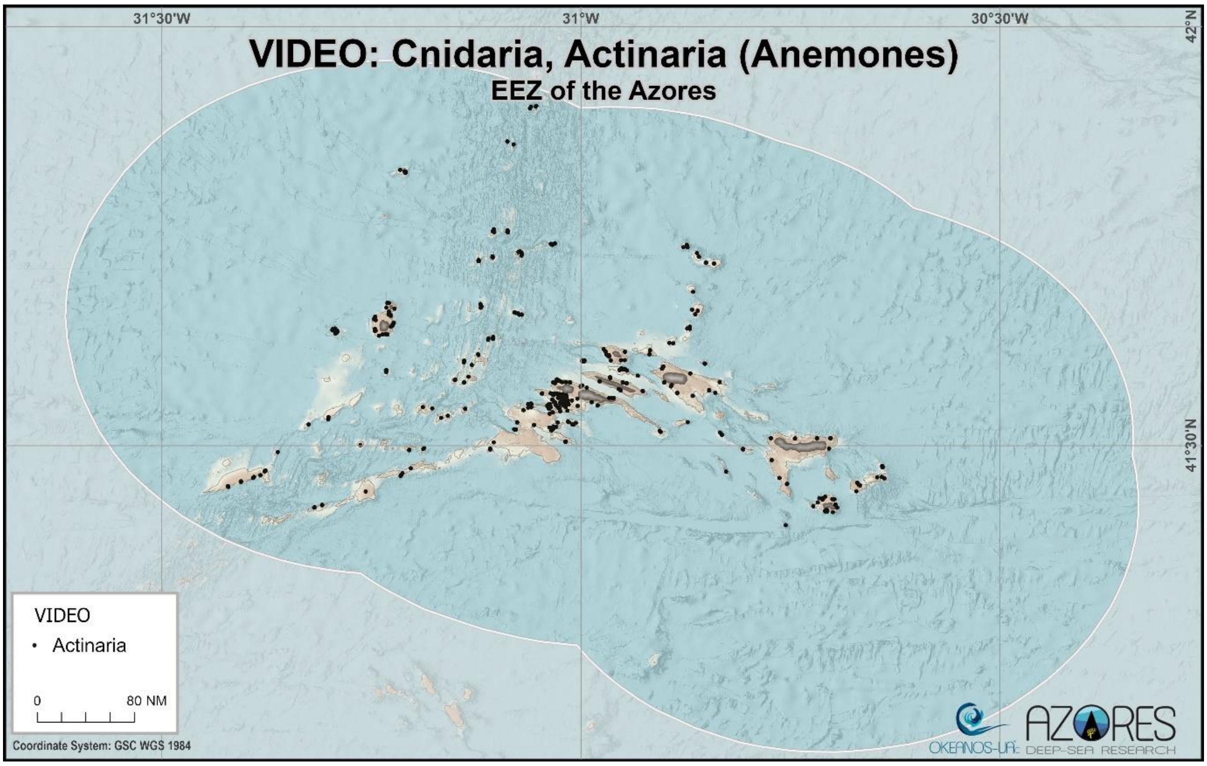



Figure 13 Geographical distribution of the Actinaria records, inside the Azores EEZ, contained in the video annotation database, as of November 1st, 2023.

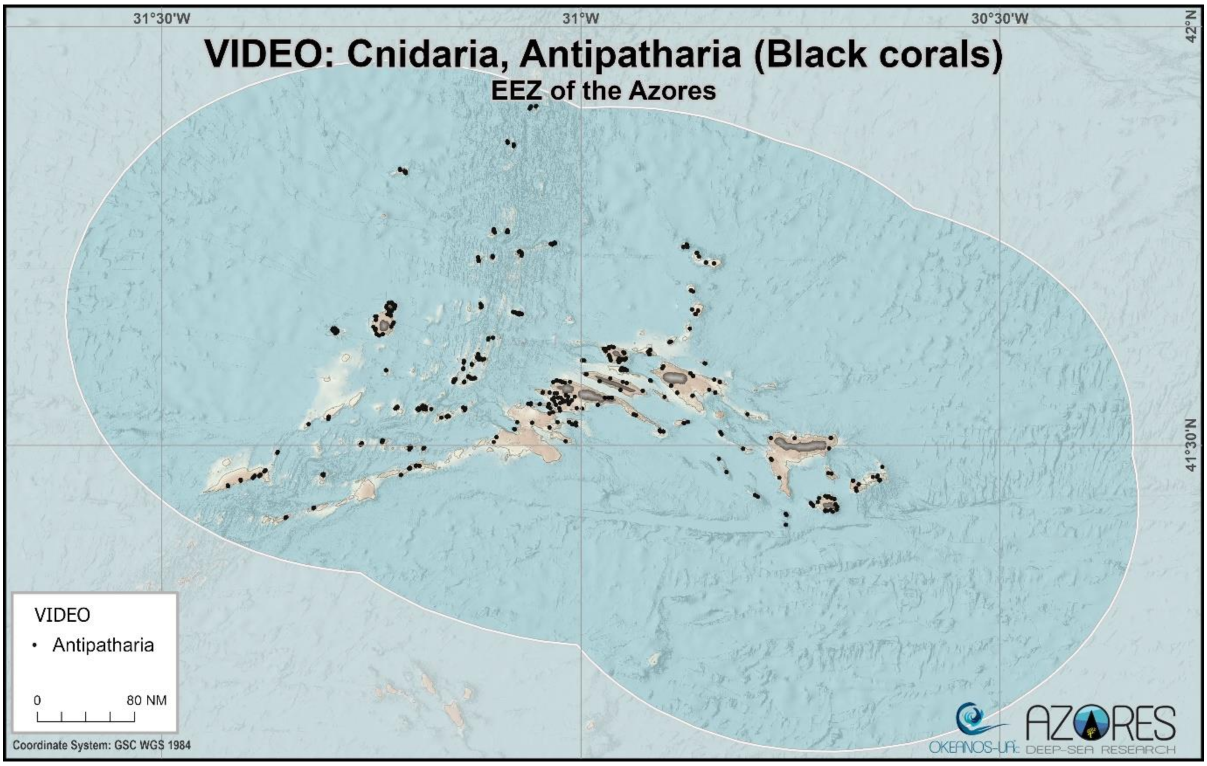



Figure 14 Geographical distribution of the Antipatharia records, inside the Azores EEZ, contained in the video annotation database, as of November 1st, 2023.

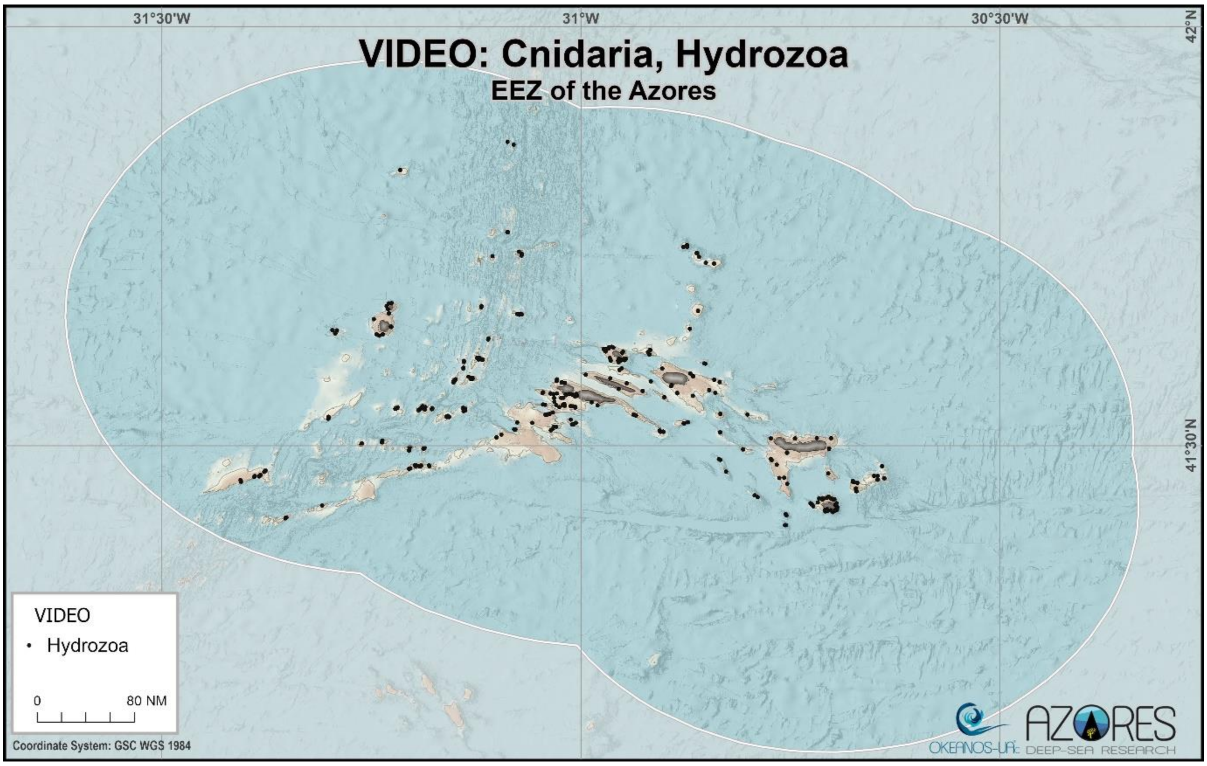



Figure 15 Geographical distribution of the Hydrozoa records, inside the Azores EEZ, contained in the video annotation database, as of November 1st, 2023.

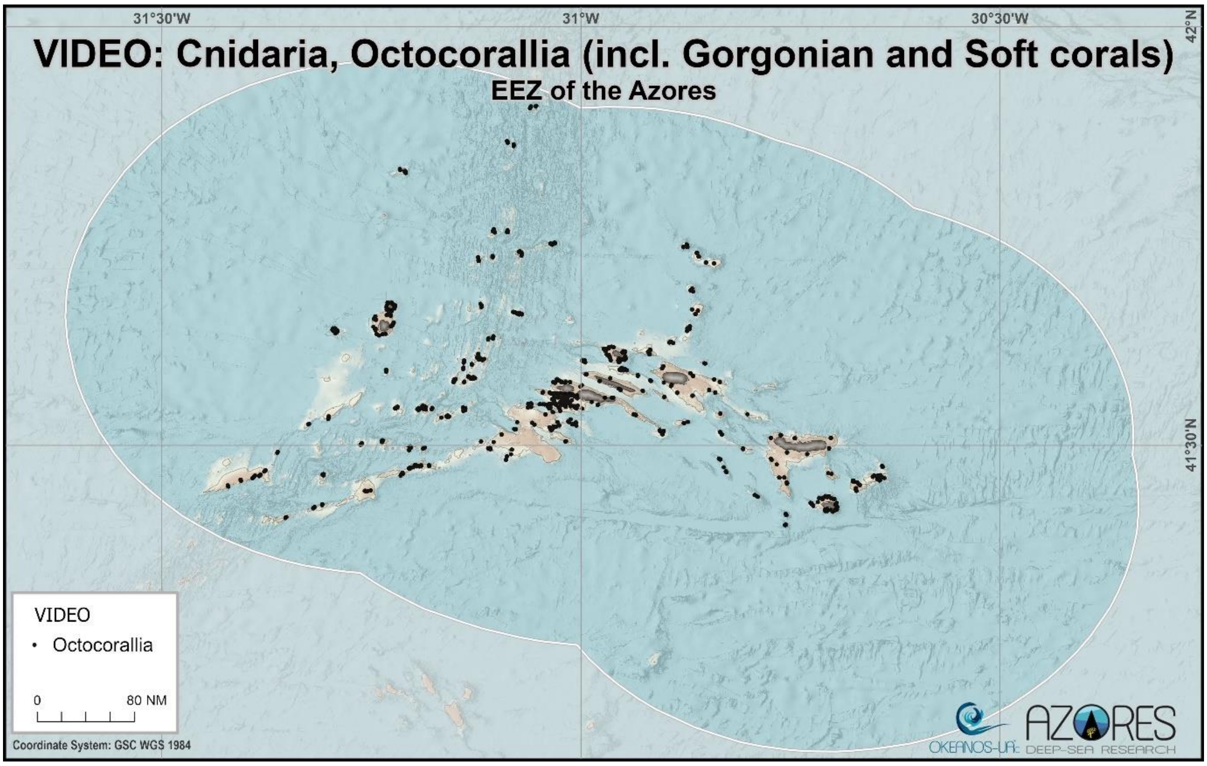



Figure 16 Geographical distribution of the Octocorallia records, inside the Azores EEZ, contained in the video annotation database, as of November 1st, 2023.

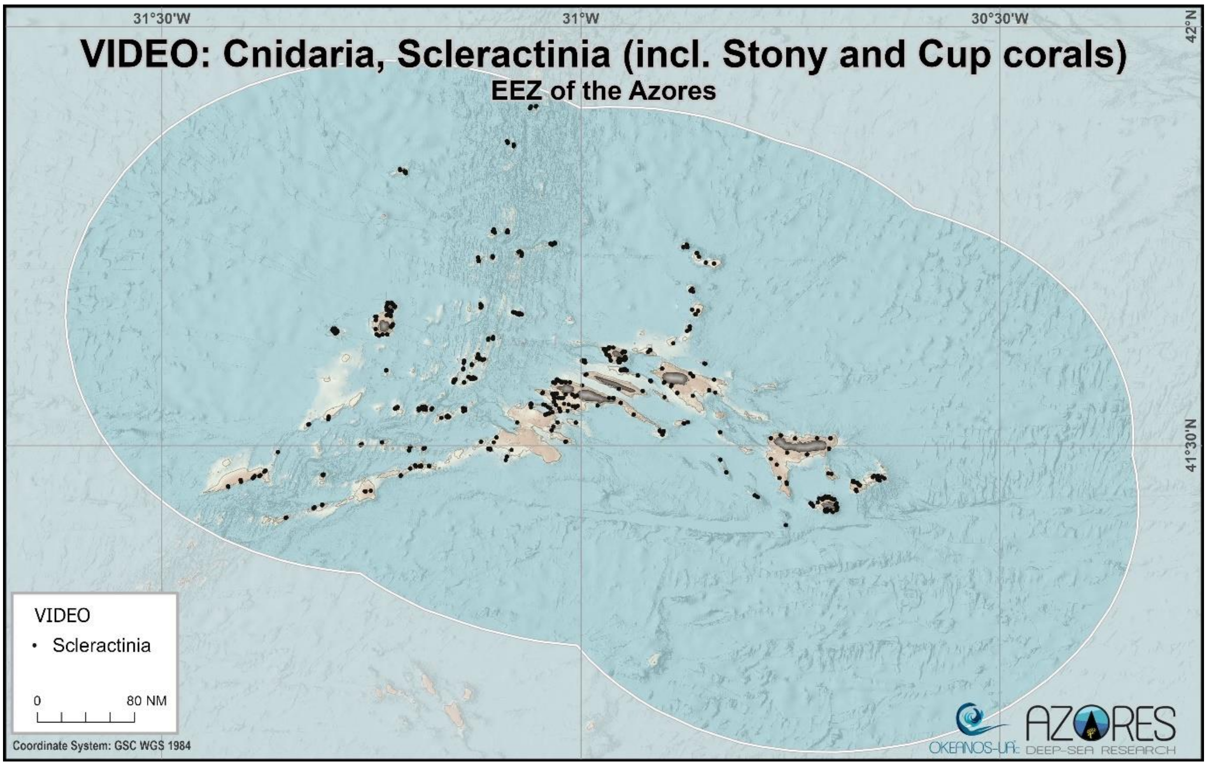



Figure 17 Geographical distribution of the Scleractinia records, inside the Azores EEZ, contained in the video annotation database, as of January 30th, 2023.

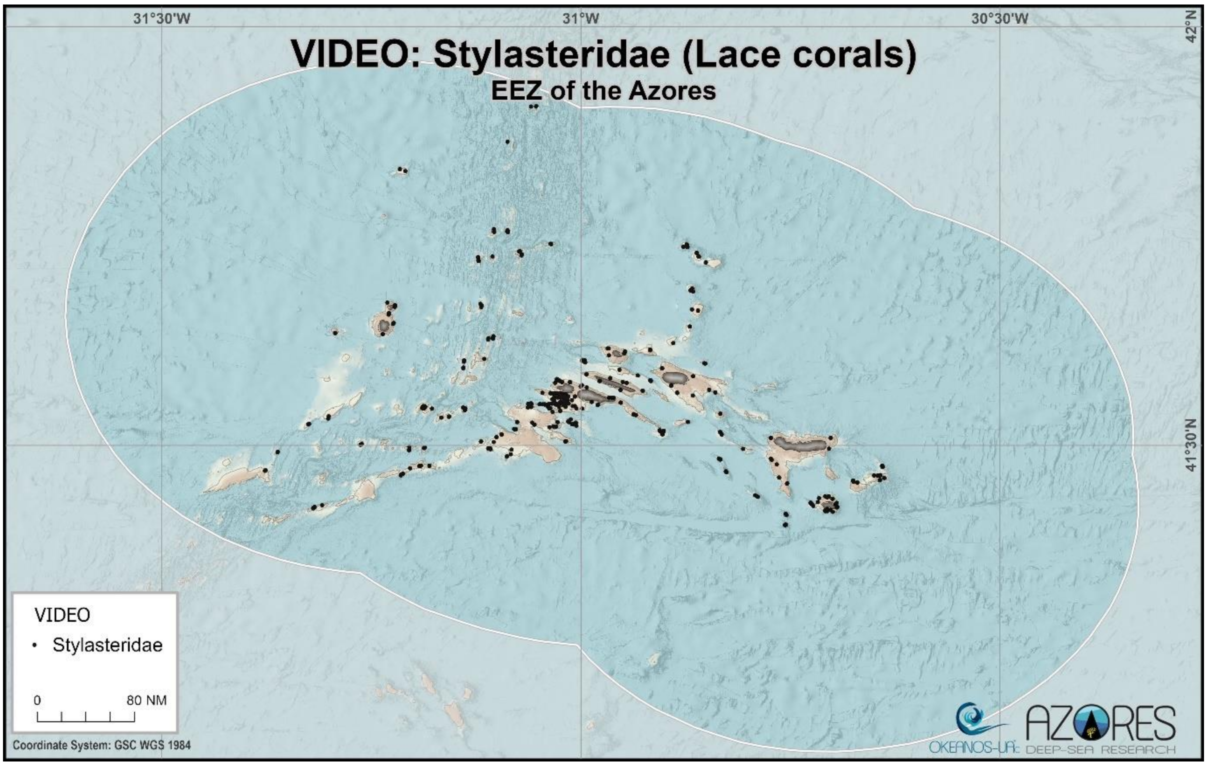



Figure 18 Geographical distribution of the Stylasteridae records, inside the Azores EEZ, contained in the video annotation database, as of November 1st, 2023.

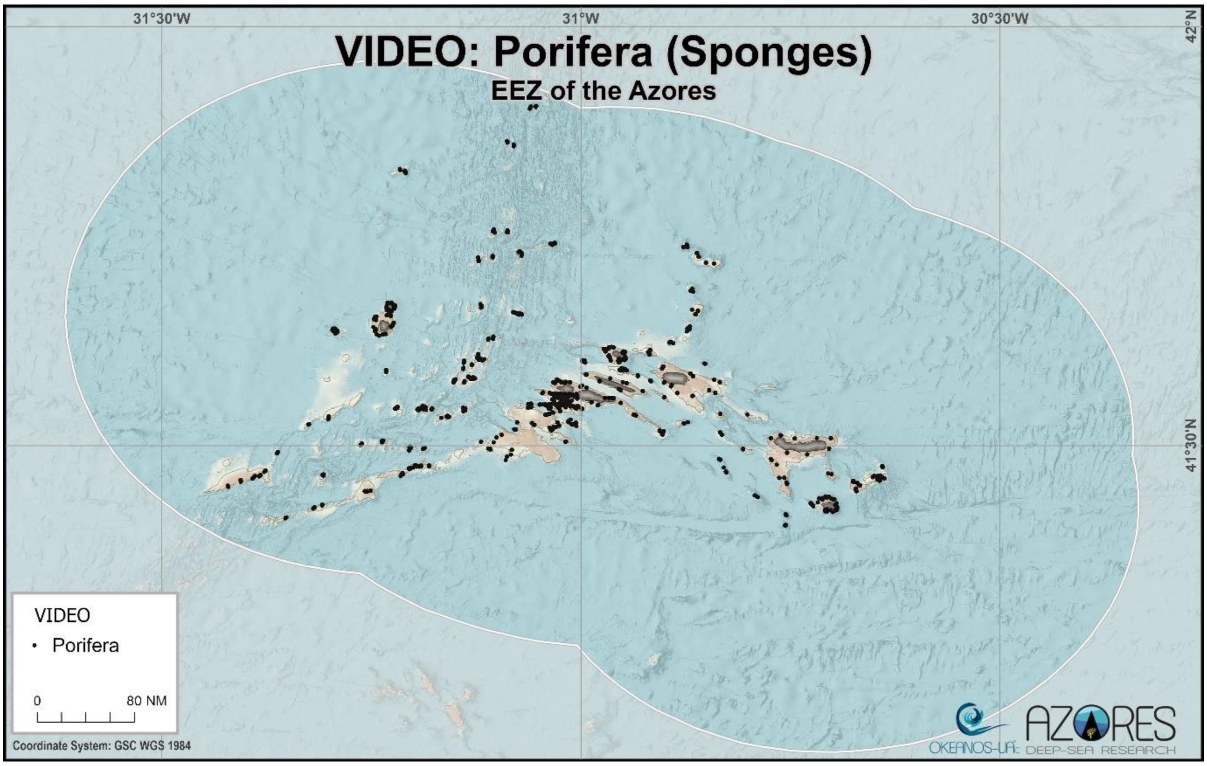



**Figure 19** Geographical distribution of the Porifera records, inside the Azores EEZ, contained in the video annotation database, as of November 1st, 2023.

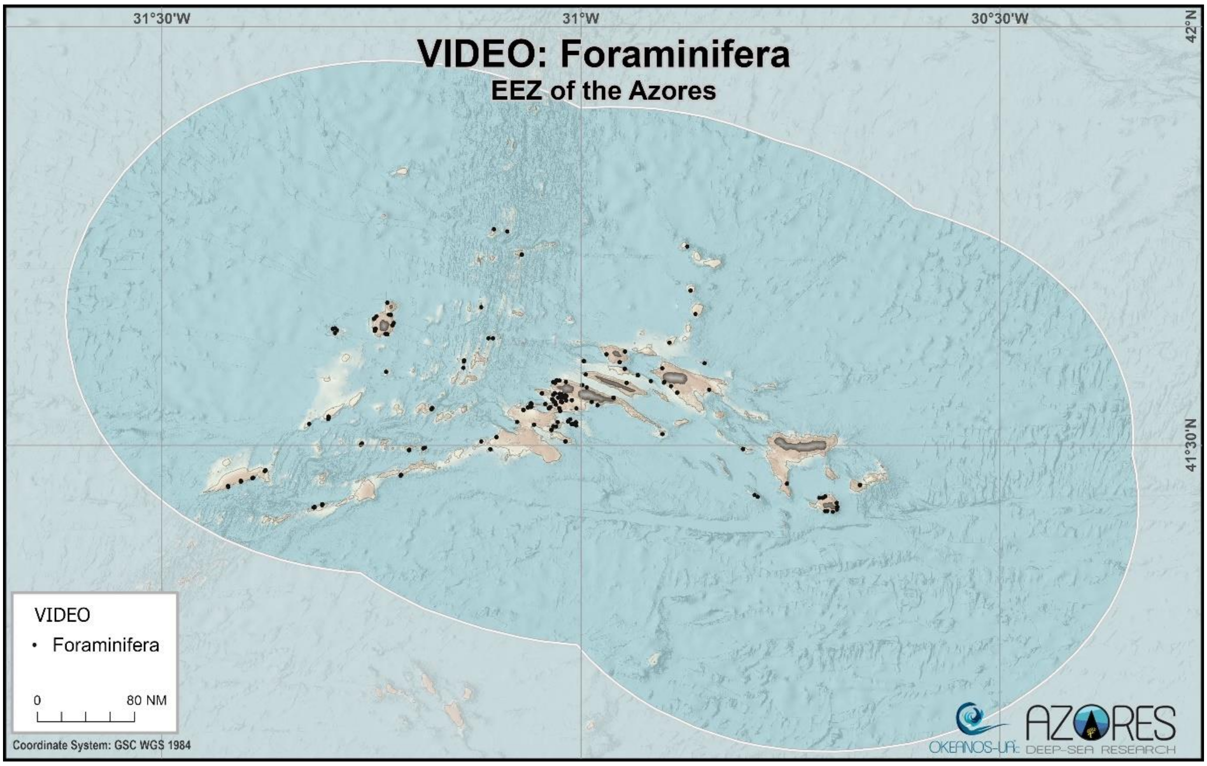



**Figure 20** Geographical distribution of the Foraminifera records, inside the Azores EEZ, contained in the video annotation database, as of November 1st, 2023.

### *6.3 Marine Biological Reference Collection (COLETA)*

Scientists from ADSR and IMAR & Okeanos-UAç have been collaborating with local fishermen to collect deep-sea invertebrate fauna accidentally captured during fishing activities. These records and their specimens obtained opportunistically have been stored and catalogued in the Marine Biological Reference Collection of the University of the Azores (COLETA) since 2006, co-coordinated by team member Dr. Marina Carreiro-Silva (Sampaio *et al.*, 2019c). The homonymous database COLETA, in addition to the taxonomic identification and photograph of the specimen, host metadata that includes geographic location, depth and collection method.

After the recent efforts to update the database with exiting records collected between 2019 and 2022 and those collected during 2023, currently COLETA contains 13,062 records, of which 6,796 refer to deep sea corals, sponges, or other deep-sea benthic megafauna organisms (Table 7). These records were originally collected by sampling programs in fishing ports of the Azores (e.g., CORAZON, HERMIONE and CoralFISH), fisheries observers' programs (e.g., CoralFISH, Discardless/MERCES/SPONGES), scientific longline surveys (e.g., ARQDAÇO, CoralFISH, CONDOR, PESCPROF, DEECON and BIOMETORE), experimental bottom trawl surveys (e.g., FISHOR), and scientific cruises within the scope of national and international projects using ROV video surveys (e.g., CONDOR, CoralFISH, MEDWAVES, BIOMETORE, BLUE AZORES 2018, ATHENA M151, Greenpeace "Defending our Oceans", M128, EXPLOSEA2, and OceanXplorer 2023) (Table 8). In recent years, a great effort has been made to make COLETA compatible with other databases, such as the database of historical records of occurrences of cold-water corals in the Azores (e.g., Campaigns of Prince Albert of Monaco in the 19th century) and other fisheries databases, to maximize the potential of this information.

The COLETA database has been continuously growing over the last years through oceanographic cruises and fishing observation programs within the scope of several regional, national and international programs (Figure 21). It has been a fundamental tool for mapping the distribution of biodiversity and vulnerable marine ecosystems indicator taxa, such as those indicators of cold-water coral gardens and sponge grounds in the Azores EEZ (Figure 22). The records of cold-water corals span the Azores EZZ, mostly in areas shallower than a 1,000 m depth. The database contains several occurrences of Actinaria (Figure 23), Antipatharia (Figure 24), Hydrozoa (Order Lepthotheca) (Figure 25), Octocorallia (Figure 26), Scleractinia (Figure 27), and hydrozoan family Stylasteridae (Figure 28). In what concerns sponges, during the provision of service a great effort was made to work with international experts and improve the species identifications of this group. Nevertheless, a large number of sponge records contained in the COLETA database are still unidentified but also span the Azores EZZ (Figure 29).

The data currently existing in the COLETA database was extracted and verified, in particular considering atypical, suspicious or missing values, for example latitude, longitude or depth, and corrected whenever necessary. Data referring to taxonomic nomenclatures were verified through WoRMS Taxon Match Tool APIs that automatically combine species lists or taxa lists with the World Register of Marine Species (WoRMS) according to systematic reviews of the various taxonomic groups (e.g., Octocorallia: McFadden *et al.*, 2022). The COLETA dataset is being used to evaluate the deep-sea invertebrate biodiversity in the Azores, to inform the checklist of species and the identification of VME indictor taxa. After the verification, the pre-existing and the new data in the COLETA database was included in "BD2: Georeferenced database of deep-sea species and habitats".

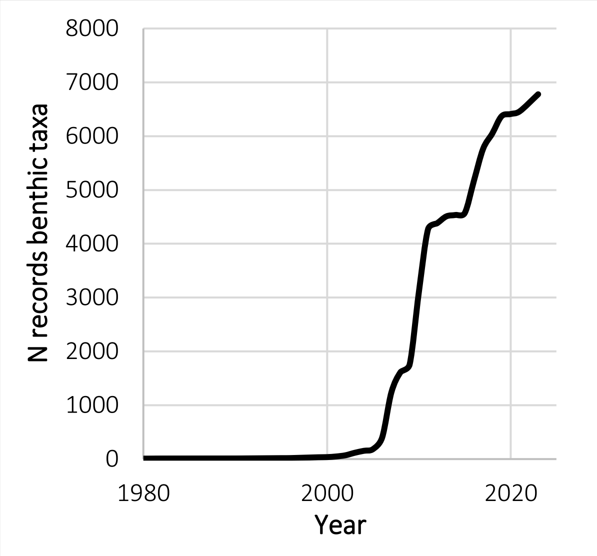



**Figure 21** Number of records of benthic taxa in the COLETA database. Year determined by date of capture, not date of entry in the dataset.

**Table 7.** Summary of the Cnidaria and Porifera records, inside the Azores EEZ, in the Marine Biological Reference Collection of the University of the Azores (COLETA), as downloaded on November 1st, 2023.

| Phylum | Grouping | N |
|---|---|---|
| Cnidaria (Inc. CWC | | 4 539 |
| | Actinaria | 222 |
| | Antipatharia | 205 |
| | Hydrozoa | 1 298 |
| | Octocorallia | 1 923 |
| | Scleractinia | 611 |
| | Stylasteridae | 222 |
| | Other | 58 |
| Porifera (Sponges) | | 1 987 |
| | Demospongiae | 1 929 |
| | Hexactinellida | 49 |
| | Calcarea | 9 |
| Other | | 270 |
| Total | | 6 796 |

Table 8. Records extracted from the COLETA database were original collected by multiple sampling programs in the Azores. Surveys years shown in ***YYYY*** correspond to the new additions made during 2023.

| Origin of the records contained in COLETA | Period | Gear | N |
|---|---|---|---|
| ARQDAÇO scientific longline surveys | 1995, 2004–2005, 2007–2008, 2010–2013, 2016-2018, ***2019, 2021, 2023*** | Bottom longline | 1877 |
| CONDOR scientific longline surveys | 2009-2012, 2015, ***2017, 2018, 2019, 2020*** | Bottom longline | 511 |
| CoralFish scientific longline surveys | 2010-2011 | Bottom longline | 263 |
| DEECON scientific longline surveys | 2007, 2008 | Bottom longline | 36* |
| EMPAFISH scientific longline surveys | 2005 | Bottom longline | 4 |
| CRUSTAÇO/MARPROF scientific trap surveys | 2009–2011 | Crustacean traps | 54 |
| FISHOR scientific longline surveys | 2002 | Bottom trawl | 20 |
| CONDOR Crustaceans scientific trap surveys | 2011 | Crustacean traps | 14 |
| PESCPROF scientific longline surveys | 2004, 2005 | Bottom trawl | 11* |
| *Chaceon affinis* experimental trap fishing | 2003 | Crustacean traps | 9 |
| BIOMETORE scientific longline surveys | 2015 | Bottom longline | 1* |
| CoralFISH fisheries' observer program | 2010, 2011 | Bottom longline & handline | 1224 |
| SPONGES/MERCES fisheries' observer program 2017 | 2017-2019 | Bottom longline & handline | 434 |
| Corazon/Hermione/CoralFISH Harbour sampling programs | 2006, 2007 | Bottom longline & handline | 763 |
| Blue Azores 2018 | 2018 | ROV | 159 |
| MEDWAVES | 2016 | ROV | 42* |
| CORALFISH 2010 | 2010 | ROV | 32 |
| EMEPC/LUSO/Açores G3 | 2008 | ROV | 31 |
| ATHENA M151 | 2018 | ROV, boxcorer, grabs | 16* |
| METEOR 58/3 | 2003 | ROV | 2 |
| Greenpeace "Defending our Oceans" remotely operated vehicle' surveys | 2006 | Towed camera | 10 |
| M128 | ***2016*** | ROV | 456 |
| EXPLOSEA2 | ***2019*** | ROV | 256 |
| OceanXplorer 2023 | ***2023*** | ROV, submersibles | 56 |
| FAIVI/IOZ | 2011 | Dredge, rock corer, box corer | 86 |
| Other surveys | | Multiple | 399 |

*These datasets contain more records located outside of the Azores EEZ. Here only those inside the EEZ are showed.

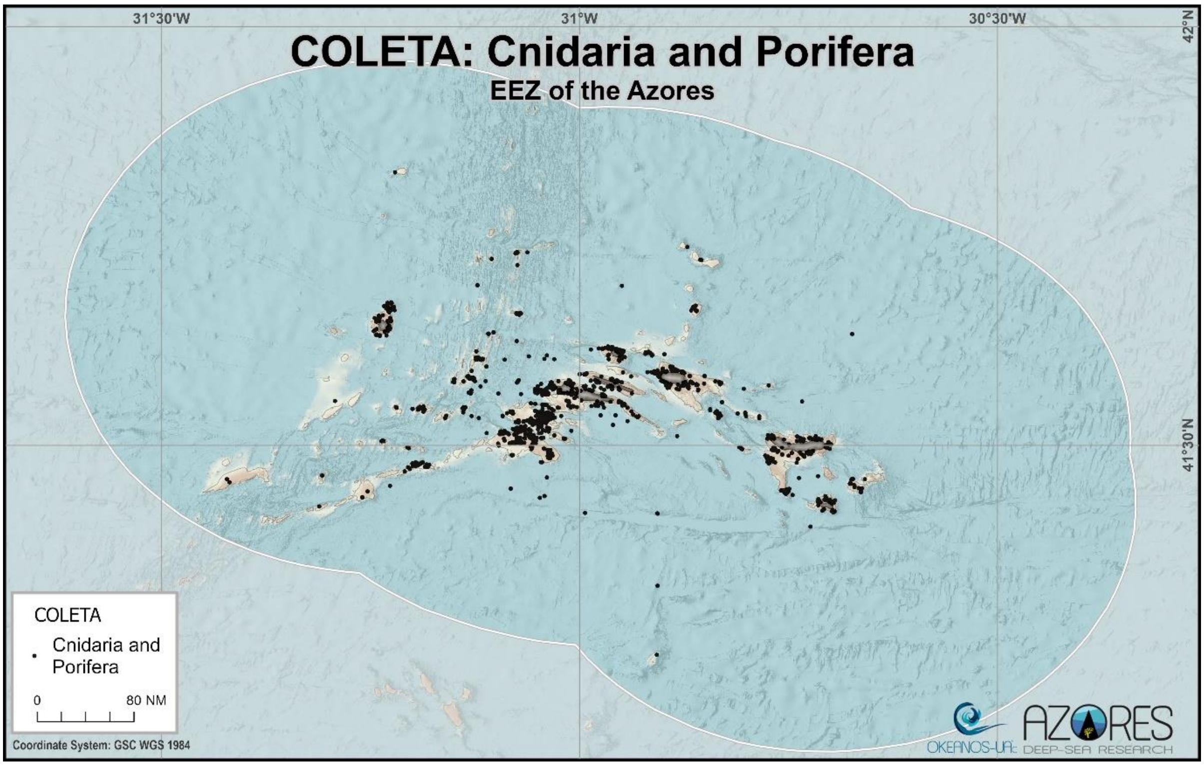



Figure 22 Geographical distribution of the 6,796 records of cold-water corals and sponges, inside the Azores EEZ, contained in the Marine Biological Reference Collection of the University of the Azores (COLETA), as downloaded on November 1st, 2023.

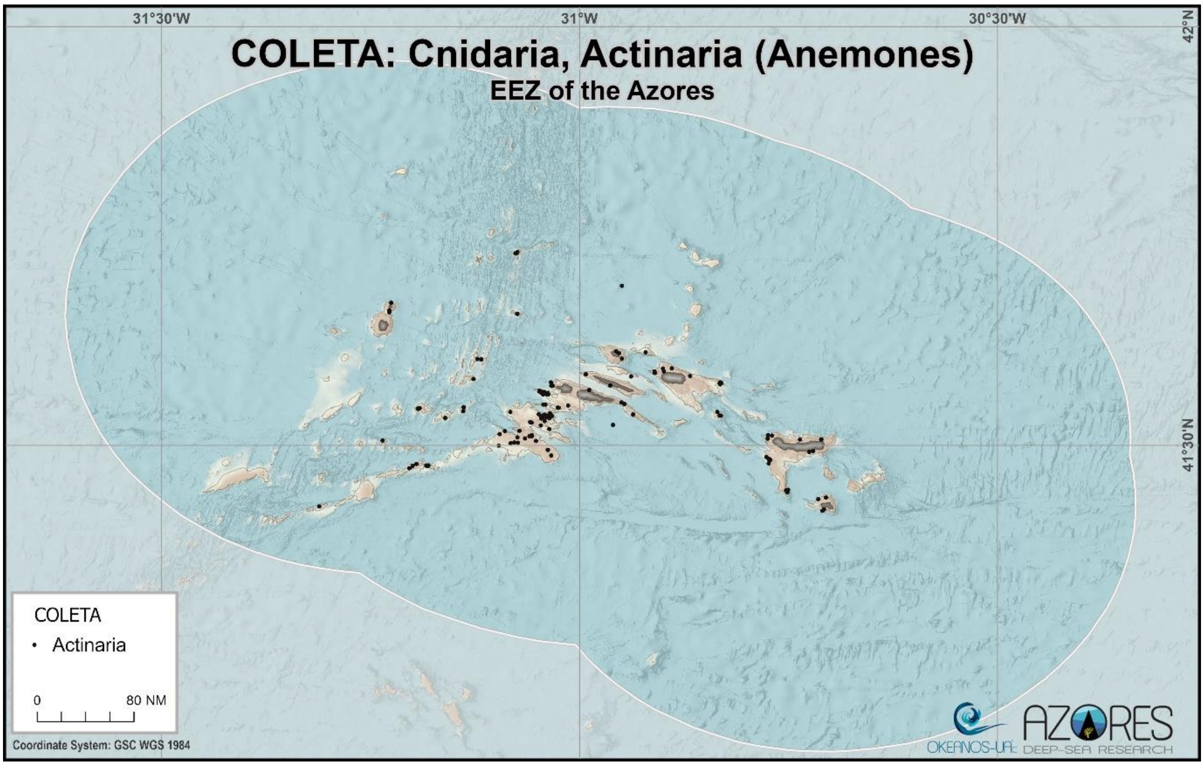



Figure 23 Geographical distribution of the Actinaria records, inside the Azores EEZ, contained in the Marine Biological Reference Collection of the University of the Azores (COLETA), as downloaded on November 1st, 2023.

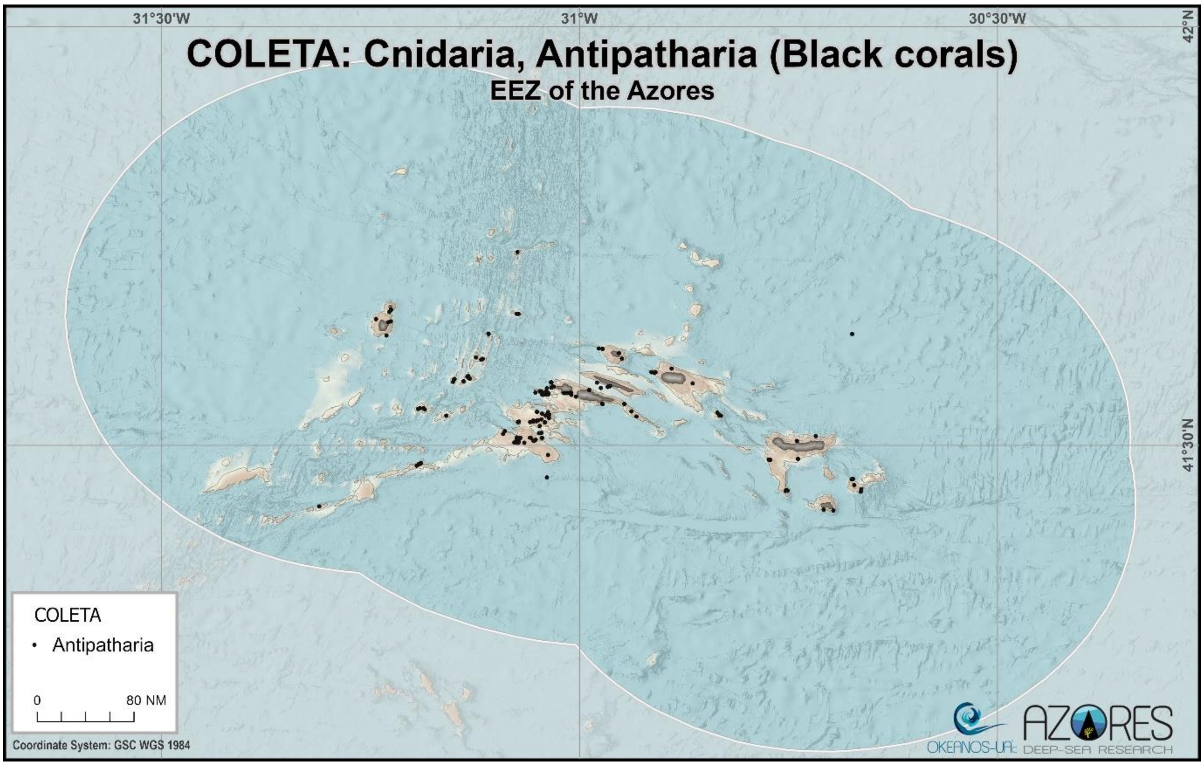



Figure 24. Geographical distribution of the Antipatharia records, inside the Azores EEZ, contained in the Marine Biological Reference Collection of the University of the Azores (COLETA), as downloaded on November 1st, 2023.

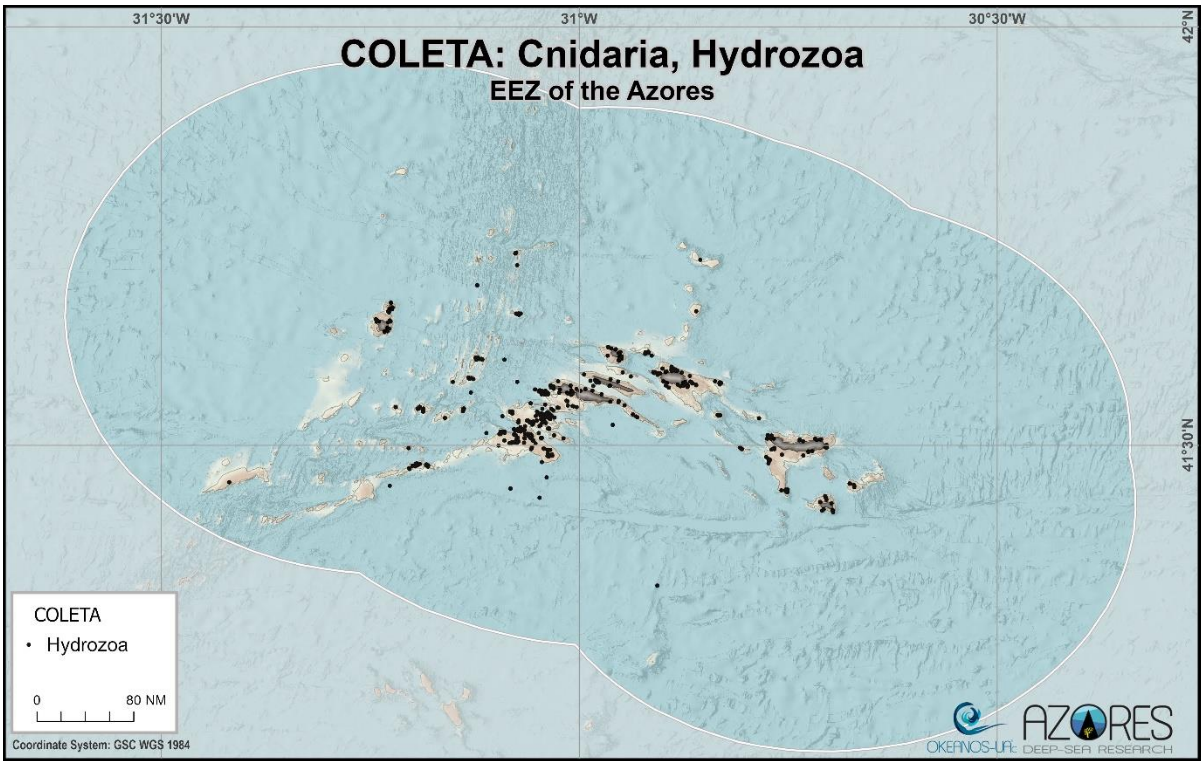



Figure 25. Geographical distribution of the Hydrozoa records, inside the Azores EEZ, contained in the Marine Biological Reference Collection of the University of the Azores (COLETA), as downloaded on November 1st, 2023.

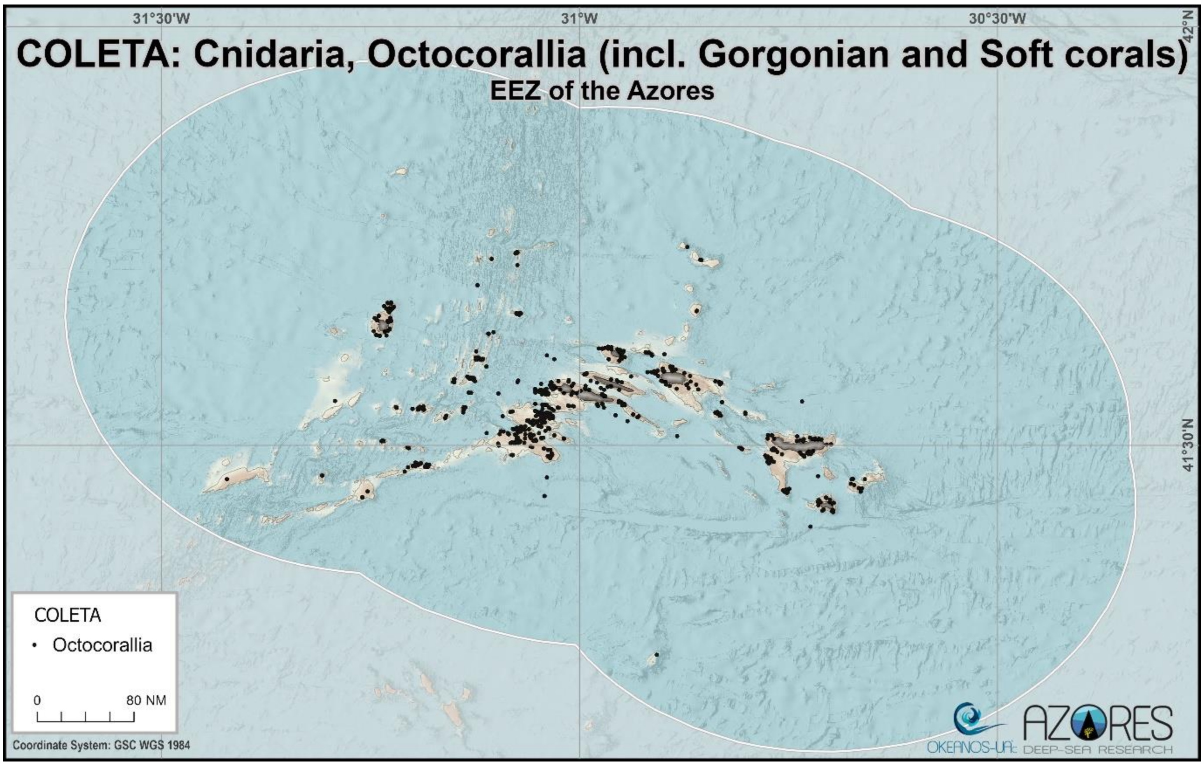



**Figure 26.** Geographical distribution of the Octocorallia records, inside the Azores EEZ, contained in the Marine Biological Reference Collection of the University of the Azores (COLETA), as downloaded on November 1st, 2023.

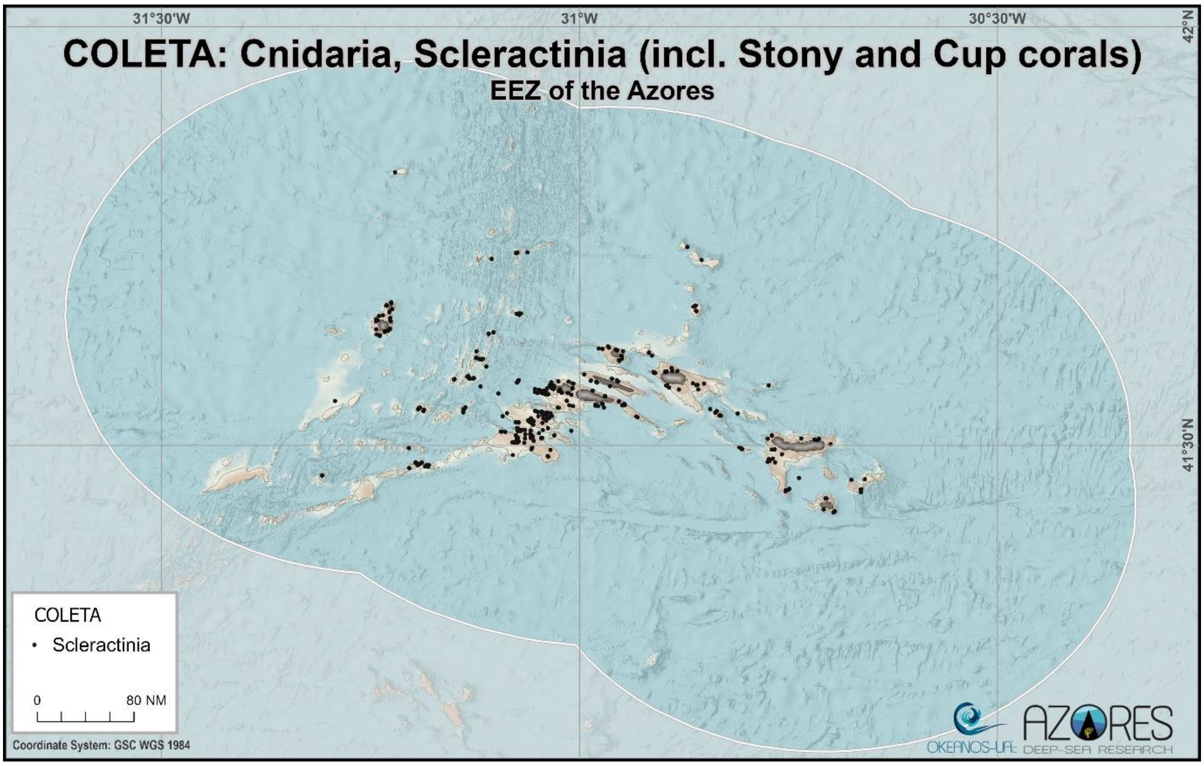



**Figure 27** Geographical distribution of the Scleractinia records, inside the Azores EEZ, contained in the Marine Biological Reference Collection of the University of the Azores (COLETA), as downloaded on November 1st, 2023.

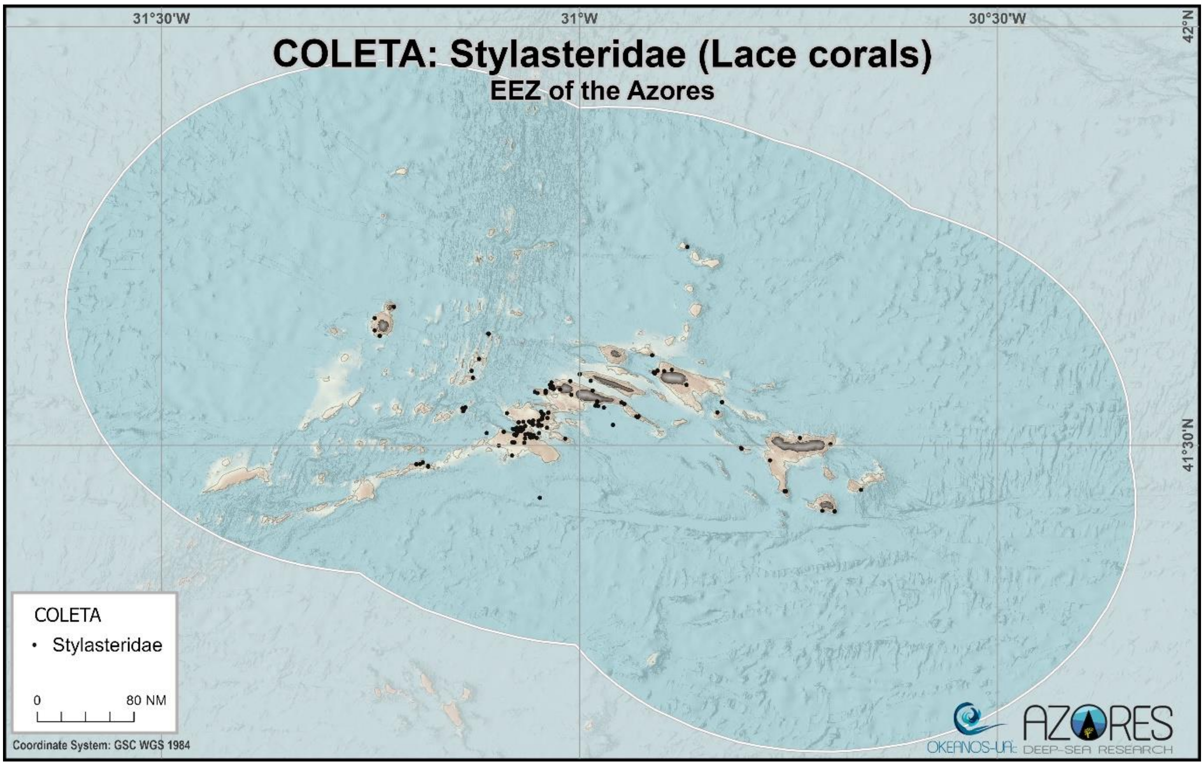



Figure 28 Geographical distribution of the Stylasteridae records, inside the Azores EEZ, contained in the Marine Biological Reference Collection of the University of the Azores (COLETA), as downloaded on November 1st, 2023.

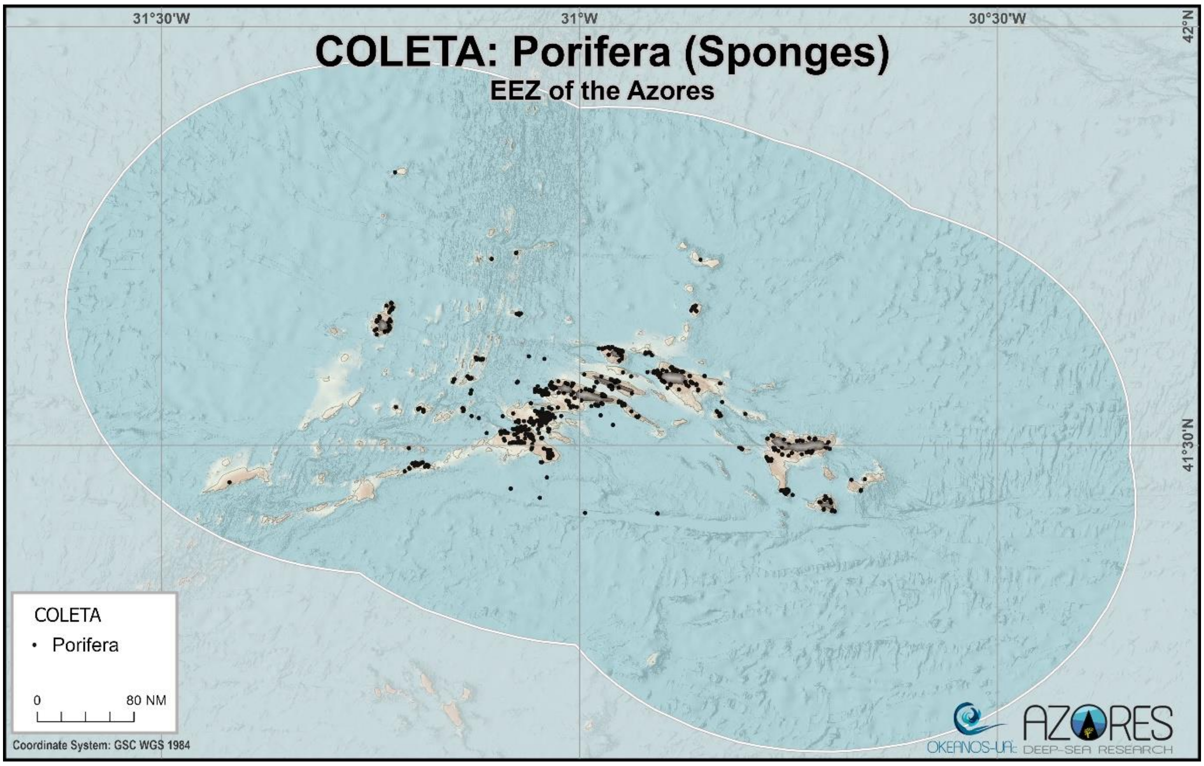



Figure 29 Geographical distribution of the 1,687 records of sponges, inside the Azores EEZ, contained in the Marine Biological Reference Collection of the University of the Azores (COLETA), as downloaded on November 1st, 2023.

## *6.4 Other public datasets*

As reported in the R1 report, we exhausted all potential sources of information available for the detailed compilation of the best existing information on the deep-sea biodiversity of the Azores. This included a compilation of the information contained in public global databases, such as the ICES Vulnerable Marine Ecosystems data portal, the NOAA Deep Sea Coral Data Portal, and the Ocean Biogeographic Information System (OBIS), were assessed. As with the COLETA data, we extracted and performed a quality check of the existing data in these repositories and conducted a harmonization of information so that it is compatible with the COLETA and the projects database. These datasets were assessed to verify whether the data resulting from these extractions have new, valid, and relevant records that complete the pre-existing information compiled from COLETA and video data. Namely, georeferenced data extracted from public global databases that were provided by ADSR projects or their partners were excluded. We also verified whether the remaining information provides new data at a relevant spatial scale. After the verifications, the resulting datasets were included in “BD2: Georeferenced database of deep-sea species and habitats”.

With the significant increase in the volume of data in the Coleta and in the video annotations datasets, we concluded that the public datasets did not contain relevant additional information on the spatial distribution of deep-sea biodiversity, including VME indicator species. Nevertheless, we report the data contained in those public datasets for reference and potential use by other users.

### ICES Vulnerable Marine Ecosystems data portal

The ICES Vulnerable Marine Ecosystems database is a portal for viewing and distributing observations of Vulnerable Marine Ecosystems in the North Atlantic. This database was created by the ICES/NAFO Working Group on Deep-water Ecology (WGDEC) and is composed of records of clear evidence of VME and records of VME indicator species. This database contains 131 records of deep-sea benthic species with potential to serve as VME indicators (Table 9; Figure 30); belonging to Cnidaria, including cold-water corals, (Antipatharia -Figure 31-, Octocorallia -Figure 32-, and Scleractinia). Most of these records may have been provided by members of the local scientific community and therefore may already be contained in the COLETA or historical databases. We assessed whether these records include new, valid, and relevant occurrences that complement the existing information and conclude that they did not add relevant information and that may increase the uncertainty on the analyses.

**Table 9** Summary of the Cnidaria and Porifera records, inside the Azores EEZ, in ICES Vulnerable Marine Ecosystems database, as downloaded on November 1st, 2023.

| Phylum | Grouping | N |
|---|---|---|
| Cnidaria (Inc. cold-water corals) | | 131 |
| | Antipatharia | 16 |
| | Octocorallia | 115 |
| Total | | 131 |

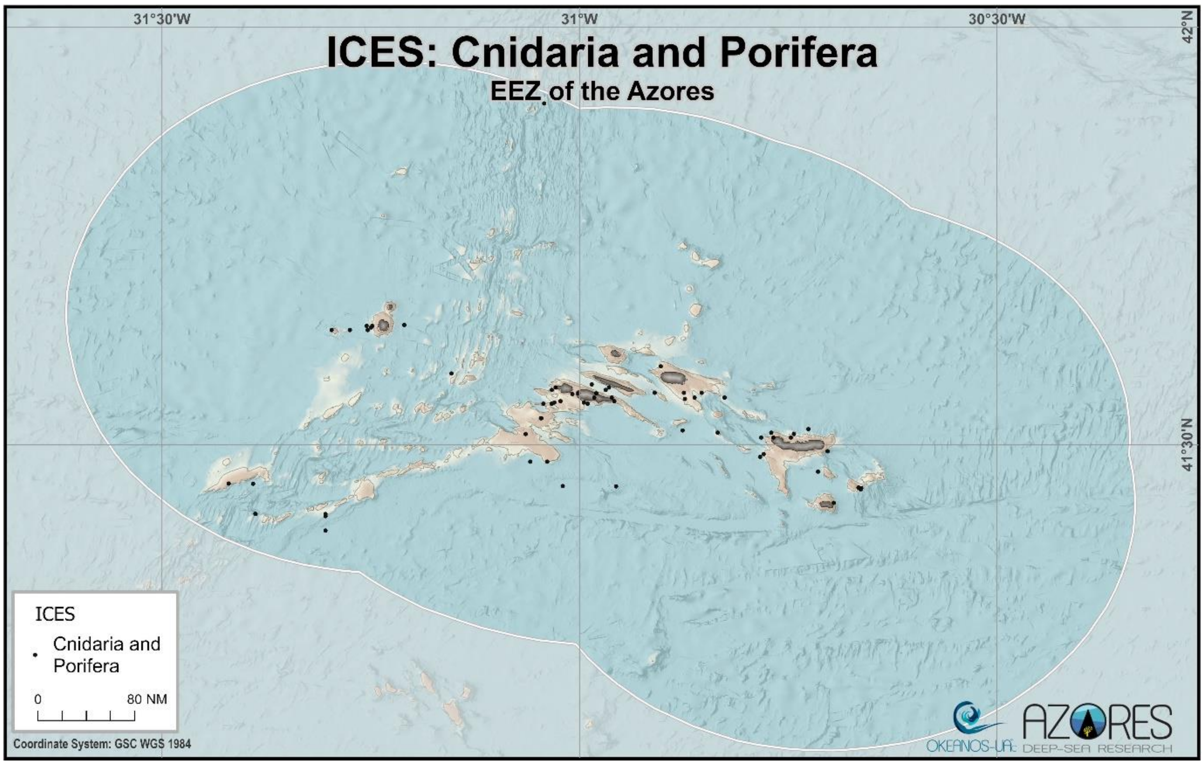



**Figure 30** Geographical distribution of the 150 records of Cnidaria and Porifera, inside the Azores EEZ, contained in ICES Vulnerable Marine Ecosystems database, as downloaded on November 1st, 2023.

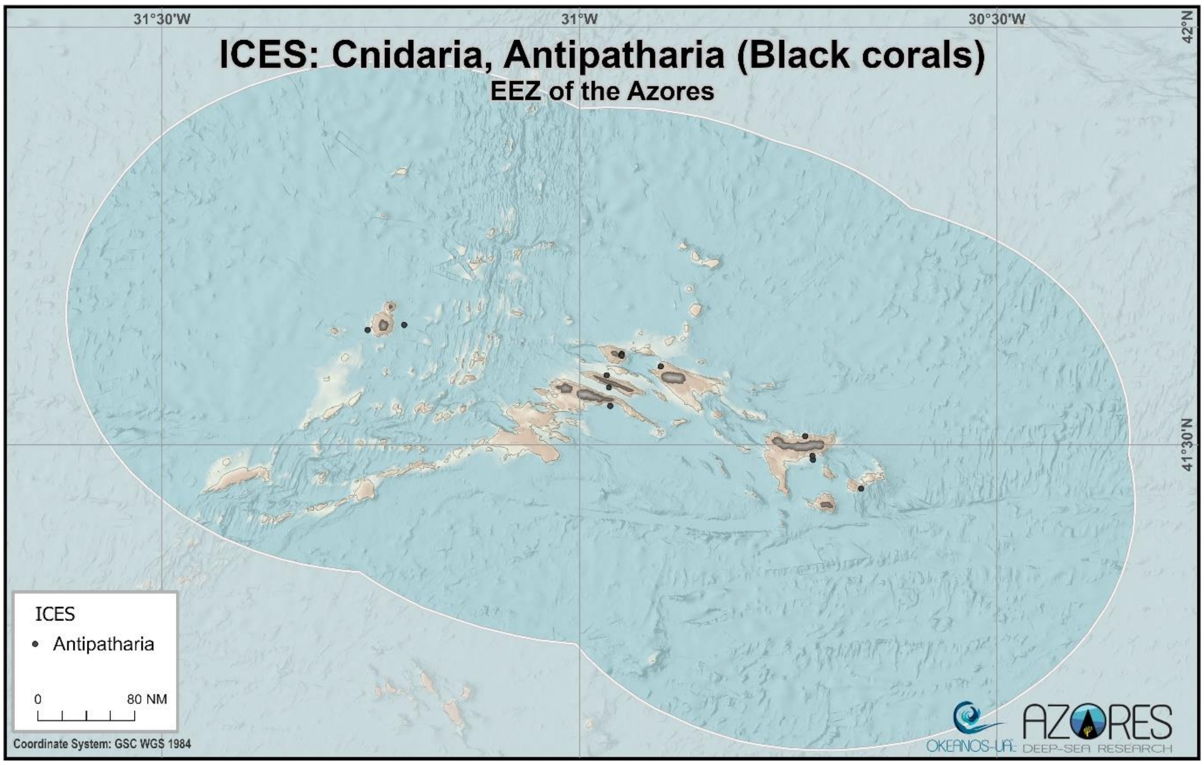



**Figure 31** Geographical distribution of the Antipatharia records, inside the Azores EEZ, contained in ICES Vulnerable Marine Ecosystems database, as downloaded on November 1st, 2023.

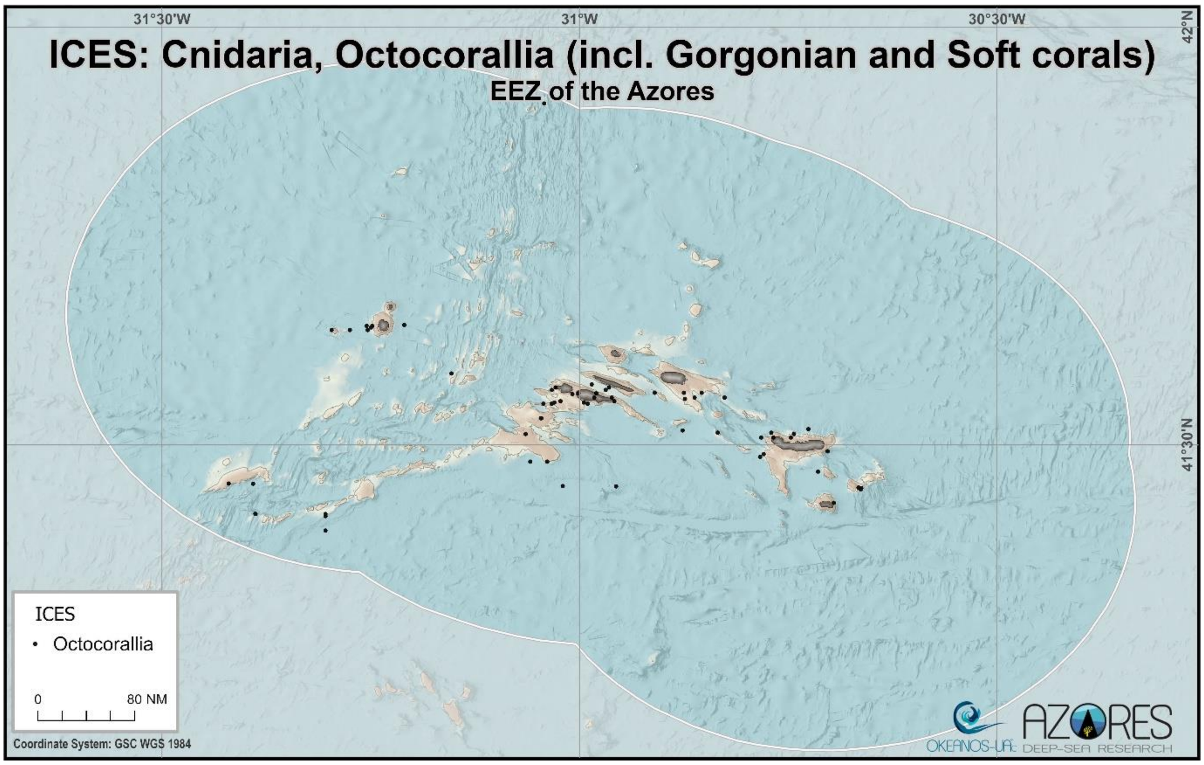



Figure 32 Geographical distribution of the Octocorallia records, inside the Azores EEZ, contained in ICES Vulnerable Marine Ecosystems database, as downloaded on November 1st, 2023.

NOAA Deep Sea Coral Data Portal

The NOAA Deep Sea Coral Data Portal provides access to data, images and technical reports on deep sea corals and sponges collected during campaigns by NOAA's Deep-Sea Coral Research and Technology Program and its partners. This Portal also aggregates historical records of samples archived in museums, research institutions and described in scientific literature. After a careful evaluation of the data contained in this dataset, we identified 126 records of Cnidaria and Porifera inside the Azores EEZ (Table 10). Most of these are historical records obtained during the Challenger Expedition in 1873, the French expedition BIAÇORES in 1971 and the Dutch expedition CANCAP-V in 1981. The associated specimens are deposited mostly in the Smithsonian Institution National Museum of Natural History and the Yale University Peabody Museum. These records still need to be validated and their usefulness assessed. A great portion of the records belong to the Scleractinia group, that includes stony and cup corals. Most of the occurrences were reported around São Miguel, Mar da Prata and Santa Maria but some are located around Flores and Corvo (Figure 33). We also assessed whether these records include new, valid, and relevant occurrences that complement the existing information and conclude that they did not add relevant information and that may increase the uncertainty on the analyses.

**Table 10** Summary of the Cnidaria and Porifera records, inside the Azores EEZ, in the NOAA Deep Sea Coral Data Portal database, as downloaded on November 1st, 2023.

| Phylum | Grouping | N |
|---|---|---|
| Cnidaria (Inc. cold-water corals) | | 125 |
| | Antipatharia | 6 |
| | Octocorallia | 3 |
| | Scleractinia | 108 |
| | Stylasteridae | 8 |
| Porifera (Sponges) | | 1 |
| Total | | 126 |

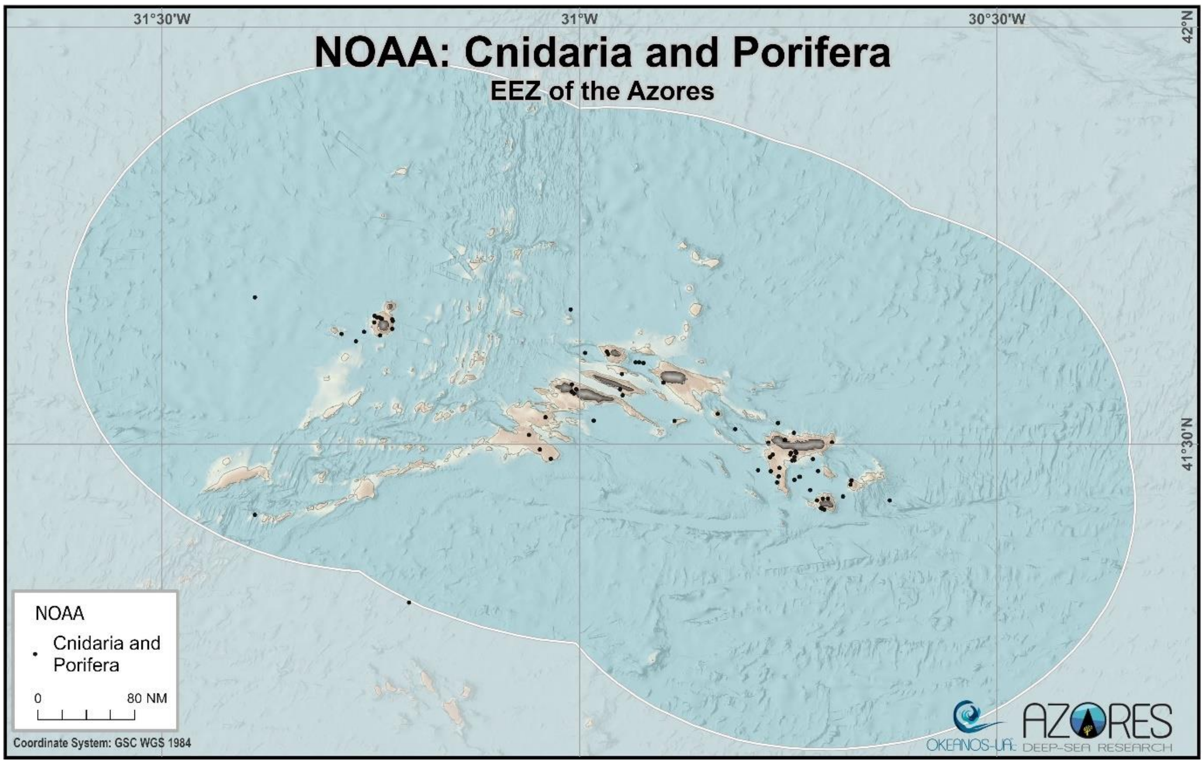



**Figure 33** Geographical distribution of the 128 records of cold-water corals sponges, inside the Azores EEZ, contained in the NOAA Deep Sea Coral Data Portal database, as downloaded on November 1st, 2023.

Ocean Biogeographic Information System (OBIS)

OBIS is an online database for information on the distribution and abundance of marine species. It was developed during the Census of Marine Life (CoML) program and aims to provide an integrated view of all data on marine biodiversity globally that can be made available in open access by the institutions providing data. The OBIS data downloaded on November 1st, 2023, revealed 1 126 records of Cnidaria and Porifera in the Azores EEZ (Table 11; Figure 34). Most of these records were compiled from historical datasets while the most recent (> year 1990) records in OBIS were provided by local scientists. Most of the records obtained from OBIS belonged to Actinaria (n= 44), Octocorallia (n=29; Figure 35), Scleractinia (n = 732; Figure 36), and sponges *sensu lato* (n= 251; Figure 37). Similarly to the other public datasets, we assessed whether these records include new, valid, and relevant occurrences that complement the existing information and conclude that they did not add relevant information and that may increase the uncertainty on the analyses.

**Table 11** Summary of the Cnidaria and Porifera records, inside the Azores EEZ, in Ocean Biogeographic Information System (OBIS) database, as downloaded on November 1st, 2023.

| Phylum | Grouping | N |
|---|---|---|
| Cnidaria (Inc. cold-water corals) | | 875 |
| | Actinaria | 44 |
| | Antipatharia | 22 |
| | Octocorallia | 29 |
| | Scleractinia | 732 |
| | Ind. | 48 |
| Porifera (Sponges) | | 251 |
| | Demospongiae | 212 |
| | Hexactinellida | 32 |
| | Ind. | 7 |
| Total | | 1 126 |

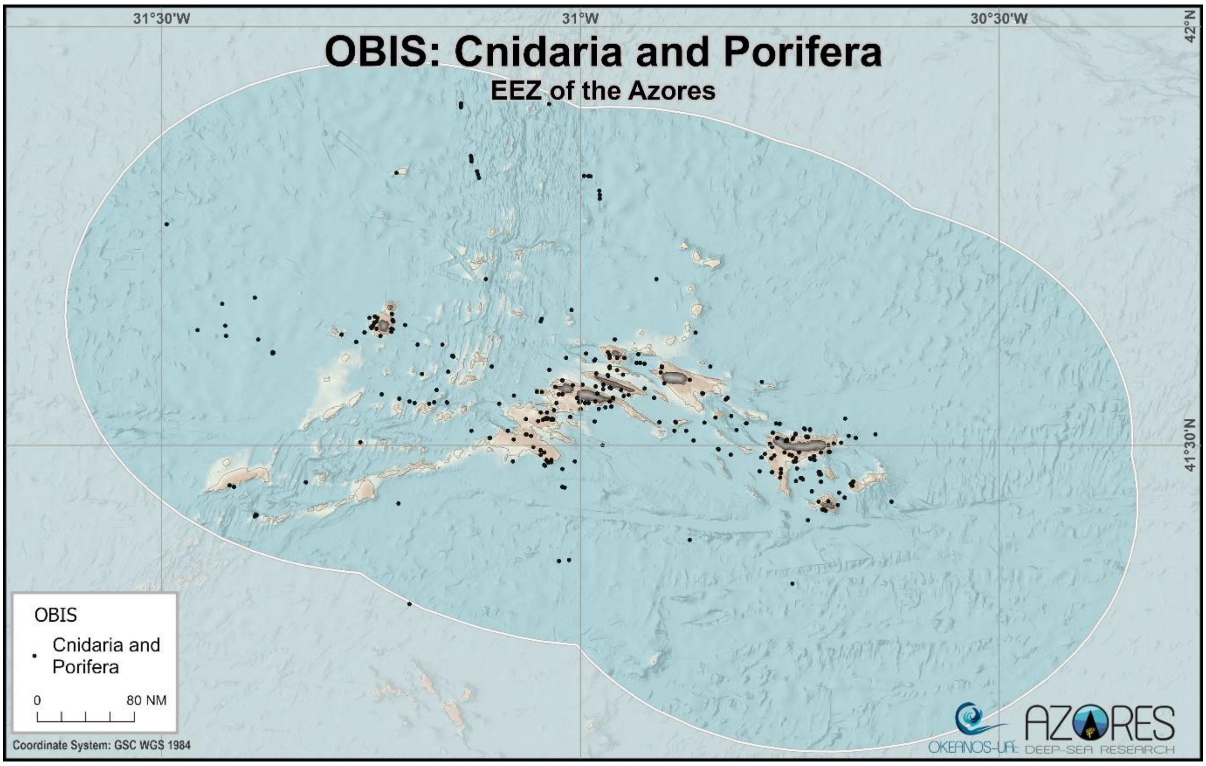



**Figure 34** Geographical distribution of the 979 records of cold-water corals sponges, inside the Azores EEZ, contained in the Ocean Biogeographic Information System (OBIS) database, as downloaded on January 20th, 2023.

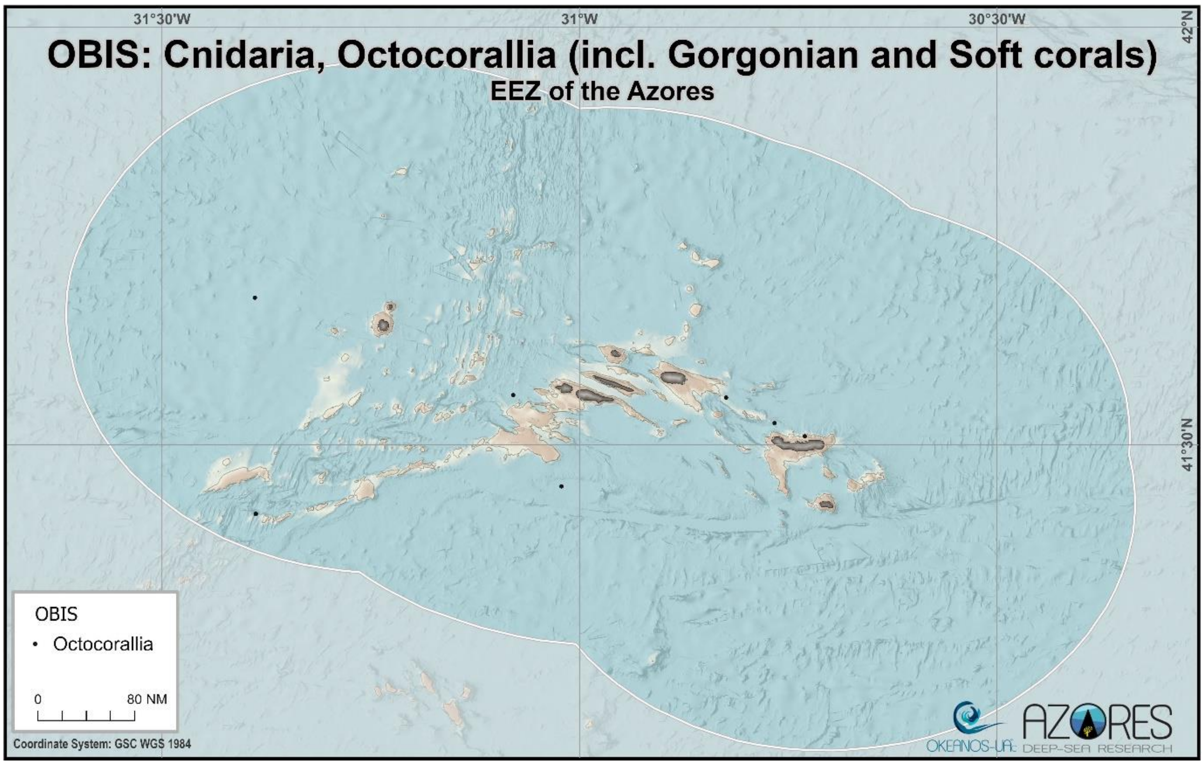



**Figure 35** Geographical distribution of the Octocorallia records, inside the Azores EEZ, contained in the Ocean Biogeographic Information System (OBIS) database, as downloaded on January 20$^{th}$, 2023.

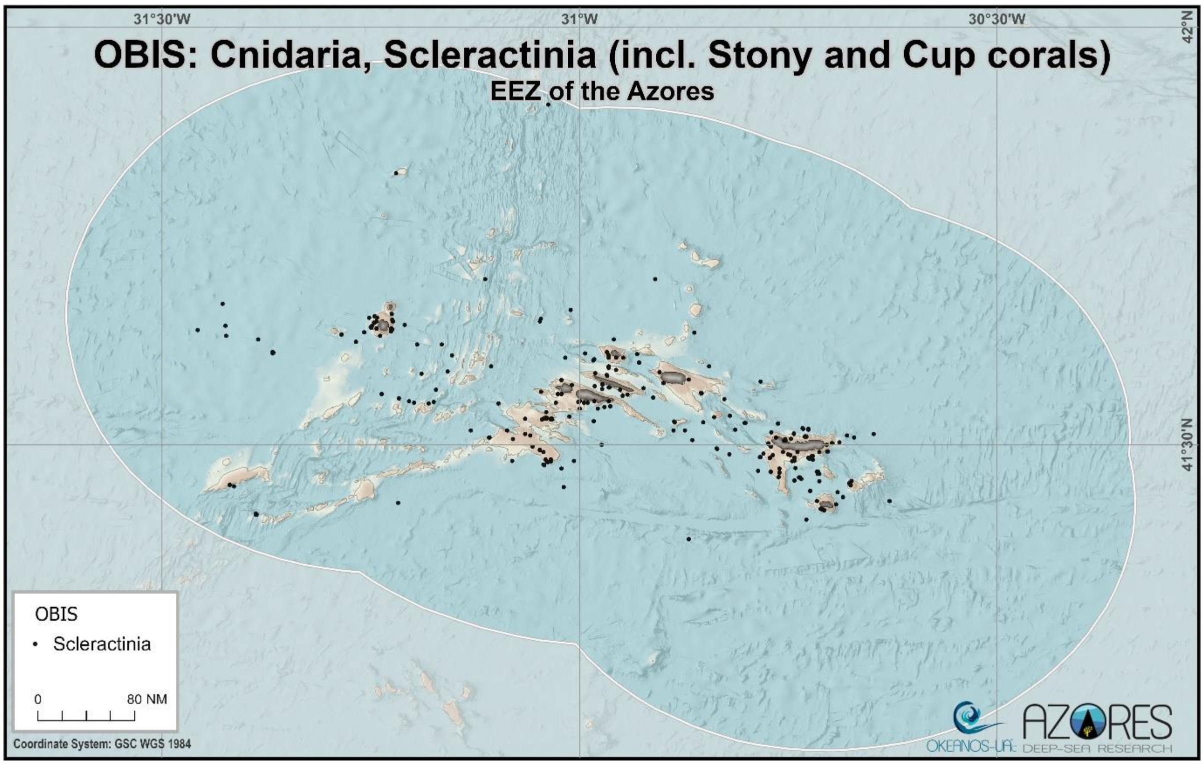



Figure 36 Geographical distribution of the Scleractinia records, inside the Azores EEZ, contained in the Ocean Biogeographic Information System (OBIS) database, as downloaded on January 20th, 2023.

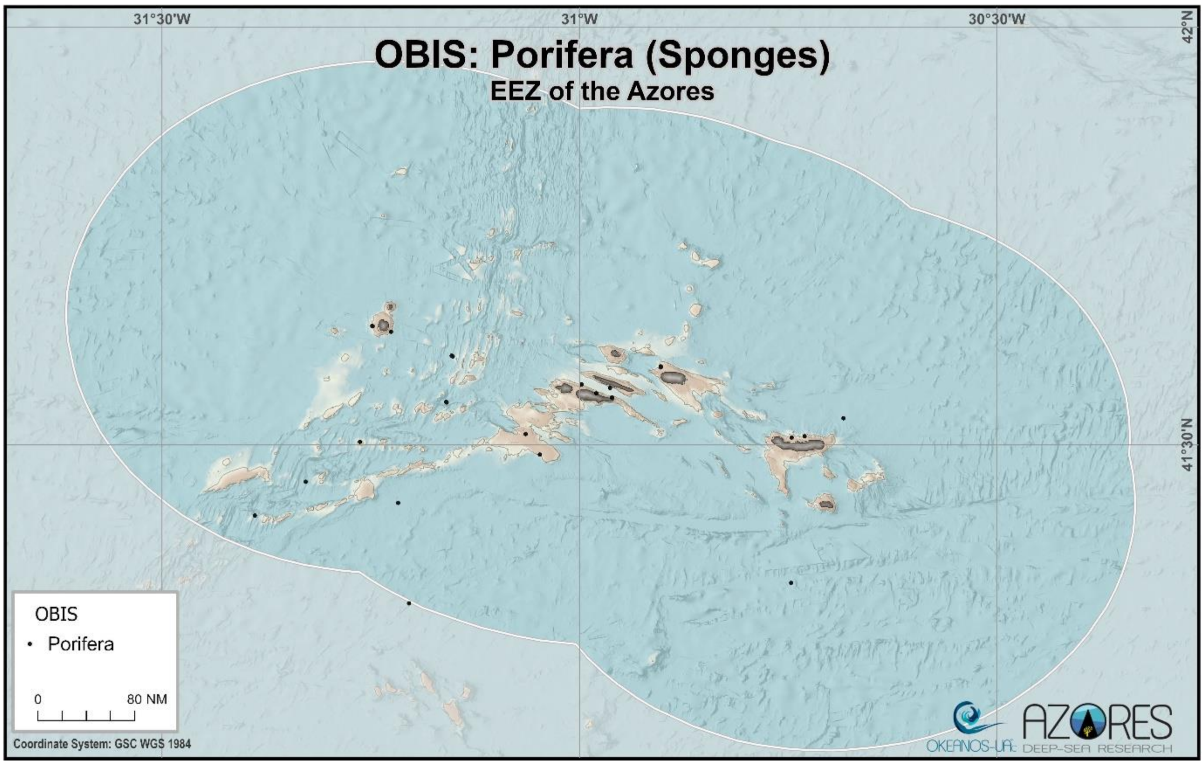



Figure 37 Geographical distribution of the Porifera records, inside the Azores EEZ, contained in the Ocean Biogeographic Information System (OBIS) database, as downloaded on January 20th, 2023.

## 7. Evaluation of areas with sufficient information

Data obtained from underwater images is considered the best tool for identifying the spatial distribution of species, communities, and habitats, but also for identifying areas that fit the criteria that defines what constitute a VME. Here, we used the compilation of the location of the videos surveys collected during all research projects (Table 5) to update the evaluation of the geographic areas with sufficient information done in the R1 report with the data compiled and analysed during this provision of services. As described in the R0 report, the assessment was implemented as follows:

- Identification of distinct geomorphological structures, called sampling areas;
- Compilation of dives down 1,000 m depth carried out in each of the sampling areas;
- Quantification of statistics for each sampling area, namely area in km$^2$, number of dives, number of linear metres surveyed, number of dives per 10 km$^2$ of sampling area, number of linear meters surveyed per 10 km$^2$ of sampling area;
- Evaluation of each sampling area against sampling statistics.

As described in the R1 report, in the context of global deep-sea exploration, due to the cost and difficulty of these operations, “it is very rare that more than two or three ROV dives are conducted on any one seamount” (Watling and Auster, 2021). Therefore, the existence of at least one dive has been considered sufficient for a quick assessment of species, communities, habitats and VMEs. In the context of this provision of services, the sampling areas considered with pre-existing information were defined as those that have more than 1,000 m of depth explored with image collection techniques. For most areas, it was attempted to achieve a sampling coverage corresponding to 1,000 m of the seafloor explored per 10 km$^2$ of sampling area. However, for those sampling areas with vast flat areas dominated by sandy bottoms, this metric becomes unnecessary, as it does not add relevant scientific information to the cost required to obtain it.

The current survey database contains a total of 1 090 underwater video transects inside the Azores sub-area of the Portuguese EEZ down to 1,000 m depth (plus 34 outside the EEZ, plus about 31 that still need to be validated), for a linear distance over the seabed of 1 456 kilometres (1 577 km if considering all the videos), spreading all the 140 sampling areas identified in the R1 report (Table 12). From these videos, about 606 have been annotated for benthic megafauna, with the remaining 484 still to be analysed, which already allows a sufficient description of the deep-sea benthic communities in each of these 140 sampling areas (Table 13Table 1): 69 in the western group (Figure 36), 49 in the northern MAR (Figure 37), 103 in the central MAR (Figure 38), 47 in the southern MAR (Figure 39), 287 in the northern central group (Figure 40), 344 in the southern central group (Figure 41), and 191 in the eastern group (Figure 42). The summary of the statistics for evaluating each sampling area (level 3) with existing information are shown in Table 13.

After assessment of each sampling area against the sampling statistics we concluded that:

- ***Number of video transects*** (i.e., dives) ***collected***: 1,090
- ***Video transects with annotations***: 606 (648 including some outside the Azores EEZ)
- ***Video transects in need of manual annotations***: 484

- ***Areas with sufficient video data***: 140
- ***Areas in need of scientific exploration***: 0

Table 12 Summary of the statistics for each large area (level 1) in terms of the number of dives, number of annotated and not annotated dives, kilometres of surveyed seabed, but also the number sampling areas (level 3) with dives and number of sampling areas that have more than 1,000 m of depth explored with image collection techniques. Those with less than 1,000 m of seabed surveyed were considered areas with substantial knowledge gaps.

| | N dives | | | Seabed | N sampling areas | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | total | annot. | not annot. | Surveyed (km) | w. dives | w. dives anno. | w. dives not annot. | surveyed ≥1,000 m | surveyed <1,000 m |
| Western Group | 69 | 64 | 5 | 94.5 | 11 | 11 | 0 | 11 | 0 |
| Northern MAR | 49 | 37 | 12 | 69.1 | 9 | 9 | 0 | 9 | 0 |
| Central MAR | 103 | 84 | 19 | 114 .2 | 16 | 16 | 0 | 16 | 0 |
| Southern MAR | 47 | 45 | 2 | 61.3 | 10 | 10 | 0 | 10 | 0 |
| Northern Central Group | 287 | 118 | 169 | 432.7 | 40 | 40 | 0 | 40 | 0 |
| Southern Central Group | 344 | 180 | 164 | 462.6 | 31 | 31 | 0 | 31 | 0 |
| Eastern Group | 191 | 78 | 113 | 222.0 | 23 | 23 | 0 | 23 | 0 |
| TOTAL | 1090 | 606 | 484 | 1 456.4 | 140 | 140 | 0 | 140 | 0 |

**Table 13** Summary of the statistics for evaluating the sampling areas with sufficient pre-existing information and with substantial knowledge gaps. Statistics include, number of dives, distance of the seabed Surveyed in meters (m), number of dives annotated with the SACFOR methodology, distance of the seabed annotated in meters (m), area of the seabed surveyed per 10 km$^2$, and number of dives not annotated. No sampling areas are in need of more scientific exploration.

| L1 | Level 2 | Area N | Level 3 | Area Km$^2$ | N Dives | N Dives Annot. | N Dives to annot. | Surveyed m | Annotated m | Area Surveyed Linear m/10 km$^2$ | Survey code |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Western Group | Hard Rock Café | L010101 | Hard-Rock Café | 262.0 | 8 | 5 | 3 | 17 136 | 10 935 | 654 | MapGES_2023_ARQ |
| | Flores/Corvo | L010201 | Corvo NW | 38.7 | 4 | 3 | 1 | 6 005 | 3 248 | 1 553 | MapGES_2021 |
| | | L010202 | Corvo NE | 33.6 | 3 | 3 | 0 | 3 278 | 3 278 | 975 | MapGES_2021 |
| | | L010203 | Corvo SE | 53.0 | 6 | 6 | 0 | 3 911 | 3 911 | 738 | MapGES_2021 |
| | | L010204 | Corvo SW | 48.7 | 7 | 7 | 0 | 3 593 | 3 593 | 738 | MapGES_2021 |
| | | L010205 | Flores NW | 118.3 | 5 | 5 | 0 | 8 793 | 8 793 | 743 | MapGES_2022 |
| | | L010206 | Flores NE | 75.2 | 6 | 6 | 0 | 7 412 | 7 412 | 986 | MapGES_2022 |
| | | L010207 | Flores E | 101.6 | 6 | 6 | 0 | 6 513 | 6 513 | 641 | MapGES_2022 |
| | | L010208 | Flores S | 134.2 | 6 | 6 | 0 | 8 336 | 8 336 | 621 | MapGES_2022 |
| | | L010209 | Flores W | 118.2 | 6 | 6 | 0 | 7 361 | 7 361 | 623 | MapGES_2022 |
| | | L010210 | Cachalote | 179.0 | 12 | 11 | 1 | 22 124 | 21 793 | 1 236 | NOAA_EX2206, MapGES_2022 |
| Northern Mid-Atlantic | South of Chaucer | L020101 | Chaucer S | 285.7 | 3 | 2 | 1 | 6 285 | 5 882 | 220 | NOAA_EX2206, iMAR_2021 |
| | | L020102 | Estrela | 254.4 | 3 | 2 | 1 | 6 976 | 6 436 | 274 | iMAR_2021 |
| | Kurchatov | L020202 | Kurchatov N | 129.8 | 3 | 2 | 1 | 6 082 | 5 916 | 469 | MapGES_2023_ARQ, iMAR_2021 |
| | | L020203 | Isolado | 99.3 | 6 | 4 | 2 | 10 011 | 7 117 | 1008 | MapGES_2023_ARQ, iMAR_2021 |
| | | L020204 | Kurchatov SE | 153.1 | 6 | 4 | 2 | 9 855 | 6 728 | 644 | MapGES_2023_ARQ |
| | | L020205 | Kurchatov S | 101.3 | 3 | 3 | 0 | 7 690 | 7 690 | 759 | iMAR_2021 |
| | | L020206 | Kurchatov SW | 769.8 | 7 | 3 | 4 | 9 579 | 4 133 | 124 | NOAA_EX2206, MapGES_2023_ARQ, iMAR_2021 |
| | | L020207 | Agulhas Corvo-Graciosa | 219.8 | 3 | 2 | 1 | 4 437 | 4 041 | 202 | iMAR_2021 |
| | | L020208 | Óscar | 191.8 | 15 | 15 | 0 | 8 183 | 8 183 | 427 | MapGES_2019 |
| Central Mid-Atlantic Ridge | Gigante | L030101 | Gigante N | 325.4 | 8 | 5 | 3 | 9 326 | 11 287 | 287 | iMAR_2021, EXPLOSEA2_2019 |
| | | L030102 | Gigante | 482.1 | 16 | 7 | 9 | 15 087 | 6 072 | 313 | Transect_2018, MapGES_2019, EXPLOSEA2_2019, BlueAzores_2018 |
| | | L030103 | Gigante Agulhas NE | 153.0 | 4 | 2 | 2 | 1 959 | 1 186 | 128 | MapGES_2019 |
| | | L030104 | Gigante Agulhas NW | 152.2 | 2 | 2 | 0 | 5 987 | 5 987 | 393 | iMAR_2021 |
| | | L030106 | Gigante 127 | 102.8 | 10 | 10 | 0 | 8 769 | 8 769 | 853 | MapGES_2019, BlueAzores_2018 |
| | | L030107 | Gigante Agulhas S | 97.3 | 4 | 3 | 1 | 3 721 | 2 902 | 383 | MapGES_2019 |
| | | L030108 | Gigante Agulhas SW | 135.7 | 9 | 8 | 1 | 10 053 | 9 565 | 741 | MapGES_2019, BlueAzores_2018 |
| | Cavala | L030202 | Ferradura E | 196.9 | 8 | 6 | 2 | 5 810 | 5 032 | 295 | MapGES_2019 |
| | | L030203 | Ferradura | 410.1 | 7 | 7 | 0 | 7 476 | 7 476 | 182 | MapGES_2019 |
| | | L030204 | Cavala | 356.9 | 17 | 17 | 0 | 17 981 | 17 981 | 504 | MapGES_2019, iMAR_2021 |
| | | L030205 | Beta | 204.1 | 6 | 5 | 1 | 5 554 | 5 540 | 272 | MapGES_2019 |
| | Picos SE Flores | L030302 | Diogo Teive | 59.1 | 3 | 3 | 0 | 5 087 | 5 087 | 861 | MapGES_2022 |

| L1 | Level 2 | Area N | Level 3 | Area Km² | N Dives | N Dives Annot. | N Dives to annot. | Surveyed m | Annotated m | Area Surveyed Linear m/10 km² | Survey code |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | L030305 | Buchanan | 449.7 | 1 | 1 | 0 | 6 117 | 6 117 | 136 | iMAR_2022 |
| | | L030306 | Cabeçote | 98.0 | 1 | 1 | 0 | 2 329 | 2 329 | 238 | iMAR_2022 |
| | | L030309 | Sardinha | 112.8 | 1 | 1 | 0 | 2 997 | 2 997 | 266 | iMAR_2022 |
| | | L030310 | Lucky Strike E | 188.6 | 6 | 6 | 0 | 5 947 | 5 947 | 315 | MapGES_2019 |
| Southern Mid-Atlantic Ridge | Alberto do Mónaco | L040102 | Menez Gwen | 78.3 | 2 | 1 | 1 | 3 200 | 3 121 | 409 | iMAR_2022, EMEPC_2009 |
| | | L040103 | Picoto | 178.5 | 5 | 5 | 0 | 4 875 | 4 875 | 273 | MapGES_2019 |
| | | L040105 | Alfa | 151.3 | 8 | 7 | 1 | 5 487 | 5 470 | 363 | MapGES_2019, iMAR_2022 |
| | | L040106 | Alfa E | 69.5 | 1 | 1 | 0 | 3 405 | 3 405 | 490 | iMAR_2022 |
| | | L040108 | Voador | 1293.2 | 19 | 19 | 0 | 16 274 | 16 274 | 126 | MapGES_2019, iMAR_2022 |
| | | L040110 | Monte Alto | 798.5 | 4 | 4 | 0 | 3 344 | 3 344 | 42 | MapGES_2019 |
| | Farpas | L040201 | Farpas | 413.2 | 2 | 2 | 0 | 5 220 | 5 220 | 126 | iMAR_2022 |
| | | L040202 | Espadarte | 487.5 | 1 | 1 | 0 | 1 739 | 1 739 | 36 | NICO_2018 |
| | Sarda | L040302 | Sarda E | 374.9 | 2 | 2 | 0 | 6 816 | 6 816 | 182 | Rainbow_2019, iMAR_2022 |
| | | L040303 | Sarda | 1144.2 | 3 | 3 | 0 | 10 986 | 10 986 | 96 | Rainbow_2019 |
| Northern Central Group | Sedlo | L050101 | Sedlo W | 179.9 | 3 | 3 | 0 | 7 823 | 7 823 | 435 | MapGES_2023_ARQ |
| | | L050102 | Sedlo | 460.3 | 14 | 4 | 10 | 27 565 | 9 023 | 599 | MapGES_2023_ARQ |
| | | L050103 | Gaillard | 189.2 | 3 | 3 | 0 | 7 232 | 7 232 | 382 | MapGES_2023_ARQ |
| | | L050104 | Borda | 235.1 | 10 | 4 | 6 | 20 002 | 10 919 | 851 | MapGES_2023_ARQ |
| | | L050105 | João Leonardes | 164.8 | 5 | 4 | 1 | 6 601 | 6 482 | 400 | MapGES_2023_ARQ, MapGES_2020 |
| | | L050106 | Serreta Mar | 191.4 | 5 | 4 | 1 | 5 202 | 4 344 | 272 | MapGES_2023_ARQ, MapGES_2020 |
| | Graciosa/São Jorge | L050203 | Mar da Fortuna | 299.3 | 10 | 6 | 4 | 11 560 | 8 053 | 386 | MapGES_2023_ARQ, MapGES_2020 |
| | | L050204 | Graciosa NW | 120.6 | 8 | 8 | 0 | 8 786 | 8 786 | 729 | MapGES_2020 |
| | | L050205 | Graciosa NE | 141.7 | 6 | 6 | 0 | 3 455 | 3 455 | 244 | MapGES_2020 |
| | | L050206 | Graciosa SE | 77.3 | 5 | 5 | 0 | 2 686 | 2 686 | 348 | MapGES_2020 |
| | | L050207 | Graciosa S | 94.8 | 7 | 6 | 1 | 3 339 | 3 211 | 352 | MapGES_2020 |
| | | L050208 | Graciosa SW | 110.8 | 6 | 6 | 0 | 3 749 | 3 749 | 338 | MapGES_2020 |
| | | L050209 | Perestrelo Bartolomeu | 60.6 | 7 | 6 | 1 | 10 088 | 8 664 | 1 664 | MapGES_2023_ARQ, MapGES_2022 |
| | | L050211 | Ilha Azul | 256.7 | 10 | 11 | 0 | 9 292 | 12 047 | 362 | MapGES_2020 |
| | | L050212 | Ilha Azul E | 78.7 | 3 | 3 | 0 | 1 842 | 1 842 | 234 | MapGES_2020 |
| | | L050213 | Ilha Azul SE | 29.0 | 1 | 1 | 0 | 2 186 | 2 186 | 754 | Terceira_2020 |
| | | L050214 | São Jorge NW | 145.3 | 8 | 2 | 6 | 11 955 | 4 386 | 823 | MapGES_2023_ARQ, MapGES_2022, EMEPC_2009 |
| | | L050215 | São Jorge NE | 108.2 | 5 | 2 | 3 | 6 427 | 3 834 | 594 | MapGES_2023_PHY, MapGES_2023_ARQ |
| | | L050216 | São Jorge E Topo | 159.0 | 8 | 1 | 7 | 30 847 | 1 745 | 1 940 | MapGES_2023_PHY, DeepWalls_2020 |
| | | L050217 | São Jorge SE | 98.8 | 5 | 1 | 4 | 56 037 | 1 774 | 5 671 | MapGES_2023_PHY, DeepWalls_2020 |
| | | L050218 | São Jorge S Urzelina | 77.2 | 8 | 1 | 7 | 19 305 | 1 472 | 2 501 | MapGES_2023_PHY, EMEPC_2009, |

| L1 | Level 2 | Area N | Level 3 | Area Km² | N Dives | N Dives Annot. | N Dives to annot. | Surveyed m | Annotated m | Area Surveyed Linear m/10 km² | Survey code |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | DeepWalls_2020, BlueAzores_2018 |
| | | L050219 | São Jorge SW Velas | 78.3 | 5 | 2 | 3 | 6 197 | 2 726 | 792 | MapGES_2022, FRN_2013-2017 |
| | | L050220 | São Jorge W Rosais | 115.1 | 17 | 2 | 15 | 13 634 | 3 022 | 1 185 | MapGES_2021, FRN_2013-2017 |
| | | L050221 | João de Melo | 256.4 | 5 | 1 | 4 | 9 677 | 1 620 | 377 | Terceira_2019, NICO_2018 |
| | Terceira | L050301 | Terceira N | 190.5 | 11 | 1 | 10 | 14 334 | 1 287 | 753 | MapGES_2023_PHY |
| | | L050302 | Terceira NE | 76.5 | 9 | 2 | 7 | 8 844 | 2 124 | 1 156 | MapGES_2023_PHY, MapGES_2020 |
| | | L050303 | Terceira E | 479.3 | 10 | 1 | 9 | 13 304 | 1 252 | 278 | MapGES_2023_PHY EMEPC_2009 |
| | | L050304 | Terceira S | 339.0 | 11 | 1 | 10 | 12 081 | 1 228 | 356 | MapGES_2023_PHY |
| | | L050305 | Terceira SW Angra | 172.3 | 4 | 2 | 2 | 5 855 | 1 466 | 340 | Terceira_2020, Terceira_2019, NICO_2018 |
| | | L050306 | Terceira W Serreta | 207.1 | 17 | 1 | 16 | 15 677 | 1 573 | 757 | Terceira_2021, MapGES_2023_PHY, MapGES_2020 |
| | | L050307 | Maçarico | 253.1 | 10 | 2 | 8 | 9 455 | 2 306 | 374 | MapGES_2023_PHY |
| | | L050308 | Álvaro Martins | 73.9 | 4 | 1 | 3 | 6 212 | 1 917 | 841 | MapGES_2023_PHY |
| | | L050309 | Beirada de Fora | 207.3 | 5 | 1 | 4 | 5 404 | 1 442 | 261 | MapGES_2023_PHY |
| | | L050310 | Gastromar | 466.7 | 9 | 1 | 8 | 10 912 | 1 400 | 234 | MapGES_2023_PHY |
| | | L050311 | Albatroz do Norte | 194.6 | 6 | 2 | 4 | 8 041 | 4 122 | 413 | MapGES_2023_ARQ |
| | Dom João de Castro | L050402 | Alcatraz | 659.9 | 4 | 1 | 3 | 2 663 | 1 296 | 40 | NOAA_EX2206, MapGES_2018 |
| | | L050403 | Dom João de Castro | 176.6 | 7 | 1 | 6 | 8 072 | 1 244 | 457 | OceanX_2023, MapGES_2018, EMEPC_2009 |
| | | L050404 | Ferraria Norte | 134.0 | 3 | 2 | 1 | 4 549 | 3 171 | 339 | MapGES_2023_ARQ |
| | | L050405 | Ferraria Mar | 236.3 | 7 | 1 | 6 | 12 332 | 1 749 | 522 | MapGES_2023_ARQ |
| | | L050406 | Girard | 544.5 | 6 | 6 | 0 | 9 499 | 9 499 | 174 | MapGES_2022 |
| Southern Central Group | Faial/Pico | L060101 | Faial NW | 73.6 | 11 | 6 | 5 | 8 715 | 4 655 | 1 184 | MapGES_2021 |
| | | L060102 | Faial N | 70.6 | 13 | 5 | 8 | 10 466 | 3 699 | 1 482 | MapGES_2021, MapGES_2019 |
| | | L060103 | Faial-Pico N | 71.8 | 11 | 2 | 9 | 11 632 | 3 641 | 1 619 | MapGES_2022, MapGES_2021, MapGES_2019 |
| | | L060104 | Pico NW | 94.8 | 12 | 1 | 11 | 11 002 | 867 | 1 161 | MapGES_2021, MapGES_2019 |
| | | L060105 | Pico NE | 104.3 | 6 | 4 | 2 | 9 248 | 7 633 | 886 | MapGES_2023_PHY, BlueAzores_2018 |
| | | L060106 | Pico S Lajes | 123.9 | 9 | 2 | 7 | 33 869 | 1 958 | 2 735 | OceanX_2023, MapGES_2021, DeepWalls_2020, BlueAzores_2018 |
| | | L060107 | Pico SW Espartel | 88.0 | 15 | 3 | 12 | 16 187 | 1 285 | 1 839 | MapGES_2021 |
| | | L060108 | Faial-Pico S | 113.4 | 17 | 9 | 8 | 15 482 | 10 007 | 1 365 | MapGES_2023_PHY, MapGES_2021, MapGES_2020, CoralFish_2010, CoralFish_2009 |
| | | L060109 | Faial S | 53.0 | 13 | 12 | 1 | 9 061 | 8 954 | 1 710 | MapGES_2023_PHY, MapGES_2021 |
| | | L060110 | Faial Filhas do Condor | 162.8 | 13 | 11 | 2 | 11 948 | 11 899 | 734 | MapGES_2021 |
| | | L060111 | Faial W Capelinhos | 149.5 | 27 | 2 | 25 | 36 959 | 1 641 | 2 472 | OceanX_2023, MapGES_2021, MapGES_2019, EXPLOSEA2_2019 |
| | | L060112 | Condor | 275.4 | 41 | 2 | 39 | 48 270 | 6 893 | 1 753 | MIDAS_2016, CoralFish_2010 |
| | | L060113 | Baixo de São Mateus | 357.3 | 25 | 25 | 0 | 22 339 | 22 339 | 625 | MapGES_2021, MapGES_2020 |

| L1 | Level 2 | Area N | Level 3 | Area Km² | N Dives | N Dives Annot. | N Dives to annot. | Surveyed m | Annotated m | Area Surveyed Linear m/10 km² | Survey code |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | L060114 | Ponta da Ilha N | 289.5 | 10 | 1 | 9 | 15 792 | 893 | 546 | OceanX_2023, MapGES_2019 |
| | | L060115 | Ponta da Ilha S | 303.1 | 4 | 3 | 1 | 5 221 | 3 699 | 172 | MapGES_2019 |
| | | L060116 | Albatroz do Meio | 157.8 | 7 | 7 | 0 | 10 052 | 10 052 | 637 | MapGES_2022 |
| | Princesa Alice | L060201 | Agulhas 12 Milhas | 438.0 | 20 | 19 | 1 | 22 905 | 21 827 | 523 | MapGES_2023_PHY, MapGES_2021 |
| | | L060202 | Condor de Fora | 163.6 | 14 | 12 | 2 | 11 047 | 9 856 | 675 | MapGES_2023_PHY, MapGES_2020 |
| | | L060203 | Agulhas 18 Milhas | 125.9 | 5 | 7 | 0 | 11 307 | | 898 | MapGES_2023_PHY |
| | | L060204 | Bourée NE | 322.5 | 7 | 7 | 0 | 12 992 | 12 992 | 403 | MapGES_2023_PHY |
| | | L060205 | Bourée E | 471.4 | 3 | 1 | 2 | 3 871 | 1 232 | 82 | OceanX_2023 |
| | | L060206 | Açor | 407.9 | 4 | 4 | 0 | 7 532 | 7 532 | 185 | MapGES_2023_PHY |
| | | L060207 | Açor S | 379.3 | 2 | 2 | 0 | 1 429 | 1 429 | 38 | CoralFish_2010 |
| | | L060208 | De Guerne N | 290.8 | 10 | 10 | 0 | 18 688 | 18 688 | 643 | MapGES_2023_PHY |
| | | L060209 | De Guerne | 490.7 | 2 | 1 | 1 | 4 256 | 2 689 | 87 | MapGES_2023_ARQ |
| | | L060210 | São Mateus de Fora | 197.3 | 9 | 9 | 0 | 8 941 | 8 941 | 453 | MapGES_2023_PHY |
| | | L060211 | Princesa Alice | 1083.8 | 7 | 1 | 6 | 28 582 | 6 599 | 264 | OceanX_2023, CoralFish_2010 |
| | | L060213 | Princesa Alice W | 616.8 | 8 | 3 | 5 | 19 445 | 5 874 | 315 | OceanX_2023, MapGES_2023_ARQ |
| | | L060215 | Princesa Alice Picos S | 688.6 | 14 | 5 | 9 | 23 360 | 9 720 | 339 | MapGES_2023_ARQ, EXPLOSEA2_2019 |
| | | L060216 | Henry Carr | 248.5 | 3 | 3 | 0 | 7 175 | 7 175 | 289 | MapGES_2023_ARQ |
| | | L060217 | Princesa Alice SW | 267.5 | 2 | 1 | 1 | 4 831 | 1 992 | 181 | MapGES_2023_ARQ |
| Eastern Group | São Miguel | L070101 | São Miguel NW | 145.2 | 9 | 1 | 8 | 10 207 | 1 571 | 703 | MapGES_2023_PHY |
| | | L070102 | São Miguel N | 307.8 | 9 | 1 | 8 | 10 856 | 1 355 | 353 | MapGES_2023_PHY |
| | | L070103 | São Miguel NE | 211.3 | 11 | 1 | 10 | 9 876 | 1 302 | 467 | MapGES_2023_PHY |
| | | L070104 | São Miguel E | 219.7 | 9 | 1 | 8 | 7 942 | 1 163 | 361 | MapGES_2023_PHY |
| | | L070105 | São Miguel SE | 271.1 | 9 | 1 | 8 | 7 703 | 1 341 | 284 | MapGES_2023_PHY |
| | | L070106 | São Miguel S | 335.5 | 11 | 1 | 10 | 12 367 | 1 379 | 369 | MapGES_2023_PHY |
| | | L070107 | São Miguel SW | 244.9 | 10 | 1 | 9 | 10 488 | 1 690 | 428 | MapGES_2023_PHY, EMEPC_2009 |
| | | L070108 | São Miguel W | 137.9 | 8 | 1 | 7 | 6 026 | 1 030 | 437 | MapGES_2023_PHY |
| | Mar da Prata | L070201 | Mar da Prata N | 459.1 | 11 | 3 | 8 | 11 613 | 3 680 | 253 | MapGES_2023_PHY, MapGES_2023_ARQ |
| | | L070202 | Mar da Prata | 0.0 | 7 | 2 | 5 | 6 456 | 2 493 | | MapGES_2023_ARQ |
| | | L070203 | Mar da Prata S | 358.2 | 10 | 2 | 8 | 9 066 | 2 977 | 253 | MapGES_2023_ARQ, MapGES_2018 |
| | | L070204 | Maria Celeste | 306.4 | 5 | 5 | 0 | 9 543 | 9 543 | 311 | MapGES_2022 |
| | | L070205 | Sauerwein | 125.3 | 2 | 2 | 0 | 2 980 | 2 980 | 238 | MapGES_2023_ARQ |
| | Formigas | L070301 | Grande Norte | 396.9 | 13 | 2 | 11 | 15 355 | 2 487 | 387 | MapGES_2023_ARQ |
| | | L070302 | Formigas | 400.3 | 20 | 10 | 10 | 21 736 | 13 067 | 543 | MedWaves_2016, MapGES_2022 |
| | | L070303 | Margrette | 362.9 | 10 | 8 | 2 | 11 691 | 10 195 | 322 | MapGES_2022 |
| | | L070304 | Margrette E | 131.8 | 5 | 4 | 1 | 4 640 | 3 958 | 352 | NOAA_EX2206, MapGES_2022 |
| | | L070305 | Margrette NE | 66.4 | 2 | 2 | 0 | 4 200 | 4 200 | 632 | MapGES_2022 |

| L1 | Level 2 | Area N | Level 3 | Area Km² | N Dives | N Dives Annot. | N Dives to annot. | Surveyed m | Annotated m | Area Surveyed Linear m/10 km² | Survey code |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Santa Maria | L070401 | Santa Maria N | 111.8 | 7 | 7 | 0 | 9 448 | 9 448 | 845 | MapGES_2022 |
| | | L070402 | Santa Maria E | 81.7 | 5 | 5 | 0 | 10 092 | 10 092 | 1 236 | MapGES_2022 |
| | | L070403 | Santa Maria SW | 83.6 | 7 | 7 | 0 | 8 105 | 8 105 | 969 | MapGES_2022 |
| | | L070404 | Santa Maria W | 129.5 | 6 | 6 | 0 | 10 550 | 10 550 | 815 | MapGES_2022 |
| | | L070405 | Santa Maria Pico W | 89.1 | 5 | 5 | 0 | 11 066 | 11 066 | 1 243 | MapGES_2022 |

### *7.1 Western Group of the Azores*

In the study area of the Western Group of the Azores (Figure 38), we have identified the following:

- ***Areas with sufficient video data***: Hard-Rock Café, Corvo NW, Corvo NE, Corvo SE, Corvo SW, Flores NW, Flores NE, Flores E, Flores S, Flores W, Cachalote.
- ***Areas in need of scientific exploration***: 0

- ***Number of video transects*** (i.e., dives) ***collected***: 69
- ***Video transects with annotations***: 64
- ***Video areas transects in need of manual annotations***: 5

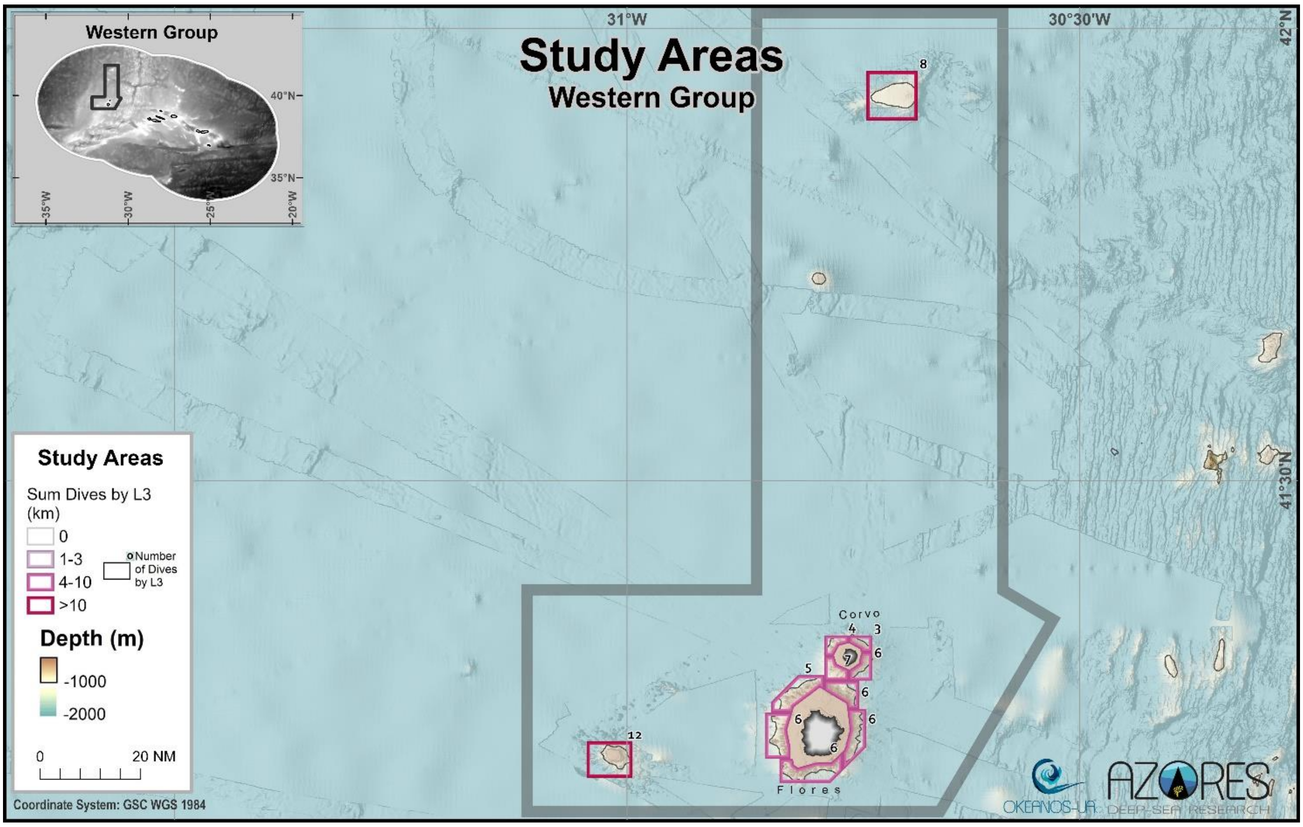



Figure 38 Sampling areas with sufficient coverage of video surveys (pinkish) and those lacking explorations (white) in the western group. Colour of the outlines are scaled to the number of km of the seafloor surveyed. Those areas with less than 1 km are shown in white. Numbers refer to the number of dives in the sampling area.

### *7.2 Northern Mid-Atlantic Ridge*

In the study area of the Northern Mid-Atlantic Ridge (Figure 39), we have identified the following:

- ***Areas with sufficient video data***: 9; Chaucer S, Estrela, Kurchatov N, Isolado, Kurchatov SE, Kurchatov S, Kurchatov SW, Agulhas Corvo-Graciosa, Óscar.
- ***Areas in need of scientific exploration***: 0

- ***Number of video transects*** (i.e., dives) ***collected***: 49
- ***Video transects with annotations***: 37
- ***Video transects in need of manual annotations***: 12

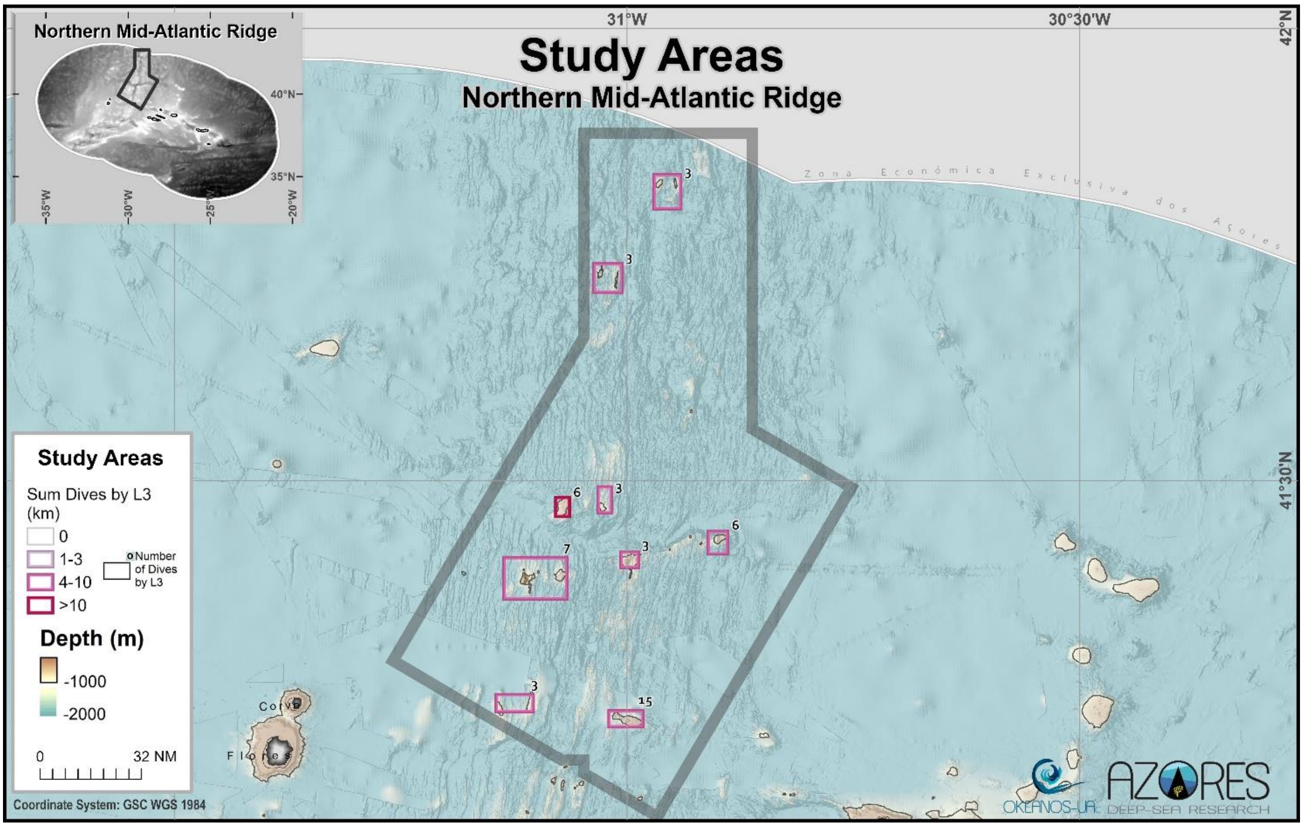



Figure 39 Sampling areas with sufficient coverage of video surveys (pinkish) and those lacking explorations (white) in the Northern Mid-Atlantic Ridge. The colour of the outlines is scaled to the number of km of the seafloor surveyed. Those areas with less than 1 km are shown in white. Numbers refer to the number of dives in the sampling area.

### 7.3 Central Mid-Atlantic Ridge

In the study area of the central Mid-Atlantic Ridge (Figure 40), we have identified the following:

- *Areas with sufficient video data*: 16; Gigante N, Gigante, Gigante Agulhas NE, Gigante Agulhas NW, Gigante 127, Gigante Agulhas S, Gigante Agulhas SW, Ferradura E, Ferradura, Cavala, Beta, Diogo Teive, Buchanan, Cabeçote, Sardinha, Lucky Strike E.
- *Areas in need of scientific exploration*: 0

- *Number of video transects* (i.e., dives) *collected*: 103
- *Video transects with annotations*: 84
- *Video transects in need of manual annotations*: 19

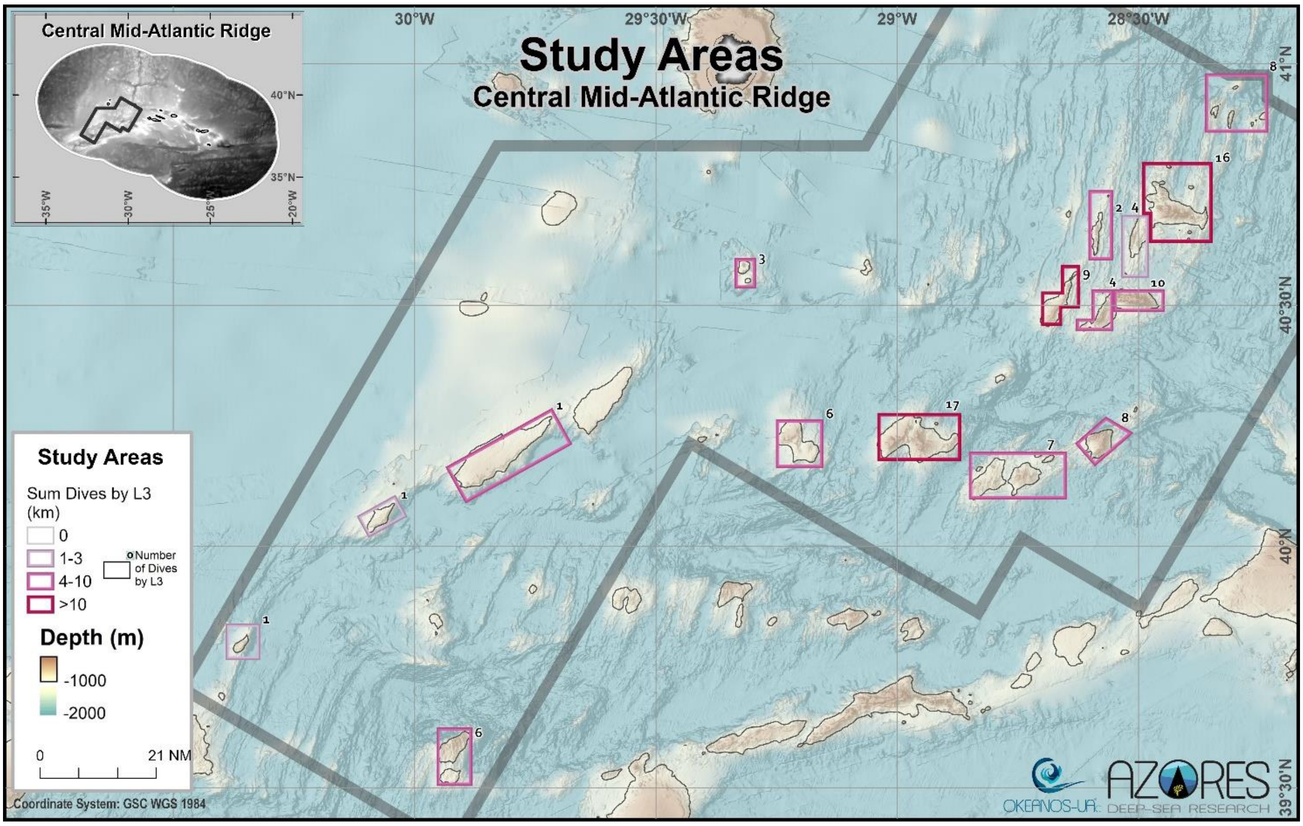



**Figure 40** Sampling areas with sufficient coverage of video surveys (pinkish) and those lacking explorations (white) in the central Mid-Atlantic Ridge. The colour of the outlines is scaled to the number of km of the seafloor surveyed. Those areas with less than 1 km are shown in white. Numbers refer to the number of dives in the sampling area.

### *7.4 Southern Mid-Atlantic Ridge*

In the study area of the Southern Mid-Atlantic Ridge (Figure 41), we have identified the following:

- ***Areas with sufficient video data***: 10, Menez Gwen, Picoto, Alfa, Alfa E, Voador, Monte Alto, Farpas, Espadarte, Sarda E, Sarda.
- ***Areas in need of scientific exploration***: 0

- ***Number of video transects*** (i.e., dives) ***collected***: 47
- ***Video transects with annotations***: 45
- ***Video transects in need of manual annotations***: 2

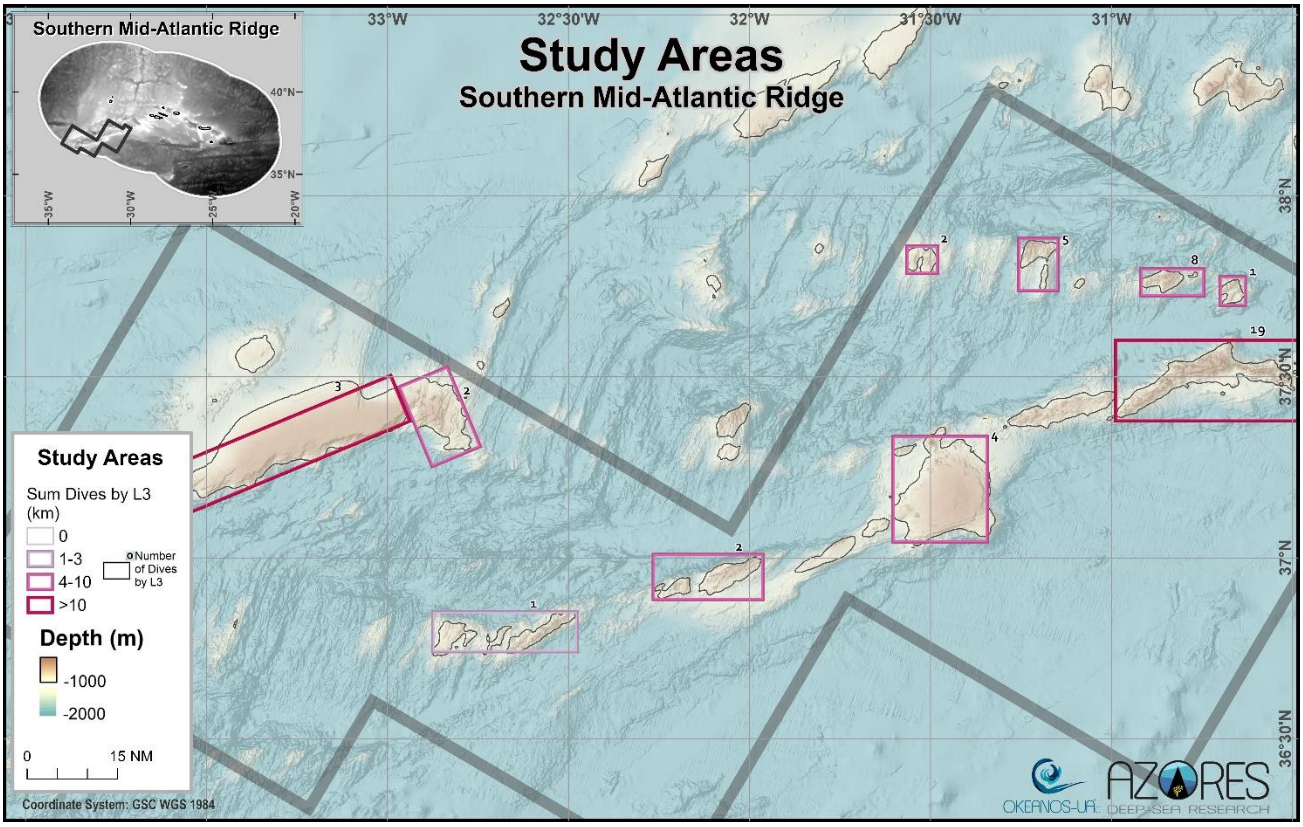



Figure 41 Sampling areas with sufficient coverage of video surveys (pinkish) and those lacking explorations (white) in the Southern Mid-Atlantic Ridge. The colour of the outlines is scaled to the number of km of the seafloor surveyed. Those areas with less than 1 km are shown in white. Numbers refer to the number of dives in the sampling area.

### *7.5 Northern part of the Central Group of the Azores*

In the study area of the Northern part of the Central Group (Figure 42), we have identified the following:

- *Areas with sufficient video data*: 40; Sedlo W, Sedlo, Gaillard, Borda, João Leonardes, Serreta Mar, Mar da Fortuna, Graciosa NW, Graciosa NE, Graciosa SE, Graciosa S, Graciosa SW, Perestrelo Bartolomeu, Ilha Azul, Ilha Azul E, Ilha Azul SE, São Jorge NW, São Jorge NE, São Jorge E Topo, São Jorge SE, São Jorge S Urzelina, São Jorge SW Velas, São Jorge W Rosais, João de Melo. Terceira N, Terceira NE, Terceira E, Terceira S, Terceira SW Angra, Terceira W Serreta, Maçarico, Álvaro Martins, Beirada de Fora, Gastromar, Albatroz do Norte, Alcatraz, Dom João de Castro, Ferraria Norte, Ferraria Mar, Girard.
- *Areas in need of scientific exploration*: 0

- *Number of video transects* (i.e., dives) *collected*: 287
- *Video transects with annotations*: 118
- *Video transects in need of manual annotations*: 169

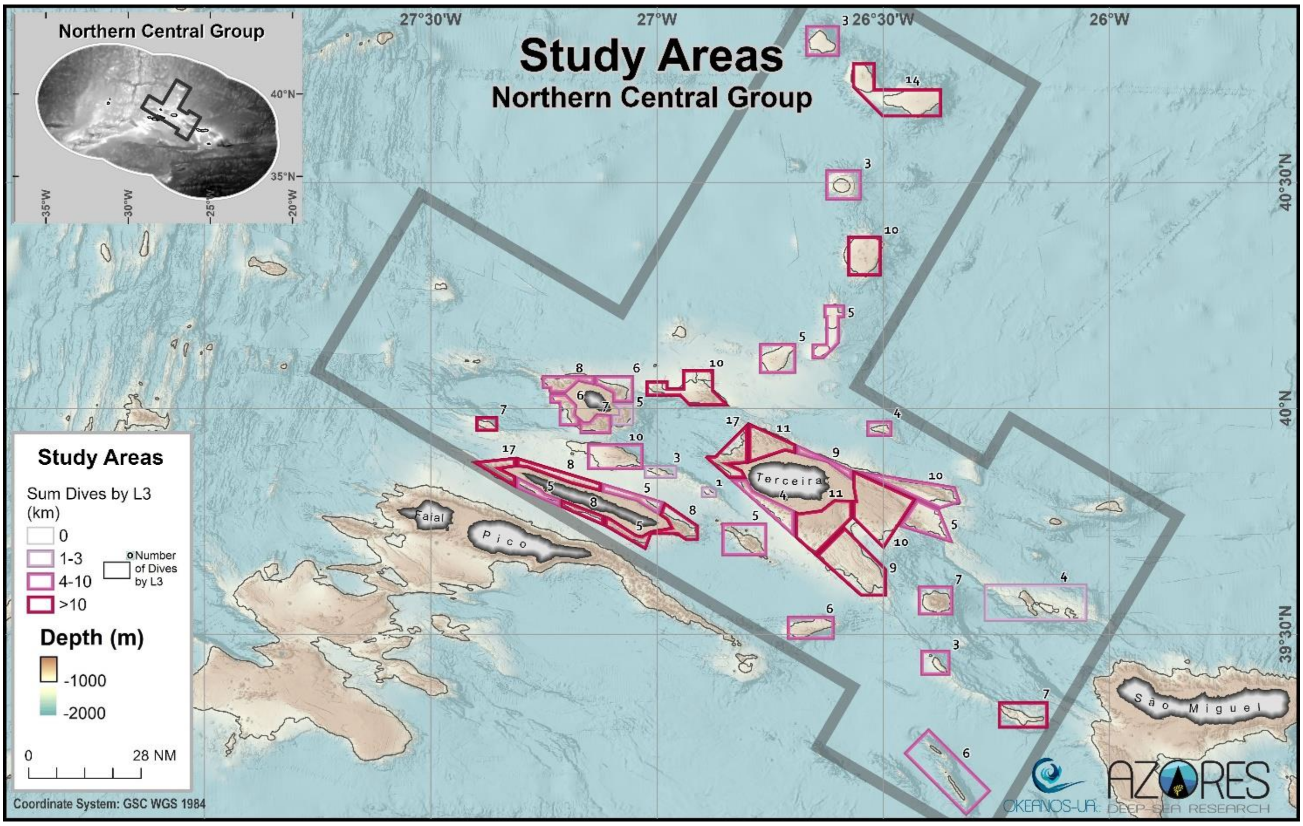



Figure 42 Sampling areas with sufficient coverage of video surveys (pinkish) and those lacking explorations (white) in the Northern part of the Central Group of the Azores. The colour of the outlines is scaled to the number of km of the seafloor surveyed. Those areas with less than 1 km are shown in white. Numbers refer to the number of dives in the sampling area.

### *7.6 Southern part of the Central Group of the Azores*

In the study area of the Southern part of the Central Group of the Azores (Figure 43), we have identified the following:

- ***Areas with sufficient video data***: 31; Faial NW, Faial N, Faial-Pico N, Pico NW, Pico NE, Pico S Lajes, Pico SW Espartel, Faial-Pico S, Faial S, Faial Filhas do Condor, Faial W Capelinhos, Condor, Baixo de São Mateus, Ponta da Ilha N, Ponta da Ilha S, Albatroz do Meio, Agulhas 12 Milhas, Condor de Fora, Agulhas 18 Milhas, Bourée NE, Bourée E, Açor, Açor S, De Guerne N, De Guerne, São Mateus de Fora, Princesa Alice, Princesa Alice W, Princesa Alice Picos S, Henry Carr, Princesa Alice SW.
- ***Areas in need of scientific exploration***: 0

- ***Number of video transects*** (i.e., dives) ***collected***: 344
- ***Video transects with annotations***: 180
- ***Video transects in need of manual annotations***: 164.

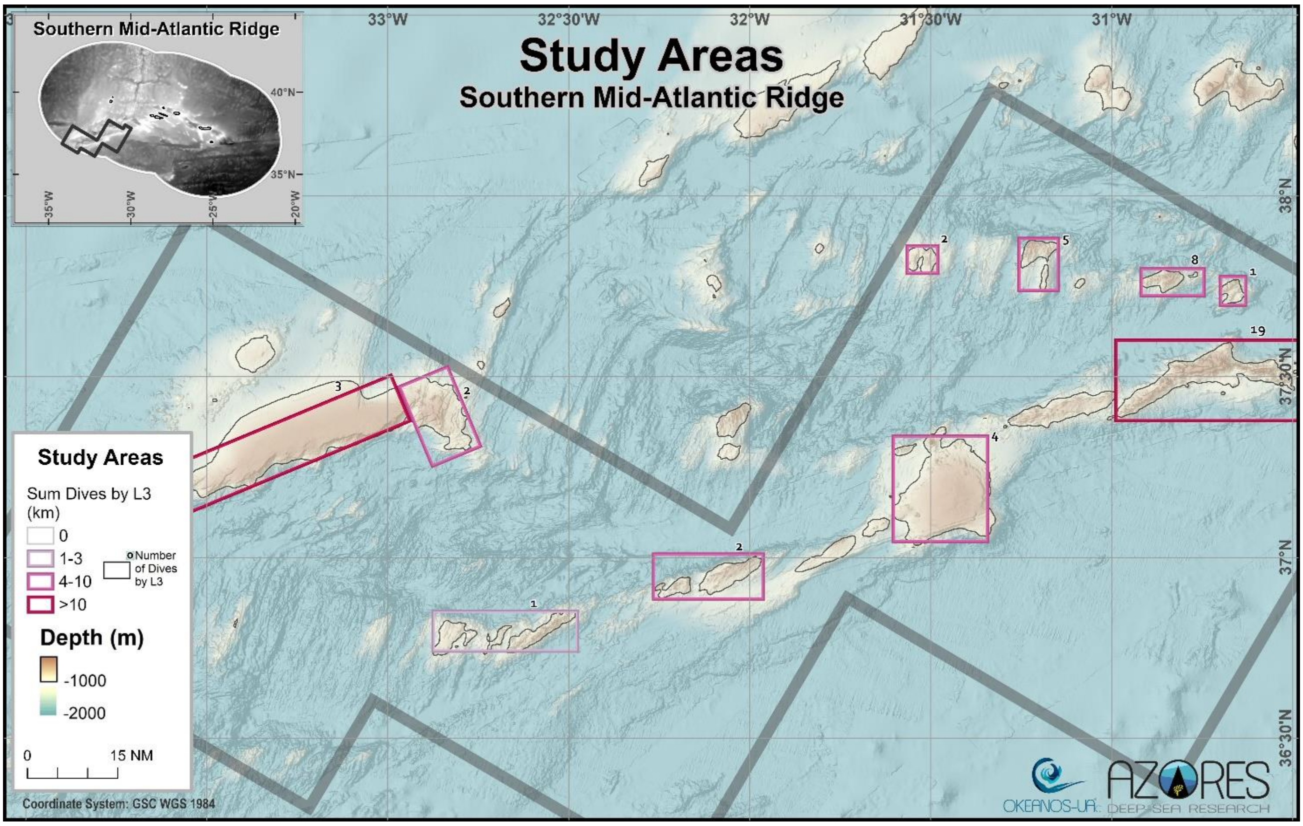



**Figure 43** Sampling areas with sufficient coverage of video surveys (pinkish) and those lacking explorations (white) in the Southern part of the Central Group of the Azores. The colour of the outlines is scaled to the number of km of the seafloor surveyed. Those areas with less than 1 km are shown in white. Numbers refer to the number of dives in the sampling area.

### *7.7 Eastern Group of the Azores*

In the study area of the Eastern Group of the Azores (Figure 44), we have identified the following:

- ***Areas in need of scientific exploration***: 23; São Miguel NW, São Miguel N, São Miguel NE, São Miguel E, São Miguel SE, São Miguel S, São Miguel SW, São Miguel W, Mar da Prata N, Mar da Prata, Mar da Prata

S, Maria Celeste, Sauerwein, Grande Norte, Formigas, Margrette, Margrette E, Margrette NE, Santa Maria N, Santa Maria E, Santa Maria SW, Santa Maria W, Santa Maria Pico W.

- *Areas with sufficient video data*: 0.

- *Number of video transects* (i.e., dives) *collected*: 191
- *Video transects with annotations*: 78
- *Video transects in need of manual annotations*: 113

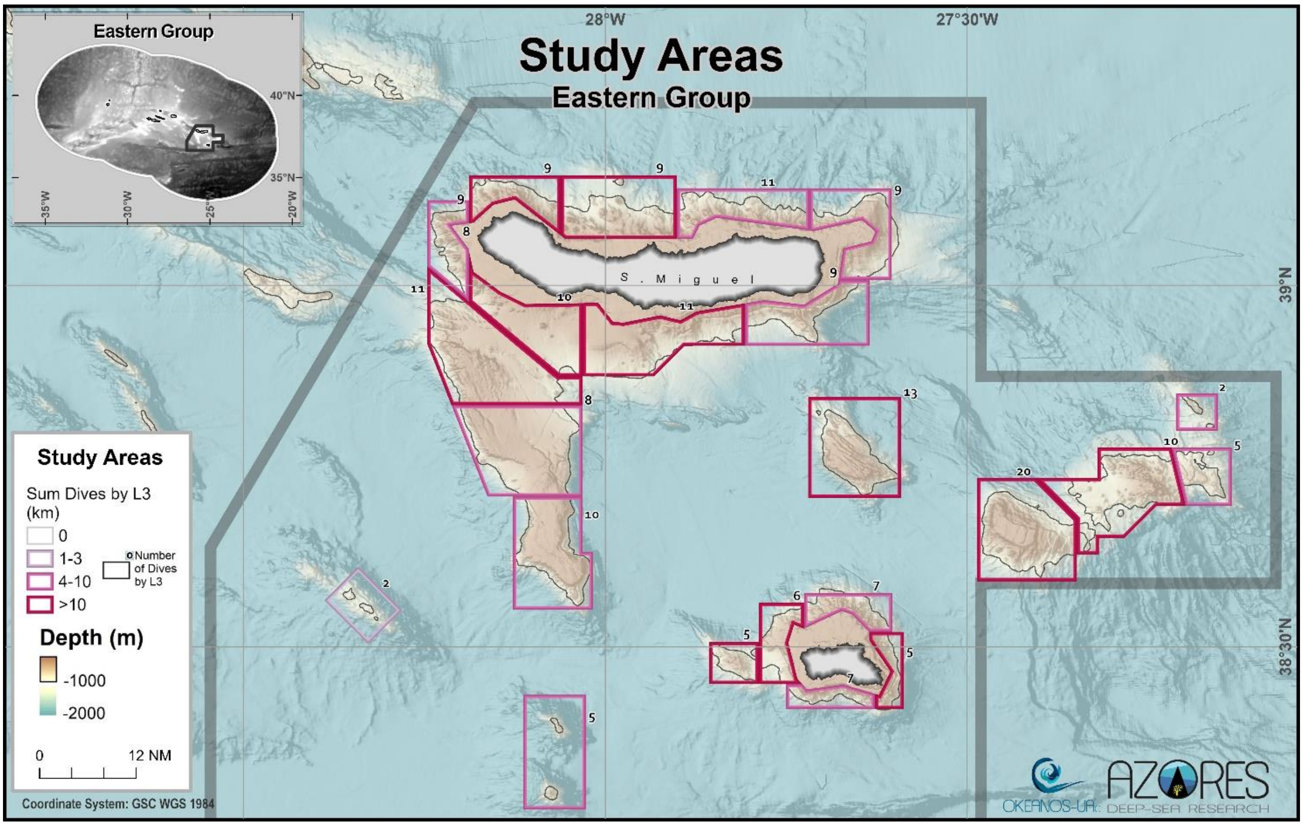



Figure 44 Sampling areas with sufficient coverage of video surveys (pinkish) and those lacking explorations (white) in the Eastern Group of the Azores. The colour of the outlines is scaled to the number of km of the seafloor surveyed. Those areas with less than 1 km are shown in white. Numbers refer to the number of dives in the sampling area.

### *7.8 Complementary information*

As mentioned above, underwater images) are the best tools for analysing the spatial distribution of deep-sea species and communities, and for identifying VMEs. However, the information obtained from the Marine Biological Reference Collection and from other public databases can complement the information collected from videos. We have identified the following complementary occurrences records:

1. In the Western Group of the Azores (Figure 45) some records for Hard-Rock Café, and many for the slopes of Corvo and Flores islands.
2. In the Northern Mid-Atlantic Ridge (Figure 46), only records for areas where video data is already available.

3. In the Central Mid-Atlantic Ridge (Figure 47), many records for areas with high video coverage, such as Gigante and 127 seamounts, and many other seamounts and ridges.
4. In the Southern Mid-Atlantic Ridge (Figure 48), some records mostly in Voador seamount which is the area with most video coverage.
5. In the northern Central Group of the Azores (Figure 49), many records in areas in need of scientific exploration, namely the Sedlo, Sedlo W and Borda seamounts, Terceira Island slopes, Ferraria Norte, and Ferraria Mar.
6. In the southern Central Group of the Azores (Figure 50), many records in Açor and Princesa Alice bank; considered areas in need of scientific exploration.
7. In the Eastern Group of the Azores (Figure 51), some records from the slopes around São Miguel Island, and for Mar da Prata.

This compilation shows that, although video data was collected in all areas, there is other sources of data to inform the spatial distribution of the megabenthic species and the biological communities in the deep sea (>200 m) to the outer limit of the Azores sub-area of the Portuguese EEZ down to 1,000 m depth.

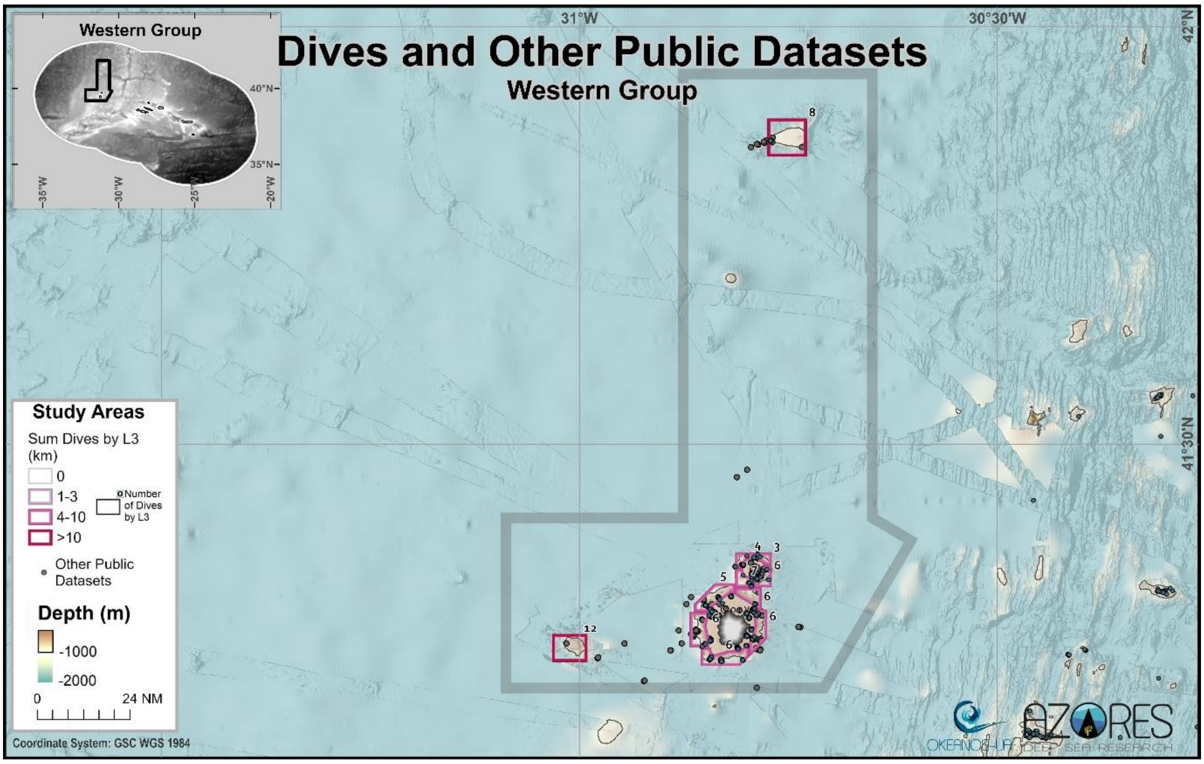



Figure 45 Occurrence records of deep-sea biodiversity obtained from the Marine Biological Reference Collection (COLETA) and from other public databases (ICES, NOAA, and OBIS) in the Western Group of the Azores.

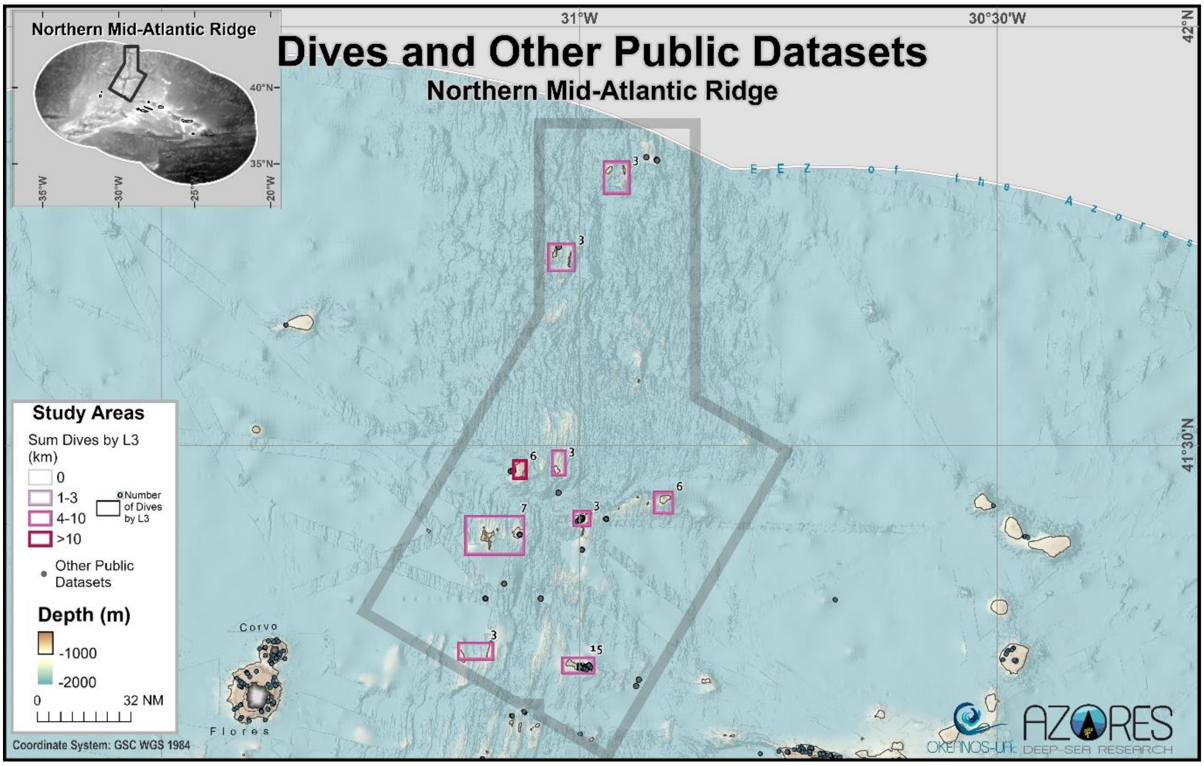



Figure 46 Occurrence records of deep-sea biodiversity obtained from the Marine Biological Reference Collection (COLETA) and from other public databases (ICES, NOAA, and OBIS) in the Northern Mid-Atlantic Ridge.

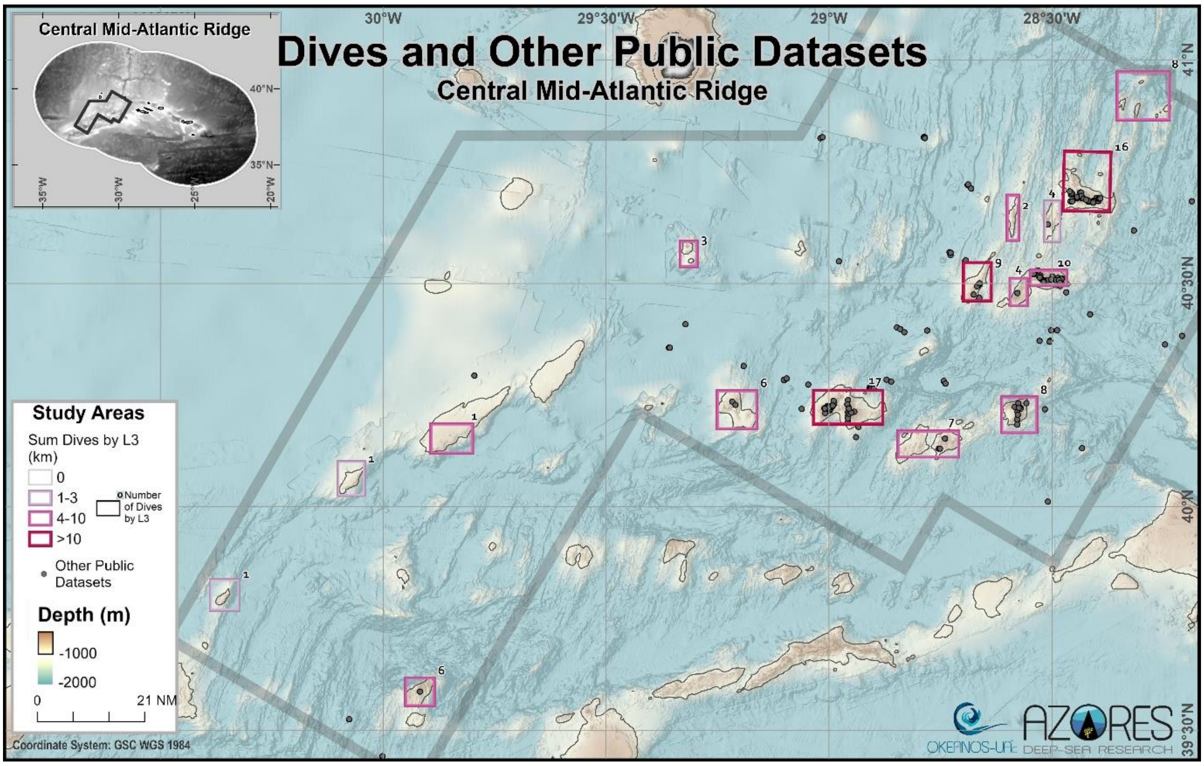



Figure 47 Occurrence records of deep-sea biodiversity obtained from the Marine Biological Reference Collection (COLETA) and from other public databases (ICES, NOAA, and OBIS) in the Central Mid-Atlantic Ridge.

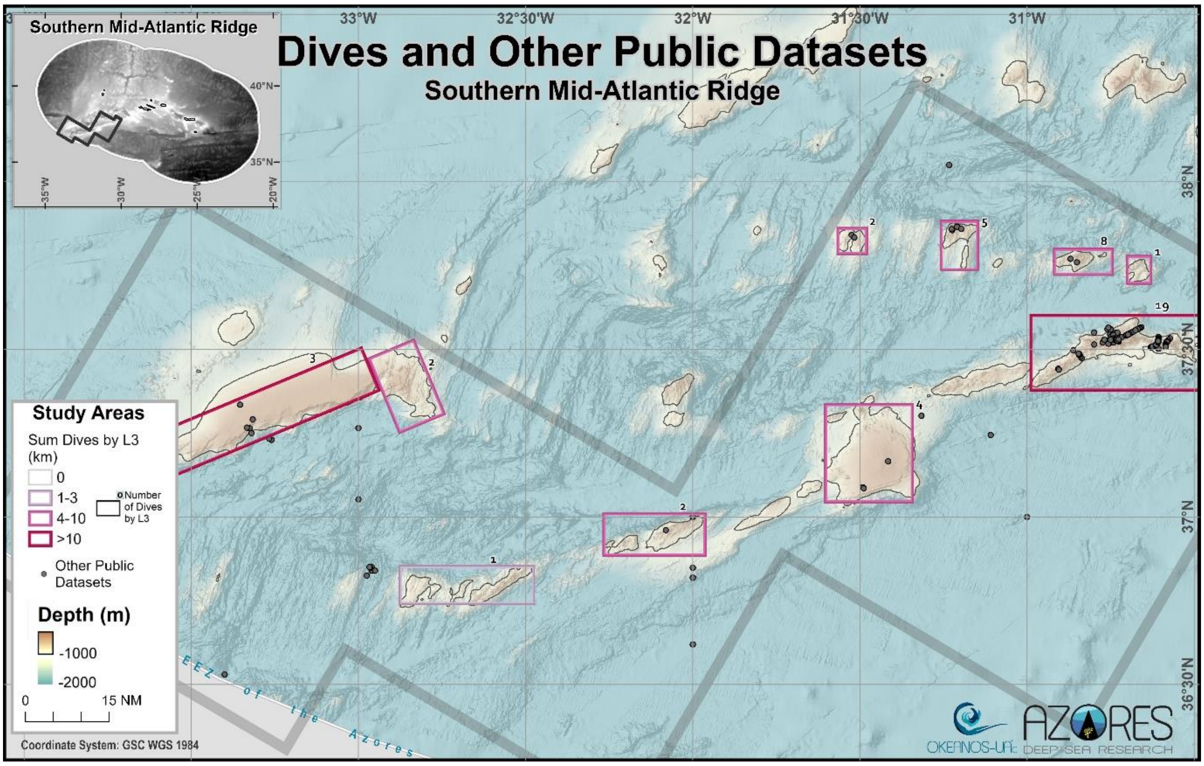



Figure 48 Occurrence records of deep-sea biodiversity obtained from the Marine Biological Reference Collection (COLETA) and from other public databases (ICES, NOAA, and OBIS) in the Southern Mid-Atlantic Ridge.

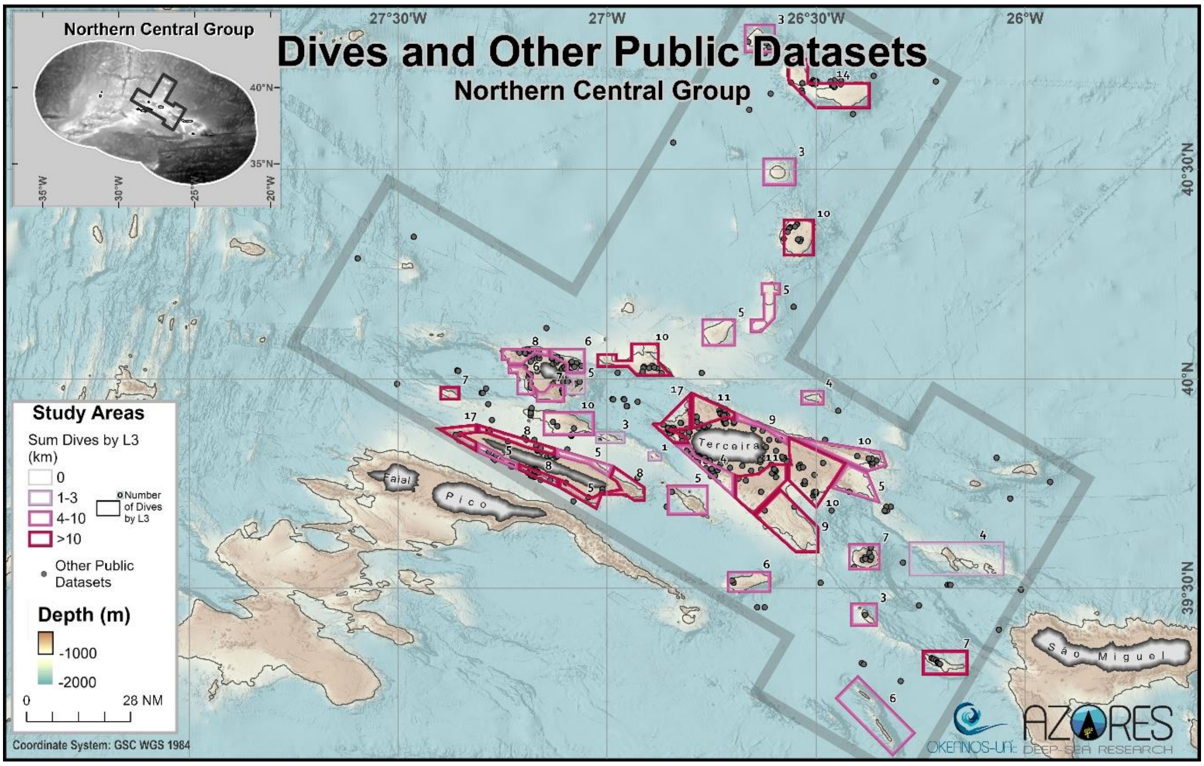



Figure 49 Occurrence records of deep-sea biodiversity obtained from the Marine Biological Reference Collection (COLETA) and from other public databases (ICES, NOAA, and OBIS) in the Northern Central Group of the Azores.

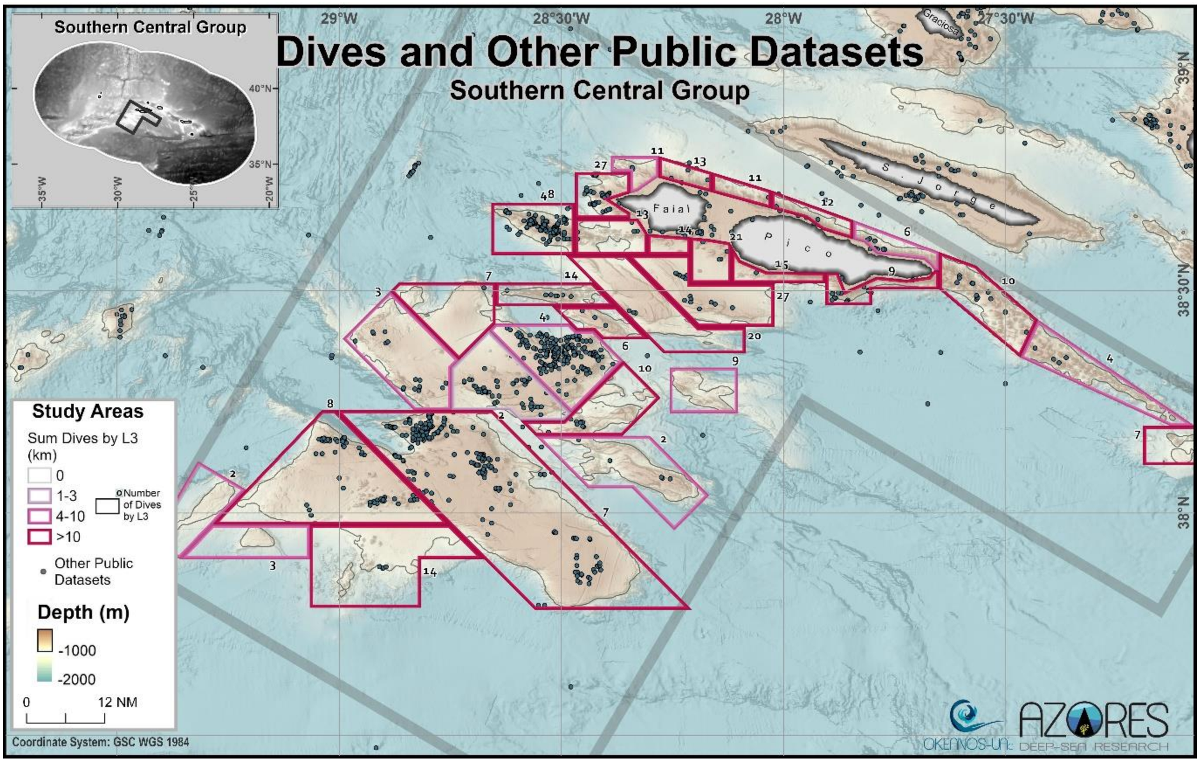



Figure 50 Occurrence records of deep-sea biodiversity obtained from the Marine Biological Reference Collection (COLETA) and from other public databases (ICES, NOAA, and OBIS) in the Southern Central Group of the Azores.

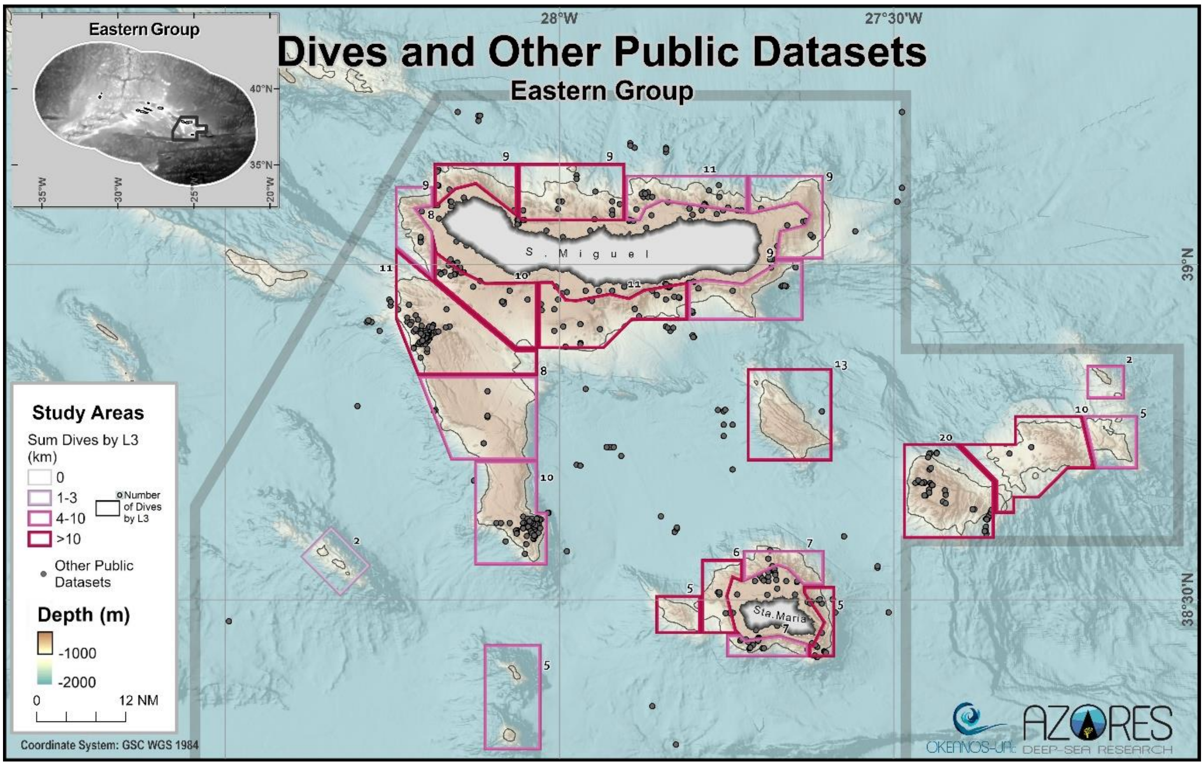



Figure 51 Occurrence records of deep-sea biodiversity obtained from the Marine Biological Reference Collection (COLETA) and from other public databases (ICES, NOAA, and OBIS) in the Eastern Group of the Azores.

# 8. Deep-sea species diversity, including VME indicator species

## *8.1 Methodologies for taxonomic identification*

Image analyses was complemented with the study of specimens and samples collected during field missions and stored in the COLETA reference collection. The taxonomic study of these specimens used an integrative taxonomic approach, which complements classic identification methods based on the analysis of morphological characters and the analysis of DNA sequences with specific genetic markers.

### Cold-water corals

The selection of the material examined (Table 14) had as priority the selection of cold-water corals considered as indicator species of VMEs, which are frequently observed in video images. In some cases, the specimens were previously analysed by experts using a classic taxonomic methodology, but still required confirmation with specific genetic markers. In other cases, as for example Paramuricea/Placogorgia and bamboo corals, a complementary analysis using both morphological characters and specific genetic markers was necessary.

*Classical taxonomy*

The classic methodology for identifying deep-sea corals is based on observing and analysing a set of distinctive morphological characters in terms of the external morphology of the colony, polyp and other specific elements of the various coral taxa, using taxonomic keys and descriptions of relevant families and genera for each taxon.

- Octocorallia: general morphology, branching pattern, polyp size, type and arrangement of sclerites (calcareous elements in octocoral tissues) (Bayer et al., 1983); Ellisellidae family (Grasshoff 1972), Paramuriceidae family (Grasshoff 1977; Carpine & Grasshoff 1985), Primnoidae family (Cairns & Bayer 2003, 2009), Coraliidae family (Sanchez 2005), Chrysogorgiidae family (Carpine & Grasshoff 1985), Keratoisididae family (Saucier et al 2021; Watling & France 2021; Morrissey et al 2022; Watling et al 2022), family Nidaliidae (Brito & Ocaña 2004, López-González & Gili 2008), family Alcyoniidae (Brito & Ocaña 2004, Molodtsova, 2013).
- Antipatharia: general morphology, branching pattern, morphology and arrangement of polyps and axial spines (Opresko, 2006); family Leiopathidae (Opresko 1998; Molodstova 2011), Schizopathidae (Opresko 2002).
- Scleractinia: general morphology, septal arrangement, presence or absence of columella (Zibrowius, 1980; Cairns 2000).
- Stylasteridae: arrangement of dactylopores and gastropores, presence or absence of gastro- and dactylostyles, orientation of the cyclostome and cenostic texture (Cairns, 1991; Zibrowius & Cairns, 1992).

The specimens examined were photographed with a scale. Macroscopic characters (e.g., morphology, size and arrangement of polyps, axial spines) were examined using a binocular microscope. Microscopic characters such as sclerites, which are essential for identifying octocorals, were examined with an optical microscope. To prepare the sclerites, a portion of the octocoral tissue was dissolved using sodium hypochlorite to allow the sclerites to dissociate and then rinsed wit distilled water. Sclerites were labelled for future examination using scanning electron microscopy (SEM) and preparation of photographs for scientific publication. The prepared material has been shared with (inter)national experts in key taxonomic groups for the identification and description of species.

Species names and taxonomy will be verified using the World Register of Marine Species (WoRMS, https://www.marinespecies.org/). The scientific names of the octocoral families will be updated based on McFadden et al. (2022) and the species names cross-checked with Sampaio et al. (2019) to include only valid scientific names for the Azores region.

Table 14 Information of the cnidaria specimens examined using taxonomic tools.

| Coleta Ref. | (morpho)specie (Family) | Local | Lat (deg) Long (deg) | Depth (m) | Date of collection | Campaing |
|---|---|---|---|---|---|---|
| **Octocorals (Sub-class Octocorallia)** | | | | | | |
| 10142 | *Viminella flagellum* (Ellisellidae) yellow morphotype | Gigante S | 38.9772 -29.8681 | 359 | 21.06.2018 | BlueAzores_2018 |
| 10768 | *Viminella flagellum* (Ellisellidae) yellow morphotype | Flores-Corvo - Ponta dos Ilhéus | 39.3123 -31.2993 | 443 | 26.06.2018 | ARQDAÇO-50-P18 |
| 7151 | *Viminella flagellum* (Ellisellidae)yellow morphotype | Vulcão Serreta | 38.793 -27.465 | 350 | 11.09.2011 | FAIVI/IOZ |
| 10096 | *Viminella flagellum* (Ellisellidae) | Gingante 127 NE | 38.7406 -30.0461 | 445 | 18.06.2018 | BlueAzores_2018 |
| 10168 | *Viminella flagellum* (Ellisellidae) | Gigante N | 39.0075 -29.9286 | 722 | 22.06.2018 | BlueAzores_2018 |
| 10191 | *Viminella flagellum* (Ellisellidae) | Gigante Agulhas S | 38.6994 -30.2300 | 440 | 23.06.2018 | BlueAzores_2018 |
| 10080 | *Paragorgia johnsoni* (Coralliidae) | Gigante Este | 38.9836 -29.8347 | 558 | 16.06.2018 | BlueAzores_2018 |
| 10081 | *Paragorgia* sp. (Coralliidae) | Gigante Este | 38.9836 -29.8347 | 558 | 16.06.2018 | BlueAzores_2018 |
| 10173 | *Paragorgia johnsoni* (Coralliidae) | Gigante Agulhas S | 38.7089 -30.2222 | 589 | 23.06.2018 | BlueAzores_2018 |
| 10174 | *Paragorgia* sp. (Coralliidae) | Gigante Agulhas S | 38.7081 -30.2219 | 564 | 23.06.2018 | BlueAzores_2018 |
| 10176 | *Paragorgia* sp. (Coralliidae) | Gigante Agulhas S | 38.7081 -30.2219 | 564 | 23.06.2018 | BlueAzores_2018 |
| 4820 | *Paragorgia johnsoni* (Coralliidae) | Óscar | 39.607 -29.307 | 578 | 23.10.2010 | CoralFISH fisheries observer |
| 5141 | *Paragorgia* sp, (Coralliidae) | Ferradura | 38.205 -30.335 | 600 | 27.09.2010 | CoralFISH fisheries observer |
| 7884 | *Paragorgia johnsoni* (Coralliidae) | Gamo N | 40.2724 -29.3574 | 477 | 20.05.2011 | CoralFISH fisheries observer |
| 10069 | *Narella* sp. (Primnoidae) | Gigante E | 38.9847 -29.8294 | 682 | 14.06.2018 | BlueAzores_2018 |
| 10070 | *Narella* sp. (Primnoidae) | Gigante E | 38.9847 -29.8294 | 682 | 14.06.2018 | BlueAzores_2018 |
| 10079 | *Narella* sp. (Primnoidae). | Gigante E | 38.9847 -29.8297 | 686 | 16.06.2018 | BlueAzores_2018 |
| 12410 | *Paramuricea* spp. (Paramuriceidae) Purple plexaurid | Princesa Alice | 37.96973 -29.3561 | 1061 | 02.06.2019 | ARQDAÇO-52-P19 |
| 11572 | *Paramuricea* spp. (Paramuriceidae) Purple plexaurid | Gigante N | 39.3526 -29.6849 | 1163 | 15.07.2019 | Explosea2_2019 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 11535 | *Paramuricea* spp. (Paramuriceidae) | Gigante N | 39.3326 -29.7567 | 1276 | 04.07.2019 | Explosea2_2019 |
| 10057 | *Placogorgia* spp. (Paramuriceidae) | Gigante 127 | 38.7175 -30.0142 | 362 | 08.06.2018 | BlueAzores_2018 |
| 10184 | *Placogorgia* spp. (Paramuriceidae) | Gigante Agulhas SW | 38.7025 -30.2275 | 464 | 23.06.2018 | BlueAzores_2018 |
| Placo1-DSL | *Placogorgia* spp. (Paramuriceidae) | Condor | 38.49515 -29.00852 | 822 | 04.10.2023 | CONDOR-57-O23 |
| 10776 | *Dentomuricea* aff. *meteor* (Paramuriceidae) | Mar da Prata N | 37.6131 -25.9109 | 343 | 03.07.2018 | ARQDAÇO-50-P18 |
| 10723 | *Dentomuricea* aff. *meteor* (Paramuriceidae) | Mar da Prata S | 37.1511 -25.6442 | 275 | 07.06.2018 | ARQDAÇO-50-P18 |
| 10783 | *Dentomuricea* aff. *meteor* (Paramuriceidae) | Mar da Prata N | 37.585 -25.9016 | 317 | 05.072018 | ARQDAÇO-50-P18 |
| **Bamboo corals** | | | | | | |
| 11533 | Keratosidae | Gigante N | 39.33265 -29.7570 | 1270 | 06.09.2023 | Explosea2_2019 |
| 11573 | Keratosidae | Gigante N | 39.3541 -29.6856 | 1121 | 15.07.2019 | Explosea2_2019 |
| 11537 | Keratosidae | Gigante N | 39.3309 -29.7538 | 1221 | 04.07.2019 | Explosea2_2019 |
| **Soft corals** | | | | | | |
| 10092 | *Gersemia* sp. (Alcyoniidae) | Gigante 127 NO | 38.7456 -30.0442 | 657 | 18.06.2018 | BlueAzores_2018 |
| 10146 | *Gersemia* sp. (Alcyoniidae) | Gigante NO | 39.0075 -29.9286 | 722 | 22.06.2018 | BlueAzores_2018 |
| 10148 | *Gersemia* sp. (Alcyoniidae) | Gigante NO | 39.0047 -29.9258 | 556 | 22.06.2018 | BlueAzores_2018 |
| 10156 | *Gersemia* sp. (Alcyoniidae) | Gigante NO | 39.0006 -29.9217 | 413 | 22.06.2018 | BlueAzores_2018 |
| 11558 | Soft coral (Alcyoniidae) | Faial W Capelinhos | 38.6112 -28.8569 | 125 | 09.07.2019 | Explosea2_2019 |
| 11559 | Soft coral (Alcyoniidae) | Faial W Capelinhos | 38.6112 -28.8569 | 125 | 09.07.2019 | Explosea2_2019 |
| 11560 | Soft coral (Alcyoniidae) | Faial W Capelinhos | 38.6112 -28.8569 | 125 | 09.07.2019 | Explosea2_2019 |
| 10689A | Soft coral (Alcyoniidae) | Flores -Corvo | 39.6587 -310963 | 245 | 13.07.2013 | ARQDAÇO-48-P17 |
| 10689B | Soft coral (Alcyoniidae) | Flores -Corvo | 39.6587 -310963 | 245 | 13.07.2013 | ARQDAÇO-48-P17 |
| 10177 | Soft coral (Alcyoniidae) | Gigante Agulhas SW | 38.7078 -30.2222 | 559 | 23.06.2019 | BlueAzores_2018 |
| **Hydrocorals (Order Anthoathecata)** | | | | | | |
| 13015 | *Errina* cf. *atlantica* (Stylasteridae) | Pico S Lajes | 38.339 -28.2473 | 1076 | 06.09.2023 | OceanX_2023 |
| **Scleractinians** | | | | | | |
| 10188 | *Eguchipsammia* cf. *cornucopia* (Dendrophylliidae) | Gigante Agulhas S | 38.7017 -30.2278 | 457 | 23.06.2018 | BlueAzores_2018 |
| 10858 | *Eguchipsammia* cf. *cornucopia* (Dendrophylliidae) | Great Meteor | 37.6759 -25.7166 | 314 | 06.10.2018 | ATHENA_M151 |
| 10880 | *Eguchipsammia* cf. *cornucopia* (Dendrophylliidae) | José Gaspar | 37.6752 -25.7167 | 309 | 12.10.2018 | ATHENA_M151 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 10883 | *Eguchipsammia* cf. *cornucopia* (Dendrophylliidae) | Açor | 38.2109 -29.0094 | 137 | 13.10.2018 | ATHENA_M151 |
| **Black corals (Order Antipatharia** | | | | | | |
| 12841 | *Bathypathes* sp. (Schizopathidae) | Faial W Capelinhos | 38.5913 -28.8899 | 885 | 27.08.2023 | OceanX_2023 |
| 12892 | *Bathypathes* sp. (Schizopathidae) | Faial W Capelinhos | 38.6621 -28.8875 | 727 | 28.08.2023 | OceanX_2023 |
| 11546 | *Leiopathes* cf. *expansa* (Leiopathidae) | Gigante N | 39.3302 -29.7534 | 1216 | 05.07.2019 | Explosea2_2019 |
| 6550 | *Leiopathes* cf. *expansa* (Leiopathidae) | Princesa Alice | 37.881 -29.367 | 393 | 11.04.2011 | CoralFISH fisheries observer |
| Leiop1-DSL | *Leiopathes* cf. *expansa* (Leiopathidae) | Faial-Pico | 38.3693 -28.1915 | 489 | 18.04.2023 | ARQDAÇO-56-P23 |
| Leiop2-DSL | *Leiopathes* cf. *expansa* (Leiopathidae) | Faial-Pico | 38.3637 -28.1838 | 1094 | 18.04.2013 | ARQDAÇO-56-P23 |
| 10315 | *Tylopathes* sp. (Stylopathidae) | São Jorge – Fajã das Almas | 38.6019 -28.1129 | 1137 | 07.06.2013 | ARQDAÇO-40-P13 |
| 8931 | *Bathypathes* sp. (Schizopathidae) | Terra Nova | 48.3483 -45.44 | 680 | 01.03.2011 | NA |
| 8933 | *Bathypathes* sp. (Schizopathidae) | Terra Nova | 47.8983 -45.875 | 754 | 03.03.2011 | NA |
| 8936 | *Bathypathes* sp. (Schizopathidae) | Terra Nova | NA | NA | 19.03.2011 | NA |

*Genetic analysis*

The taxonomic identification with morphological characters was complemented by in-depth genetic analysis, with a view to identifying unknown species and validating taxonomic identification based solely on the analysis of morphological characters. Multiple molecular and genetic tools have been developed for this purpose, and there was a need to adopt different methodologies suitable for each case, which were designed specifically for each group of organisms. This need is due to the low polymorphism found in some deep-sea corals, which reduces the effectiveness of the genetic markers traditionally used to distinguish closely related species.

*DNA extraction*

Analysed specimens have been obtained over the past decades in the Azores region, being currently kept in the COLETA collection. Those include octocorals (n=42) and hexacorals (n=10, including 7 antipatharians or black corals, and 3 scleractinian). DNA from specimens was extracted from ethanol-preserved tissue following a modified protocol of the Qiagen DNEasy Blood and Tissue Kit. DNA extracts were quantified using a Qubit fluorometer, and DNA was checked for quality using a NanoView spectrophotometer and agarose gel electrophoresis.

In an attempt to identify genus to species-level biological diversity, two different genomic methods were used to obtain DNA sequencing data: DNA barcoding - the conventionally used method in genetic analysis particularly when species-specific genetic markers (~600 bp base pairs) are known; and genome skimming (or low-coverage whole genome sequencing) - a novel method that enables to extract 100s to 1,000s of single-copy nuclear loci (e.g., ultraconserved elements [UCEs] and exons) to be used in phylogenetic studies.

*Genomic approaches*

### *DNA barcoding*

DNA extracts were used to build distinct PCR amplicon libraries from the amplification of several marker genes, widely used for DNA barcoding studies of anthozoans. These included the mitochondrial COI gene (cytochrome c oxidase subunit 1), the mitochondrial mutS-like DNA repair gene (mtMutS) (specific to octocorals), the mitochondrial intergenic spacer (IGR), the mitochondrial 16S rRNA gene, the nuclear 28S rDNA gene and the nuclear internal transcribed spacer gene (ITS) (Table 15). The PCR primers for each target region were chosen based on the reference literature. PCR amplifications were carried out in a 50-µL reaction volume containing 1X PCR buffer, 6 mM $MgCl_2$, 0.3 µM for both of each primer, 0.03 mM dNTP, 3 U taq polymerase and 20 ng of DNA extract and were performed in a T100TM Thermal cycler (BIO-RAD). PCR products were gel purified using the QIAquick kit (Qiagen) and Sanger sequenced in both directions by StabVida (Caparica, Portugal). Trace files (.ab1) were analysed, aligned and proofread in Geneious Prime V2023.1.2 (https://www.geneious.com). After alignment, consensus sequences were constructed for each specimen and barcode marker. DNA sequences were then searched against the non-redundant nucleotide database of NCBI using BLAST (Basic Local Alignment Search Tool), and for each the best similarity matches with the GenBank database was obtained.

### *Genome skimming*

DNA library preparation for genome skimming (or low-coverage whole genome sequencing) (Table 15) was carried out in the Laboratories of Analytical Biology of the National Museum of Natural History at the Smithsonian Institution, in Washington D.C, in the scope of the collaboration established between Andrea Quattrini and our group, that begun with the present research project. The methodological approach and sequencing details followed the protocol outlined in Quattrini et al. (2018) (Figure 52).

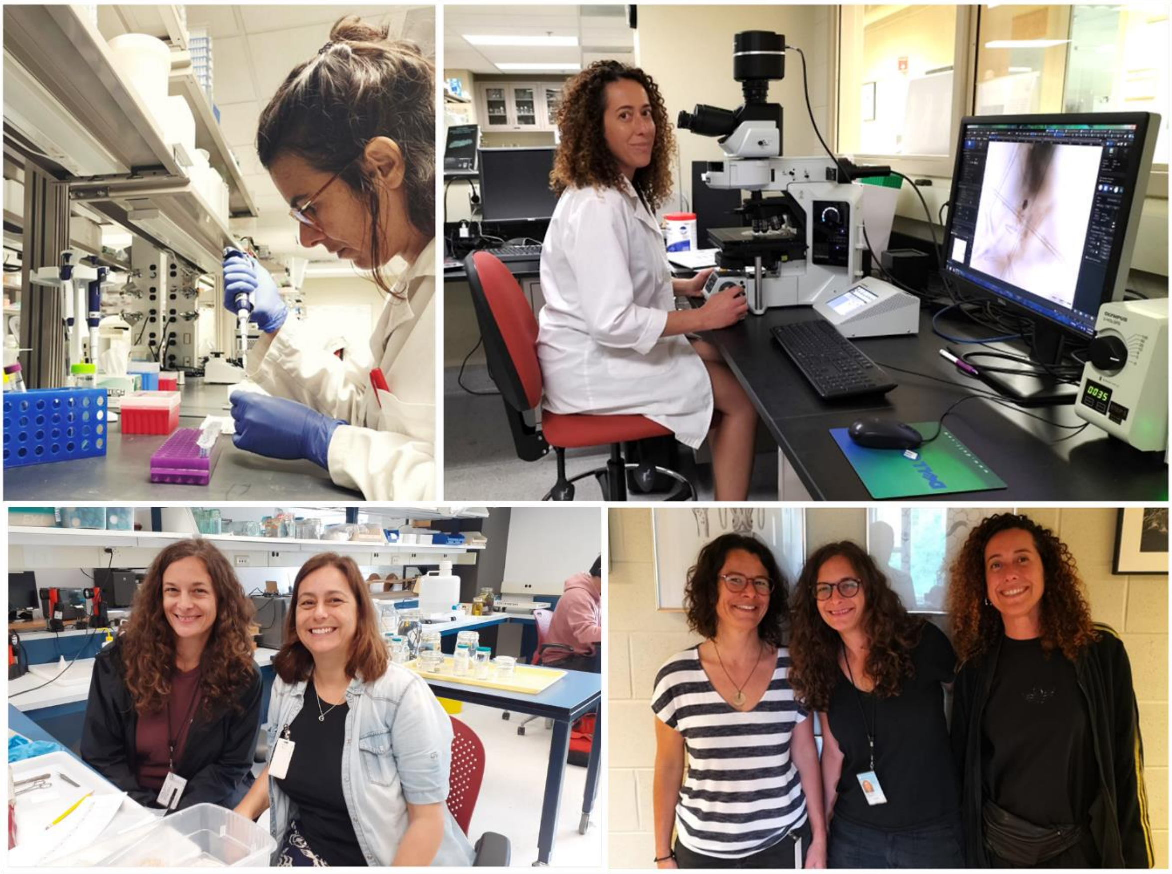


**Figure 52** ADSR team members Teresa Cerqueira, Manuela Ramos and Marina Carreiro-Silva visiting the cold water coral taxonomy expert Andrea Quattrini at the Smithsonian Institution – National Museum of Natural History, USA.

### *Sequencing Analyses of UCEs and exons*

Ultraconserved elements (UCE) and exon nuclear loci were bioinformatically obtained from the high-throughput sequencing data. First, raw reads were trimmed using Trimmomatic v 0.39 (Bolger et al., 2014) and assembled using Spades v. 3.15 (Prjibelski et al. 2020). Spades assemblies were then passed to phyluce v 1.7 (Faircloth 2016) to bioinformatically extract UCE and exon loci using previously published bait sets for octocorals (octo-v2, Erickson et al., 2020). The phyluce pipeline followed some modifications outlined in Quattrini et al. (2018, 2020). Before aligning with MAFFT v7.130b (Katoh and Stanley 2013), data was combined with existing UCE and exon loci extracted from octocoral samples with previously published target-capture data. After alignment, phyluce was used to create a 60% taxon-occupancy matrix for all loci. Phylogenomic analyses were conducted using maximum likelihood in IQTree v 2.1 (Nguyen et al., 2015) on the concatenated datasets with ultrafast bootstrapping (-bb 1,000, Hoang et al., 2018). Phylogenomic tree was plotted in FigTree v. 1.4.4.

Table 15 Molecular and genetic tools used with the different specimens examined.

| Taxonomic group | Species (Family) | Genetic tool |
|---|---|---|
| **Octocorals (Sub-Classe Octocorallia)** | *Viminella flagellum* yellow morphotype (Ellisellidae) | DNA barcoding (28S, MutS, COI, 16S, ITS, ITS-) |
| | *Viminella flagellum* white morphotype (Ellisellidae) | DNA barcoding (28S, MutS, COI, 16S, ITS, ITS-2) |
| | *Paragorgia* sp. (Coralliidae) | DNA barcofing (28S, MutS, ITS-2) |
| | *Narella* cf. *regularis* (Primnoidae) | DNA barcoding (28S, MutS, ITS-2) |
| | *Paramuricea* spp. (Paramuriceidae) | Genome skimming<br>DNA barcoding (28S, MutS, COI) |
| | *Placogorgia* spp. (Paramuriceidae) | Genome skimming<br>DNA barcoding (28S, MutS) |
| | *Dentomuricea* aff. *meteor* (Paramuriceidae) | Genome skimming<br>DNA barcoding (28S, MutS) |
| **Bamboo corals (Family Keratosididae)** | Family Keratosididae | Genome skimming<br>DNA barcoding (28S, MutS) |
| **Soft corals (Family Alcyoniidae)** | Soft corals (Alcyoniidae) | Genome skimming<br>DNA barcoding (28S, MutS, COI, 16S, ITS) |
| | *Gersemia* (Alcyoniidae) | Genome skimming<br>DNA barcoding (28S, MutS, ITS-2) |
| **Scleratinians (Order Scleractinia)** | *Eguchipsammia* cf. *cornucopia* (Dendrophylliidae) | DNA barcoding (28S, MutS, COI, COI-D, IGR, ITS) |
| **Black corals (Order Antipatharia)** | Leiopathes cf. expansa (Leiopathidae) | DNA barcoding (28S, ITS-2, ITS-Ap) |
| | *Bathypathes* spp. (Schizopathidae) | DNA barcoding (28S, ITS-2, ITS-Ap) |
| | *Tylopathes* sp. (Stylopathidae) | DNA barcoding (COI) |

Table 16 DNA amplicon libraries crated for each individual sample. Tested barcoding genes are indicated as green and red after a good or failed result in the posterior DNA sequencing.

| Taxa | | sample ID | DNA Barcoding | | | | | | | | | | Genome skimming |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | r | M | C | C | I | 1 | I | I | I | |
| Octocorals (Sub-class Octocorallia) | *Viminella flagellum* yellow morphotype | 7151 | ✓ | | ✗ | ✗ | | | ✓ | | ✗ | | |
| | | 10142 | ✓ | | ✗ | ✗ | | | ✓ | ✓ | ✗ | | |
| | | 10768 | ✓ | | ✗ | ✗ | | | ✓ | ✗ | ✗ | | |
| | *Viminella flagellum* white morphotype | 10096 | ✗ | | ✓ | ✓ | | | ✓ | ✓ | ✗ | | |
| | | 10168 | ✓ | | ✗ | ✗ | | | | ✗ | ✗ | | |
| | | 10191 | ✓ | | ✗ | ✗ | | | | ✗ | ✗ | | |
| | *Paragorgia johnsoni* | 4820 | ✓ | | ✓ | | | | | | | | |
| | | 5141 | ✗ | | | | | | | | | | |
| | | 7884 | ✓ | | ✓ | | | | | | ✗ | | |
| | | 10080 | ✗ | | ✓ | | | | | | ✗ | | |

| Taxa | | sample ID | DNA Barcoding | | | | | | | | | | Genome skimming |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | r | M | C | C | – | 1 | – | – | – | |
| | | 10081 | ✗ | | | | | | | | | | |
| | | 10173 | ✗ | | ✓ | | | | | | ✗ | | |
| | | 10174 | ✗ | | | | | | | | | | |
| | | 10176 | ✗ | | | | | | | | | | |
| | *Narella* sp. | 10069 | ✓ | | ✗ | | | | | | ✓ | | |
| | | 10079 | ✗ | | | | | | | | | | |
| | | 10070 | ✓ | | ✗ | | | | | | ✗ | | |
| | | 10156 | ✗ | | | | | | | | | | |
| | *Paramuricea* spp. | 11535 | ✓ | | ✓ | ✗ | | | | | | | ✓ |
| | | 11572 | ✓ | | ✓ | ✗ | | | | | | | ✓ |
| | | 12410 | ✗ | | ✗ | ✗ | | | | | | | ✓ |
| | | USNM1673620 | ✓ | | ✓ | | | | | | | | ✓ |
| | *Placogorgia* spp. | 10057 | ✓ | | ✓ | | | | | | | | ✓ |
| | | 10184 | ✓ | | ✓ | | | | | | | | ✓ |
| | | USNM1674011 | ✓ | | ✓ | | | | | | | | ✓ |
| | *Dentomuricea* aff *meteor* | 10723 | ✗ | | ✗ | | | | | | ✓ | | |
| | | 10776 | ✗ | | ✗ | | | | | | | | ✓ |
| | | 10783 | ✗ | | ✗ | | | | | | ✓ | | |
| Bamboo Corals (Family Keratosididae) | | 11573 | ✓ | | ✗ | | | | | | | | ✓ |
| | | 11533 | ✗ | | ✗ | | | | | | | | ✓ |
| | | 11537 | ✗ | | ✗ | | | | | | | | ✓ |
| Soft corals (Family Alcyoniidae) | | 10177 | ✗ | | | ✗ | | | | | | | ✓ |
| | | 11558 | ✗ | | ✓ | ✗ | | | ✓ | ✓ | | | ✓ |
| | | 11560 | ✗ | | ✓ | ✗ | | | ✓ | ✓ | | | ✓ |
| | | 10689A | ✓ | | ✓ | ✓ | | | ✓ | ✓ | | | ✓ |
| | | 10689B | ✓ | | ✓ | ✓ | | | ✓ | ✗ | | | ✓ |
| | | 10092 | ✓ | | ✓ | | | | | | ✓ | | |
| | | 10146 | ✓ | | ✗ | | | | | | ✓ | | |

| Taxa | | sample ID | DNA Barcoding | | | | | | | | | | Genome skimming |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | r | M | C | C | _ | 1 | _ | _ | _ | |
| | | 10148 | ✓ | | ✓ | | | | | | ✓ | | |
| | | 10156 | ✗ | | | | | | | | | | |
| Scleractinians (Order Scleractinia) | *Eguchipsammia* sp. | 10858 | ✓ | ✓ | | ✗ | ✓ | ✓ | | ✓ | | | |
| | | 10880 | ✓ | ✓ | | ✓ | ✗ | ✓ | | ✓ | | | |
| | | 10883 | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | | | |
| Black Corals (Antipatharia) | *Leiopathes* sp. | Leiop_1 | ✗ | | | | | | | | ✓ | ✗ | |
| | | Leiop_2 | ✓ | | | | | | | | ✓ | ✗ | |
| | *Bathypathes* sp. | 8931 | ✓ | | | | | | | | ✗ | ✗ | |
| | | 8933 | ✗ | | | | | | | | ✓ | ✗ | |
| | | 8936 | ✗ | | | | | | | | ✓ | ✗ | |
| | | 12841 | ✓ | | | | | | | | | ✗ | |
| | | 12892 | ✗ | | | | | | | | | ✗ | |
| | *Tylopathes* sp. | 10315 | | | | ✓ | | | | | | | |

### Deep-sea sponges

As in the case of corals, the selection of the material examined prioritised species of sponges (Phyllum Porifera) that are indicators of VME, frequently observed in the videos collected and which are easily recognisable on the basis of images. Sponges form aggregations of great structural complexity and density, but there is still limited knowledge of their taxonomic identification and biodiversity. The difficulty in their taxonomy is due to the high morphological plasticity in this group (polymorphism) or the absence of obvious external characters in certain species. For this reason, until recently, sponges observed in images have been classified on the basis of morphological characters (e.g., shape: arborescent, globular, massive, encrusting, etc.) and colouration. The opportunity to compare the species visualised in situ by image with the material collected on the scientific missions within the scope of this service made it possible to assign a taxonomic name to many species that are only known by their shape, i.e. as (morpho)species.

Taxonomic identification of the Porifera group was carried out by analysing external and internal morphological characters. Morphological characters for the identification of sponges include macroscopic characters such as the shape of the sponge, colour, consistency, texture, size and arrangement of the openings of the aquifer system (oscules). Microscopic characters mainly refer to the type and size of the spicules, the skeletal elements present in their tissues. To analyse the macroscopic characters, the specimens were measured (height, width) using a ruler and a mallet and their external morphology was documented by photograph. Transversal sections were made to include a brief description of aspects of structural morphology (e.g. organisation of the spicules in the tissues, oscules, etc.) using a dissecting microscope. To prepare the spicules, a small portion of each sample was placed in nitric acid to dissolve the organic material (spongin) and isolate the siliceous spicules, and boiled until all the material was dissolved. The spicules were then rinsed and dehydrated in alcohol. Final preparations of the spicules were made by mounting them on slides and coverslips with resin (e.g. Eukit) for later observation and measurement by light microscopy. Spicules were stored for later examination using SEM.

The taxonomic identification of the selected specimens followed the Porifera System (Hooper & van Soest, 2002) and available glossaries for morphology and spicules (Boury-Esnault 1997, Lukowiak et al. 2022) and using basic bibliography on the sponge fauna of the Azores (e.g. Topsent 1892, 1904, 1928). Specific literature was used for each taxa:

- Glass sponges (Class Hexactinellidae): Families Pheronematidae (Tabachnick & Menshenina, 2002), Euplectellidae (Tabacknick, 2002); Farreidae (Reiswig, 2002; Lopes et al. 2011); Euretidae (Reiswig & Wheeler, 2002), Rossellidae (Tabachick, 2002; Tabachnick & Menshenina, 2007) and Aphrocallistidae (Reiswig, 2002);
- Massive sponges (Class Demospongiae): Families Pachastrellidae and Geodidae (Maldonado et al. 1996 and 2002; Uriz, 2002; Cardenas & Rapp 2012, 2013 and 2015), Family Axinellida (Alvaréz & Hooper, 2002) and the Families Macandrewidae, Corallistidae and Azoricidae (Pisera & Levi, 2002a, b, c; Carvalho et al. 2015 and 2020).

The various compilations and checklists for the Atlanto-Mediterranean region were also used (e.g. Burton, 1928 and 1930; Tabachnick & Collins, 2008; Vacelet & Boury-Esnault, 1987; Boury-Esnault, et al. 1994).

| COLETA/Ref.Nr. | Species (to be confirmed) | Class | Local | Lat | Depth | Exp. year |
|---|---|---|---|---|---|---|
| 2517 | *Aphrocallistes sp.* | Hexactinellida | Fora do Aeroporto, Faial | 38,5180 - 28,7160 | 457 | Geralda, 1980 |
| 9906 | *Aphrocallistes sp.* | Hexactinellida | Menez Gwen | na | na | DeepFun 2012 |
| 2442 | *Asconema sp.* | Hexactinellida | Atlantis | 34,2400 - 30,3400 | 843 | Arquipélago, 2007 |
| 10074 | *Asconema sp.* | Hexactinellida | Banco Gigante | 38,9844 - 29,8297 | 665 | Blue Azores 2018 |
| 11187 | *Asconema sp.* | Hexactinellida | Banco Açores | 38,2432 - 29,0706 | 673 | Manuel de Arriaga, SPONGES, 2017 |

| COLETA/Ref.Nr. | Species (to be confirmed) | Class | Local | Lat | Depth | Exp. year |
|---|---|---|---|---|---|---|
| 11101 | *Asconema sp.* | Hexactinellida | Banco Açores | 38,2420 - 29,0695 | 645 | Manuel de Arriaga, SPONGES, 2017 |
| 12935 | *Cf. Xestospongia friabilis* | Demospongiae | Banco Princesa Alice | 38,0551 - 29,3052 | 779 | OceanX 2023 |
| 13011 | *Cf. Haliclona (Halichoclona) magna* | Demospongiae | Pico S Lajes | 38.3443 - 28.2443 | 848 | OceanX 2023 |
| USNM 1673996 | *Cf. Haliclona (Halichoclona) magna* | Demospongiae | MARNA Shallow | 43,9536 - 28,5283 | 580 | EX2206 |
| 9982 | *Characella cf. connectens* | Demospongiae | Ormonde | 36,7930 - 10,9639 | 1114 | MEDWAVES, 2016 |
| 9568 | *Characella cf. pachastrelloides* | Demospongiae | Atlantis | 34,1380 - 30,0125 | 500 | Arquipelago Biometore, 2015 |
| 10018 | *Characella cf. tripodaria* | Demospongiae | Pico | 38,4983 - 28,1931 | 522 | Blue Azores 2018 |
| 10130 | *Characella pachastrelloides* | Demospongiae | Banco Gigante | 38,9756 - 29,8517 | 464 | Blue Azores 2018 |
| 10129 | *Characella pachastreloides* | Demospongiae | Banco Gigante | 38,9753 - 29,8517 | 476 | Blue Azores 2018 |
| 11755 | *Chonelasma ijimai* | Hexactinellida | Rift of Princesa Alice | 38,4181 - 29,7289 | 2414 | M128 Meteor |
| 10090 | *Desmacella grimaldii* | Demospongiae | Banco Gigante | 38,7453 - 30,0442 | 645 | Blue Azores 2018 |

| COLETA/Ref.Nr. | Species (to be confirmed) | Class | Local | Lat | Depth | Exp. year |
|---|---|---|---|---|---|---|
| 12936 | *Echynostylinos reticulatus* | Demospongiae | Banco Princesa Alice | 38,0541 - 29,3078 | 732 | Ocean X 2023 |
| USNM 1673614 | *Euplectella cf. suberea* | Hexactinellida | João Valadão Ridge | 38,1587 - 26,2364 | 2121 | EX2206 |
| USNM 1673638 | Euretidae gen. new | Hexactinellida | East of Formigas Rift | 37,3550 - 24,3799 | 714 | EX2206 |
| 10059 | *Exsuperantia archipelagus* | Demospongiae | Banco 127 | 38,7156 - 30,0136 | 546 | Blue Azores 2018 |
| 10195 | *Exsuperantia archipelagus* | Demospongiae | Banco Gigante | 38,7089 | 440-589 | Blue Azores 2018 |
| 11594 | *Exsuperantia arquipelagus* | Demospongiae | Banco D. João de Castro | 38,2103 | 256 | M128 |
| 11756 | *Farrea laminaris* | Hexactinellida | Rift of Princesa Alice | 38,4181 - 29,7289 | 2414 | M128 Meteor |
| 10013 | *Farrea sp.* | Hexactinellida | Pico | 38,4947 - 28,1747 | 736 | Blue Azores 2018 |
| USNM 1674029 | *Farreidae sp1* | Hexactinellida | Cachalote Seamount | 39,9706 - 31,9706 | 1499 | EX2206 |
| 2184 | *Geodia sp.* | Demospongiae | Graciosa | 39,1400 - 28,1500 | 651-700 | ARQDAÇO-27-P07 |
| 10034 | *Geodia sp.* | Demospongiae | Pico | 38,3503 - 28,2781 | 615 | Blue Azores 2018 |
| 10012 | *Haliclona filholi* | Demospongiae | Norte Pico | 38,4947 - 28,1747 | 736 | Blue Azores 2018 |

| COLETA/Ref.Nr. | Species (to be confirmed) | Class | Local | Lat | Depth | Exp. year |
|---|---|---|---|---|---|---|
| 10084 | *Haliclona filholi* | Demospongiae | Banco Gigante | 38,9844 - 29,8325 | 663 | Blue Azores 2018 |
| 9374 | *Haliclona filholi* | Demospongiae | Banco Açores | na | na | ARQDAÇO-38- 2012 |
| 10163 | *Haliclona implexa (white morph)* | Demospongiae | Banco Gigante | 38,9750 - 29,9206 | 402 | Blue Azores 2018 |
| 10139 | *Haliclona implexa (yellow morph)* | Demospongiae | Banco Gigante | 38,9772 - 29,8681 | 352 | Blue Azores 2018 |
| USNM 1674018 | *Hertwigia sp. "white morph" spec. nov.* | Hexactinellida | Kurchatov Ridge | 40,6627 - 29,3861 | 1689 | EX2206 |
| 13007 | *Lissodendoryx (Ectyodoryx) foliata* | Demospongiae | Pico, Sul Lajes | 38,3395 | 1060 | Ocean X 2023 |
| USNM 1674019 | *Melonanchora cf. elliptica* | Demospongiae | Kurchatov Ridge | 40,6638 | 1664 | EX2206 |
| USNM 1673623 | *Neoschrammeniella sp.* | Demospongiae | East Formigas Rift | | 627 | EX2206 |
| 12951 | *Nethea amygdaloides* | Demospongiae | Banco Princesa Alice | 38,0236 | 645 | OceanX 2023 |
| 12960 | *Nethea amygdaloides* | Demospongiae | Banco Princesa Alice | 38,0218 | 730 | OceanX 2023 |
| USNM 1673617 | *Xestospongia sp.1* | Demospongiae | East of Formigas Rift | 37,3544 | 838 | EX2206 |
| 10881 | *Oceanapia cf. azoriensis* | Demospongiae | José Gaspar | 37,6706 | 533 | METEOR, ATHENA, 2018 |
| 10010 | *Oceanapia coriacea* | Demospongiae | Pico | 38,4956 | 830 | Blue Azores 2018 |
| USNM 1673615 | *Oopsacas cf. minuta* | Demospongiae | João Valadão Ridge | 38,1600 | 2047 | EX2206 |

| COLETA/Ref.Nr. | Species (to be confirmed) | Class | Local | Lat | Depth | Exp. year |
|---|---|---|---|---|---|---|
| 11934 | *Petrosia (Strongylophora) vansoesti* | Demospongiae | Cone Eastern Capelinhos | 38,6057 | 146 | M128 Meteor |
| 11649 | *Phakellia ventilabrum* | Demospongiae | N Flank Terceira BAsin | 39,2908 | 1204 | M128 Meteor |
| 10061 | *Phlyctaenopora (Phlyctaenopora) bitorquis* | Demospongiae | Banco 127 | 38,7156 | 546 | Blue Azores 2018 |
| 10065 | *Poecillastra compressa* | Demospongiae | Banco Gigante | 38,9847 | 682 | Blue Azores 2018 |
| USNM 1674014 | *Poecillastra compressa* | Demospongiae | Zenith | 42,3409 | 1011 | EX2205 |
| 2581 | *Raspailia (Parasyringella) falcifera* | Demospongiae | Sedlo | 40,3480 | 1069-1156 | FISHOR |
| 10874 | *Regadrella sp.* | Hexactinellida | Great Meteor | 30,0862 | 906 | Athena M151 - 2018, R/V METEOR |
| 11856 | *Siphonodictyon viridicens* | Demospongiae | Cone South East D. João de Castro | 38,2043 | 429 | M128 Meteor |
| 11908 | *Siphonodictyon viridicens* | Demospongiae | Ridge on the N Flank Hirondelle Basin | 38,2287 | 414 | M128 Meteor |
| USNM 1673621 | *Spongosorites sp.* | Demospongiae | East Formigas Rift | 37,3538 | 609 | EX2206 |

## *8.2 Analyses of age and growth of deep-sea specimens*

Accurate estimates of age and growth rates of habitat forming species, such as cold-water corals and sponges, are important for a proper assessment of their vulnerability and recovery to anthropogenic impacts (FAO 2009; Clark et al. 2016, 2019). In addition, given that longevity is directly related to gamete output necessary for population maintenance, accurate age structure of these organisms is essential for proper, long-term resource management (Fountain et al 2019). The importance of deep-sea coral growth and ageing studies for risk assessment to anthropogenic impacts, has been put forward by several institutes that provide advice to management authorities, namely NOAA in the USA (Prouty et al., 2017) and the National Institute of Water & Atmospheric Research Ltd (NIWA) in New Zealand (Tracey el. 2018).

In the scope of this project, we quantified the age and growth of specimens of corals and sponges with an important role in habitat provision and ecosystem functioning based on their large size and high structural complexity. The species prioritised for analysis were the black coral *Leiopathes* sp., the octocorals *Callogorgia verticillata, Paracalypthrophora josephinae, Dentomuricea* aff. *meteor* and *Viminella flagellum* and the sponge *Pheronema carpenteri* that have been stored at COLETA (Figure 53, Figure 54, Figure 55, Figure 56,Figure 57,Figure 58,Figure 59).

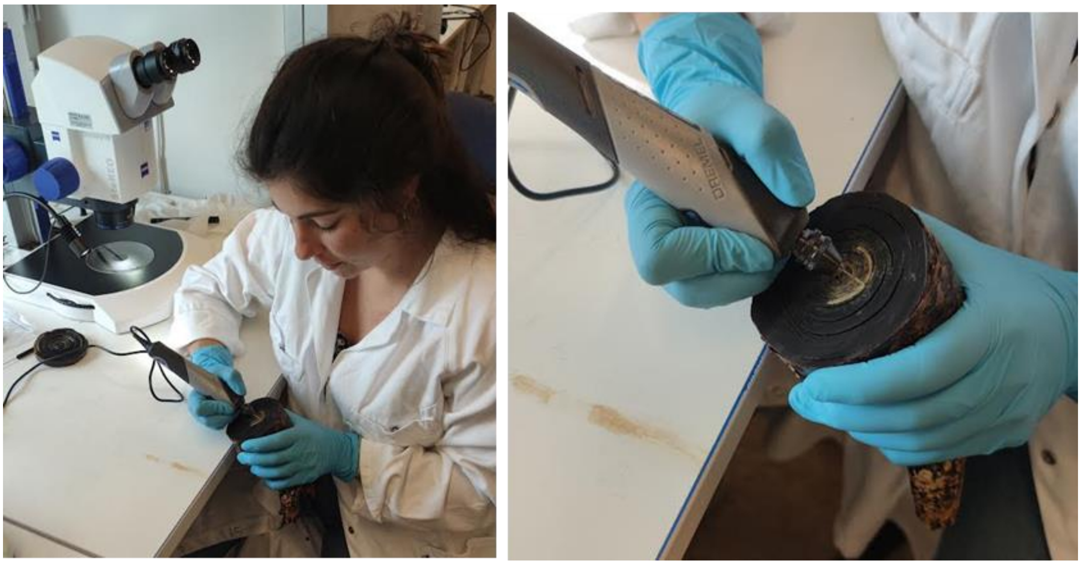


**Figure 53** Example of the microdrilling process to extract skeletal samples for C-14 analysis from the basis of the coral colony axis. In this case the black coral *Leiopathes*.

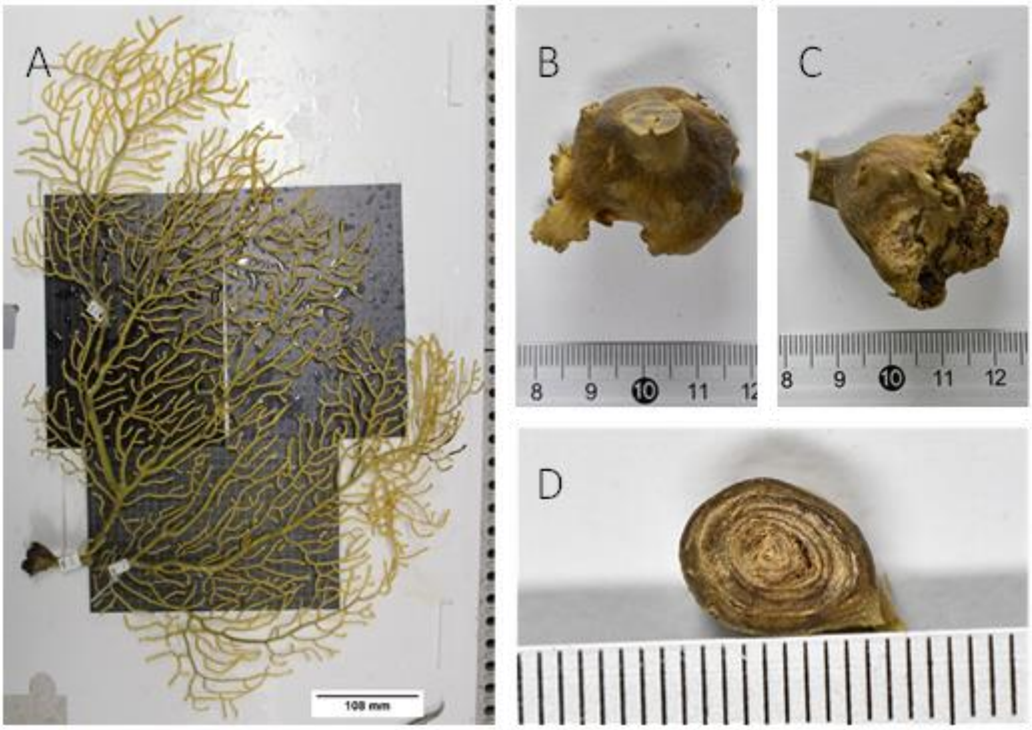



**Figure 54** *Dentomuricea* aff *meteor*, D.meteor1, collected with ROV "SaltaPocinhas" on Condor Seamount, at 200-220m depth. A- complete colony; B- colony base top view; C- colony base side view; D- base cut perforated for sample analysis.

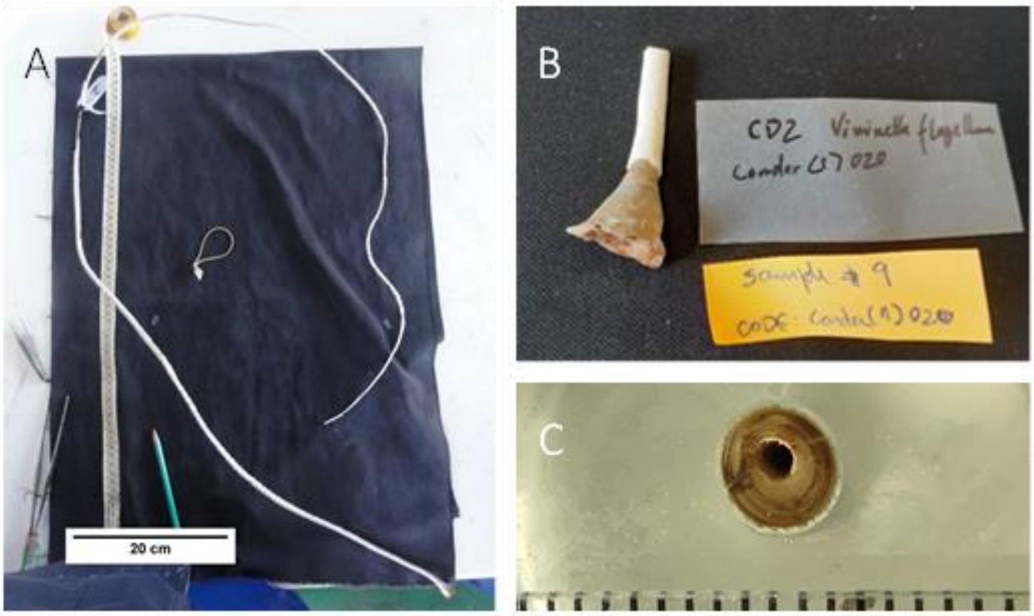



**Figure 55** *Viminella flagellum*, DOP-12751 (CD2), collected as experimental longline bycatch at Seamount Condor Seamount, at 207m depth. A- full colony; B- colony base; C- base cut perforated for sample analysis.

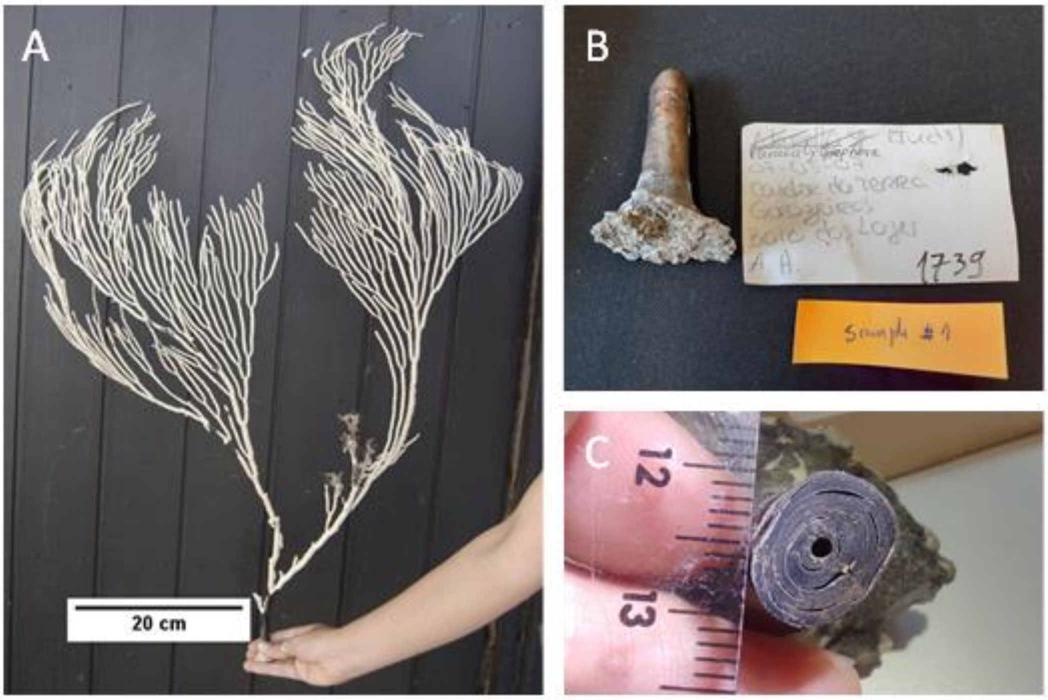



Figure 56 *Paracalypthrophora josephinae*, DOP-1739, collected as longline fishing bycatch at Seamount Condor Seamount, at 219-366m depth. A- full colony; B- colony base side view; C- base cut perforated for sample analysis.

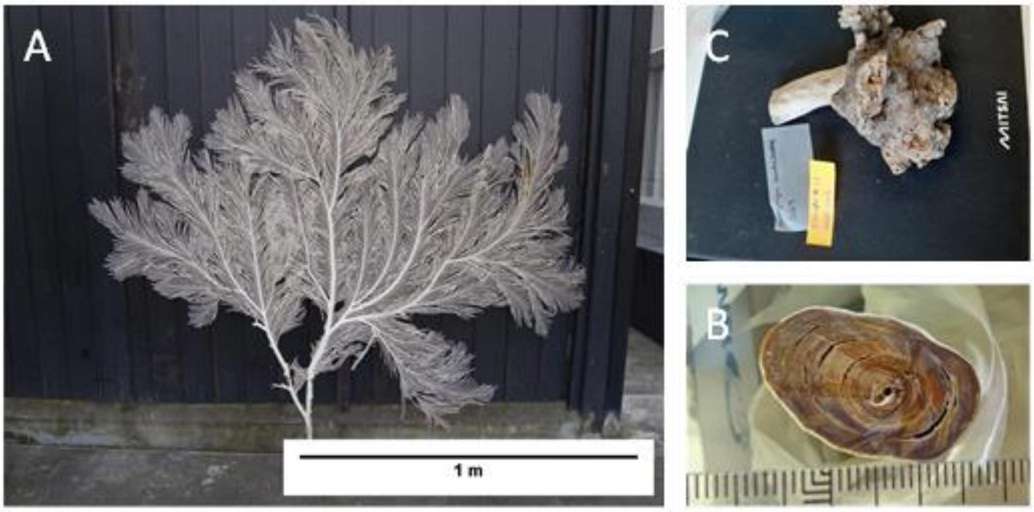



Figure 57 *Callogorgia verticillata*, DOP-1269, collected as longline fishing bycatch at Seamount Açor Seamount, at 377m depth. A- full colony; B- base cut perforated for sample analysis; C- colony base side view.

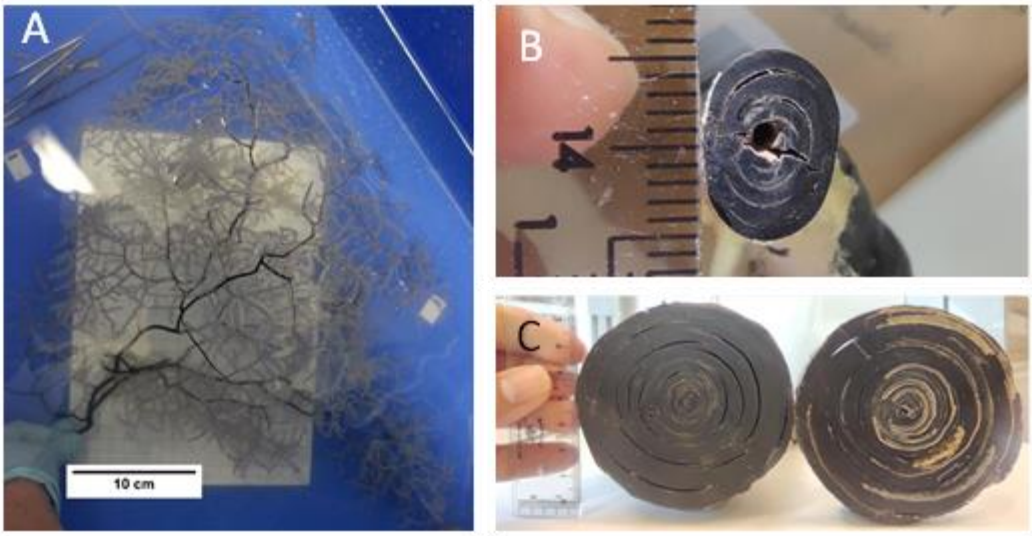



Figure 58 *Leiopathes glaberrima*, DOP-11373 (R93), collected as longline fishing bycatch at Princesa Alice Seamount, at 268m depth; A- colony branch; B- base cut perforated for sample analysis; C- Leiopathes sp., "BigBlackcoralBase", collected as longline fishing bycatch, no available data for collection site and depth, colony base cut section perforated for sample analysis.

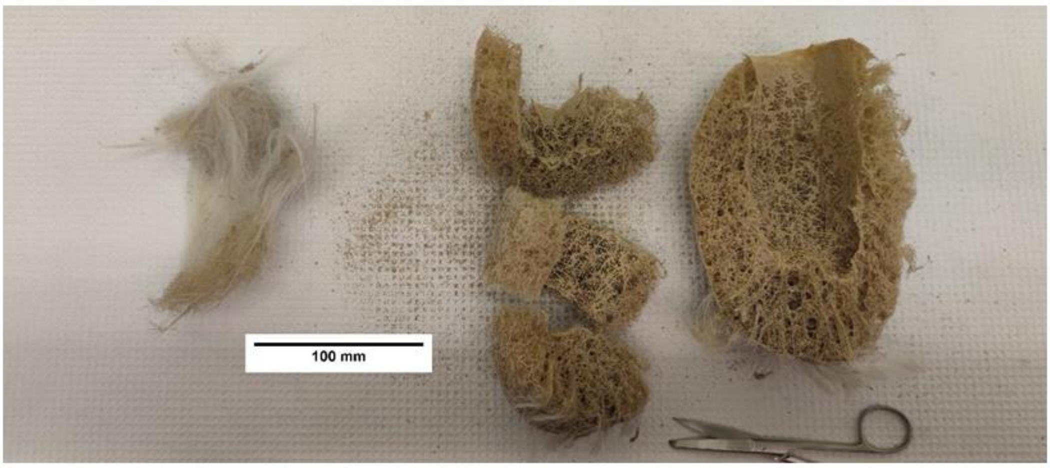



Figure 59 *Pheronema carpenteri*, DOP-2214, collected as experimental longline fishing bycatch at Biscoitos Slope, Terceira Island, at 253-297m depth; body cut longitudinally in half, one half cut into three longitudinal sections for separate analysis.

The method selected for age and growth determination of our specimens was a radiometric dating method with the radioisotope carbon-14 (14C). This method relies on the fact that a very small amount of natural carbon in the atmosphere is radioactive in the form of 14C and this is incorporated into the coral skeleton when it forms its calcium carbonate or protein and chitin (Adkins et al 2002, reviewed by Tracey et al 2017). Similar to trees on land, many corals have concentric growth rings that allow us to track growth patterns, with the oldest age representing the centre of the coral axis and the most recent age, the outer ring of the coral axis.

Because the half-life of radiocarbon is known to be 5,730 years, this method can be used to reliably age specimens to 50,000 years ago, but beyond that, the activity of 14C becomes too small to detect (Adkins et al 2002). During the 1950s–60s, there was a rapid increase of atmospheric 14C resulting from the testing of nuclear devices; this so-called "bomb carbon" created a global signal of 14C that can be traced in atmospheric, terrestrial, and marine environments. Bomb radiocarbon quickly became incorporated in the carbonate of hard tissues (coral skeletons, fish otoliths) in concentrations proportional to those in the water column. The level of 14C in hard tissues can determine whether the corals were growing before, during, or later than the main years of 14C increase (1958–65), using appropriate reference 14C chronologies for the region (Tracey et al., 2017).

Samples of five species of corals and one sponge (Table 17) were sent to Dr Nick Kamenos lab at Umeå University, Sweden. Samples were prepared by a member of the ADSR Gal-la Edery during her visit to Umeå University in May-June 2022 (Figure 53). The methodology used for sample preparation followed descriptions in Carreiro-Silva et al. (2013). Briefly, cross sections were taken from the bases of the colonies with a hand saw, and the axis polished perpendicularly with different sandpaper thickness, from thinker to finest (P400, P1200, P2500 and P4000). Sandpaper was wetted with MiliQ water to help the polishing and avoid surface scratches. When the coral rings were clearly visible and distinguishable, the axis surface was cleaned with MiliQ water and sonicated to eliminate all the dust particles that may have become attached.

A sample series of skeletal samples, oriented along the radius, was extracted using the micro milling machine for each colony section (Figure 53). Sample extraction began at the edge and progressed along radial lines successively toward the axial core. The microdriller with diamond drill bits of different diameters (0.5-1.5 mm) were used to take the samples. For the thinner corals, drilling was performed under a binocular stereomicroscope. A minimum mass of 0.5 mg of C per sample was extracted. The centre was drilled for each colony trying to take the lesser number of rings possible. A largest drill bit was used when necessary to achieve the minimum sample mass. Ultimately, 30 samples were selected.

Extracted samples were submitted as powder to the University of Lund, Sweden where the outer 20% by weight of sample material was removed using dilute HCl. Samples were then rinsed in distilled water, dried, ground and converted to $CO_2$ via hydrolysis with 85% $H_3PO_4$. Sample $CO_2$ was cryogenically purified and an aliquot converted to graphite via Fe/Zn reduction. Graphite was submitted to the Accelerator Mass Spectrometry (AMS) Laboratory, where sample 14C/13C ratios were determined using an AMS and measured to 3‰ counting precision. All results were appropriately background corrected and normalized to δ13CVPDB‰ of −25 according to standard conventions. Associated errors (1σ) include components from the counting statistics on the sample, modern reference standard, process blank and instrumental error. Calibration to calendar years was conducted with OxCa1 version 13 using the Marine13 radiocarbon age calibration curve.

Table 17 Data of the specimens used in this study. Collection year and site (seamount) were known for all specimens, with the exception of black coral Leiopathes sp. (BigBlackcoralBase) which was brought by a fisherman. Axis diameter: maximum values at the sample extraction plane. Height: vertical colony height.

| Specimen ID | Species | Date | Collection Site | Latitude/ Longitude | Depth (m) | Axis max. Ø (mm) | Height/ length(mm) |
|---|---|---|---|---|---|---|---|
| BigBlackcoralBase | *Leiopathes sp* | na | na | na | na | 83,8 | un. |
| D.meteor 1 | *Dentomuricea aff meteor* | 24/03/2017 | Condor Seamount | na | 200-220 | 9,7 | 512 |
| D.meteor 2 | *Dentomuricea aff meteor* | 24/03/2017 | Condor Seamount | na | 200-220 | 5,6 | 421 |
| D. meteor 3 | *Dentomuricea aff meteor* | 24/03/2017 | Condor Seamount | na | 200-220 | 8,6 | 296 |
| D. meteor 4 | *Dentomuricea aff meteor* | 24/03/2017 | Condor Seamount | na | 200-220 | 6,5 | 421 |

| Specimen ID | Species | Date | Collection Site | Latitude/ Longitude | Depth (m) | Axis max. Ø (mm) | Height/ length(mm) |
|---|---|---|---|---|---|---|---|
| D. meteor 6 | *Dentomuricea aff meteor* | 24/03/2017 | Condor Seamount | na | 200-220 | 9,1 | 412 |
| C02629 | *Viminella flagellum* | 17/05/2008 | Princesa Alice Seamount | 38,0033 -29,3377 | 204-250 | 2,7 | 774 |
| C05571 | *Viminella flagellum* | 03/02/2011 | Seamount Gigante | 38,9850 -29,9050 | 287 | 5,6 | 1989 |
| C06327 | *Paracalyptrophora josephinae* | 26/06/2010 | Seamount Voador | 37,5450 -30,7440 | 363 | 10,2 | 536 |
| C06424 | *Paracalyptrophora josephinae* | 27/06/2010 | Seamount Voador | 37,5270 -30,7570 | 278 | 6,5 | 370 |
| C10456 | *Viminella flagellum* | 17/06/2013 | Ponta da Barca, Graciosa Island | 39,1465 -28,06307 | 581 | 3,9 | 686 |
| C10628 | *Callogorgia verticillata* | 23/06/2017 | Mar da Prata (north) | 37,6002 -25,8862 | 237 | 6,6 | 670 |
| C10651 | *Callogorgia verticillata* | 27/06/2017 | São Lourenço, Santa Maria Island | 37,0005 -25,0258 | 259 | 6,2 | 645 |
| C10669 | *Callogorgia verticillata* | 02/07/2017 | Mar da Prata (north) | 37,5799 -25,9052 | 763 | 20,7 | 1515 |
| C10680 | *Callogorgia verticillata* | 11/07/2017 | Seamount Açor | 38,2224 -28,9727 | 274 | 6,9 | 767 |
| C11373 | *Leiopathes glaberrima* | 13/06/2017 | Seamount Princesa Alice | 37,9047 -29,1853 | 268 | 10,6 | 352 (inc.) |
| C10634 | *Viminella flagellum* | 24/06/2017 | Mar da Prata (south) | 37,1748 -25,6426 | 276 | 4,5 | 1201 |
| C1269 | *Callogorgia verticillata* | 04/04/2007 | Seamount Açor | 38,1200 -29,1900 | 377 | 25,0 | 1345 |
| C12751 | *Viminella flagellum* | 09/10/2020 | Seamount Condor | 38,5379 -29,0535 | 207 | 4,4 | 1830 |
| C12757 | *Viminella flagellum* | 10/10/2020 | Seamount Condor | 38,5473 -29,0518 | 208 | 3,9 | 1355 |
| C1739 | *Paracalyptrophora josephinae* | 07/05/2007 | Seamount Condor | 38,5170 -28,9330 | 219-366 | 11,0 | 790 |
| C2211 | *Dentomuricea aff meteor* | 07/05/2007 | Biscoitos, Terceira Island | 38,4833 -27,9883 | 225-249 | 16,5 | 334 |
| C2214 | *Pheronema carpenteri* | 07/05/2007 | Biscoitos, Terceira Island | 38,8600 -27,2200 | 253-297 | 61,4 (osculum) | 187 (body) |
| C2534 | *Dentomuricea aff meteor* | 07/05/2007 | Biscoitos, Terceira Island | 38,8553 -27,2095 | 277 | 13,4 | 174 (inc.) |
| C3570 | *Viminella flagellum* | 17/09/2009 | Seamount Condor | 38,5223 /28,9940; 38,5696 -28,9586 | 210-1175 | 3,9 | 1706 |
| C3630 | *Viminella flagellum* | 23/09/2009 | Seamount Condor | 38,5180 -28,9910 | 232 | 3,7 | 1331 |
| C3770 | *Callogorgia verticillata* | 19/06/2010 | Seamount Princesa Alice | 37,7350 -28,9010 | 475-530 | 13,4 | 876 (inc.) |
| C7898 | *Callogorgia verticillata* | 23/05/2011 | Seamount Cavala | 38,3105 -30,7009 | 402 | 21,6 | 1344 |
| C8218 | *Callogorgia verticillata* | 18/08/2011 | Canal Pico-Faial | 38,3174 -28,8010 | 549 | 16,5 | 1565 (inc.) |
| DOP-AC17 | *Viminella flagellum* | 17/11/2017 | Seamount Condor | 38,5385 -29,0514 | 186 | 4,5 | 1364 |
| Sample 06 | *Dentomuricea aff meteor* | na | na | na | na | 18,5 | 948 |

The data obtained for the age of individual extracted samples and total colony age (lifespan of the colony) using the calibrated radiocarbon ages are presented in Table 18. Data collected so far points out that most of the samples had ages younger than modern age, this means they are less than 80 years old (indicated as <Modern). This may be related to the small size of the specimens analysed. Since larger and likely older specimens were also sent for analysis, further data should give estimates of close to maximal ages of colonies still found today in the Azores. Age estimates for two large specimens of the octocoral *Callogorgia verticillata* (Figure 57) showed that this species, which can attain a large size 1,70 m in height can live for up to 500 years old. Interestingly the larger black coral axis was found until today (Figure 58c, axis diameter 83.5 mm) gave maximum age estimates 2000 years (Table 18), which is wrongly the same as the age obtained for a previously date *Leiopathes* with an axis diameter of 33 cm (DOP-1985, Carreiro-Silva et al. 2013).

**Table 18** Results from radiocarbon assays separated by species (Specimen ID) and into the consecutive sample series taken along each radial axis (Sample ID = laboratory record). Provided values are assumed (−17‰) and measured (given to 0.1‰) δ13C values, with the measured radiocarbon fraction modern (Fm), calculated Δ14C, and conventional radiocarbon age (CRA). >Modern: >1950

| Specimen ID | Species | Date of collection | Sample ID | Sample mass (mg) | δ13C (‰) | Fm | CRA (yr) |
|---|---|---|---|---|---|---|---|
| C10651 | *Callogorgia verticillata* | 27.06.2017 | SUERC-92640 | 21.3 | -2.2 | 0.9685 | 257 |
| C10669 | *Callogorgia verticillata* | 02.07.2017 | SUERC-92641 | 10.5 | -1.2 | 0.9424 | 477 |
| C10680 | *Callogorgia verticillata* | 11.07.2017 | SUERC-87417 | 8.4 | -10.5 | 1.0946 | >Modern |
| C6327 | *Paracalyptrophora josephinae* | 26.06.2010 | UCID22759 | 2.82 | NA | 1.0807 | >Modern |
| C6424 | *Paracalyptrophora josephinae* | 27.06.2010 | UCID22760 | 2.5 | NA | 1.0791 | >Modern |
| New3 | *Dentomuricea* aff. *meteor* | 24.03.2017 | SUERC-87418 | 6.3 | -17.1 | 1.0382 | >Modern |
| C10628 | *Callogorgia verticillata* | 23.06.2017 | SUERC-92642 | 15.1 | -2.7 | 1.0755 | >Modern |
| NA | *Leiopathes* sp. | NA | SUERC-92643 | NA | -16.5 | 0.8441 | 1361 |
| NA | *Leiopathes* sp. | NA | SUERC-92644 | NA | -16.5 | 0.8318 | 1479 |
| NA | *Leiopathes* sp. | NA | SUERC-92645 | NA | -16.5 | 0.8204 | 1590 |
| NA | *Leiopathes* sp. | NA | SUERC-92646 | NA | -16.3 | 0.8121 | 1672 |
| NA | *Leiopathes* sp. | NA | SUERC-92650 | NA | -16.9 | 0.7835 | 1959 |

## *8.3 Methodologies and definitions for VME indicator taxa*

The ICES/NAFO provides a comprehensive list of deep-water VME habitats, indicators, and their characteristic taxa, which is regularly reviewed by the ICES/NAFO Working Group on Deep-water Ecology (WGDEC) (ICES, 2019, 2020). The list includes 12 VME indicator types, corresponding to the main taxonomic groups of benthic fauna in the NE Atlantic, including stony, soft and cup corals, gorgonians, black corals, sea-pens, anemones, sponges and chemosynthetic spp. (seeps and vents), which are indicative of 10 VME habitat types, such as coral reefs and gardens, sponge aggregations, sea-pen fields, hydrothermal vents/cold seeps, xenophyophores aggregations, and several habitat subtypes (ICES, 2020a). The inclusion of new VME indicators and its representative taxa in the list is partly based on outputs of the ICES Workshop on VME (WKVME) (e.g., ICES, 2016), which updates the VME list specifically for use in data submissions to the ICES VME database, and partly based on new evidence provided by experts of the WGDEC group.

In 2019 and 2020, the EU requested the WGDEC to provide advice on additional VME indicator species to be included in Annex III of the EU deep-sea access regulations. Marina Carreiro-Silva as part of the WGDEC, recommended the inclusion of several species of stony corals, gorgonians, and sponges as VME indicator species in the Azores. These proposed new indicator species were selected because they were known to form structurally complex habitats based on video surveys but were frequently accidentally captured (bycatch) during longline fisheries. The proposed new indicator taxa were further assessed by the WGDEC against the criteria for defining what constitutes a VME (FAO, 2009). The methodology used for the assessment was based on a qualitative scoring following the guidelines established in Morato *et al.* (2018):

- Rarity: assessed according to presence on the IUCN red list, and if the representative taxa was known to be endemic, rare, threatened, or declining.
- Functionality: assessed by evaluating if the representative taxa were known to create nursery areas for other species, or known for having higher level ecosystem role, such as nutrient cycling and water filtration.
- Fragility: assessed according to the fragility of the representative taxa against physical contact, the height and complexity of its structure, and the capacity for retraction, retention, or re-growth or if being naturally protected in some way.
- Life-history: assessed against the longevity, fecundity, age at maturity, growth rate, and known frequency of recruitment success.
- Structural complexity: assessed based on structural habitat created, frame-building, and presence of commensal or closely associated species.

The qualitative scoring included four categories based on (1) the existence of direct evidence fitting to the criteria; (2) whether it was inferred from the literature on other species; (3) the non -existence of information available or (4) the criteria not being met. According to the FAO guidelines only one criterion needed to be meet for a species to be VME indicator species. For the present report we have updated this initial list with proposed new indicator taxa based on information collected during recent field campaigns (section 5). The new indicator taxa were evaluated against the criteria for VME indicator taxa by the ADSR group, and will be brought to the next WGDEC meeting for a formal proposal of inclusion on the ICES VME indicator taxa list. We have also reassessed some taxa that are presently part of the ICES VME list because of their ecological importance in other region of the Atlantic but may not be as relevant for the Azores.

## *8.4 Known deep-sea species in the Azores (MCS)*

### Cold-water corals

*Octocorals (Sub-class Octocorallia)*

*Viminella flagellum (Johnson, 1863) "yellow morphotype" (Family Ellisellidae)*

There are two morphotypes of *Viminella* commonly observed on images, the white morphotype previously identified for the Azores as *Viminella flagellum* (Studer 1901) and a yellow morphotype for which we wanted confirmation of the species identification. Specimens of the yellow morphotype were examined by Íris Sampaio (2020).

**Material examined:** Morphological examination of the yellow morphotype collected from Gigante S at 359 m depth (C10142), Flores-Corvo - Ponta dos Ilhéus at 443 m depth (C10768), Vulcão Serreta at 350 m depth (C7151). This material was compared with the white morphotype C10049, C10056, C10096, C10168, C10191 for the differential diagnosis. Genetic analysis of specimens COLETA C10142, C10768, C7151 and C10096, C10168, C10191.

**Morphological Description**

**Colony:** Unbranched, flexible and flagelliform colonies up to 2 m in height with three to four series of cylindrical polyps on each edge of the stem or with zigzag (Figure 60A-C).

**Polyps:** Calyx wall with rods, girled spindles and double cones (Figure 60D, E).

**Sclerites:** Coenenchyme with symmetrical double heads, slightly elongated double heads, capstans, and spindles in the subsurface of the coenenchyme and in the wall of calyces (Figure 60F-J).

**Colour:** yellow to orange coloration

**Molecular analyses:** DNA sequences of representative specimens of *Viminella* yellow morphotype were compared with previously identified *Viminella flagellum* white morphotype individuals, by means of different DNA barcodes (e.g. 28S, COI, 16S, ITS and MutS) (Table 16, Appendix 1). All DNA sequences from the different samples aligned between them for the different barcode markers, strongly suggesting that the specimens belong to the same species. BLAST analysis of the mtMutS gene - the most widely used marker for DNA barcoding of octocorals - returned a 100% similarity match with a *V. flagellum* record from the NE Atlantic (Accession: KF803747).

**Remarks:** Comparison of colonies, polyps and sclerome morphology by Sampaio (2020) have shown similarities among white and orange specimens. Therefore, based on the morphological and DNA sequences comparison we conclude that the yellow morphotype is *Viminella flagellum*.

**Habitat and distribution**: In the Azores, the yellow morph of *V. flagellum* has been shown on seamount summits of hard bottoms, at bathyal depths 250-370 m, while the white morph has been shown to be deeper than 600 m. The species *V. flagellum* is reported to have a distribution along the Atlantic Ocean.

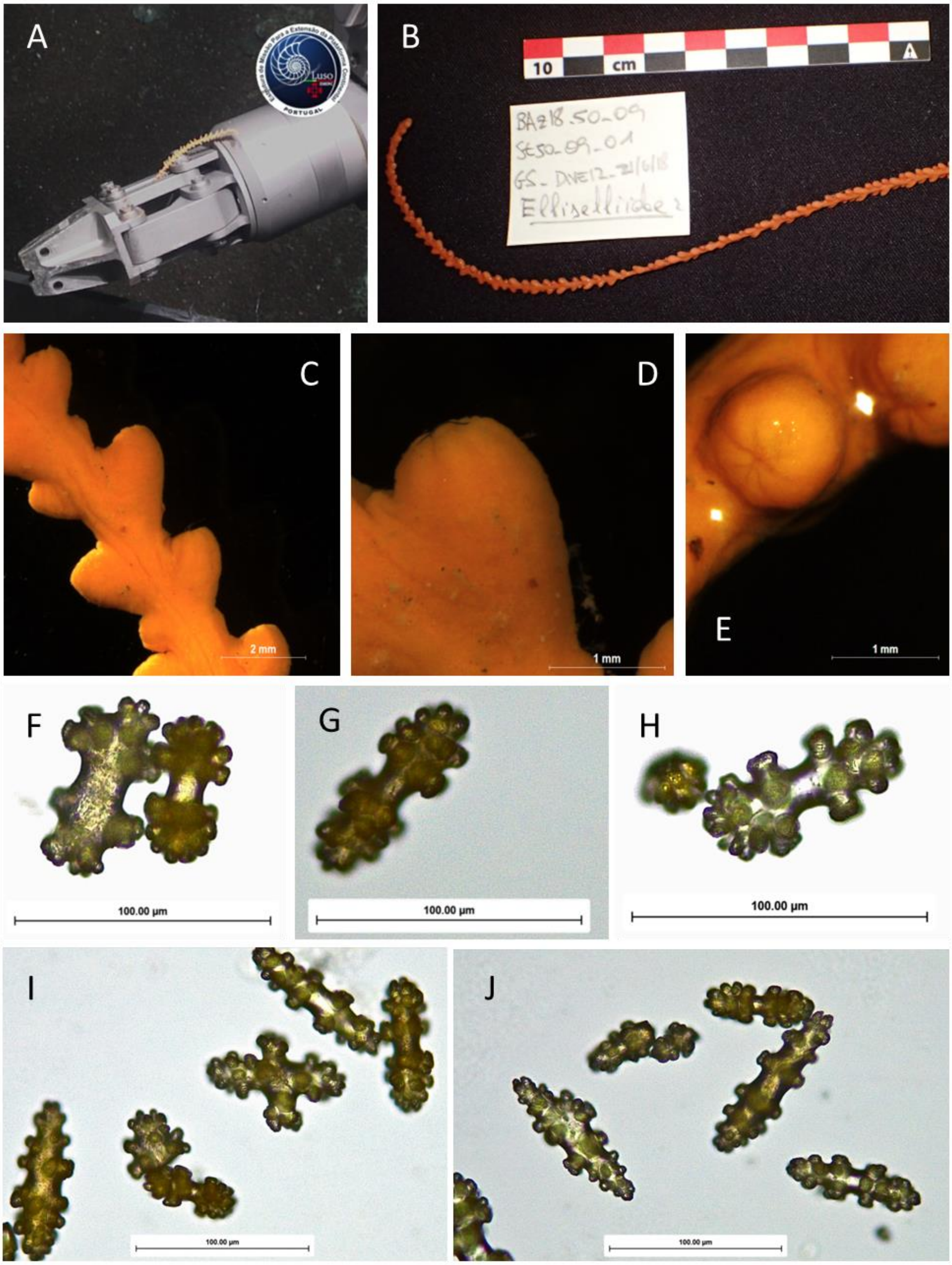



Figure 60 *Viminella flagellum.* (A) Photo taken in situ of the specimen C10142 in Gigante S at 359 m depth using a submersible ROV (Campaign BlueAzores_2018); (B) photo ex situ of the complete specimen; (C-E) detail of the polyps and its distribution on the colony; (F-H) sclerites from the coenenchyme; (I-J) sclerites from the polyp.

*Paragorgia jonhsoni Gray, 1862 (Family Coralliidae)*

*Paragorgia arborea* (Linnaeus, 1758) and *Paragorgia joh*nsoni Gray, 1862 are two *Paragorgia* species reported for the Azores (Braga-Henriques et al. 2013; Sampaio et al., 2019). During video surveys, white and red morphotypes of the genus *Paragorgia* have been observed in multiple locations in the Azores. The cosmopolitan species *Paragorgia arborea* was given to the Azores in 2007 based exclusively on video images (Mortensen et al., 2007). Later, *Paragorgia john*soni was also reported for the Azores based on specimen examinations (Braga-Henriques et al., 2013). Several white and red morphotypes have been collected in recent cruises in the Azores giving the opportunity for a careful examination and taxonomic identification. White and red morphotypes have been morphological examined by Sampaio (2020).

Material examined: Morphological examination and molecular analysis of specimens collected from Gigante E at 558m depth (C10080 and C10081) and from Gigante Agulhas S at 589m depth (C10173) and 564m depth (C10174, C10176).

**Morphological description**

Colony: Highly branched colonies up to 120 cm in height in the Azores (Figure 61A, Morato et al., 2021) with terminal branches (except autozooid clumps) smaller than 5 mm in diameter (Figure 61B, C). Numerous short, lateral branches arise from the main branches with an irregular but clavate appearance, without axial skeletal structures other than a medulla formed by unfused sclerites (Grasshoff, 1979; Sánchez, 2005).

Polyps: Presence of dimorphic polyps, reproductive siphonozooids, and feeding autozooids. Autozooid and siphonozooid polyps located towards one side of the colony (Grasshoff, 1979). Autozooids clustered in distinct nodules (Figure 61 D-F).

Sclerites: Surface cortex sclerites with a smooth ornamentation, dominated by six- radiate sclerites averaging 0.05 mm in length (Figure 61G-M).

Colour: White and red morphotypes

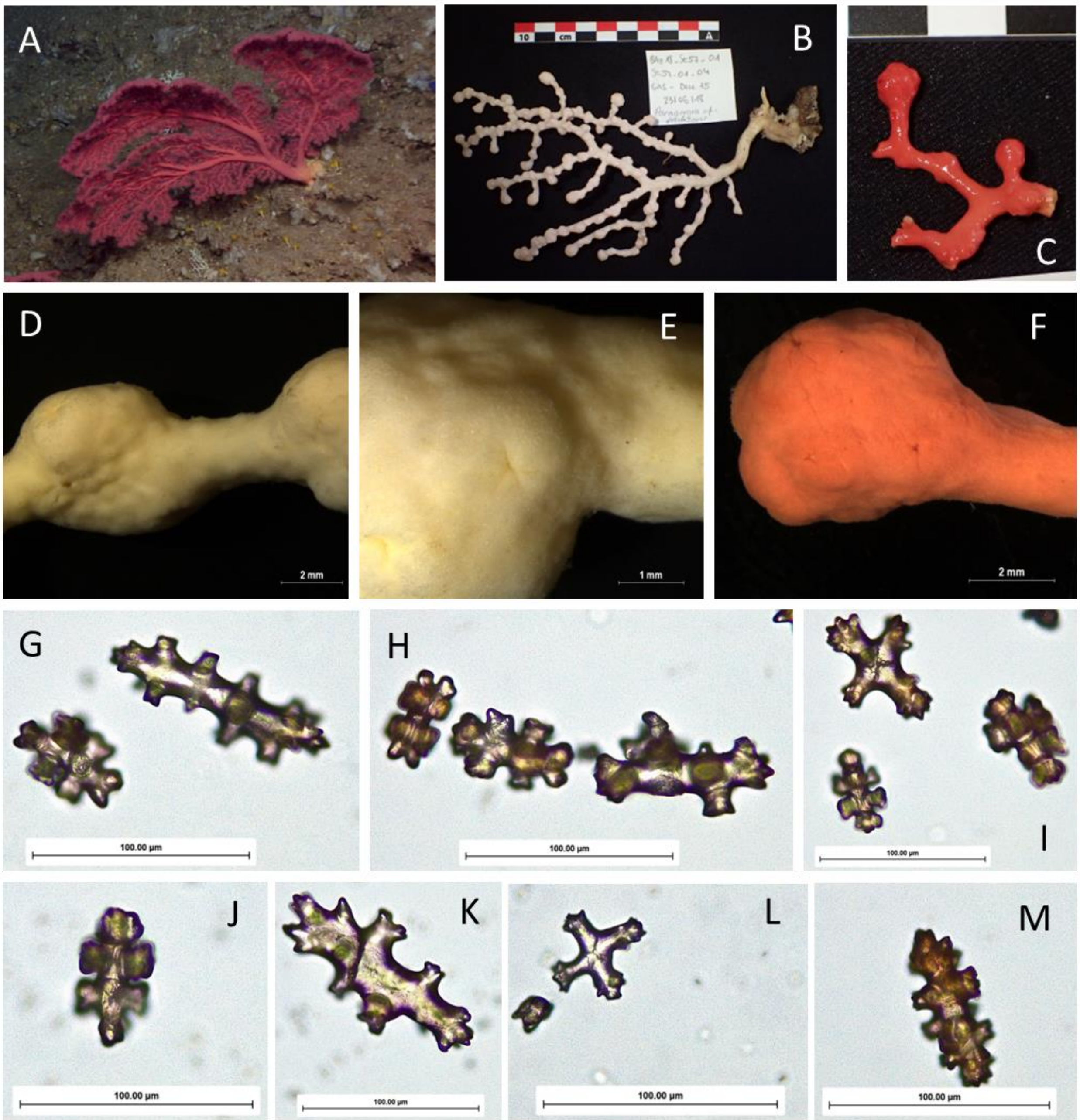



Figure 61 *Paragorgia johnsoni*. (A) Photo taken *in situ* using the ROV LUSO (campaign BlueAzores_2018); (B) photo *ex situ* of a small complete colony os the specimen C10173 collected in Gigante - Agulhas S at 589 m depth using the ROV LUSO (campaign BlueAzores_2018); (C) photo *ex situ* of a fragment of a red morph colony (C1008) collected in Gigante E at 558 m depth using the ROV LUSO (campaign BlueAzores_2018); (D-E) detail of the polyp arrangement on the colony (C10173); (F) detail of the polyp arrangement of the colony (C10081) ; (G-I) sclerites in the coenenchyme of the specimen C10081; J-M) sclerites in the polyp of the specimen C10081.

Molecular analyses: We successfully obtained DNA sequences from 28S and *mt-MutS* barcodes from C7884, C10080, C10173, C4820 specimens (Table 16, Appendix 1). Using these molecular markers, we were able to classify these individuals as belonging to *Paragorgia johnsoni* species. Genbank BLAST analysis of all the MutS barcode sequences returned a 100% similarity match with *Paragorgia johnsonny* (Accessions: JX128348, KP714006). The combined information obtained from the additional 28S barcodes did support these results. Additional high-throughput sequencing data (e.g. genome skimming) and phylogenomic methods in collaboration with colleagues at NMNH will provide a more insights into the phylogeny of *Paragorgia johnsoni* members in the Azores.

**Remarks:** *Paragorgia arborea* is characterized by having "terminal branches (except autozooid clumps) with more than 5 mm in diameter and surface radiate sclerites with subdivided and grooved ornaments" (Sanchez 2005). In contrast, the specimens examined had terminal branches smaller than 5 mm in diameter and surface cortex sclerites had a smooth ornamentation, characteristic of *P. jonhsoni*. Based on the similar morphology and sclerome presented by both red and white morphotypes they were identified as *P. johnsoni*.

**Habitat and distribution:** In the Azores, the species *Paragorgia johnsoni* has been recorded at a bathyal depth of 300-750 m, on slopes of ridges. This species has a reported distribution along the Atlantic Ocean and Mediterranean Sea, with depth ranges of 400-3,000 m.

*Narella cf. regularis (Family Primnoidae)*

Some colonies of the sea-fan *Narella* observed in video appear to have an equal, dichotomous branching rather than the traditional lyrate branching characteristic of *Narella bellissima* (Figure 62A, B). This raised the question to whether *Narella regularis* could also occur in the Azores. As such, specimens of suspected *N. regularis* were examined by Sampaio (2020).

As reported by Sampaio (2020), *Narella regularis* (Kukënthal, 1915) was given to the Azores by Tixier-Durivault & D'Hondt 1974 but it was synonymized by Grasshoff (1986) to *Narella bellissima* (Sampaio et al. 2019). Currently, there is another species with the name *Narella regularis* (Duchassaing & Michelotti, 1860) that is valid (Cairns & Bayer 2003). This species was originally named *Primnoa regularis* and corresponds to a distinct species with distribution in the NW Atlantic, and which so far has not been reported for the Azores.

**Material examined:** Morphological examination and molecular analysis of specimens collected from Gigante E seamount at 682 m depth (C10069, C10070) and 686 m depth (C10079).

**Morphological description**

**Colony:** Medium sized colonies (up to 20 cm in height), dichotomous branched but not in a lyriform pattern (Figure 62A).

**Polyps:** Polyps arranged in whorls, all polyps facing downward in contracted condition. Polyps with 3 pairs of large body scales (Figure 62B, C).

**Sclerites:** The sclerites are set as scales disposing as conspicuous armor around the polyp (Figure 62C, D).Figure 62C, D). The coenenchymal scales of most species are relatively thin, having the same thickness as a body wall scale, and have edges that slightly overlap those of other adjacent coenenchymal scales (Figure 62E-G).Figure 62E-G). Distal margin of basal scales projecting only as a pair of short, rounded lobes, oriented downward to axis; lateral part of basal scales meeting as smooth curve, not a 90o angle and not ridged; regularly and profusely branched.

**Colour:** White

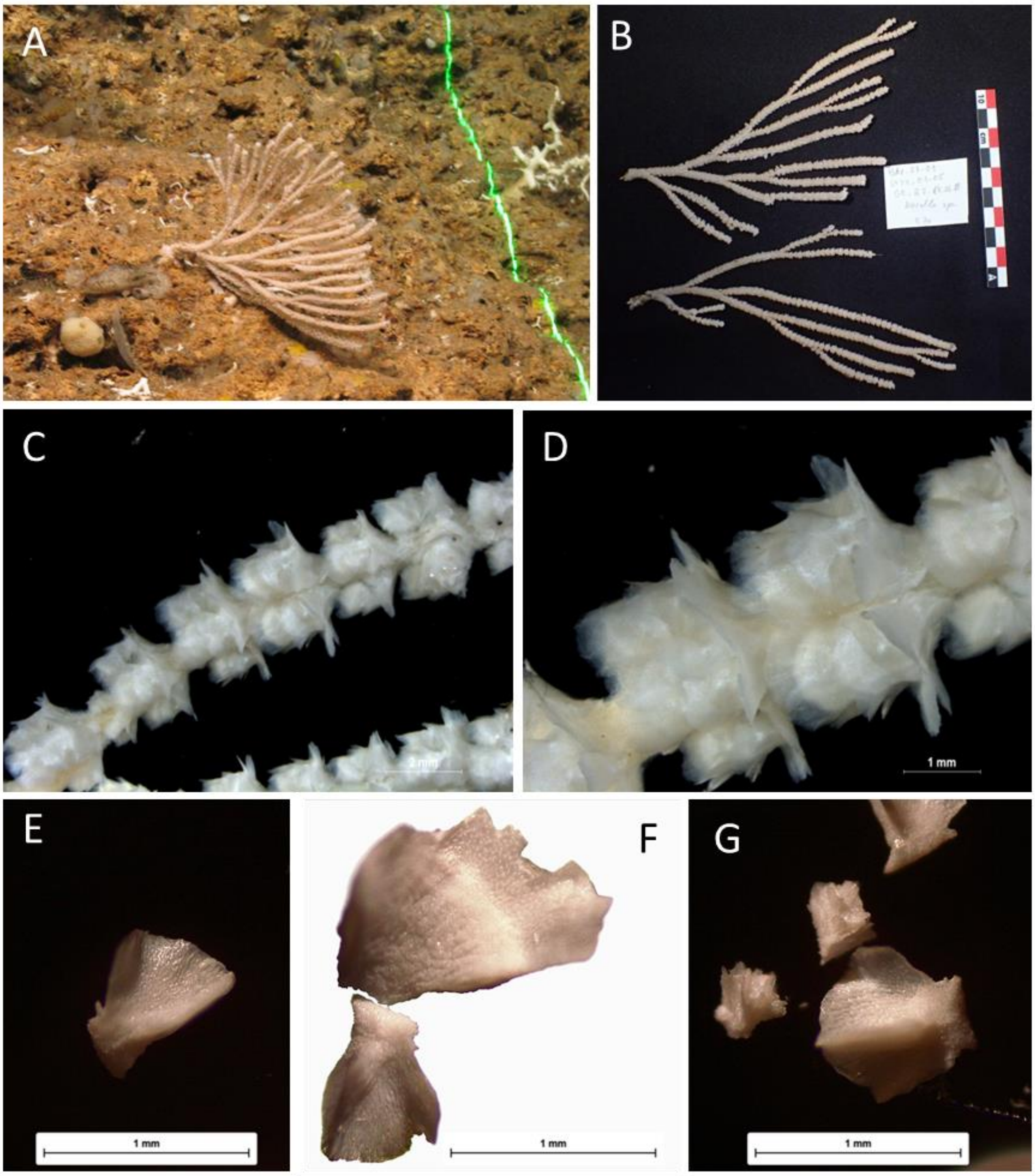



Figure 62 *Narella* sp. (A) Photo taken *in situ* of the specimen C10069 in Gigante E seamount at 682 m depth using the ROV LUSO (BlueAzores_2018); (B) photo *ex situ* of the complete colony showing the branching arrangement; (C-D) detail branch and polyps arrangement on the colony; (E-G) sclerites in the form of scales.

Molecular analyses: We successfully obtain DNA sequences from 28S and ITS-2 barcodes (Table 16, Appendix 1). Using these molecular markers, we could not classify *Narella* specimens beyond the genus level. BLAST analysis best hits of 28S barcoding sequences returned a <95% identity matches with e.g. *Narella* sp. (Accessions: KP324622, KP324552), as *Narella bellissima* and *Narella regularis* 28S sequences are still missing from GenBank database. This reinforces the need for further investigations in order to generate more barcoding records from species from the deep-sea. Additional high-throughput sequencing data (e.g. genome skimming) and phylogenomic methods in collaboration with colleagues at NMNH will provide a powerful alternative to solve the species boundaries within *Narella* members.

**Remarks:** Following the diagnostic morphological characters in the key of the genus *Narella* in the Atlantic Ocean (Cairns & Bayer 2003). The specimens examined do not branch in a lyriform pattern, as expected for *N. bellissima*. In addition, the body wall scales are not smooth, as described for *N. bellissima*, but granular and ridged instead (Fig. 9, 10 in Cairns & Bayer 2003). However, other characteristics like prominent lobes projecting perpendicular to the axis on the distal margin of the basal scale indicate similarity *to N. bellissima* (Figure 62C, D). Either *N. bellissima* also occurs with strictly dichotomous branching, which is not reported in the literature, or this might be other species, possibly *N. regularis*, but this needs the examination of a higher number of specimens to detect the full range of variability of branching and sclerite morphology. Thus, it is recommended to collect more specimens of both types of equal dichotomous and lyrate branching.

**Habitat and distribution:** In the Azores, the regular dichotomous branching morph of *Narella* has been recorded at bathyal depths 600-1000 m, on hard/soft bottoms. *N. bellissima* has a Amphi-Atlantic distribution, recorded between 161–1698 m, while *N. regularis* is distributed in the Northwest Atlantic, between 366–792 m (Cairns & Taylor 2019).

*Family Paramuriceidae*

Our video images show diverse morphospecies, often forming structuring habitats, that were classified as members of the Plexauridae family, generally referred to as plexaurids. Morphospecies with a larger more arborescent structure were of particular interest for taxonomic clarification because of their ecological importance as bioengineering species. Two genera were of particular interest, *Paramuricea* and *Placogorgia*.

These genera previously classified within the family Plexauridae, have now been assigned to the family Paramuriceidae after a revised classification of Octocorallia by McFadden et al (2022).

Following description in McFadden et al (2020), members of the Family Paramuriceidae Bayer, 1956, have a proteinaceous skeletal hollow axis with wide cross-chambered central core and usually a very thin coenenchyme. Colonies are erect, unbranched or branched (sparse and whip-like to profuse, often reticulate), planar or bushy. Polyps monomorphic, retractile into prominent calyces or non-retractile but with heavily armored polyp body wall giving the appearance of a cylindrical calyx. Polyps heavily armed with spindles, usually large and often bent or spinose, typically arranged as collaret and points. Calyces with thornscales, thornspindles, long spindles or short high-warted sclerites, typically differing in form from coenenchymal sclerites. Sclerites of coenenchyme in two layers: outer layer of thornspindles, thornstars or their derivatives; inner layer of simple or branched spindles.

*Morphotype "purple plexaurid" – new ID Paramuricea sp.*

**Material examined:** Morphological examination and molecular analysis of specimen C12410 collected in Princesa Alice seamount at 1061 m depth.

**Colony:** Colonies are erect planar and sparsely branched with medium sizes (30 cm) (Figure 63A).

**Polyp:** Polyps monomorphic and retractile into prominent calyces. Anthocodium with big sclerites (Figure 63B, C).

**Sclerites:** Following the taxonomic key for the genus identification for *Paramuricea* in Grasshoff (1977). Coenenchyme is thin, calyces projected, and the projection of the thornscales is smooth or slightly warted (Figure 63B, C). Calyx and coenenchym without thornspindels and calyx not in "fujifama" form (Figure 63C-G).Figure 63C-G). Calyces with thornscales, thornspindels, long spindels or short high warted spindels (Figure 63C-G). Thornscales higher than broad with smooth projection or more or less warted (Figure 63), coenenchyme with simple or branched spindels (Figure 63E), coenenchyme with simple or branched spindels (Figure 63E).

Similarities with *Paramuricea placomus*: Sclerites of the coenenchyme are spindels (Figure 63Figure 63E), Thornscales with long warted projection (Figure 63Figure 63G), Basal part of the thornscales with slender projections. Coenenchyme with small spindels (Figure 63Figure 63E).

**Coulor:** purple

**Remarks:** The sclerome presents similarities with descriptions for *Paramuricea placomus* in Grasshoff (1977). However, *P. placomus* is only known to occur at the Boreal Atlantic, in general its calyces are more projected and the projection of its calyces' thornscales are more rounded and shorter than the thornscales of our specimen. The sclerome of our specimen also presents some similarities with Paramuricea grandis Verrill, 1883 (Carpine & Grasshoff 1985). Therefore, a comparison with type specimens and DNA sequences are necessary for the confirmation of the species ID. For now, the species identification according to its morphological characters should be *Paramuricea* sp.

**Habitat and distribution:**

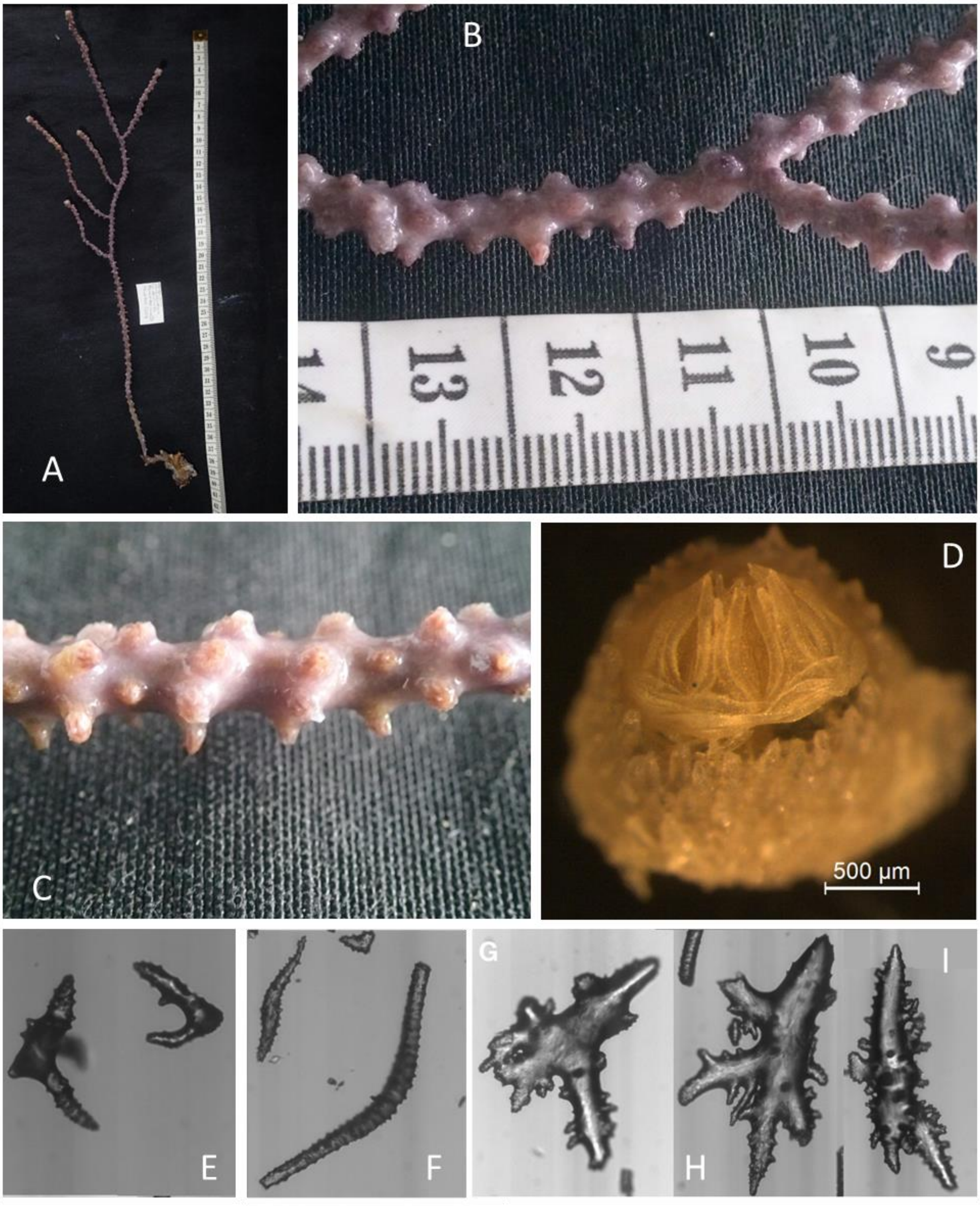



Figure 63 *Paramuricea sp.* (A) Photo *ex situ* of the complete colony C12410 collected as longline fisheries bycatch in Princesa Alice seamount at 1061 m depth; (B-C) detail of the polyp arrangement on the colony; (D) whole polyp showing arrangement of sclerites; (E) sclerome of the coenenchyme, (F-I) sclerome of the polyp. Photos of the polyp and sclerites from Sampaio (2020).

*Morphotype "purple plexaurid 2" – new ID Paramuricea candida Grasshoff, 1977*

**Material examined:** Morphological examination and molecular analysis of specimen C11572 collected in Gigante N at 1163 m depth.

**Colony:** Colonies are erect planar and sparsely branched, with medium sizes (15-20 cm) (Figure 64A).

**Polyp:** Polyps monomorphic and retractile into prominent calyces. Anthocodium with big sclerites (Figure 64B, C)

**Sclerites:** Following the taxonomic key for the genus identification for *Paramuricea* in Grasshoff (1977). Coenenchyme is thin, calyces projected and the projection of the thornscales is smooth or slightly warted (Figure 64C, D, J). Calyx and coenenchym without thornspindels and calyx not in "fujifama" form (Figure 64D, E). Calyces with thornscales, thornspindels, long spindels or short high warted spindels (Figure 64C-L). Thornscales higher than broad with smooth projection or more or less warted (Figure 64J), coenenchyme with simple or branched spindels (Figure 64E, F).

Similarities with *P. candida*: Sclerites of the coenenchyme are spindels (Figure 64E, F), thornscales with short, smooth spine (Figure 64J).

**Coulor:** Purple

**Remarks:** Sclerome characteristics suggest *Paramuricea candida*.

**Habitat and distribution:**

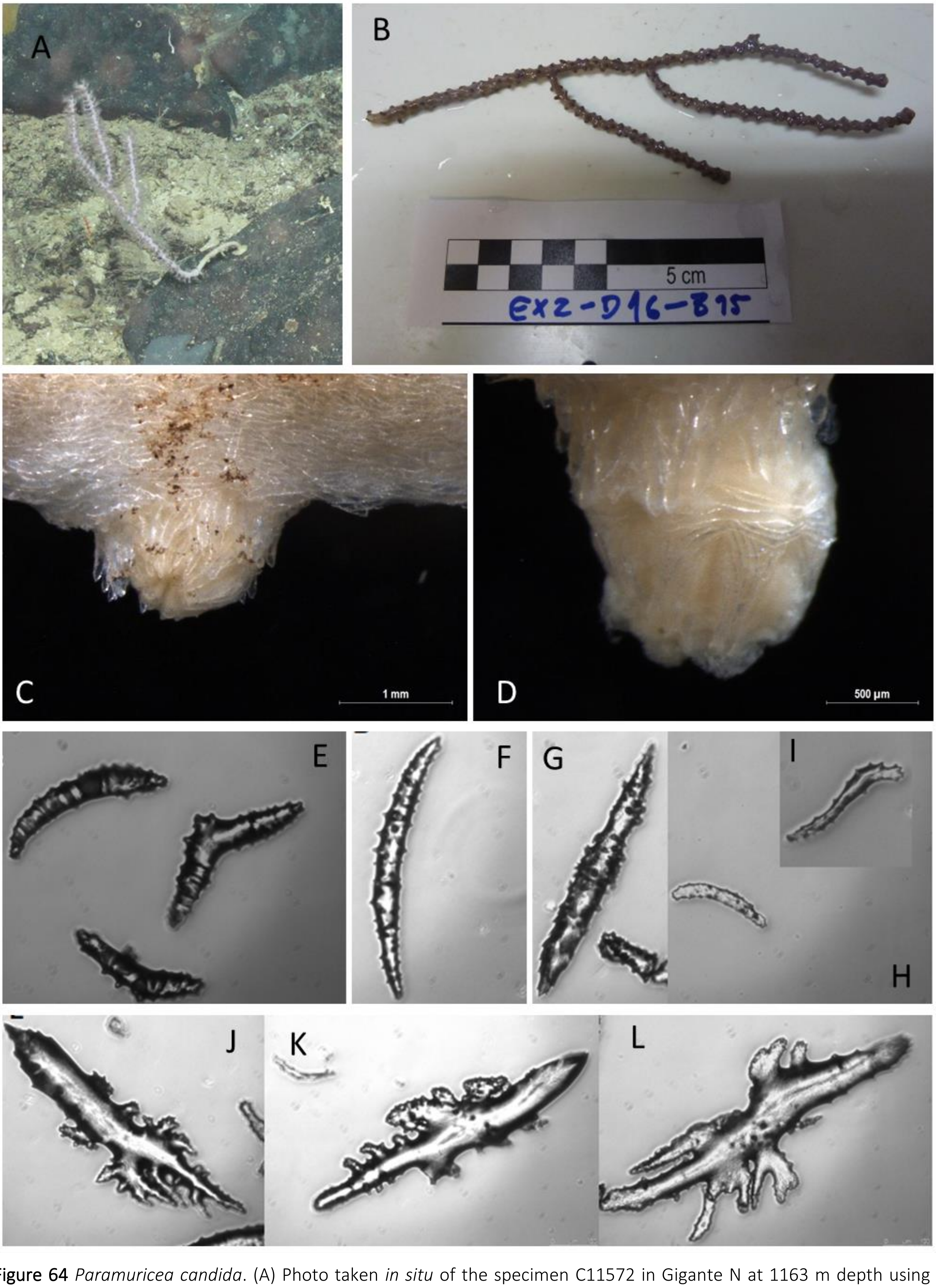



Figure 64 *Paramuricea candida*. (A) Photo taken *in situ* of the specimen C11572 in Gigante N at 1163 m depth using a submersible ROV (Explosea2_2019); (B) Photo *ex situ* of the complete specimen; (C-D) detail of the polyp structure; (E) sclerites from the coenenchyme; (F-L) sclerites from the polyp. Photos of the sclerites from Sampaio (2020).

*Morphotype "yellow plexaurid" – new ID Placogorgia Terceira Grasshoff, 1977*

**Material examined:** Morphological examination and molecular analysis of specimens collected in Gigante 127 at 362 m depth (C10057) and Gigante Agulhas SW at 464 m depth (C10184).

**Colony shape:** Colonies are erect and bushy, with medium size (10 cm) (Figure 65 and Figure 66A, B) with curved end branches from the apical part of the colony towards the base.

**Polyps:** Polyps abundant, more or less sparsely arranged except in the tip of the branches where they are crowded, resulting in a slightly clavate morphology. Polyps monomorphic, non-retractile but with heavily armored polyp body wall giving the appearance of a cylindrical calyx. Anthocodium with big sclerites (Figure 65 andFigure 66C, D).

**Sclerites:** Following the taxonomic key for the genus identification for Placogorgia in Grasshoff (1977). Calyces with thornscales, thornspindels, long spindels or short high warted spindels (Figure 65H, I, Figure 66G). Spines with a few tubercles, edges serrated principally at the tip (Figure 65H, Figure 66G). Thornscales higher than broad with smooth projection or more or less warted (Figure 65H, I, Figure 66G). Coenenchyme with thorny sclerites (Figure 65F; Figure 66G).

Similarities with Placogorgia terceira: Projections of the thornscales and the thornstars big, thin and slender (Figure 65F-I, Figure 66F,G).

**Colour:** Yellow-orange

**Remarks:** According to morphological characters this species was assigned to the species *Placogorgia terceira*.

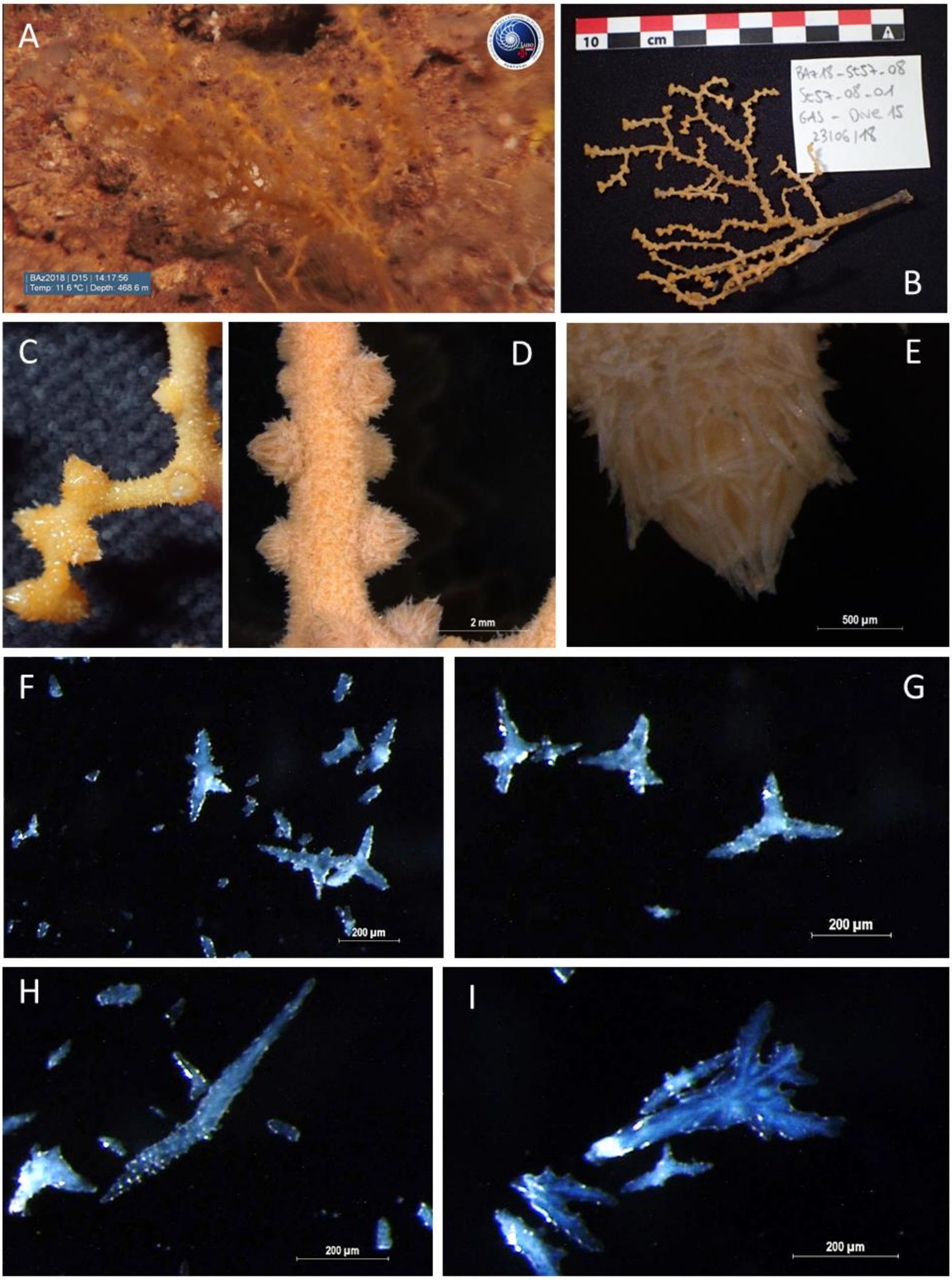



Figure 65 *Placogorgia terceira* (A) Photo taken *in situ* of the specimen C10184 in Gigante - Agulhas S at 464 m depth using a submersible ROV (BlueAzores_2018); (B-D) photo *ex situ* of the complete specimen and arrangement of the polyps on the colony; (E) detail of the polyp structure; (F-G) sclerites from the coenenchyme; (H-I) sclerites from the polyp.

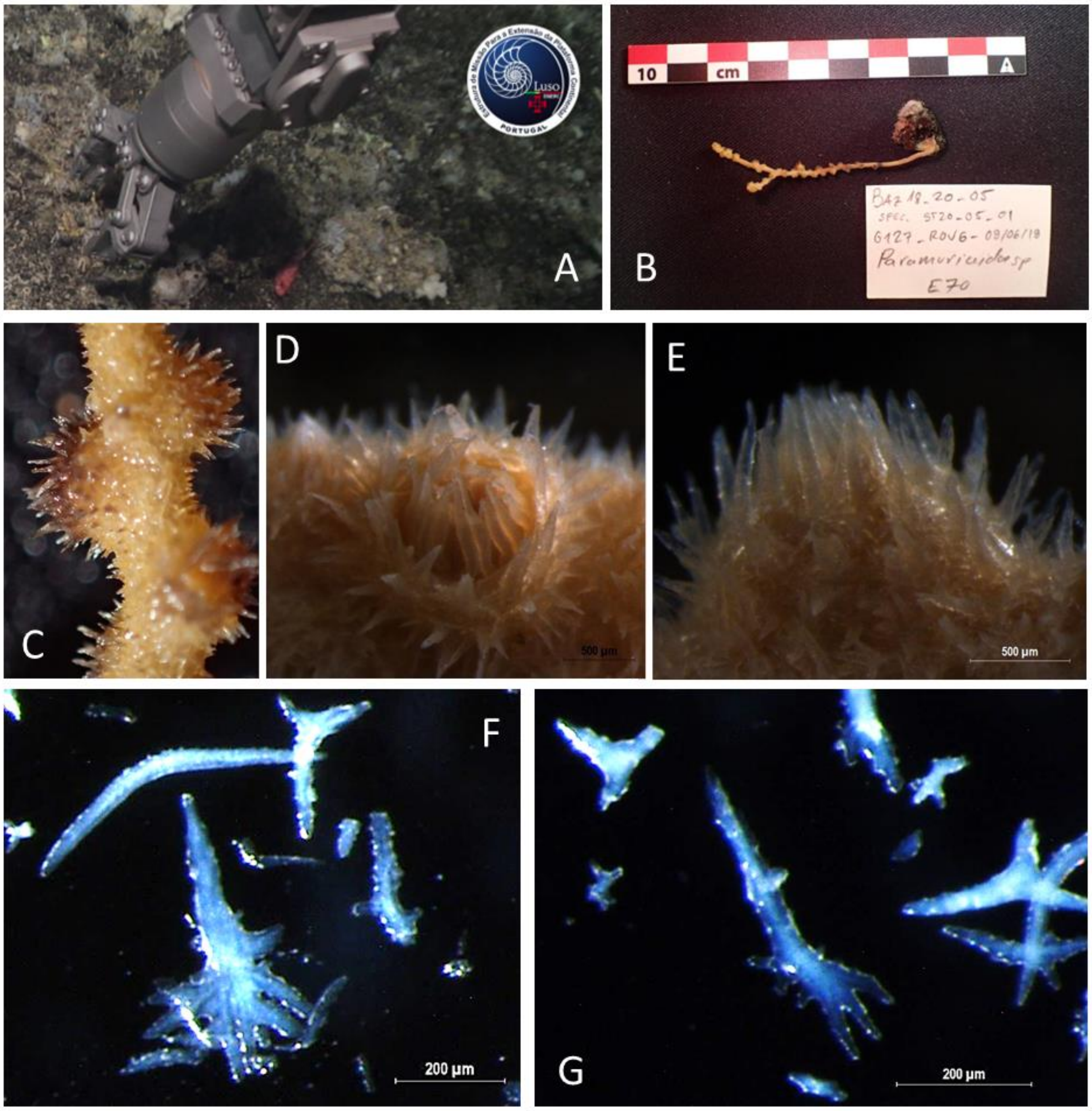



Figure 66 *Placogorgia terceira* (A) Photo taken *in situ* of the specimen C10057 in Gigante 127 at 362 m depth using a submersible ROV (BlueAzores_2018); (B-C) photo *ex situ* of the complete specimen and arrangement of the polyps on the colony; (D-E) detail of the polyp structure; (F) sclerome of the coenenchyme; (G) sclerome of the polyp.

*Morphotype "large orange plexaurid" – new ID Placogorgia sp.*

**Material examined:** Morphological examination and molecular analysis of specimens collected at Condor Seamount at 850 m depth (Placo1-DSL).

**Colony shape:** Colonies are erect and bushy, with large size (50 cm in height) (Figure 67 A, B) with curved end branches from the apical part of the colony towards the base.

**Polyps:** Polyps abundant, more or less sparsely arranged except in the tip of the branches where they are crowded (Figure 67A, B), resulting in a slightly clavate morphology. Polyps monomorphic, non-retractile but with heavily armored polyp body wall giving the appearance of a cylindrical calyx (Figure 67C). Anthocodium with big sclerites (Figure 67C, D)

Sclerites: Following the taxonomic key for the genus identification for Placogorgia in Grasshoff (1977). Calyces with thornscales, thornspindels, long spindels or short high warted spindels (Figure 67I-L). Spines with a few tubercles, edges serrated principally at the tip (Figure 67K, L). Coenenchyme is thin, calyces projected and the projection of the thornscales is smooth or slightly warted (E-H). Coenenchyme with thorny sclerites (Figure 67F, G).

Coenenchyme sclerites present similarities to both *P. intermedia* and *graciosa*, sclerites presenting one or several projections, therefore we need further sclerite examination with SEM to examine in detail the morphology of the sclerites.

Colour: Orange

**Remarks:** Based on the sclerome morphology were able to distinguish species of the genus Paramuricea and *Placogorgia* (Grassoff, 1977). Both genera are distinguished fundamentally by the presence of thorny sclerites in the coenenchyme in Placogorgia, which was easily recognizable in our material. Although some authors have suggested subtle differences in the thornscales (Bayer, 1959; Grasshoff, 1977), this was difficult to recognize in our observations as we likely need a scanning electron microscopy to detect them. The differences between these two genera are often unclear because their sclerites represent a continuum of morphological variation (see McFadden et al., 2011). In addition knowledge about the morphology and variability of the North Atlantic species of *Placogorgia*, is very limited and has been rarely described. The difficulties in identification and likelihood of misidentification of *Placogorgia*, is exemplified in Taboada et al., (2019), where what has been identified as *Paramuricea placomus*, was actually *Placogorgia*. This type of misidentification may be more common than acknowledged, and a general revision of the *Placogorgia-Paramuricea* genus is necessary (REF).

Furthermore, although the *Paramuricea* specimens examined here presented clear differences in colour and branching pattern, with specimens of colour purple and sparse branches, and Plagogorgia specimens presenting orange coloration and more bushy colonies, we have also observed yellow colonies of Paramuricea based on the genetic material deposited at the NMNH (See molecular results). Therefore, caution should be taken in distinguishing these genera based on colour from video images.

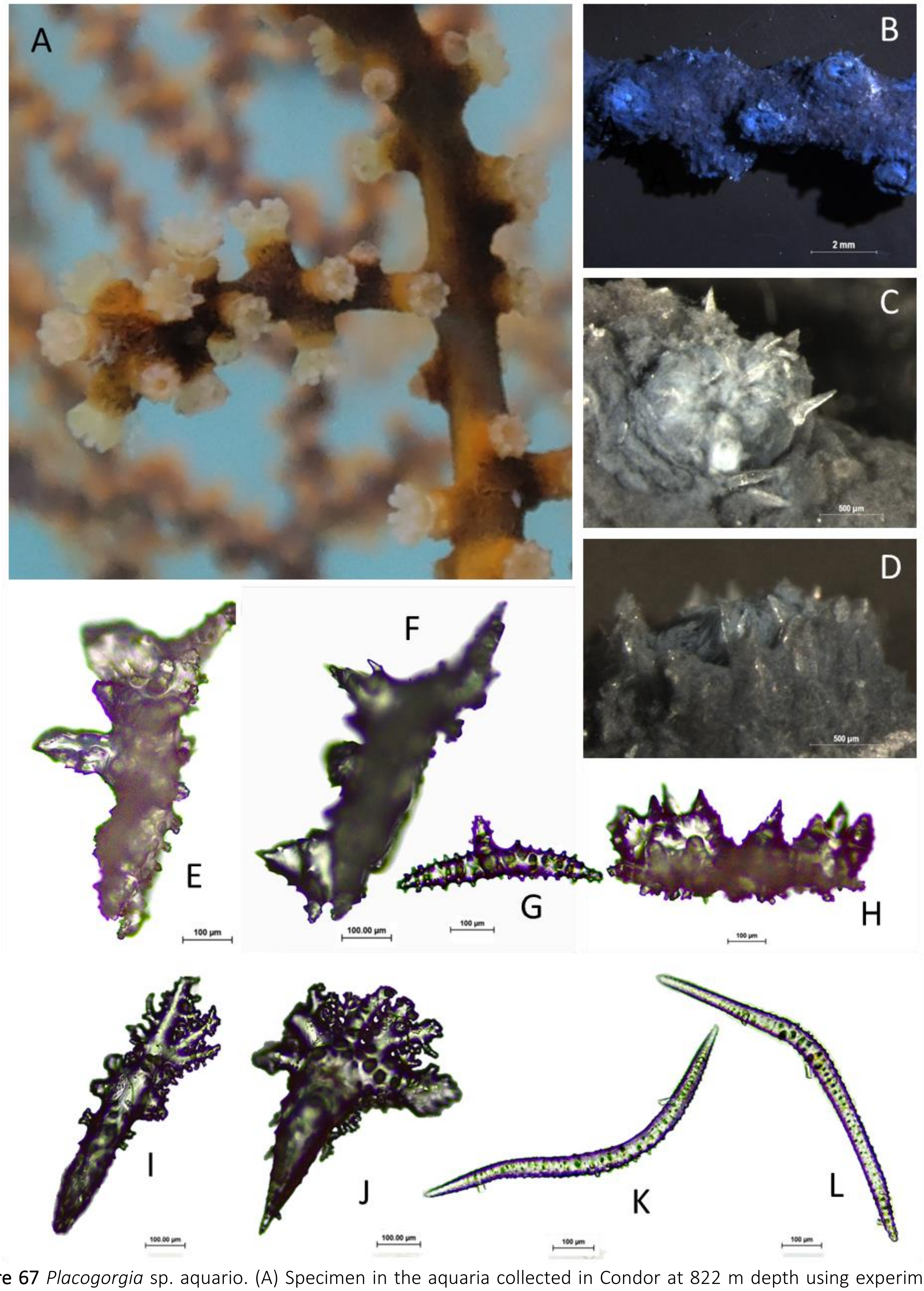



Figure 67 *Placogorgia* sp. aquario. (A) Specimen in the aquaria collected in Condor at 822 m depth using experimental longline; (B-D) photo *ex situ* of the arrangement of the polyps on the colony; (C-D) detail of the polyp structure; (E-H) sclerome of the coenenchyme; (I-L) sclerome of the polyp.

*Dentomuricea aff. meteor*

Material examined: Morphological examination and molecular analysis of specimens collected in Mar da Prata N at 343 m depth (C10776), 275 m depth (C10723) and 317 m depth (C10783).

Colony shape: Following description in Grasshoff (197/), colonies up to 80 cm in height branched in a single plane (Figure 68A). Branches generally branching off almost perpendicular to the axis (Figure 68B). Colonies have a characteristic candelabrum-like shape and round branches with retractable polyps (Figure 68B)

Polyps: Polyps monomorphic. Thick coenenchyme with calyces not prominent. Anthocodium completely retractable (Figure 68C, D).

Sclerites: Sclerites arranged in an irregular arrangement around the calyces, their plate part is elongated and lobed and their spine is blunt. Coenenchyme with two layers of sclerites: surface layers with spindle-like sclerites with one-side expansions; the lower layers are filled with spindle-like sclerites; calyx with spiny plates. Anthocodium with 3-4 narrow transverse rows of neck ring sclerites and large opercular sclerites.

Colour: Mustard yellow

Remarks: The specimens examined, and generally the *Dentomuricea* in the Azores, presents strong similarities in the sclerome of the originally described *Dentomuricea meteor* by Grasshoff (1977) for the Great Meteor seamount, there are subtle changes in the shape and ornamentation of the sclerites that should be examined with SEM for details morphology. Therefore, based on the morphological examination we can still not include if our *Dentomuricea* in the Azores is distinct from *Dentomuricea meteor* in the Great Meteor.

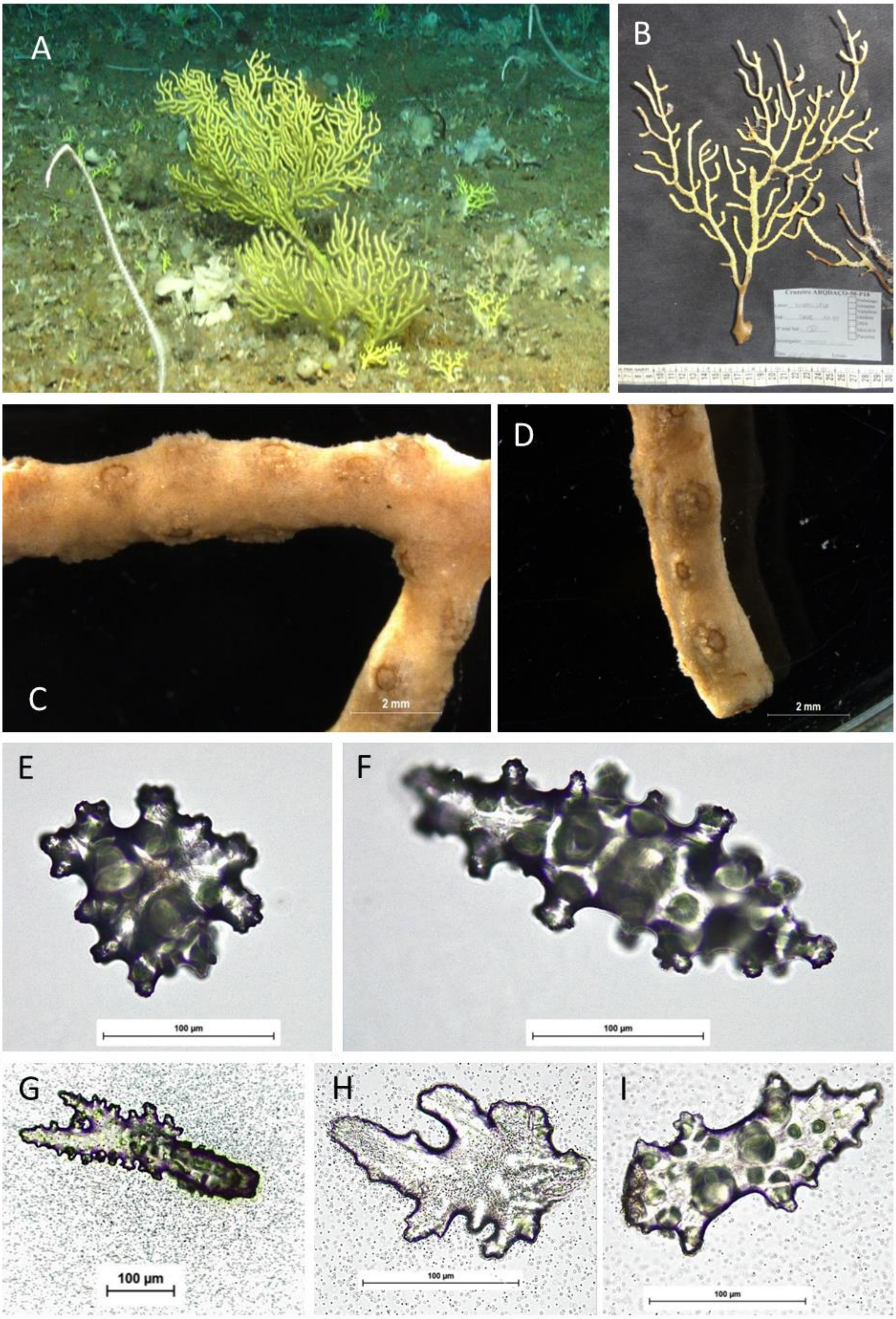



Figure 68 *Dentomuricea* aff *meteor* (A) Photo taken *in situ* at Gigante Seamount Complex with ROV LUSO (Campaign BlueAzores_2018); (B) Photo *ex situ* of the specimen C10776 collected in Mar da Prata N at 343 m depth as longline

fisheries bycatch; (C-D) detail of the arrangement of the polyps on the colony; (E-F) sclerome of the coenenchyme; (G-H) sclerome of the polyp.

## Molecular analyses

The Paramuriceidae specimens of interest were previously identified as belonging to *Paramuricea* (C11535, C11572, C12410); *Placogorgia* (C10057, C10184) and *Dentomuricea* (C10776) genera. It is known that currently available molecular markers are insufficient at resolving species boundaries for the majority of individuals belonging to the Paramuriceidae family, therefore the DNA sequencing data from the studied specimens was obtained following a genome skimming approach.

All molecular work was carried out in the Laboratories of Analytical Biology at the Smithsonian Institution. The work was done in strict collaboration with Dr. Andrea Quattrini, the curator of the coral collection of the National Museum of Natural History, in Washington DC. In this context, we had the opportunity to compare our samples with USNM museum samples belonging to *Paramuricea* genus (e.g. USNM1674012 and USNM1674017), sampled in the Azores during the OkeanosExplorer expedition in 2022.

On average 9 million PE reads were obtained per specimen, which assembled into 141,853 to 979,735 contigs. From the contigs, we were able to recover 177 to 1433 UCEs and exon nuclear loci per specimen. The 60% taxon-occupancy matrix included 946 loci that were concatenated into an alignment with other octocoral samples from prior genome skimming and target-capture work from Quattrini et al 2023. A phylogenetic tree was constructed which included a total of 445 taxa.

The sub-tree plotted for the Paramuriceidae family Figure 69 showed two main clades: an upper clade formed by members from the mesophotic depth, and a lower clade that clustered all members from the deep-sea. The phylogeny strongly supports a divergent set of taxa with 100% bootstrap, revealing that the majority of the analysed Paramuriceidae specimens from the Azores clustered together in a separate clade (coloured in blue and pink in Figure 69). Within this clade, individuals belonging to *Placogorgia* genus (pink clade) are distinct from the ones belonging to *Paramuricea* genus (blue and green clades), which greatly support the taxonomic findings that distinguish the two genera. *Dentomuricea* specimen is forming a separate branch in the tree suggesting that this individual is distantly related to their counterparts in the deep-sea, and belong to a different genus. We still lack molecular data for the type species of *Dentomuricea* aff. *meteor*, which will be useful to clarify the taxonomy of this species.

**Habitat and distribution:** In the Azores, the species *Dentomuricea* aff *meteor* has been recorded at bathyal depth of 150-800 m, on slopes of ridges. This species has a reported distribution the Nort-East Atlantic Ocean and Mediterranean Sea, with depth ranges of 200-400 m.

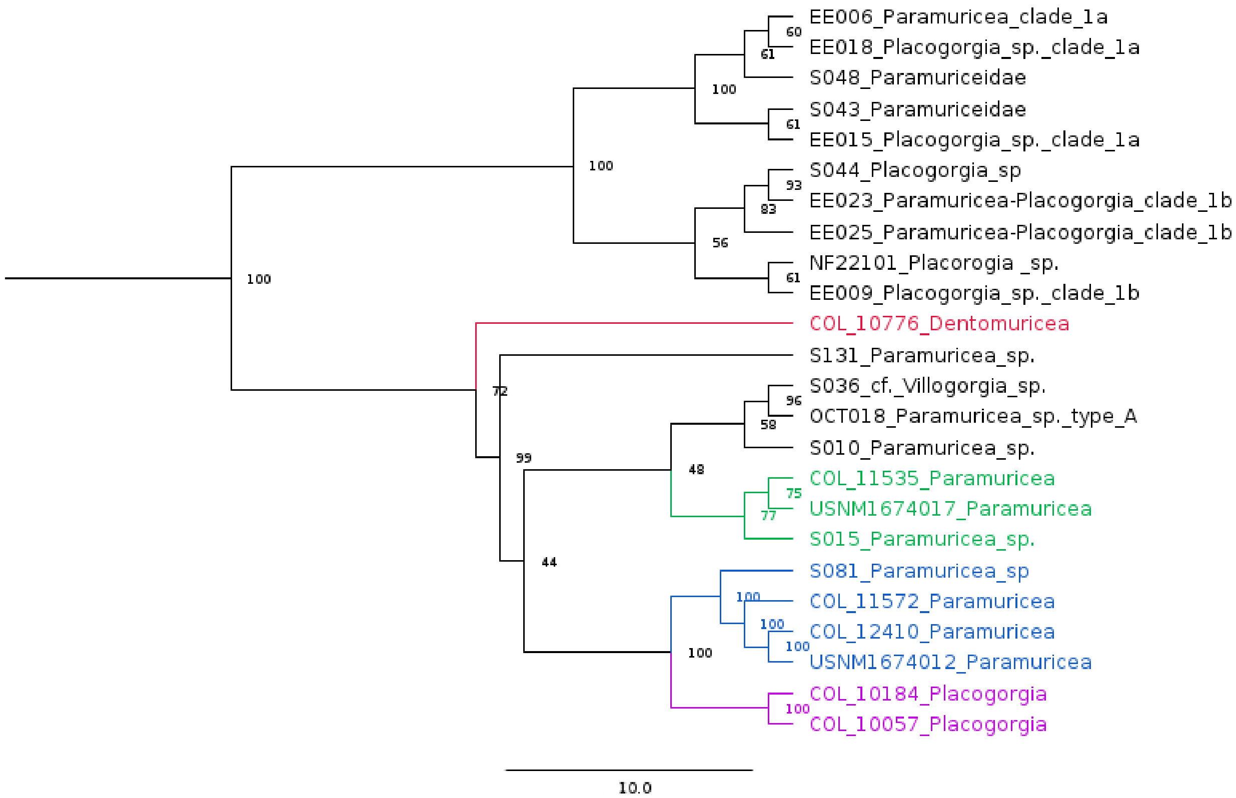



**Figure 69** Sub-tree of a maximum likelihood phylogeny of Paramuriceidae members based on a 60% complete matrix containing 946 loci. Taxa in different colours represent the studied species from the Azores (except S015 - Southeastern USA, 959m; and S081 - Gulf of Mexico, 527 m). The phylogeny was midpoint rooted in the complete tree (data not shown).

*Bamboo corals (Family Keratoisididae)*

Bamboo corals, which are used to refer to the family Keratoisididae, are characterised by an articulated axis comprising alternating sequences of proteinaceous nodes and calcium carbonate internodes, which are globally distributed and exclusively deep sea (Watling et al., 2011). The family has been subjected to numerous revisions (e.g. Heestand Saucier et al., 2021, Lapointe and Watling 2022; Watling et al 2022; Morrissey et al., 2022, 2023). Phylogenetic analyses of the keratoisidids have revealed that branching pattern is not diagnostic of any genus and that these genera are polyphyletic (France 2007). Overall, there is a lack of robust morphological markers within Keratoisididae, but subtle characters such as sclerite microstructure and ornamentation seem to be shared within groups and warrant further investigation as taxonomically diagnostic characters (Morrissey et al 2022, 2023). Because of this, Morrissey (2022, 2023) developed an alphanumeric system, based on a three-gene-region phylogeny together with already published morphological data, to define species groups within Keratoisididae.

During video analysis we have observed several bamboo corals, recognizable by their skeletal internode characteristics, but that are difficult to assign to species due to the recent revisions of the family. Here we used an alphanumeric system developed by Morrissey et al (2022, 2023) to define species groups of bamboo corals in the Azores.

*Morphotype "Keratoisididae_branched" – new ID Keratosididae Clade B1*

Examined material: Morphological examination and molecular analysis of the specimen collected from Gigante N at 1221 m depth (C11573).

Colony: Colony dichotomously branched (Figure 70A, B). Unclear if branching occurs at the nodes or internodes. Coenenchyme is cream with pink polyps densely populating all sides (Figure 70C).

Polyps: Polyps are barrel shaped (Figure 70D).

Sclerites: Needles (≈ 4.7 mm – 1 mm) and scales (≈ 400 µm – 100 µm) are present in the body wall (Figure 70 E,F). Intertentacular sclerites present. Body sclerites are arranged obliquely at the bottom of the polyp before changing to a longitude orientation along the polyp about 1/3 from the proximal end of the polyp (Figure 70E, F). In Morrissey et al (2022) no sclerites were observed in the coenenchyme (Morphotype 11 – Haplotype 6, Fig S12) but here smaller scales were present in the coenenchyme (≈ 300 µm – 160 µm, Figure 70H). Flattened rods (≈ 300 µm – 100 µm) are found in the tentacles and thorned rodlets in the pharynx.

Colour: Pink

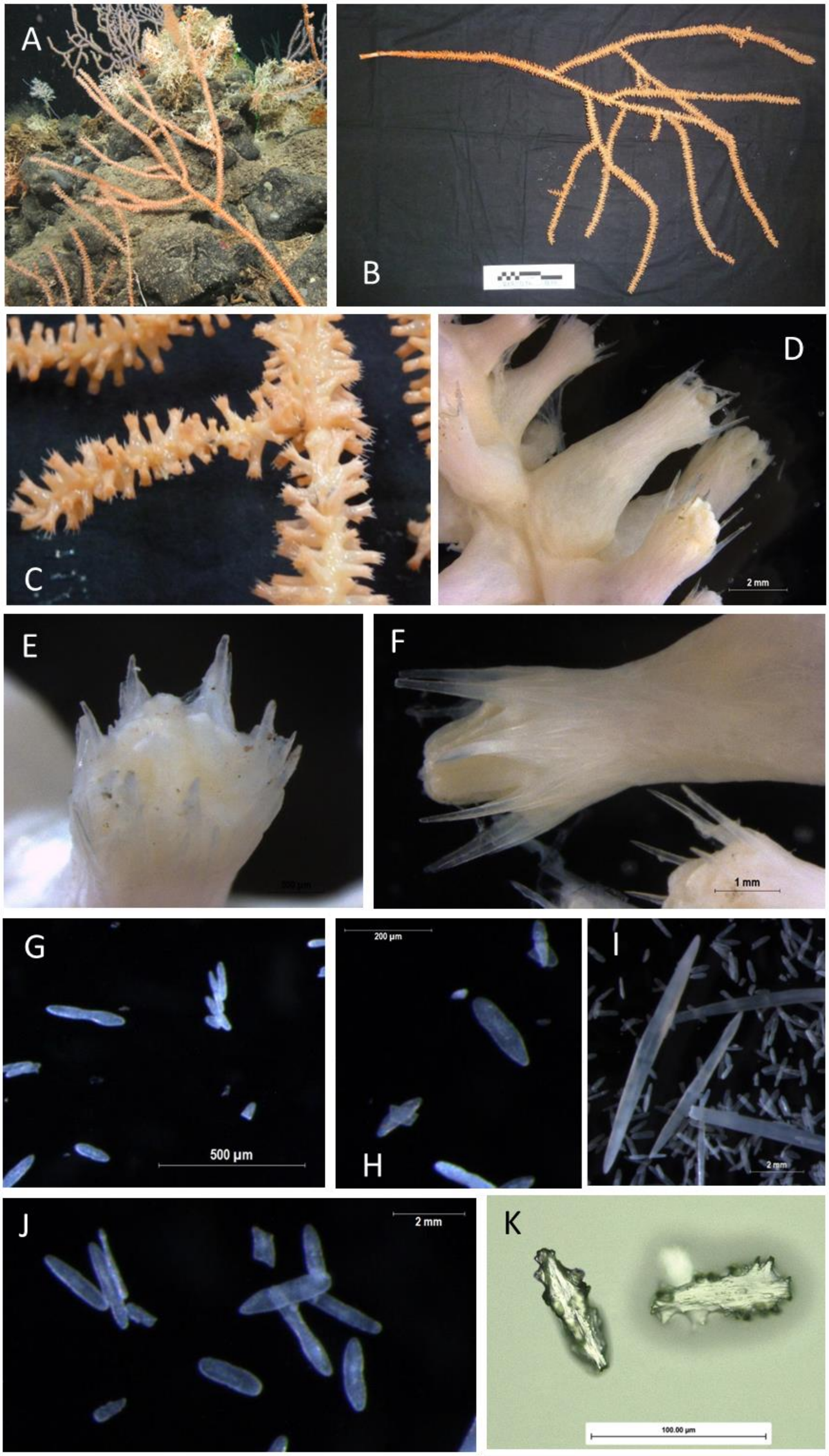

A
B
C
D
2 mm
E
F
1 mm
G
500 µm
200 µm
H
I
2 mm
J
2 mm
K
100.00 µm

Figure 70 Keratosidideae Clade B1 (A) Photo *in situ* of the whole colony C11573 in Gigante N at 1121 m depth using the ROV LUSO (Campaign Exploseas2_2019); (B) photo *ex situ* of the whole colony; (C) whole polyp showing arrangement of the sclerites; (D-F) detail of the polyp; (G-H) Sclerites in the coenenchyme; (I-J) sclerites in the polyp; (K) sclerites in the pharynx.

*Morphotype "Keratoisididae_sparse_branched" – new ID Keratosididae Clade B1*

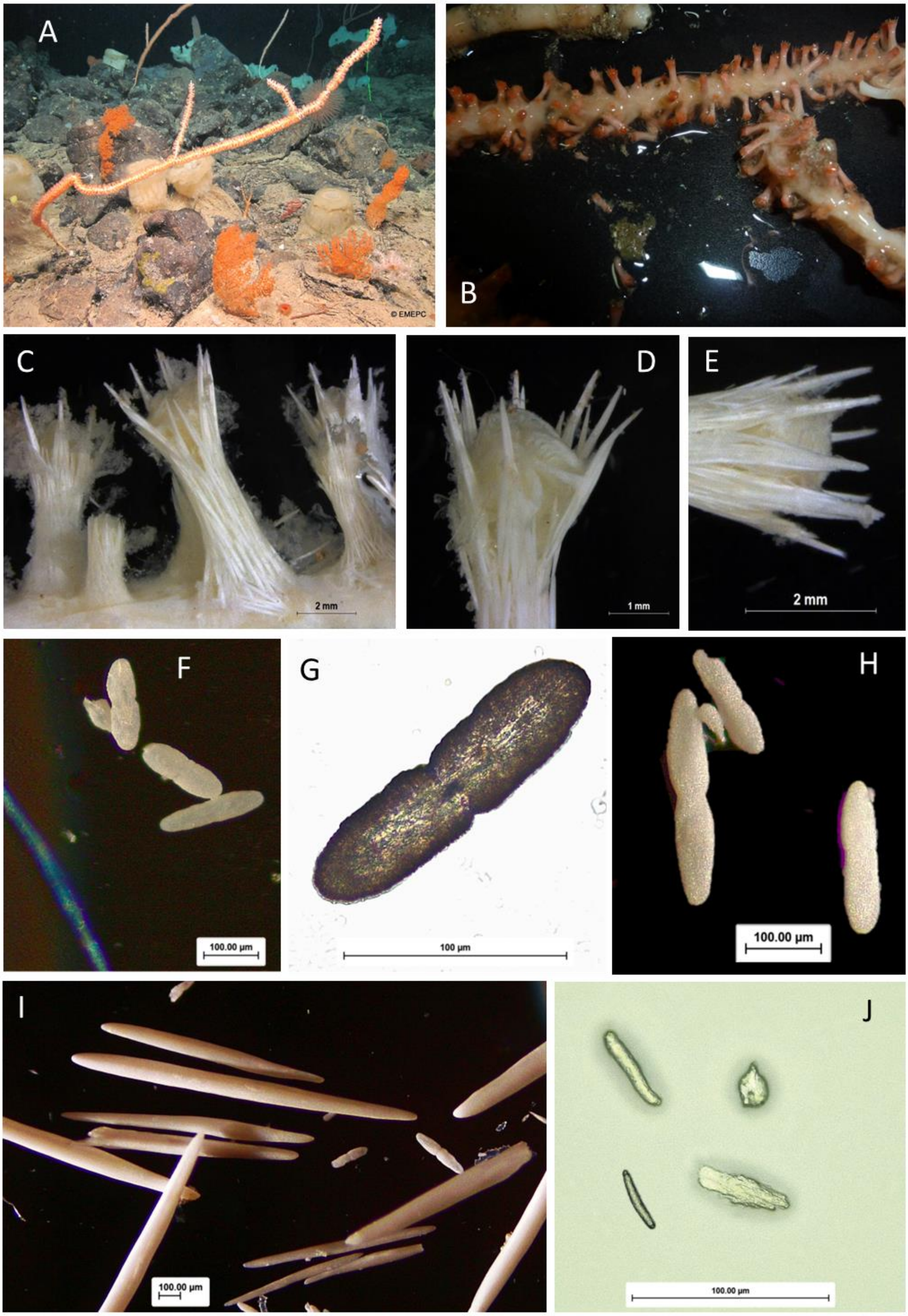
Examined material: Morphological examination and molecular analysis of the specimen collected from Gigante N at 1270 m depth (C11533).

Colony: Colony sparsely dichotomously branched to unbranched (Figure 71A, B). Unclear if branching occurs at the nodes or internodes. Coenenchyme is thick and cream with dark orange polyps populating all sides but less dense (Figure 71C).

Polyps: Polyps are slightly barrel shaped, but slender (Figure 71D)

Sclerites: Needles (≈ 4.7 mm – 1 mm) and scales (≈ 400 µm – 100 µm) are present in the body wall (Figure 71E, F). Intertentacular sclerites present. Body sclerites are arranged obliquely at the bottom of the polyp before changing to a longitude orientation along the polyp about 1/3 from the proximal end of the polyp (Figure 71E, F). Sclerites have a more opaque appearance than C11573 above. Scales are often pinched at the waist (Figure 71G). In Morrissey et al. (2022) no sclerites were observed in the coenenchyme (Morphotype 11 – Haplotype 6, Fig S12) but here smaller scales were present in the coenenchyme (≈ 300 µm – 160 µm, Figure 71H). S Flattened rods (≈ 300 µm – 100 µm) are found in the tentacles and thorned rodlets in the pharynx.

Colour: Pink


A
© EMEPC
B
C
2 mm
D
1 mm
E
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F
100.00 µm
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J
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**Figure 71** Keratosidideae Clade B1 (A) Photo *in situ* of the whole colony C11533 in Gigante N at 1270 m depth using the ROV LUSO (Campaign Exploseas2_2019); (B) photo *ex situ* of portion of a colony showing the arrangement of the polyps; (C-E) whole polyp showing arrangement of the sclerites; (F-G) Sclerites from the coenenchyme; (H-I) Sclerites from the polyp; (J) sclerites from the pharynx.

*Morphotype "Keratoisididae_arborescent" - new ID Keratosididae Clade J3*

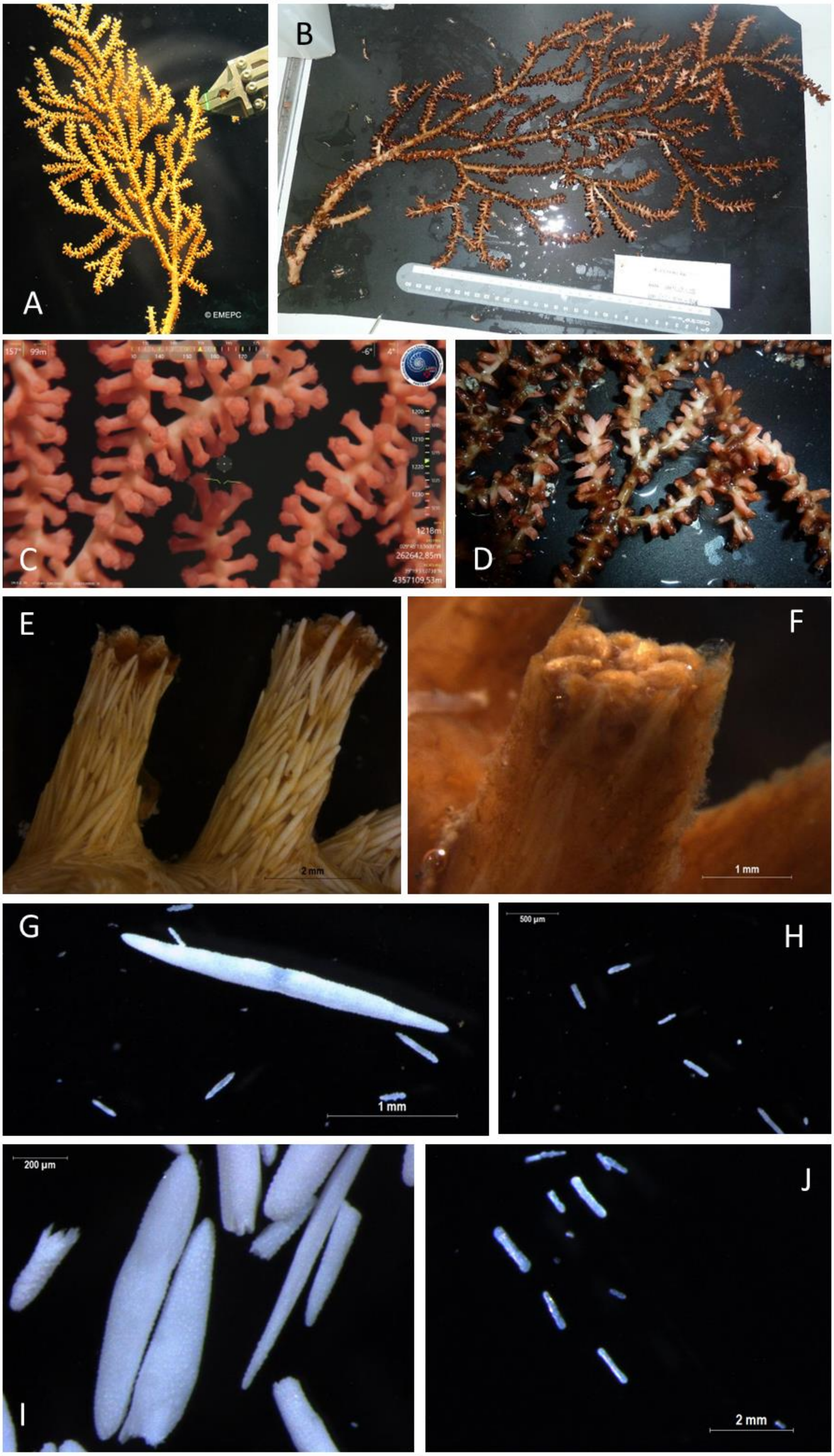
**Examined material:** Morphological examination and molecular analysis of specimens collected in Gigante N 1221 m depth (C11537).

## Morphological description

**Colony:** Planar colonies with dichotomously branching from the nodes. Coenenchyme is tick and cream to orange with dark orange polyps (Figure 72A, B) resembling Morphotype 23 – Haplotype 20 in Morrisey et al (2022) (Fig. S25).

**Polyps:** Polyps are barrel shaped, covered with a thick tissue, and densely populated all sides of the coenenchyme (Figure 72E). The tentacles fold over the mouth (Figure 72F)

**Sclerites:** Needles and spindles are arranged longitudinally along the body (≈ 2.3 mm – 680 µm) and coenenchyme (≈ 2.3 mm – 750 µm, Figure 72E, G). There are smaller scales with lobed margins present in the coenenchyme (≈ 300 µm – 160 µm, Figure 72H). All body and coenenchyme sclerites are heavily granulated along the middle of the sclerite (Figure 72I, J). Flattened rodlets (≈ 360 µm – 90 µm) are found in the tentacles and elongated diamond shaped rods (≈ 120 µm – 75 µm) are found on the pharynx.
**Colour:** Orange to dark orange.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© EMEPC
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200 µm
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2 mm

**Figure 72** Keratoisididae Clade J3 (A) Photo *in situ* of the colony C11537 in Gigante N at 1221 m depth using ROV LUSO (Exploseas2_2019); (B) *ex situ* photo of the whole colony showing branching pattern; (C) photo *in situ* showing detail of polyp arrangement (D) photo *ex situ* showing detail of polyp arrangement (E) whole polyp showing arrangement of sclerites; (F) polyp detail showing tentacles on polyp; (G-H) Sclerites from the coenenchyme; (I) sclerites from the polyp; (J) sclerites from the pharynx.

## Molecular analyses

The Keratoisididae specimens of interest (C11533, C11537, C11573) were analysed following a genome skimming approach, as outlined in the previous section of *Paramuriceidae* family. During the work at the National Museum of Natural History, we had the opportunity to compare our samples with USNM museum samples belonging to Keratoisididae family (e.g. USNM1674002, USNM1674007, USNM1674009, and USNM1674022), sampled in the Azores during the OkeanosExplorer expedition in 2022. All molecular analysis was performed as previously described in the above mentioned section.

The sub-tree plotted for the Keratoisididae family (Figure 73) separated our samples into two clades: the upper clade formed by two main clusters with members belonging to B1 clade (coloured in orange in Figure 73), and a lower clade in which the samples clustered with J3 clade. The phylogeny strongly supports divergent sets of taxa with 100% bootstrap, which greatly support the taxonomic findings that distinguish the two groups.

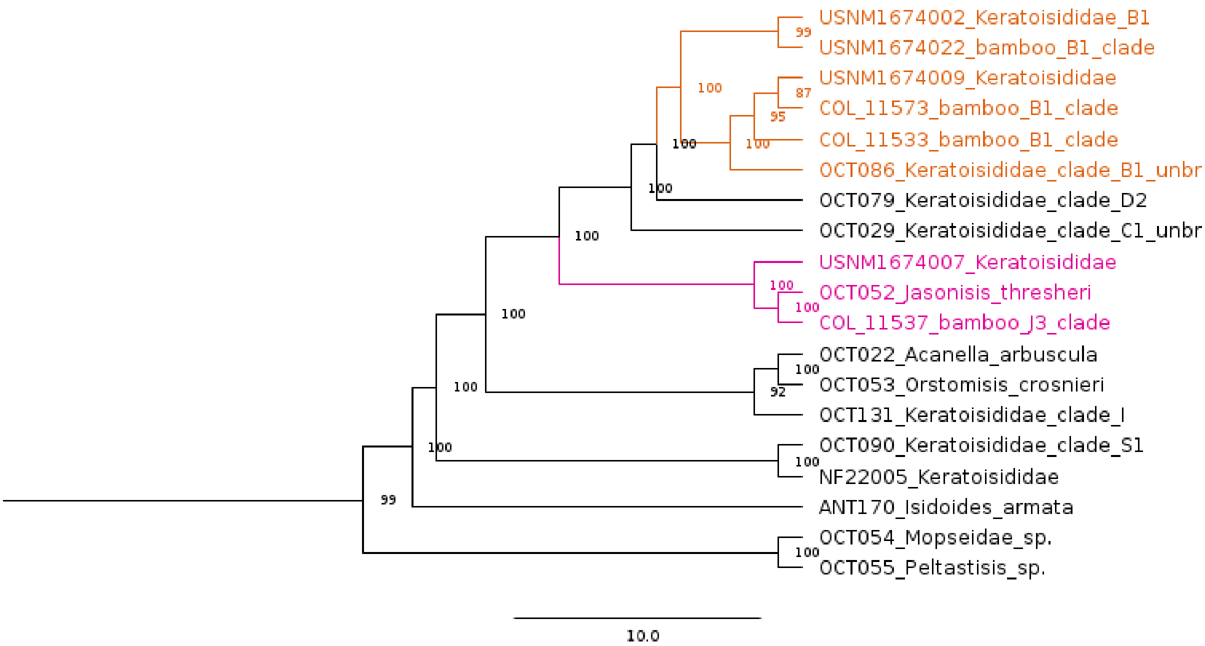



**Figure 73** Sub-tree of a maximum likelihood phylogeny of Keratoisididae members based on a 60% complete matrix containing 946 loci. Taxa in different colours represent the studied species from the Azores (except OCT086 and OCT052). The phylogeny was midpoint rooted in the complete tree (data not shown).

*Soft corals (Family Alcyoniidae)*

Soft corals are conspicuous elements of mesophotic and deep-sea benthic communities for which there is limited information in the Azores. Despite not being not being considered VME indicator species in the Azores, they may harbour cryptic species and potential high diversity. Therefore, it was considered as a priority group to examine using an integrative taxonomic approach.

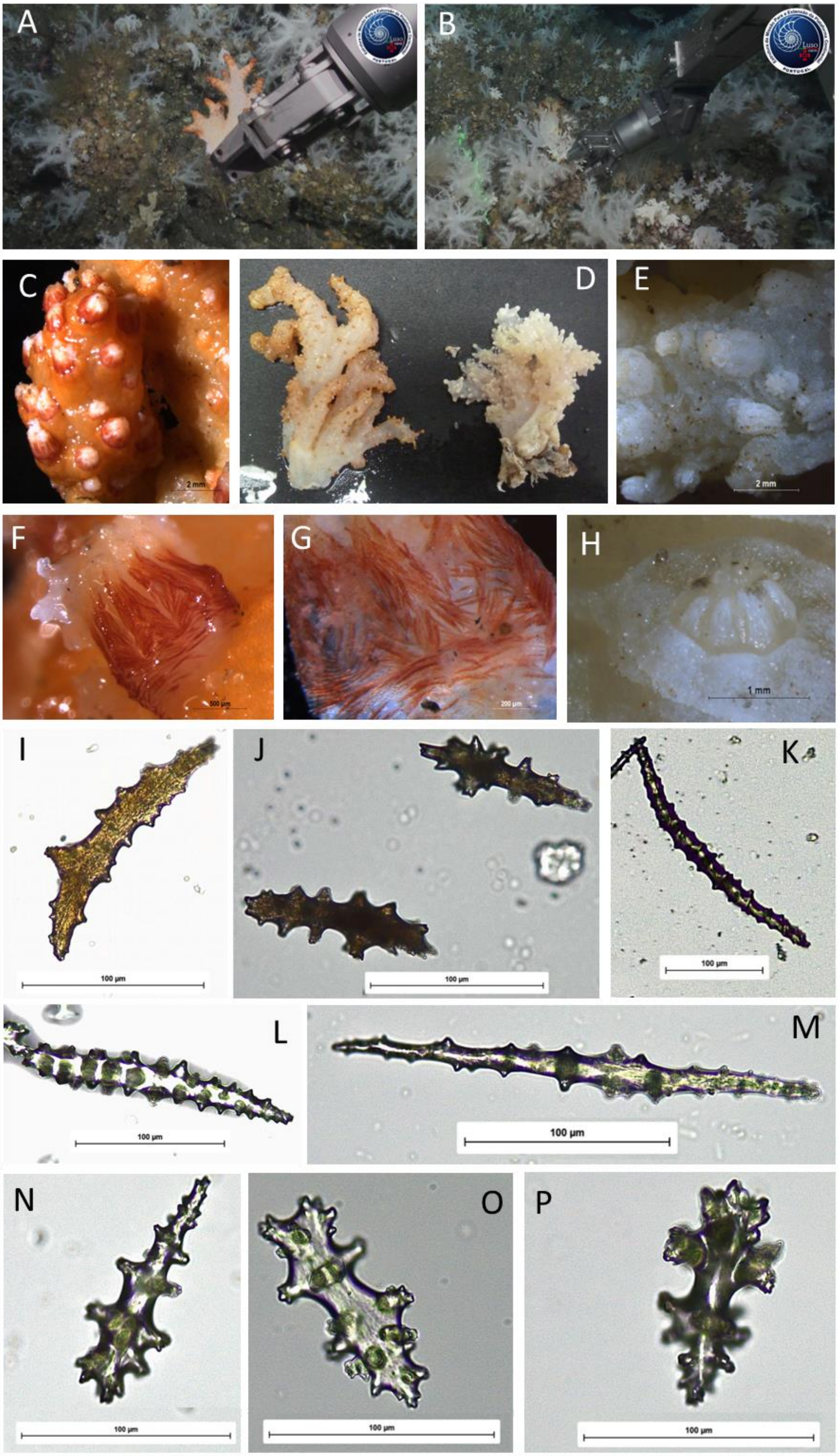
The challenges in species identification of the family Acyoniidae is related to the fact that the family has served as a repository for genera that lack characters to support their placement in other more narrowly circumscribed families (McFadden and van Ofwegen et al. 2013). For example, the diagnosis of the genus Alcyonium has been broadened to include almost every possible colony growth form observed within Alcyoniidae as well as a diversity of different sclerite types and arrangements (McFadden and van Ofwegen et al. 2013). The family Acyoniidae is also one of the most phylogenetically heterogeneous (McFadden et al., 2010) making it difficult to assign species to the different genera and knowing what are the most suitable diagnostic morphological characters.

In the scope of this project, we have compiled morphological and genetic information of several species of soft corals in the Azores, which is summarised below. This information has been shared with specialists in soft coral taxonomy Dr. Catherine McFadden from Harvey Mudd College and Dr. Andrea Quattrin from the NMNH in the USA, in a common effort to identify species present in the Azores and its relationship with other species in the North Atlantic.

**Material examined:** Morphological examination and molecular analysis of specimens collected in Faial W Capelinhos at 125 m depth (C11558, C11559, C11560), Flores-Corvo at 245 m depth (C10689A, C10689B).

*Morphotypes "White and pink soft corals" – new ID Alcyonium sp.*

Morphology: White and pink morphotypes were found together in a dense aggregation covering the summit of a small extinct volcano at 125 m depth of the Capelinhos area (Figure 74A, B). Images of these specimens and sclerites were shared with Catherine McFadden during the Octocoral taxonomy training school in Israel. In her opinion the specimens belonged to the genus Alcyonium (which was also confirmed with genetics, see below), but we needed to examine the sclerites with scanning electron microscopy for a proper identification.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L
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100 µm
N
100 µm
O
100 µm
P
100 µm

**Figure 74** *Alcyonium* sp. (A) Photo taken *in situ* of a pink morphotype (C11558) in Faial W Capelinhos at 125 m depth using the ROV LUSO (campaign Explosea2_2019); (B) Photo taken *in situ* of a white morphotype (C11559) in Faial W Capelinhos at 125 m depth using the ROV LUSO (Explosea2 campaign); (C-E) photo *ex situ* of the whole colony showing arrangement of the branches and polyps; (F-H) Detail of an anthocodia showing sclerite arrangement; (I-K) sclerites of the polyp (C11558); (L-P) sclerites of the coenenchyme (C11559).

## Molecular analyses

The *Alcyonium* specimens of interest (C11558, C11560, C10689A and C10689B) were analysed following a genome skimming approach, as outlined in the previous section of *Paramuriceidae* family.

The sub-tree plotted for the *Alcyonium* members (Figure 75) separated our samples into two clusters (coloured in blue and pink in Figure 75) that form, on the other hand, a single clade. This clade is sufficiently distinct from the other ones in the tree, suggesting that the analysed specimens from the Azores might belong to a new species. This separation is supported by 100% bootstrap value for the node.

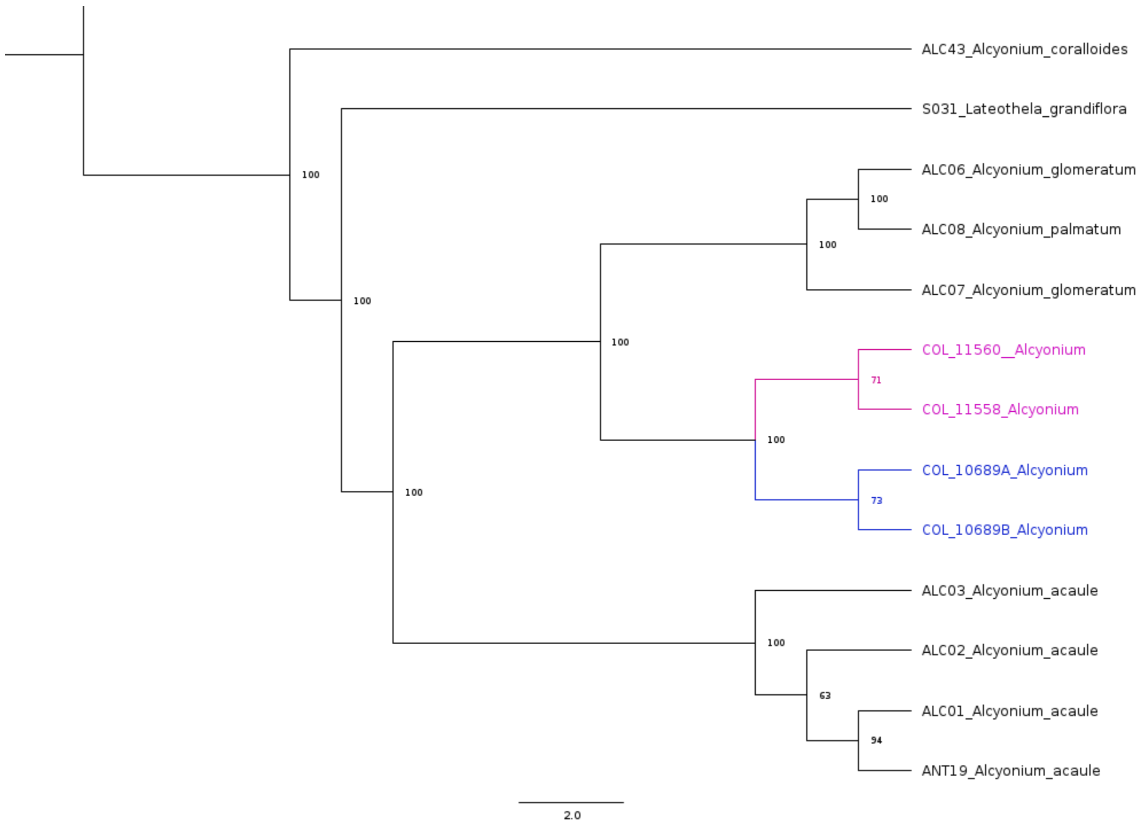


**Figure 75** Sub-tree of a maximum likelihood phylogeny of *Alcyonium* members based on a 60% complete matrix containing 946 loci. Taxa in different colours represent the studied species from the Azores. The phylogeny was midpoint rooted in the complete tree (data not shown).

*Morphotype "purple soft coral" – new ID Family Aquaumbridae*

**Morphology:** Soft coral often observed associated to rocky bottoms at depths of 500-1000 m depth (Figure 76).

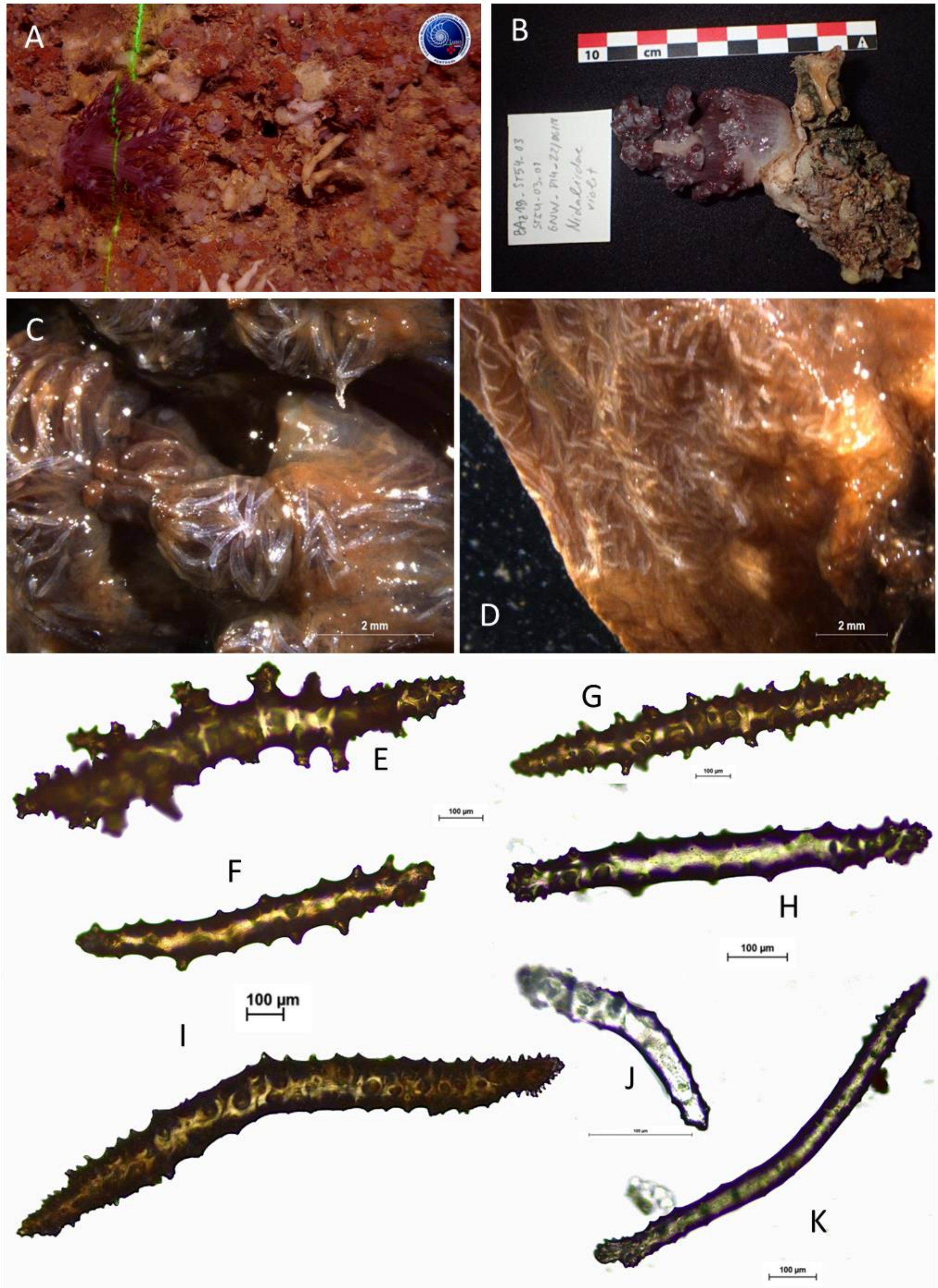


Figure 76 “Purple soft coral” A) Photo taken *in situ* of the specimen C10148 in Gigante NO at 556 m depth using a submersible ROV LUSO (BlueAzores_2018); (B) photo *ex situ* of the whole colony; (C) detail of an anthocodia showing sclerite arrangement; (E-H) sclerites from the coenenchyme; (I-J) sclerites from the polyp.

*Cf. Gersemia – new ID Aquaumbra sp. (Family Aquaumbridae)*

**Morphology:** The soft coral *Gersemia* (Figure 77) has been reported for the Azores firstly as *Voeringia clavata* Danielssen, 1887 by Studer (1890), but then transferred to the genus *Gersemia clavata* (Danielssen, 1887) by Utinomi (1961) (Sampaio et al., 2019). Until recently, there were no specimens that could be used for the taxonomic validation of the name which have been given to images. New molecular genetic evidence gathered during the project, suggests that Gersemia may have been so far misidentified and in fact be a new species of the family Aquaumbridae (see section on molecular genetics below).

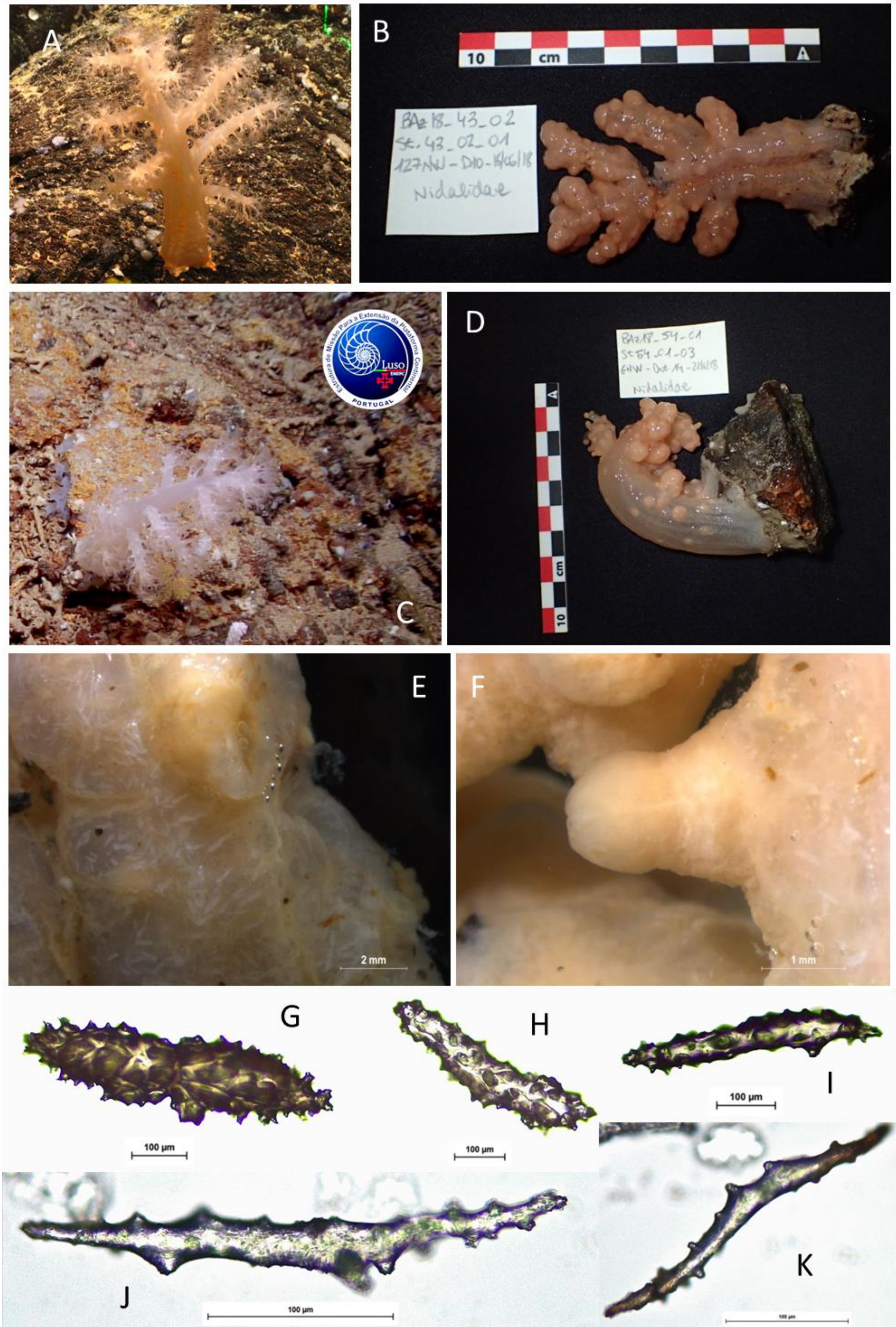
A
B
10 cm
BAz18_43_02
St.43_02_01
Nidalidae
C
D
BAz18_54_01
Nidalidae
10 cm
E
2 mm
F
1 mm
G
100 µm
H
100 µm
I
100 µm
J
100 µm
K

Figure 77 cf. *Gersemia* A) Photo taken *in situ* of the specimen C10092 in Gigante 127 NO at 657 m depth using a submersible ROV LUSO (campaign Explosea2_2019); (B) photo ex situ of the whole colony showing arrangement of the branches and polyps (C10092); (C) Photo taken *in situ* of the specimen C10146 in Gigante NO at 722 m depth using a submersible ROV LUSO (BlueAzores_2018); (D) photo ex situ of the whole colony showing arrangement of the branches and polyps (C10146); (F-H) Detail of an anthocodia showing sclerite arrangement (C10092); (G-I) Sclerites from the coenenchyme (C10092); (J-K) Sclerites from the polyp (C10092).

Molecular analysis: We successfully obtained DNA sequences from 28S and MutS barcodes (Table X, Appendix 1). Using MutS molecular marker, we were able to include C10092 and C10148 specimens in a big MutS gene alignment containing more than 843 members of Octocorallia (dataset of McFadden et al. 2022). Phylogenetic analyses agree in placing both specimens in Aquaumbridae family. Additionally, molecular analysis point C10092 as belonging to *Aquaumbra* genus whereas C10148 is more likely a new species of Aquaumbridae (Figure 78).

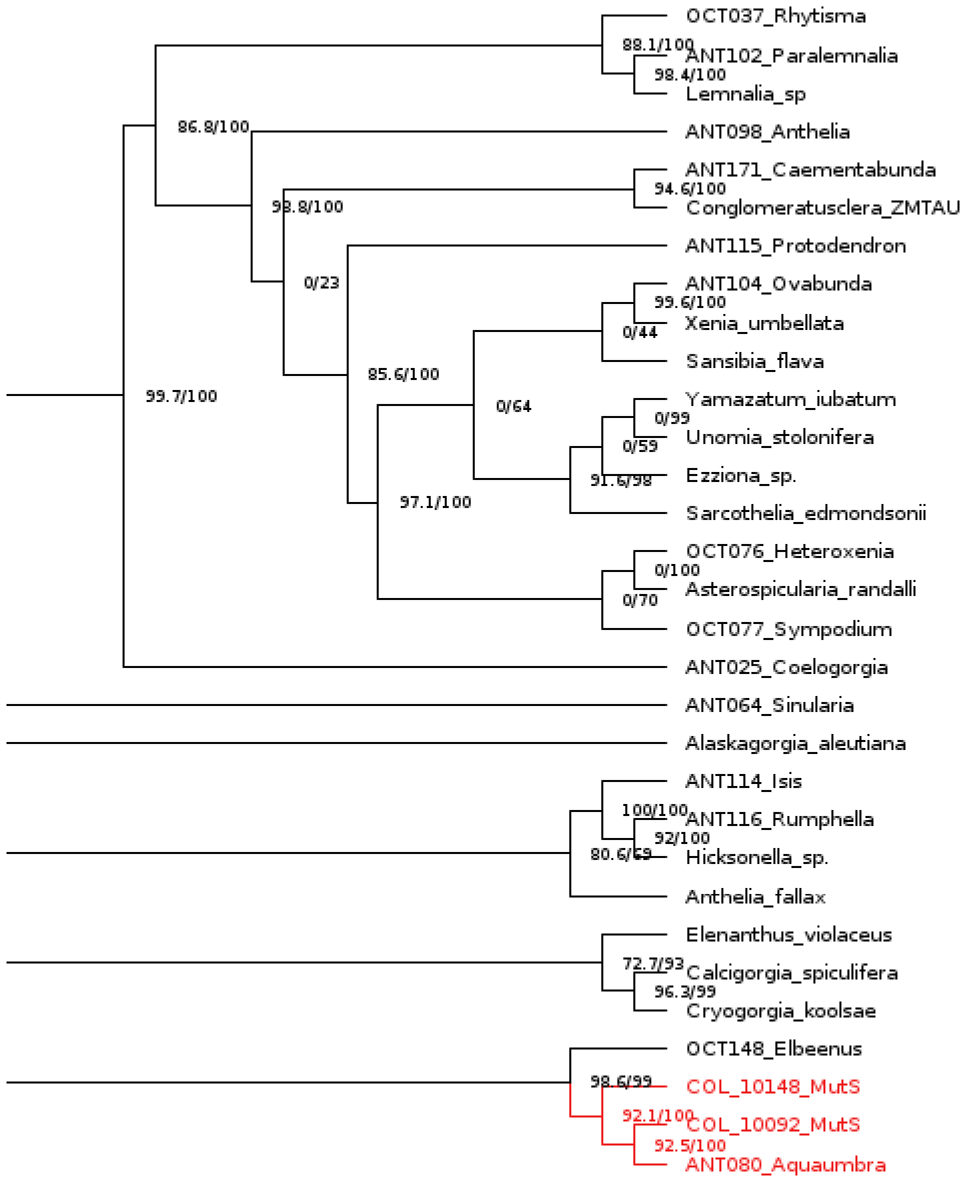


**Figure 78** Sub-tree of a maximum likelihood phylogeny of Aquaumbridae members reconstructed using RAxML and 1000 bootstrap. Taxa in red represent the studied species from the Azores. The phylogeny was midpoint rooted in the complete tree (data not shown).

*Lace corals (Hydrozoa, Family Stylasteridae)*

In the Azores, there are two larger bioengineering lace corals, the endemic species *Errina dabneyi* which is very common and quite abundant in some areas and frequently collected as bycatch during longline fishing. Another species commonly observed in video images, but that is not often collected, is the lace coral *Errina* cf. *atlantica*. This species forms medium to large colonies (up to 30 cm diameter) and has been observed to occur together with *Lophelia pertusa* in reef-like communities in the Capelinhos area and as isolated colonies on seamounts of the central group. During the OkeanosExplorer in 2022 and OceanX campaign in 2023 we had the opportunity to collect and examine specimens of *E.* cf. *atlantica* to confirm its taxonomic identity.

*Errina atlantica Hickson, 1912*

**Material examined:** Morphological examination and molecular analysis of the specimen collected from Pico S Lajes at 1076 m depth (C13015).

**Morphological description**

**Colony:** Following description in Zibrowius and Cairns (1992)**,** colonies bushy and sparsely branched of medium to large size (15-30 cm) (Figure 79A, B). Branches cylindrical gradually tapering to rather thin distal branches 0.8-1.0 mm in diameter (Figure 79B, C). Coenosteum white, reticulate-granular in textura (Figure 79C, D). Strips 65-95 um wide; granules 10-14 um in diameter.

**Polyps**: Polyps polymorphic and retractile. Gastropores are circular 0.22-0.30 mm in diameter, without a proximal lip (Figure 79D, E). Gastropores concur predominantly on anterior face and lateral branches. Gastropore tube lacking ring palisade. A slender, sharply pointed gastrostyle occupies the lower 50-60% of gastropore tube. Gastrostyle vertically ridge and spinose. Dactylopore spines individualized, with groove directed proximately and occurring primarily on the anterior face and lateral branch edges of distal branches and less frequently on larger diameter branches. Dactylopore spines short, about 1.14-0.16 mm in height on distal branches. Width of dactylopore spines 0.25-0.27 mm; width of groove 0.09-0.12 mm or almost one half width of spine. Female ampullae hemispherical about 0.70 mm in diameter. Male ampullae superficial on branch tips becoming internal on larger diameter branches; mature ampullae about 0.5 mm in diameter, each with 1-3 apical efferent pores 50-60 um in diameter.

**Colour:** White

Remarks: *Errina atlantica* presents morphological similarities to *E. aspera*. However, it distinguished by by the more pronounced bushy appearance, the absence of imbricate dactylopore spines in the coenestal surface, and presence of individual, rather than clustering of the dactylopore spines (see comparative diagnosis table in Zibrowius and Cairns (1992) (page 46). We have also observed tubes produced by eunicid polychates, a distinguishing diagnostic character of *E. atlantica* noted by Zibrowius and Cairns (1992).

Habitat and distribution: Reported distribution in the North-East Atlantic with a depth range of 610-1180 m, in slope areas.

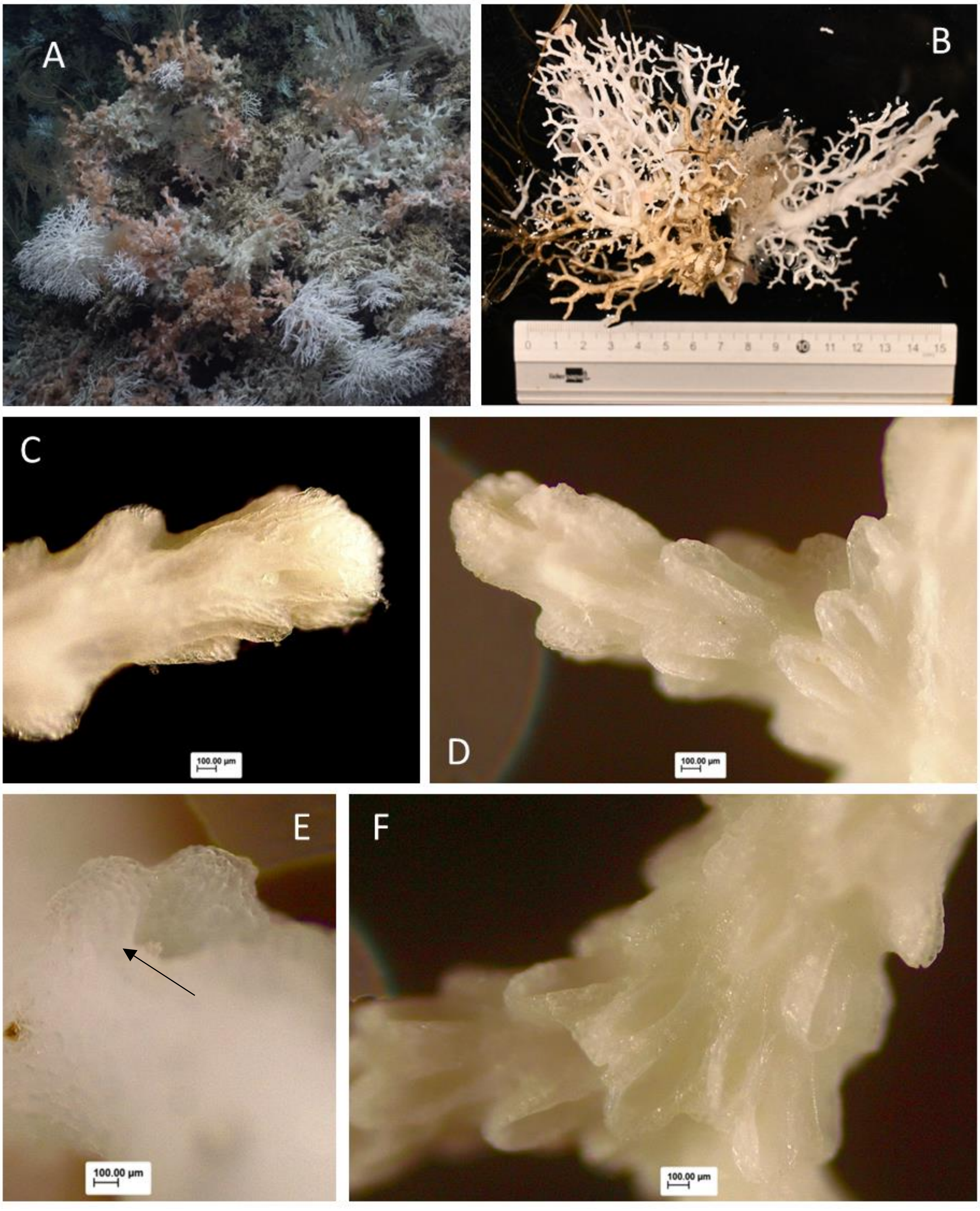


Figure 79 *Errina atlantica* C13015. (A) Photo taken *in situ* using the LULA1000 submersible (Fundação Rebikoff Niggeler, DeepWalls project); (B) Photo *ex situ* of the complete specimen C13015 collected in Pico S Lajes at 10076m depth using the submersible Neptune (OceanX_2023) showing the branching arrangement (notice the tube by eunicid worm); (C-G) Detail of the gastro- and dactylopores; (F) Detail of the gastrostyle; (G) Detail of dactylopore.

*Scleratinians (Order Scleractinia)*

*Eguchipsammia cf. cornucopia (Dendrophylliidae)*

**Material examined:** Specimens collected in Banco Gigante – Agulhas Sul at 457 m depth (C10188), Great Meteor at 314 m depth (C10858), José Gaspar at 309 m depth (C10880) and Açor Central Bank at 137 m depth (C10883).

**Morphological description**

**Colony shape:** Following the diagnosis for *Eguchipsammia* Cairns, 1994 (Cairns 2000), corallum commonly unattached (recumbent), the result of asexual budding of a parent corallum (Figure 80A, B); intratentacular budding also occurs. Third generation budding rare. Synapticulotheca usually partially covered with epitheca.

Morphological characters of *E. cornucopia* (Cairns 2000), corallum subcylindrical, elongate, and usually irregularly bent or curved (Figure 80C). Most coralla appear to originate by asexual budding from the edge zone of a parent corallum, some coralla having as many as 50 buds or hud scars on their theca. large robust coralla are most common (e.g., the synapse), having corallites as long as 13 cm and a calicolar diameter up to 17.4 x 15.0 mm; a smaller class of coralla is known, the coralla of which are identical to the typical form but grow only to a calicullar diameter of 8-9 mm and rarely contain more than 48 septa.

**Corallites:** Septa arranged in a Portalès plan. Paliform lobes may be present; columella spongy. *E. cornucopia* has septa hexamerally arranged in 5 cycles, but filth cycle never known to be complete, large coralla having about 72 septa. Septa not exsert: S1 and 92 equal in size; remaining septa arranged in a Portalès plan, small paliform lobe occurring before the S3. Fossa shallow containing a well-developed, discrete, swirled columella that is elliptical in cross section (Figure 80E). Vesicular endothecal dissepiments common in elongate coralla.

**Colour:** Yellow

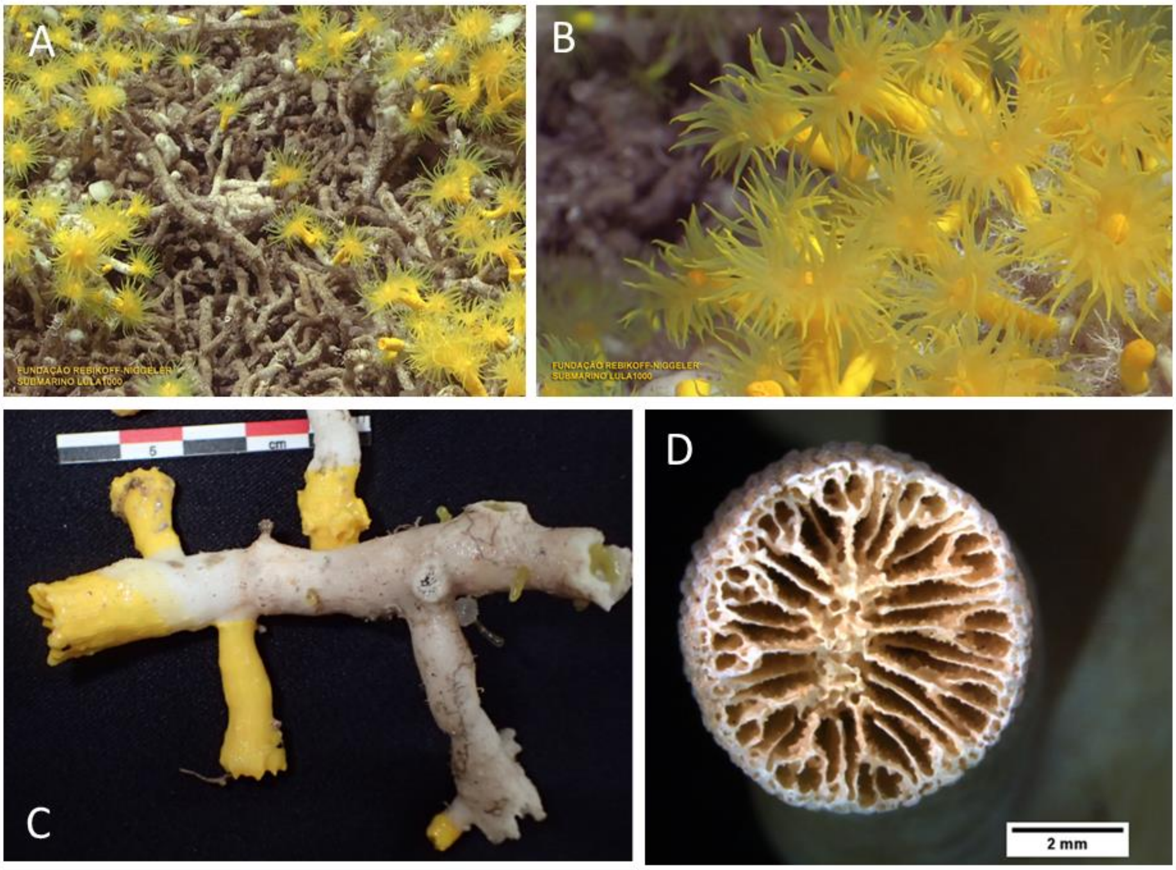


Figure 80 *Eguchipsammia cornucopia* (A-B) Photo taken *in situ* of an *Eguchipsammia* reef taken in Mont' Ana at 300 m depth with Submersible LULA 1000; (C) photo *ex situ* of the complete specimen C10188 in Gigante Agulhas S at 457 m depth using a submersible ROV LUSO (BlueAzores_2018); (C) detail of the inner skeleton.

**Molecular analyses:** We successfully obtained DNA sequences from 28S, rDNA, COI, COI-D, IGR, and ITS barcodes (Table 16, Appendix 1)Using these molecular markers, we could not clarify the taxonomy of *Eguchipsammia* specimens. Phylogenetic analyses with several dendrophylliid sequences available from Genbank agreed in classifying our specimens closely related to *Dendrophyllia cornigera* (HG965322, HG965323, MW375835). In regards with the morphological characters, members of the genus *Eguchipsamia* were previously assigned to the genus *Dendrophyllia* (Zibrowius and Cairns 1980) but were later transferred to a *Eguchipsammia* (Cairns 2000) based on their corallum commonly unattached and synapticulotheca usually partially covered with epitheca. Nevertheless, some authors (Zibrowius pers. comm) think that this new genus may be artificial and represents a particular growth form of *Dendrophyllia*.

The information obtained with these analyses support the need for additional high-throughput sequencing data (e.g. genome skimming) and phylogenomic methods to solve the species boundaries within *Eguchipsammia* members.

**Habitat and distribution:** This species has a reported distribution along the North Atlantic Ocean, with a depth range of 80-900m.

*Black corals (Order Antipatharia)*

The Azores harbours a rich diversity of black corals, with several species with high structural complexity and an important ecological role on deep-sea benthic communities. The taxonomy of black corals is challenging because many species are known from only one or a few specimens. In addition, single-locus and full mitochondrial genomes lack the required phylogenetic resolution to resolve relationships between closely related species and genera (Horowitz et al 2023). The inclusion of molecular data in taxonomic studies is clarifying which morphological features are diagnostic and homologous (traits passed down from a common ancestor) and which are analogous (similar traits independently evolved) (Horowitz et al 2022, 2023). For example, general branching characteristics can often be analogous among different genera. These findings show the importance of using integrated morphological and molecular data when making taxonomic decisions to identify and incorporate homologous features in the taxonomic decision-making process. These findings also point out to the need for an integrated taxonomic review of the order, and subsequent revisions based on holotype and topotype material for Antipatharia (Horowitz et al 2023).

In an effort to contribute to the clarification of black coral species identification, we have compiled morphological and genetic information of important bioengineering black coral species in the Azores, which is summarised below. This information has been shared with specialists in black coral taxonomy, namely Dra. Tina Molodstova from the Shirshov Institute of Oceanology (Russia), Drs Jeremy Horowitz and Andrea Quattrin from the NMNH, in a common effort to identify species present in the Azores and its relationship with other species in the North Atlantic.

*Leiopathes cf. expansa (Family Leiopathidae)*

**Material examined:** Morphological examination and molecular analysis of specimens collected from Gigante N at 1216 m depth (C11546), Princesa Alice at 393 m depth (C6550), Faial-Pico at 489 m depth (Leiop1-DSL), and 1094 m depth (Leiop2-DSL).

**Morphology:** An example of the information of the general morphology and characteristics of the branches and spines is presented in Figure 81. Specimens that we have tentatively assigned to *Leiopathes expansa* based on forms with sinusoidal stem and branches, and very short branchlets forming flabellate fronds (Molodstova 2011). However, specimens also present similarities with *L. grimaldii* (Molodstova 2011). Therefore, they need further examination of the shape and distribution of spines using scanning electron microscopy.

**Molecular analyses:** We successfully obtained DNA sequences from 28S and ITS barcodes (Table 16, Appendix 1). Using these molecular markers, we could not classify *Leiopathes* specimens beyond the genus level. Genbank BLAST analysis of the 28S barcode sequences returned three different matches with *Leiopathes* species above 99.6% identity (*Leiopathes expansa, Leiopathes glaberrima and Leiopathes montana*). The combined information obtained from the additional ITS barcodes didn't clarify this taxonomic issue. Additional high-throughput sequencing data (e.g. genome skimming) and phylogenomic methods in collaboration with colleagues at NMNH will provide a powerful alternative to solve the species boundaries within *Leiopathes* members.

**Habitat and distribution:** The species *Leiopathes expansa* has reported distribution in the North-East Atlantic. The genus *Leiopathes* has reported distribution along the North Atlantic, Mediterranean Sea, and Pacific.

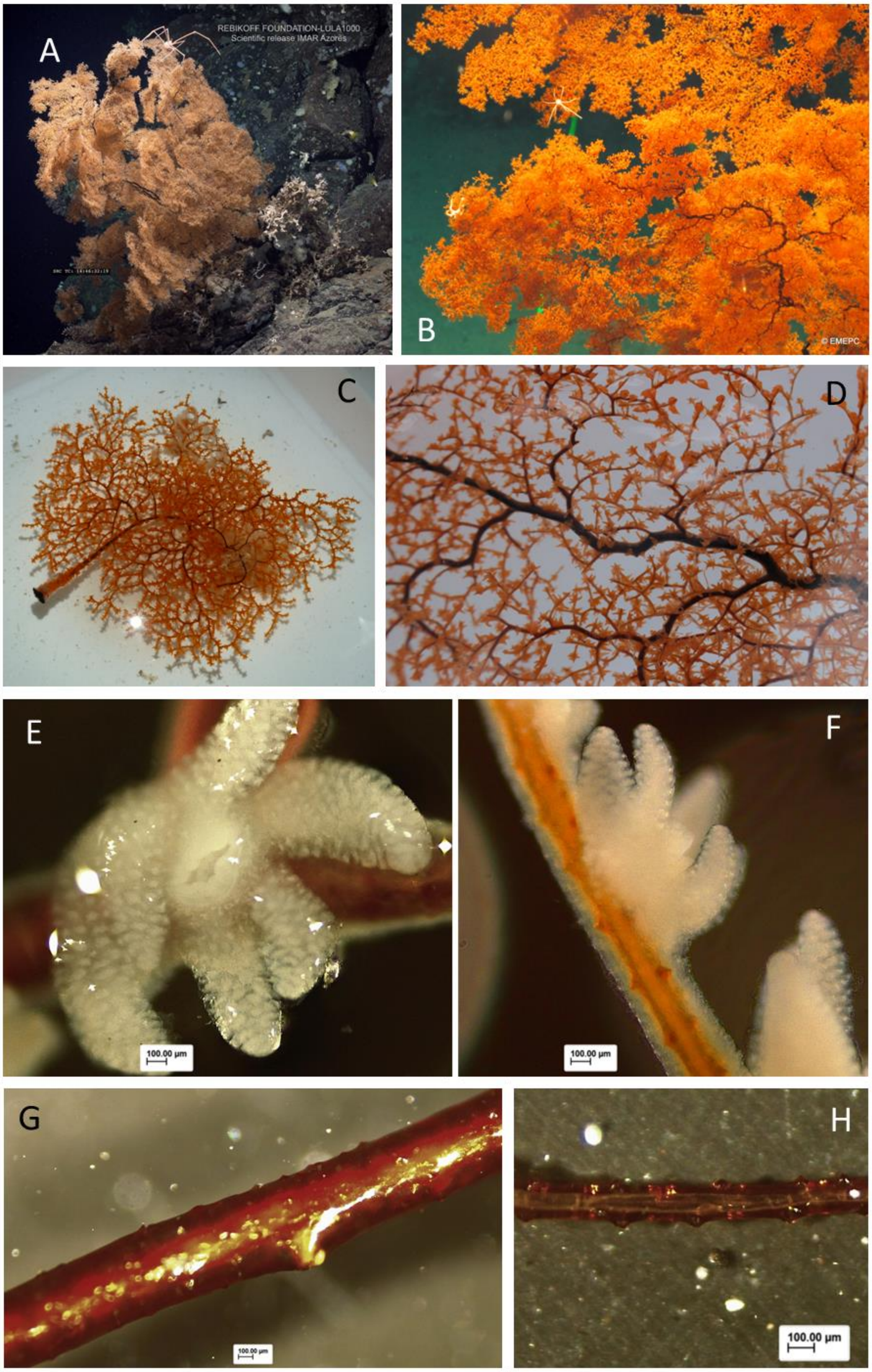


**Figure 81** *Leiopathes* cf. expansa. (A) Photo taken *in situ* on the island slope of Pico Island at 1000 m depth using the LULA1000 submersible (Fundação Rebikoff Niggeler, DeepWalls project); (B) Photo taken *in situ* on the mid Atlantic Ridge at depth below 1000 m with ROV LUSO (Campaign Exploseas2) ; (C) photo *ex situ* of a small complete preserved corallum (C11546); (D) Close view of colony and branchlet arrangement (C9935); (E-F) Close view of polyps (C6550); (G-H) Section of a branchlet showing size and arrangement of spines (C6550).

*Bathypathes spp. (Family Schizopathidae)*

**Material examined:** Morphological examination and molecular analysis of specimens collected in Faial W Capelinhos at 885 m depth (C12841) and 727 m depth (C12892). Further genetic analyses were also conducted with other material stored in COLETA with a white morphotype C8931, C8933, C8936 for the differential diagnosis.

**Morphology:** There are two apparently distinct species of *Bathypathes* found in the Azores that can attain large sizes (20-60 cm in height) (Figure 82). Within the scope of the project, we have compiled information on the morphological characteristics of these two species to further examine it in detail in collaboration with Dr Tina Molodtsova.

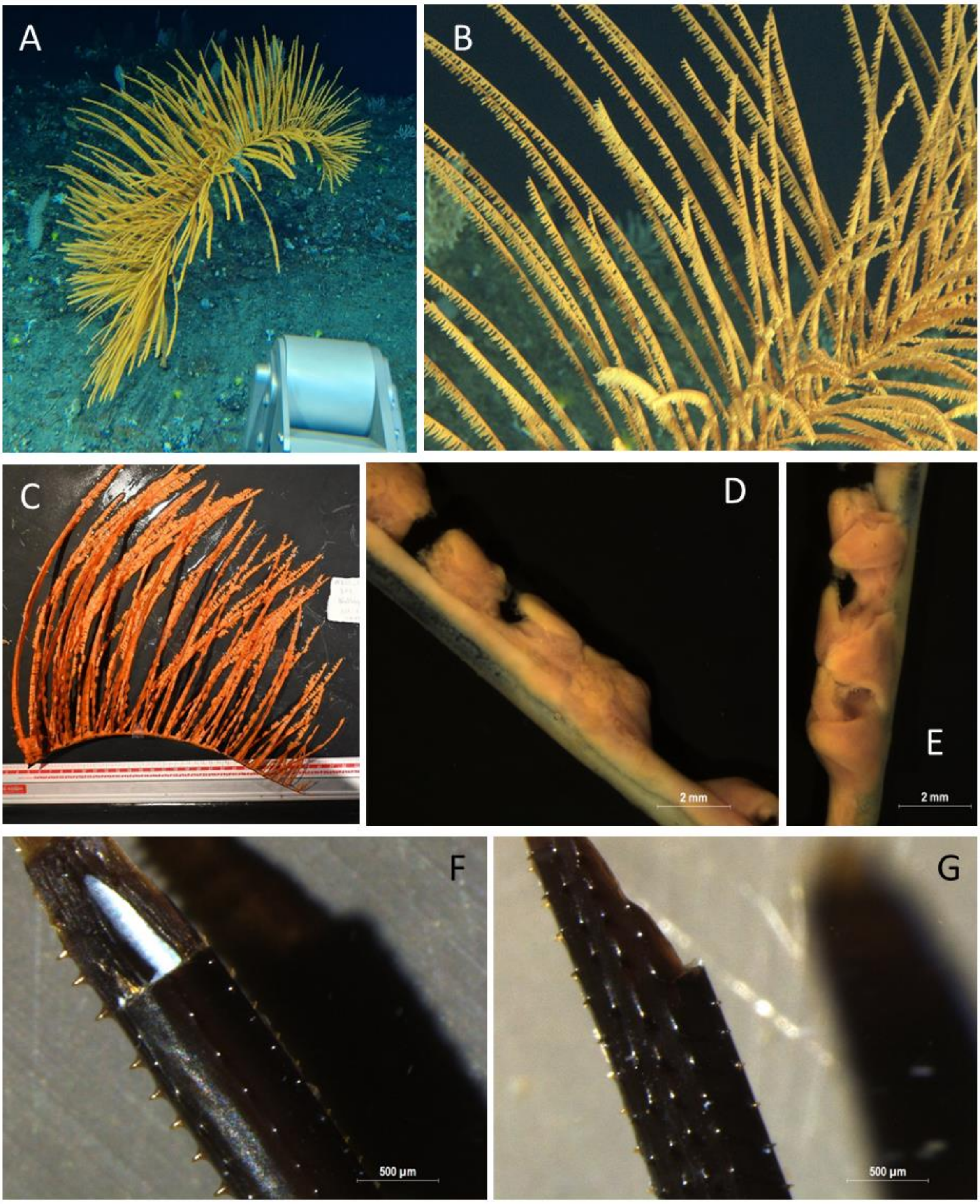


Figure 82 *Batypathes* sp. (A-B) Photo taken *in situ* of the specimen C12892 at Faial W Capelinhos at 727 m depth using Submersible (OceanX_2023); (C) photo *ex situ* of the entire corallum showing pinnule arrangement; (D-E) photo of the preserved polyps; (F-G) section of a pinnule showing size and arrangement of spines.

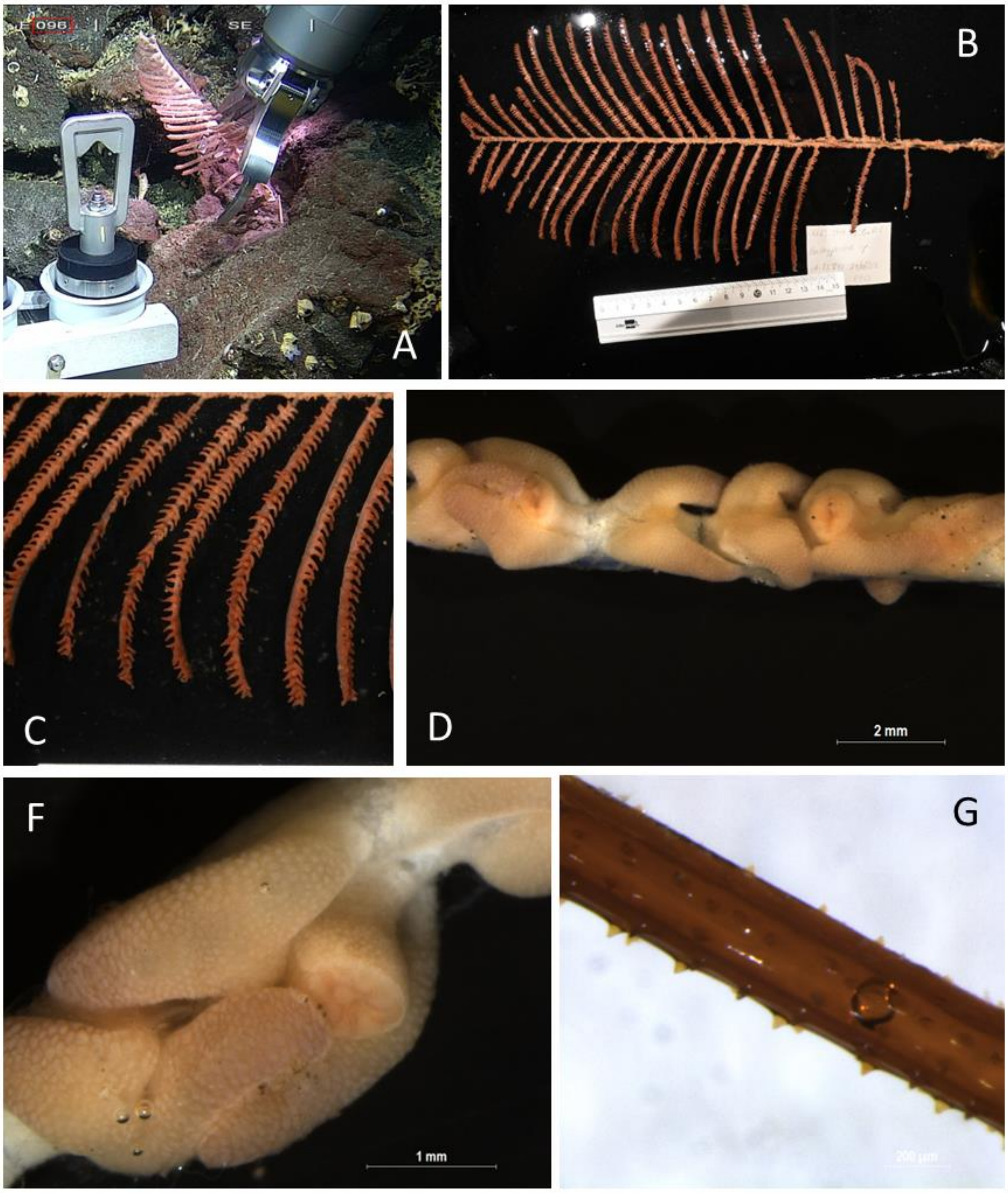


Figure 83 *Batypathes* sp. (A) Photo taken *in situ* of the specimen C12841 at Faial W Capelinhos at 885 m depth using a Submerible ROV (OceanX_2023); (B) photo *ex situ* of the entire corallum showing pinnule arrangement; (C) detail of the pinnules; (D) preserved polyps; (G) section of a pinnule showing size and arrangement of spines.

Molecular analyses: We successfully obtained DNA sequences from 28S and ITS barcodes (Table 16, Appendix 1). Using these molecular markers, we could not classify *Bathypathes* specimens beyond the genus level. Genbank BLAST analysis of the 28S barcode sequences returned a 100% similarity match with *Bathypathes sp.*, published by our colleagues at NMNH (Accession: OM799164). The combined information obtained from the additional ITS barcodes didn't clarify this taxonomic issue. Additional high-throughput sequencing data (e.g. genome skimming) and phylogenomic methods in collaboration with colleagues at NMNH will provide a powerful alternative to solve the species boundaries within *Bathypathes* members.

**Habitat and distribution:** The genus *Bathypathes* has reported distribution along the North Atlantic, Indian and Pacific Ocean.

*Tylopathes sp. (Family Stylopathidae)*

**Material examined:** Sample collected close to São Jorge island - Fajã das Almas at 1137 m depth, Azores, NE Atlantic (C10315).

**Morphology:** Colonies of *Tylopathes* sp. have been only seldom observed at 900-100 m depth in the Azores. Despite their uncommon occurrence this black coral forms one of the largest and most impressive colonies with one specimen attaining 3 m in height (Figure 84A). The corallum of this genus is flabellate, often with overlapping branches, and sometimes with cylindrical, reticulated worm runs formed by smallest branchlets (Figure 84B-D, Opresko 2006), which give it a dense thick appearance, and support rather large associated fauna (Figure 84B). The species identification is being done in collaboration with Tina Molodtsova.

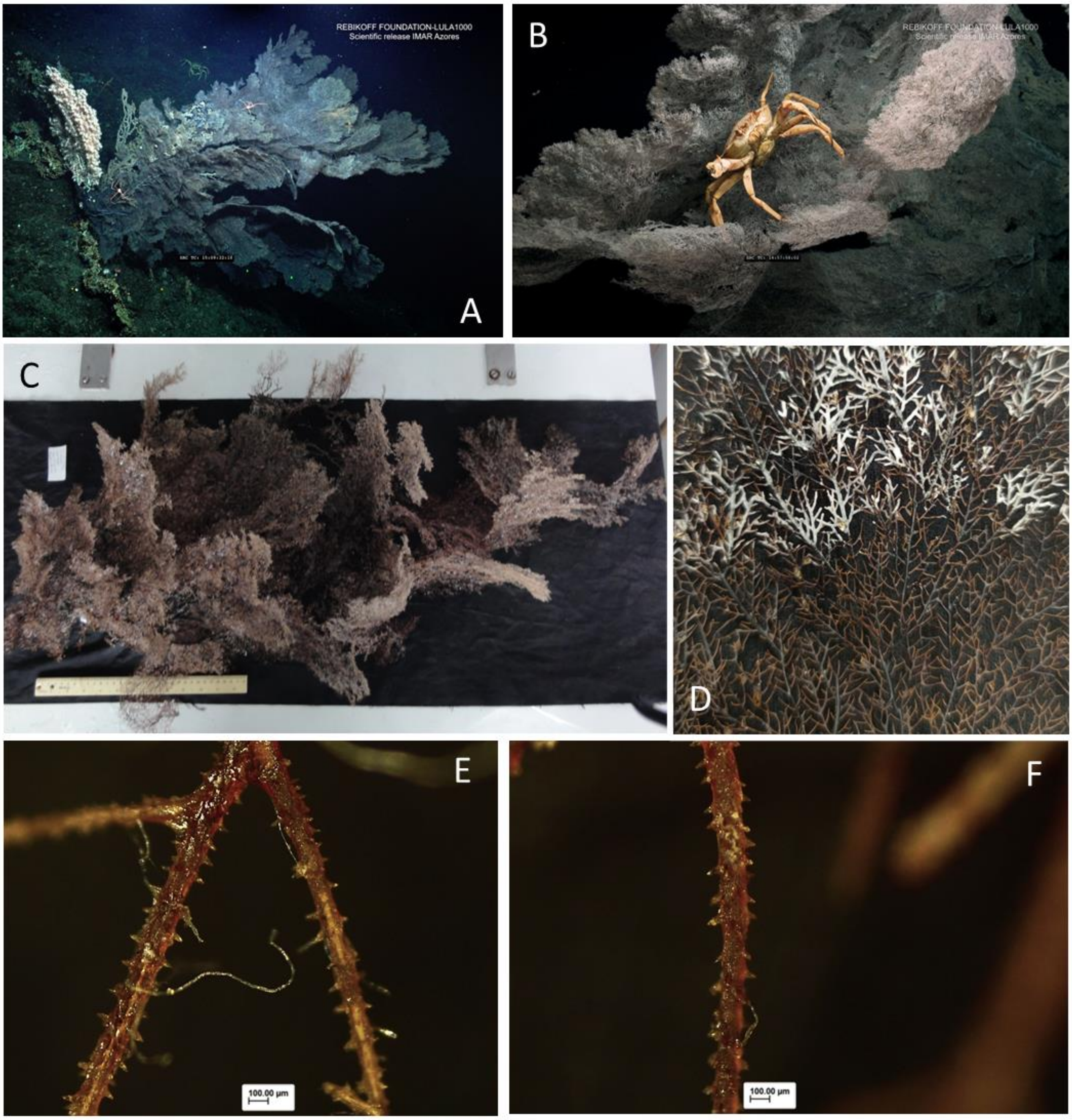


**Figure 84** *Tylopathes* sp. (A-B) Photo taken *in situ* using a Submersible LULA 1000 (Fundação Rebikoff-Niggeler, DeepWalls project); (C) photo *ex situ* of the specimen C10315 collected as longline fisheries bycatch close to São Jorge - Fajã das Almas; (D) detail of the colony showing the branchlet arrangement; (E-F) section of a pinnule showing size and arrangement of spines.

**Molecular analyses:** For the C10315 specimen we successfully obtained DNA sequences from COI barcode (**Table 16**, Appendix 1). Using this molecular marker, we could not classify *Tylopathes* specimens beyond the genus level. Genbank BLAST analysis of the COI barcode sequences returned a 100% similarity match with *Tylopathes sp.* n. NB-2020 from the study of its complete mitochondrial genome (Accession: MT318859). Additional high-throughput sequencing data (e.g. genome skimming) and phylogenomic methods in collaboration with colleagues at NMNH will provide a powerful alternative to solve the species boundaries within *Tylopathes* members.

**Habitat and distribution:** The genus *Tylopathes* has reported distribution at some point in the Nort-East Atlantic, Pacific and Indo-Pacific Ocean.

### 9.2.2 Deep-sea sponges

*Glass sponges - Class Hexactinellida*

*Family Rosselidae*

**Subfamily Rossellinae**

***Asconema fristedti*** **Tabachnick & Menshenina, 2007**

**AphiaID 255144**

**Material examined:** C2010 - local: Princess Alice Bank at 366 m (Vessel Neuza Mar Corazon, CoralFish 2007), C2442 – local: Atlantis at 843.4 m; (R/V Arquipelago, 2007); C10074 – local Gigante Bank at 665 m (R/V Gago Coutinho, BlueAzores Exp. 2018); C11187 and C11101– local: Açores Bank at 673 and 645 m respectively, (Vessel Manuel Arriaga, 2017).

### Morphological description

**External morphology:** The body is tubular or funnel-like, basiphytose with thin walls (1 mm) and very large osculum (Figure 85).


**Figure 85** *Asconema fristedti ex situ* external morphology. A. *Asconema fristedti cf. nordazoriensis* Entire Specimen C2010 from Princess Alice Bank (366 m depth); B. Entire Specimen C11187 from Açores Bank (673 m depth); C. Entire Specimen C2442 from Atlantis Seamount (843 m depth); *Asconema fristedti cf. fristedti*: D. Entire Specimen C10074 from Gigante

Bank (665 m depth); E. Wall thickness specimen C10074; F. Dermalia are pentactins with the unpaired ray directed outside the body of specimen C10074.

**Spicules:** Definition (*sensu* Tabachnick and Menshenina, 2007): *Asconema fristedti* is characterized by presence of two types of hypodermal and hypoatrial pentactins: with smooth and spined tangential rays (no hypoatrial hexactins with spiny ray directed outside the body); dermal and atrial spicules of uniform size and similar shape with gradually tapering rays; atrial pentactins equal to the dermal ones are numerously present, as well as dermal and atrial hexactins which are also common in some specimens; oxyoidal and usually various discoidal microscleres are present (Figure 86).

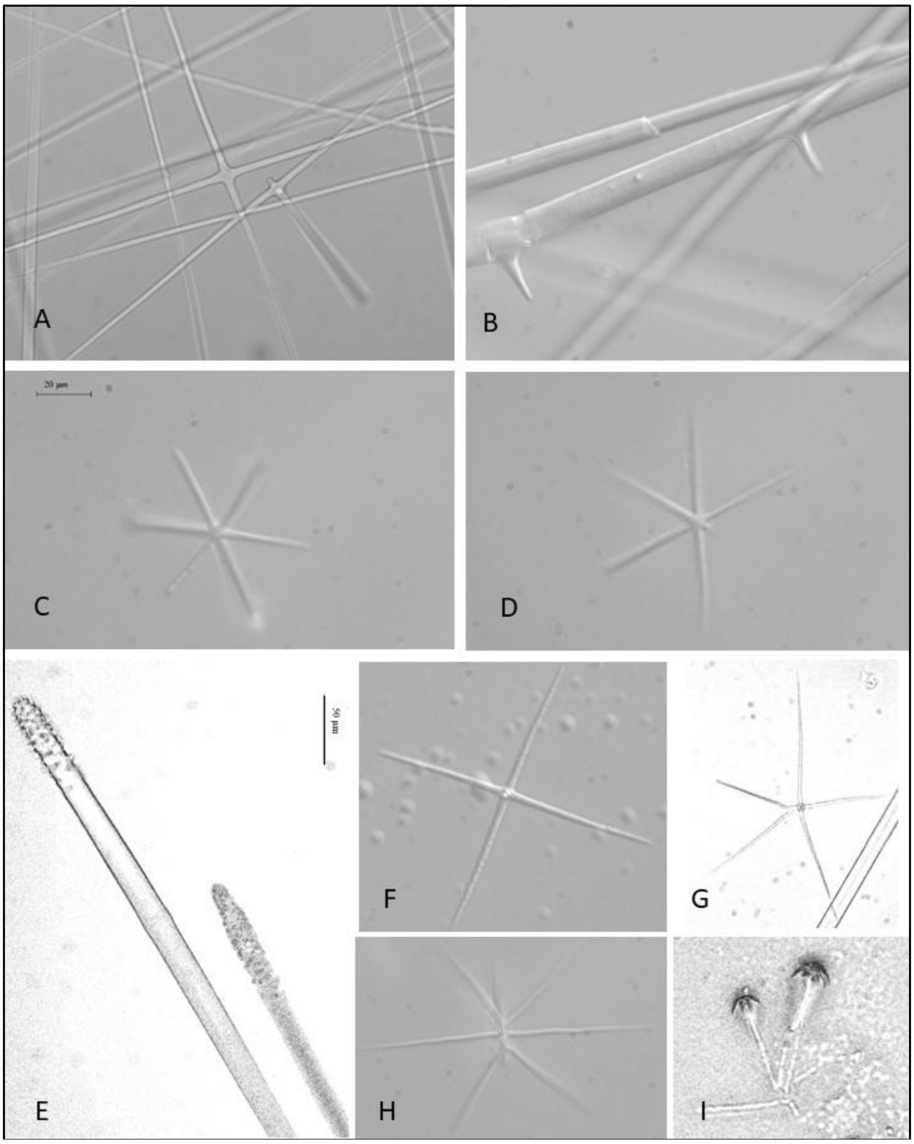


**Figure 86.** ***Asconema fristedti*** **Spicules**. A. Atrial Pentactins; B. Dermal Pentactins; C. Atrial Hexactin; D. Atrial Pentactin; E. Choanosomal Diactins; F. Stauractin; G. Oxyhexactin; H. Oxyhemihexaster; I. Ray tips of Macrodiscohexaster.

**Remarks:** Macrodiscohexasters were not found in specimens Figure 85 A, B and C. Apparently, as they are absent, these specimens are suggested to be *Asconema fristedti nordazoriensis*. According to Tabachnick and

Menshenina (2007) they are characterised not only by absence of macrodiscohexasters but also a relatively large number of dermal stauractins. However, in specimen C10074 (Figure 85 D), it was found two loose ray tips of a macrodiscohexaster in a provisory preparation. Although a rare finding it is suggested that this specimen might be *Asconema fristedti fristedti*. To understand if there are macrodiscohexasters at the other specimens, if they are absent or just very rare, more specimens should be examined.

**Habitat and distribution:** Central Atlantic (from the Azores to Iceland), depth 190–4270 m (Tabachnick and Menshenina, 2007).

*Family Euretidae*

### *Euretidae gen. new*

**Material examined:** Specimen USNM 1673638 collected during Expedition EX2206 (ROV Dive D02, Station 03B, Sample A01) at East of Formigas Rift (37.355 N; -24.3799 W), 714.23 m depth.

#### Morphological description

**External morphology:** Tubular Euretidae which grow through dichotomous subdivision of basal tubes of approximately equal diameter. Body form a network of irregularly branching stock with anastomoses; with alveolar external surface created by framework-supported ridges circumscribing conspicuous depressions, some of which penetrate the entire wall as parietal oscula (see Euretidae in Reiswig and Wheeler, 2002) (Figure 87).

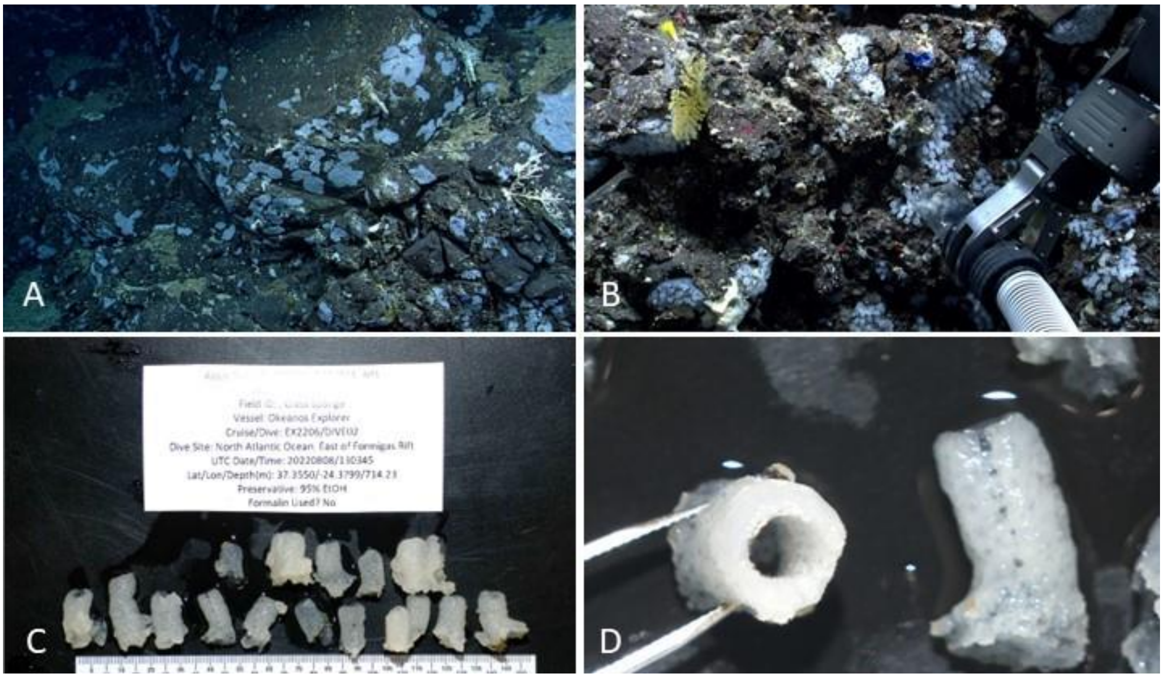


**Figure 87** Euretidae gen. new *in situ.* A. and B. Specimen USNM 1673638 collected during Expedition EX2206 (ROV Dive D02 Sample 03B-A01) at East of Formigas Rift, 714.23 m depth. Specimen USNM 1673638 *ex situ* External morphology: C. Specimen tubes after collection; D. Zoom image of the tube framework of the same specimen.

**Spicules:** Pentactines present. Oxyhexasters as only microscleres. Uncinates present but scopules absent (Figure 88).

**Remarks:** We could not assign the species for this specimen once it has characteristics of several genus within family Euretidae. It is close to *Gymnorete alicei* described for the Azores, however scopules neither tyloscopules were not found in this material. Thus, we keep the family name until more work is done.

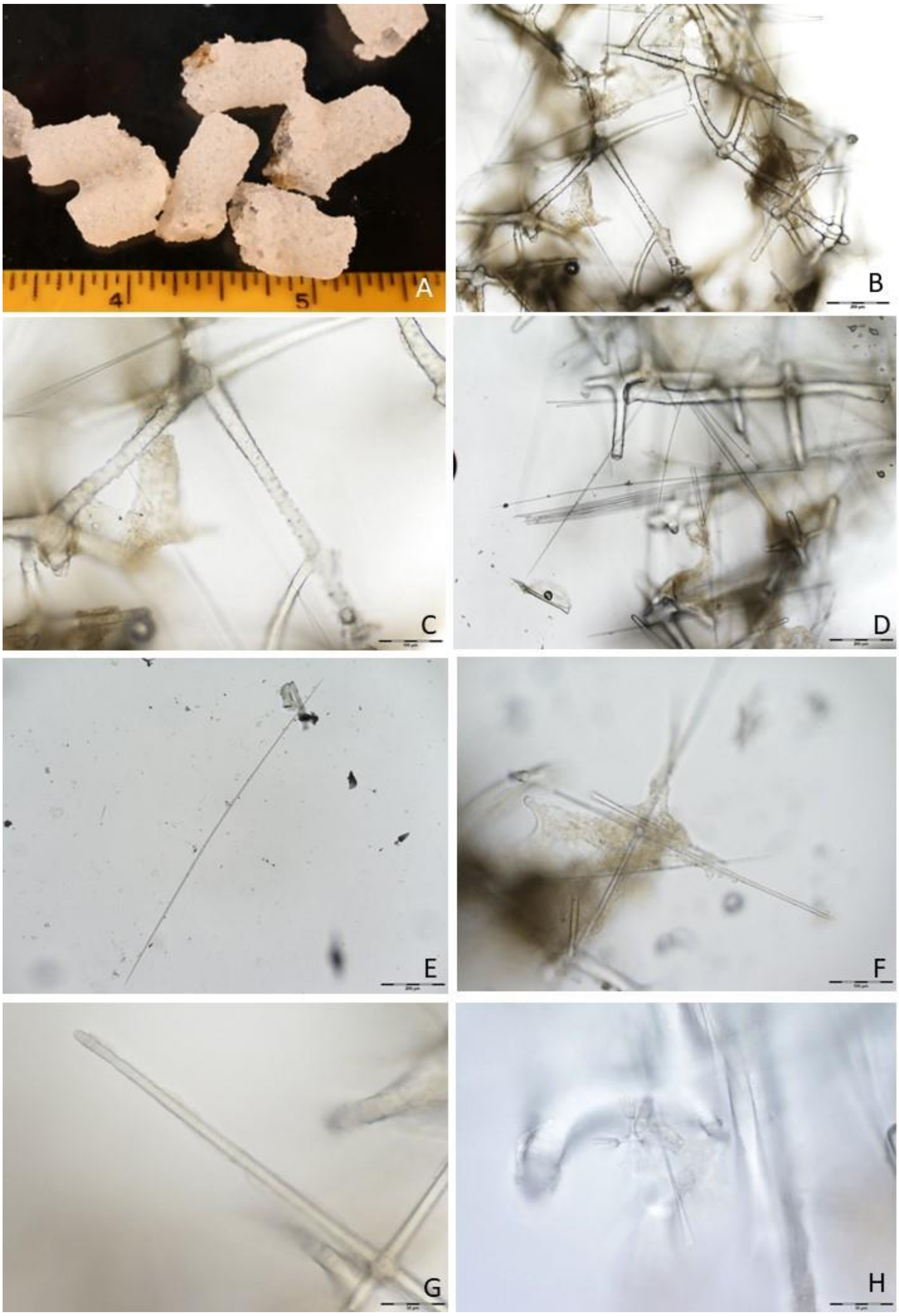


**Figure 88** A. Fragments of specimen USNM 1673638. B. dictyonal framework; C. coarsely roughed beams of dictional frame; D. atrial framework; E. Uncinate; F. Pentactin; G. Detail of tip of pentactin; H. discohexaster.

**Habitat and distribution:** This species is always found in steep walls of islands slopes (e.g. Pico) and seamounts. Usually associated with the crinoid *Cyathidium foresti* and the oyster *Neopycnodonte zobrowii.*

Subfamily Chonelasmatidae

*Chonelasma ijimai* Topsent, 1901

AphiaID 134384

**Material examined:** C11755 - M128 Meteor (Station 810, ROV DIVE 403, Sample 03), at Rift Princesa Alice Bank (Lat: 38º11.845' N, Lon: 29º33.644' W) at 2414 m depth.

Morphological description

**External morphology:** The specimen was collected as four plate-like fragments from an unknown body form. It might be in a funnel shape as the other Atlantic *Chonelasma* species (e.g. *C. choanoides*). *Chonelasma spp.* are large lamellate hexactinellids. Macroscopic inspection of the fragments reveals the striking quadrunx pattern of tissue and water canals characteristic of the genus (Figure 89).

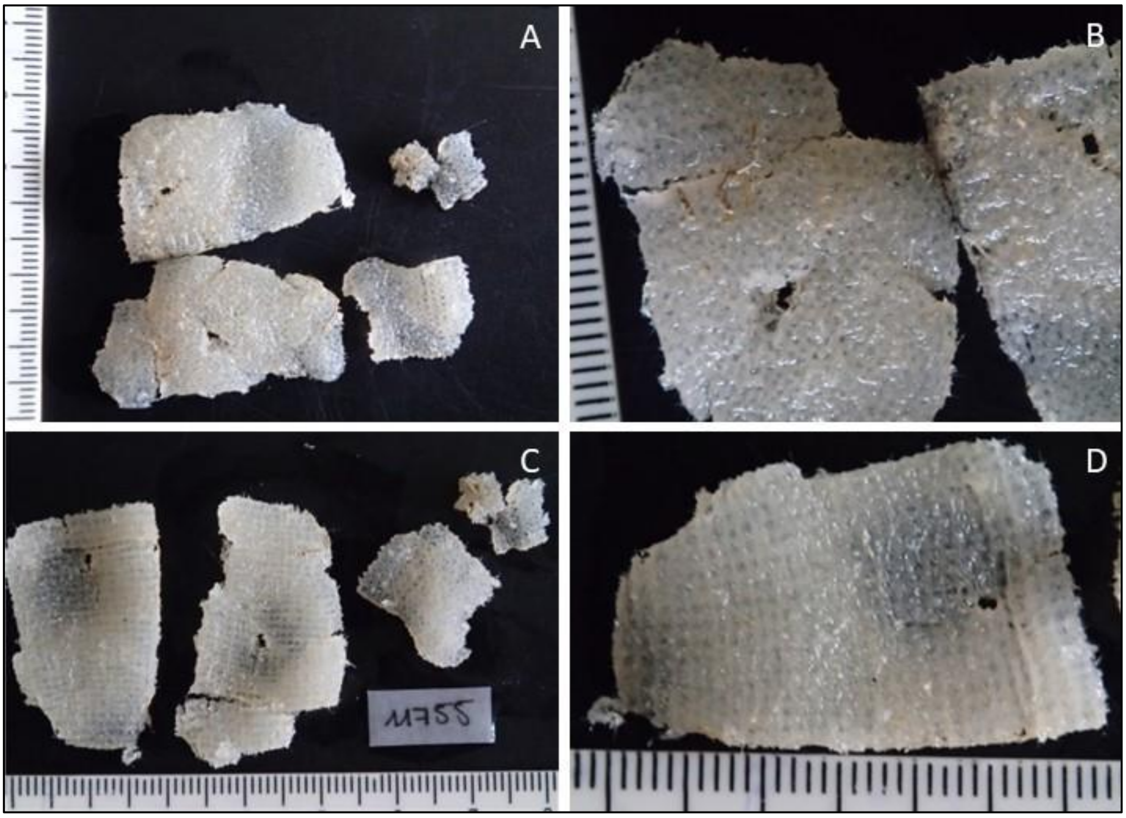


**Figure 89** *Chonelasma ijimai ex situ,* external morphology. A. specimen C11755 external side view. B. detail of texture of the external side (dermal layer) showing epirhysal (water canals) openings; C. Same specimen, inner side (gastral layer) view; D. detail of the mesh framework (perpendicular and longitudinal beams) showing the quadrunx pattern.

**Spicules:** After reviewing literature, *Chonelasma* species, spiculation follow an overall similarity. However, *C. ijimai* possess two types of scopulus. Microscleres are only discohexasters (Figure 90).

**Remarks:** Reiswig and Mehl (1994) had deciphered the differences between *C. choanoides* and *C. lamella* once previous descriptions were based in fragments being poorly understood, introducing some ambiguity in the distinction of species. The skeleton framework arrangement of *C. ijimai* is similar to the North Atlantic cited species *C. choanoides*, consisting of three distinct layers, only one of each is channelized. As described for *C. choanoides*, also *C. ijimai* dermal layer consists of a moderately tight network of dictional beams forming regular meshes, penetrated by a set of radial channels (epirhyses), usually distributed without clear pattern (Figure 89 A. and B.). The inner side consists of a series of parallel transverse lamellae spaced ca. 1 mm apart, oriented perpendicular to the growing edge and joined by elongate longitudinal beams with outline long rectangular meshes. The middle layer is not channelized. It is highly recommended to do molecular analysis, to see if it is a true different species or is a species complex. Regarding differences between *C. choanoides*, we also question/doubt if scopules differences and smaller oxyhexasters in *C. ijimai* are relevant characters to distinguish species.

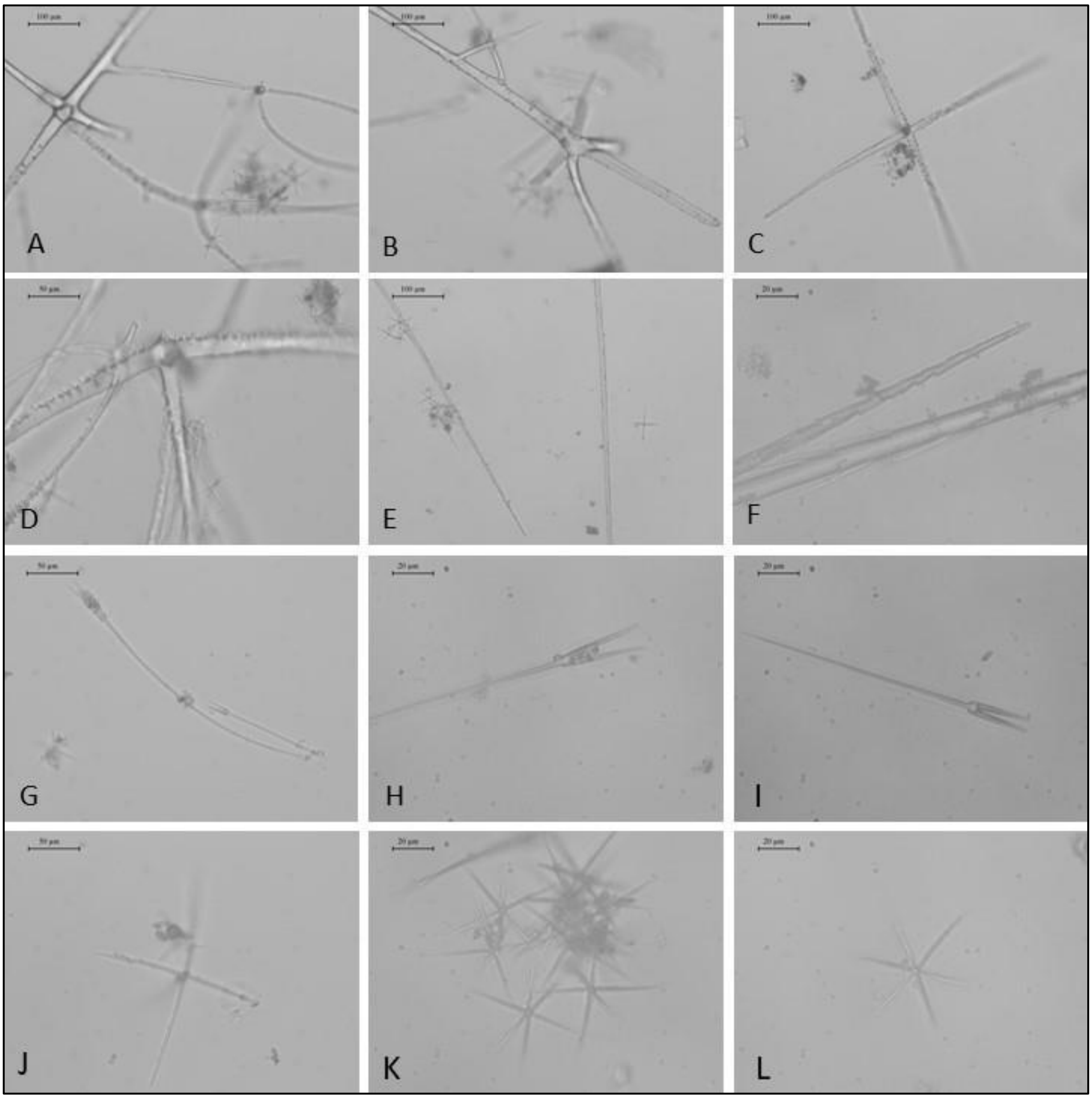


Figure 90 *Chonelasma ijimai* spicules. A. and B. Dermal beams showing tipical spination and septa. C. Pentactin; D. Pentactin coarse spination on the outer surface; E. and F. Uncinates with barbs; G. Two types of scopules; H. Scopule type I, bigger with thin rays; I. Scopule type II, smaller size with enlarged head and thicker rays; J. Oxyhexaster, K. and L. Discohexasters.

**Habitat and distribution:** Found in muddy sand. The specimen analysed in this work was found in volcanic outcrops, however covered with pelagic and clastic sediments that are deposited with variable coverage. *Chonelasma ijimai* was found between S. Miguel and Terceira Islands at 1165 m. The specimen Type is a small fragment (Campaign 1895 Hirondelle, St. 578, coordinates: 38º26’ N/26º30’45’’W). The present material studied in this work is the second fragment found after Topsent (1904).

*Family Aphrocallistidae*

*Aphrocallistes beatrix*, Gray 1858

AphiaID 134380

Material examined: C2517- Local: Faial; Depth 457, Expedition: Geralda 1980; C9906 - Local: Menez Gwen, Expedition: DeepFun 2012.

Morphological description

External morphology: Body form as simple branching tubes to networks of branching and anastomosing tubules to funnel-form; rigid wall; wall structure very regular (Figure 91).

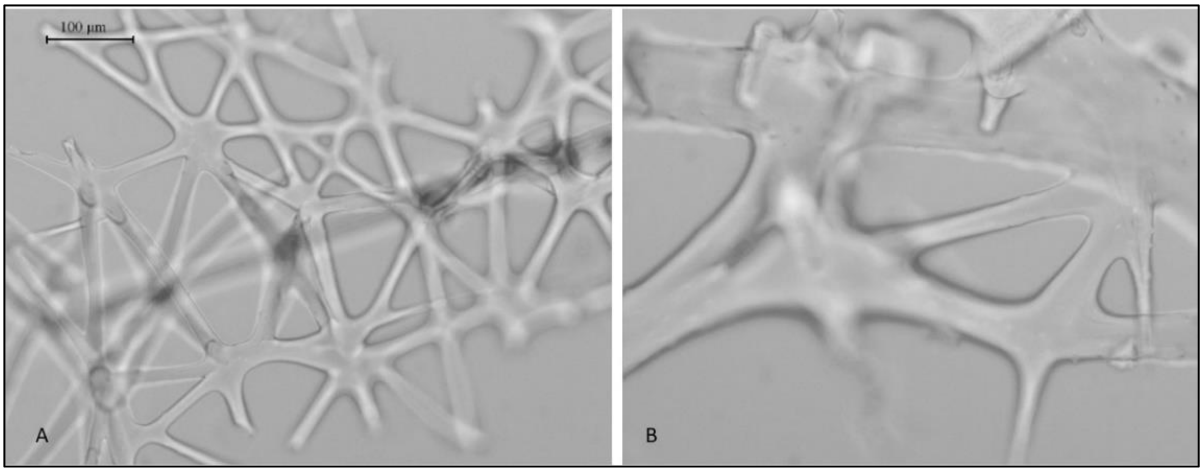


Figure 91 *Aphrocallistes beatrix* internal morphology A. Mesh framework specimen 2517; B. Specimen C9906.

Spicules: Body wall consists of conspicuous hexagonal honeycomb of straight channels (diarhyses) (see Figure 92 dictyonal framework fragments of specimens C2517 and C9906). Megascleres are dermal pinular hexactins, two forms of scopules, atrial diactins and uncinates. However, it some abnormal spicules were observed. For instance, some dermal pinnular hexactins were found with two bushy projecting pinnular rays. Also, several tyloscopules (type I like), were found with malformations, bearing a single tine at the shaft upper part below the "head". Uncinates with barbs ornamentation and atrial diactins with four small knobs vary in size and spination. Choanossomal oxyhexactins have sharp conical spines (Figure 92).

Remarks: More preparations should be made to address the hypothesis of simple abnormalities or of a different and new scopulus type not documented before in literature. Abundances and measurements should be taken also of the atypical dermal hexactins with two projecting pinnular rays, not documented before either. Microscleres as discohexasters and oxyhexasters (micro and elongate forms) similarly corresponding to anterior descriptions worldwide (Ijima, 1926; Reiswig and Kelly 2011).

Habitat and distribution: Attached to hard substrate; was also observed attached to massive demosponges at sedimentary areas; depth range worldwide 60-2949 m (according to Reiswig and Kelly, 2011). Cosmopolitan.

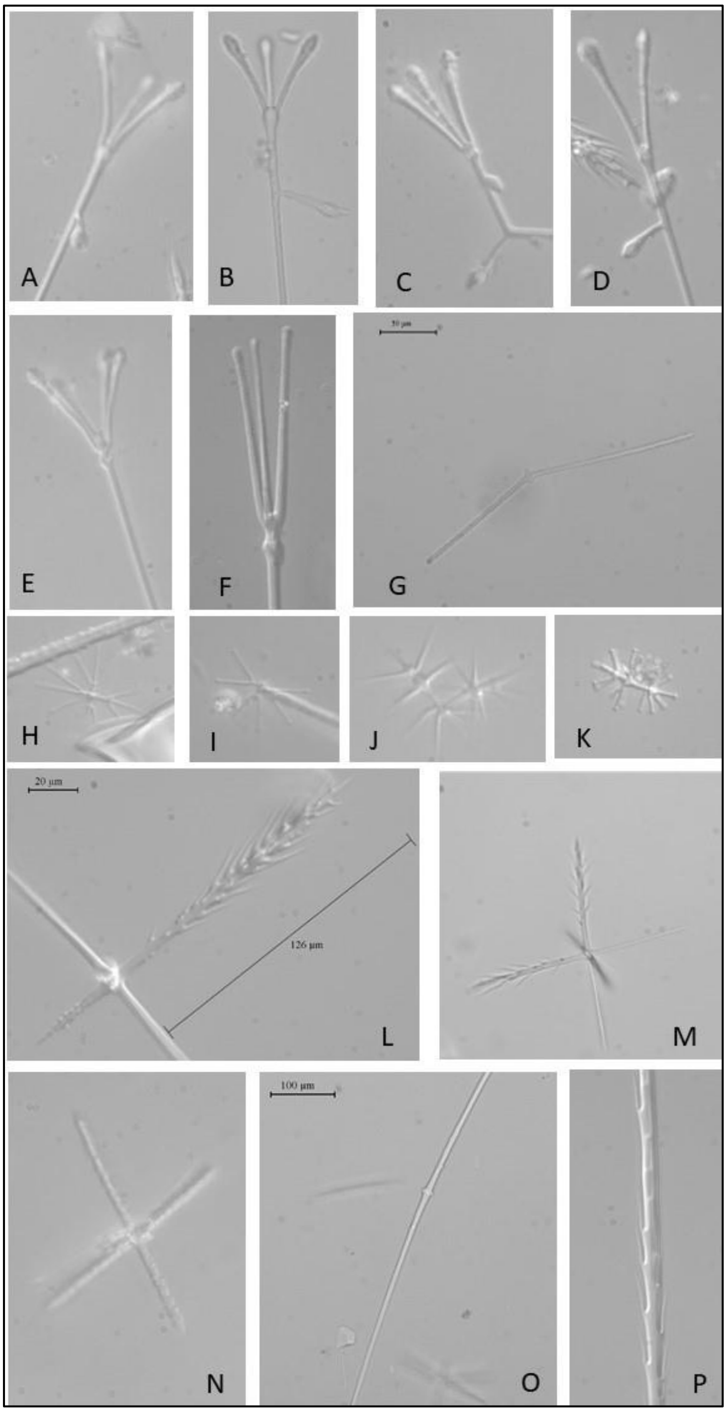


Figure 92 *Aphrocallistes beatrix* spicules. A. B. and C. specimen C2517 Scopulus abnormal shapes or malformations (?) and D. specimen C9906; E. Scopulus (Tyloscopule) Type I normal form; F. Scopulus Type II (Strongyloscopule) normal form; G. Atrial Diactin; H. and I. Microdiscohexasters; J. Hemioxyhexasters; K. Elongate Hemidiscohexaster; L. Pinular Dermal Hexactin common form: M. Aberrant Pinular Dermal Hexactin with two bushy projecting pinnular rays; N. Choanossomal oxyhexactin; O. Atrialia P. Uncinate middle segment showing barbs ornamentation detail.

*Family Euplectellidae*

Subfamily Corbitellinae

*Hertwigia sp.* "white morph" spec. nov.

AphiaID 132115

**Material examined:** Specimen USNM 1674018 collected during Expedition EX2206 (ROV Dive D06, Station 08B) at Kurchatov Ridge (40.6627 N; -29.3861 W), 1688.6 m depth.

## Morphological description

**External morphology:** Corbitellinae with plexiform walls (composed of dichotomously branching tubes). White colour alive and after preservation in alcohol (Figure 93).

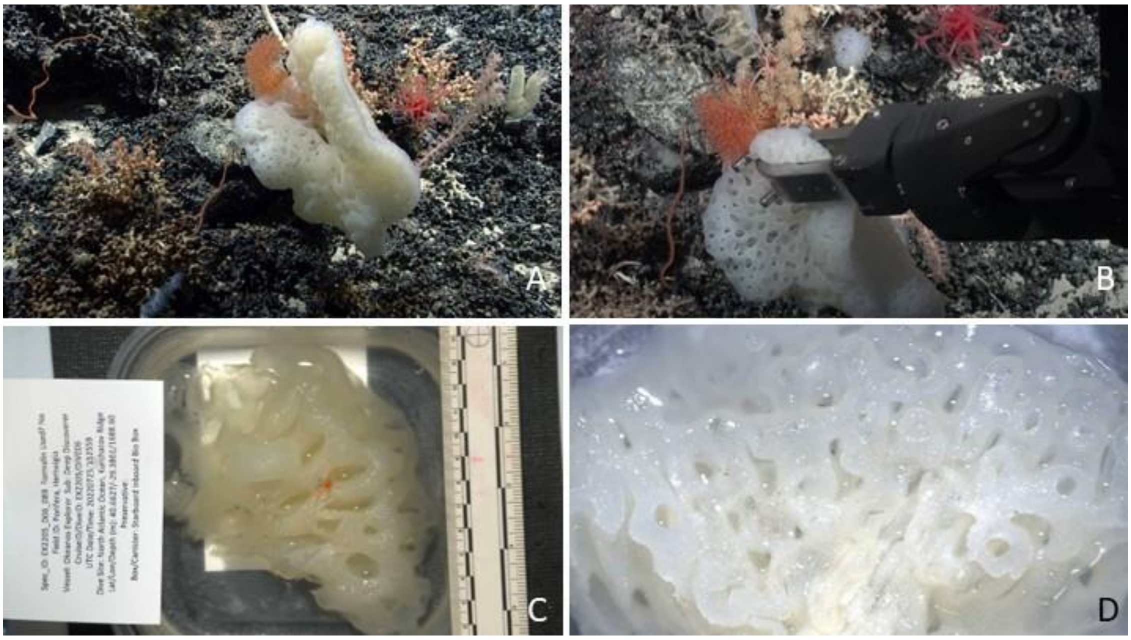


**Figure 93** *Hertwigia sp*ec. nov. *in situ* External morphology. A. and B. Specimen USNM 1674018 collected during Expedition EX2206 (ROV Dive D06 Sample 08B) at Kurchatov Ridge, 1688.6 m depth. C. and D. *ex situ*. Specimen after collection.

**Spicules:** Choanosomal diactines are smooth. Spiny hexactines. Microcleres vary having discoidal, sigmoidal (drepanocomes and plumicomes), oxyoidal, floricoidal outer ends and codonhexasters (Figure 94).

**Remarks:** The analysed specimen it is distinguished by *Hertwigia falcifera* (the only known species under the genus *Hertwigia*) by the presence of a very distinctive spicule, the codonhexasters. This remarkable spicule is found in some other particular euplectellids (e.g. see genus *Dictyocalyx* in Tabachnick, 2002, *Amphidiscella* in Reiswig, 2014 and *Bolosoma* in Castelo-Branco *et al.* 2019). This is the reason why the *Hertwigia* “white morph” can not be assigned as *H. falcifera*, and possibly not even in the genus *Hertwigia* (Castelo-Branco *pers. comm.*). It is recommended to do molecular analysis to place it under the euplectellids.

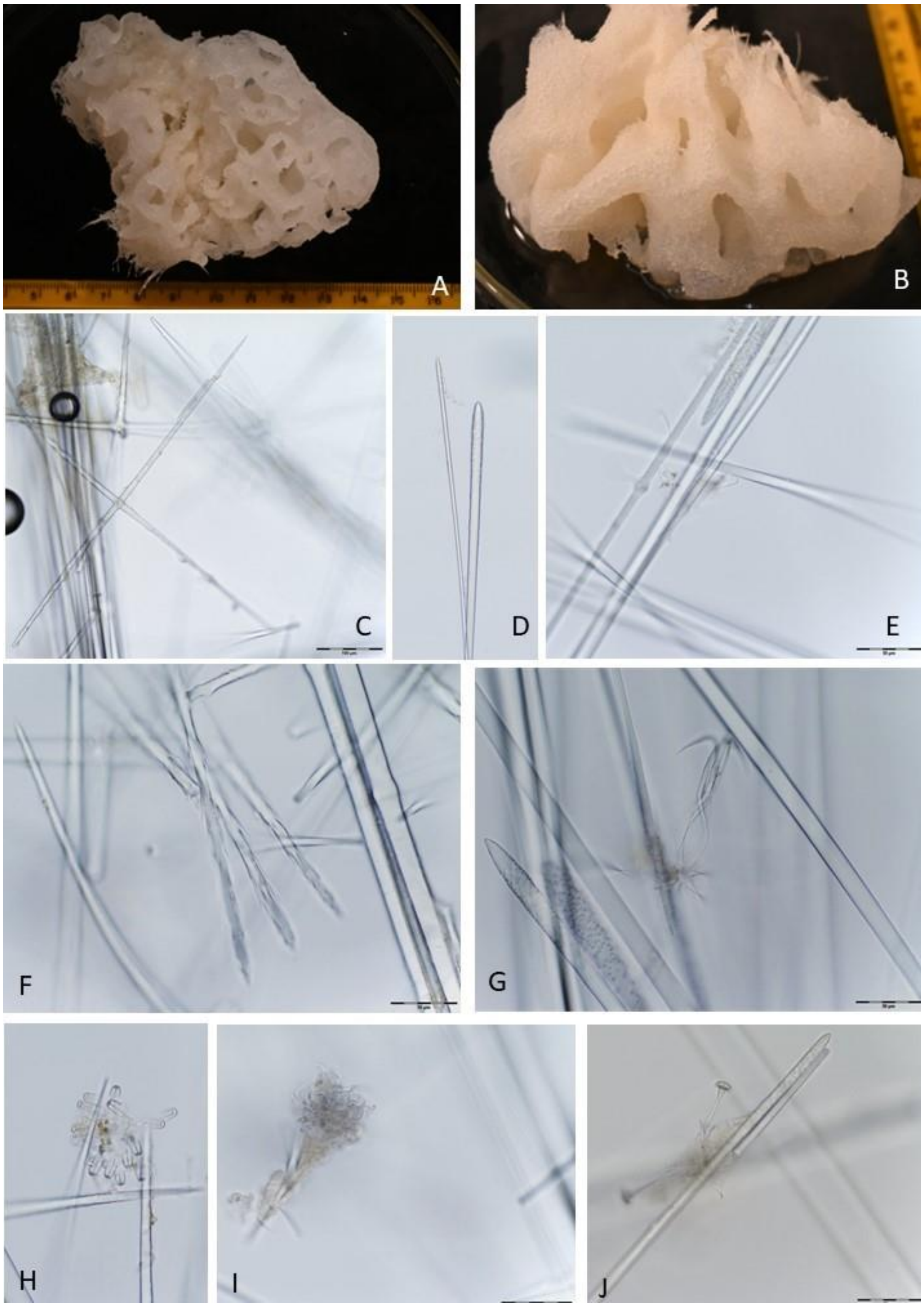


Figure 94 *Hertwigia new sp.* spicules. Specimen USNM 1674018 A. morphology *ex-situ* internal side view; B. external side view; C. dermal pinnular hexactin; D. smooth outer end of choanosomal diactines; mid segments of choanosomal diactines; F. pinnular hexactins outer ends; G. drepanocome; H. codonhexaster; I. floricome; J. spirodiscohexaster.

**Habitat and distribution:** Bellow 1,500 m. Inhabits deep bathyal areas of the MAR ridges and seamounts.

*Family Euplectellida*

***Euplectella cf. suberea***

**AphiaID 134401**

**Material examined:** Specimen USNM 1673614 collected during Expedition EX2206 (ROV Dive D01, Station 03B) at João Valadão Ridge (38.1587 N; -26.2364 W), 2120.97 m depth.

## Morphological description

**External morphology:** Known under the name of "Venus flower basket". Body shape tubular. Osculum is covered by a sieve-plate. Basalia form a single tuft characteristic of the genus *Euplectella*. Numerous lateral oscula and lateral body surface with large diactins (Figure 95).

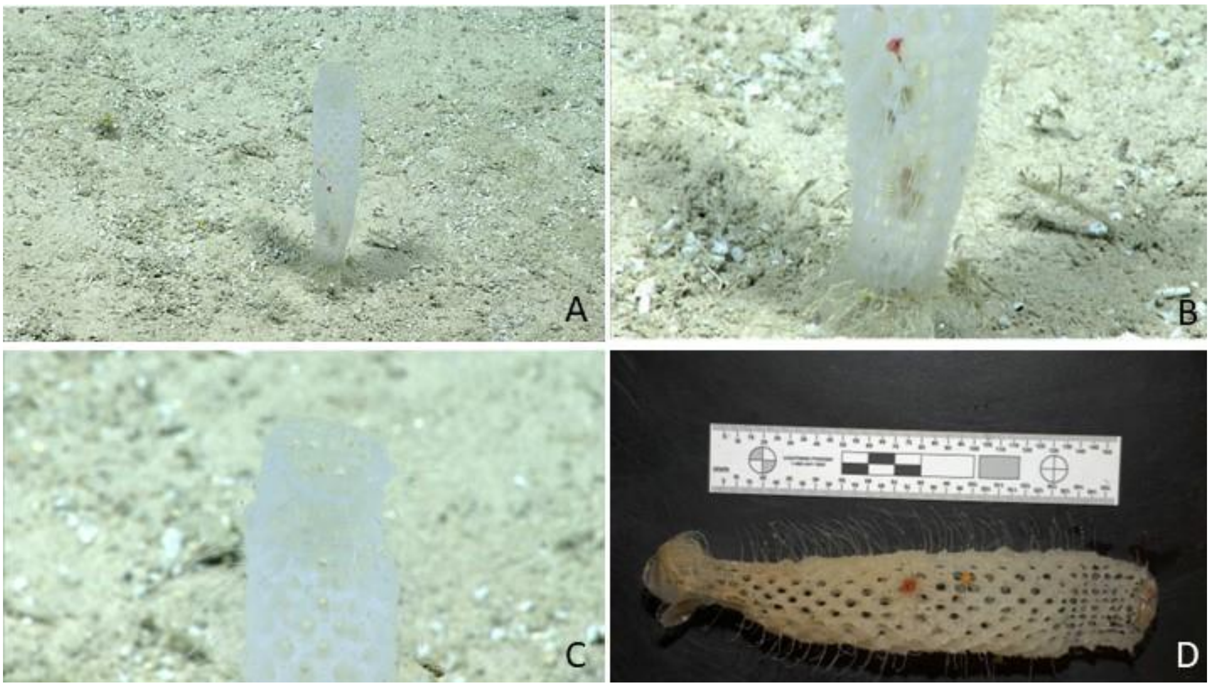


Figure 95 *Euplectella cf. suberea in situ* External morphology. A. Specimen USNM 1673614 collected during Expedition EX2206 (ROV Dive D01 Sample 03B) at João Valadão Ridge, 2120.97 m depth. B. and C. *in situ* Zoom images of external base and upper shape; D. Specimen ex situ, after collection.

**Spicules:** Dermalia are hexactines. Atrialia are pentactines. Choanosomal spicules are pentactines and diactines. Microscleres are floricomes (Figure 96).

**Remarks:** *Euplectella suberea* is the well-known species in the North Atlantic (Tabachnick and Collins, 2008). Besides the similarity in the shape and microscleres type, there are some difficulties in distinguishing species of *Euplectella*, and measurements should be taken for comparisons before assuming it is the wide distributed a *E. suberea* or a different species (see description Tabachnick and Colins, 2008; Tabacknick and Menshenina, 2013). In the present work few microscleres were observed, and most of them were found broken, once these spicules are very small and fragile. More assessments of different material for an accurate comparison should be attempted.

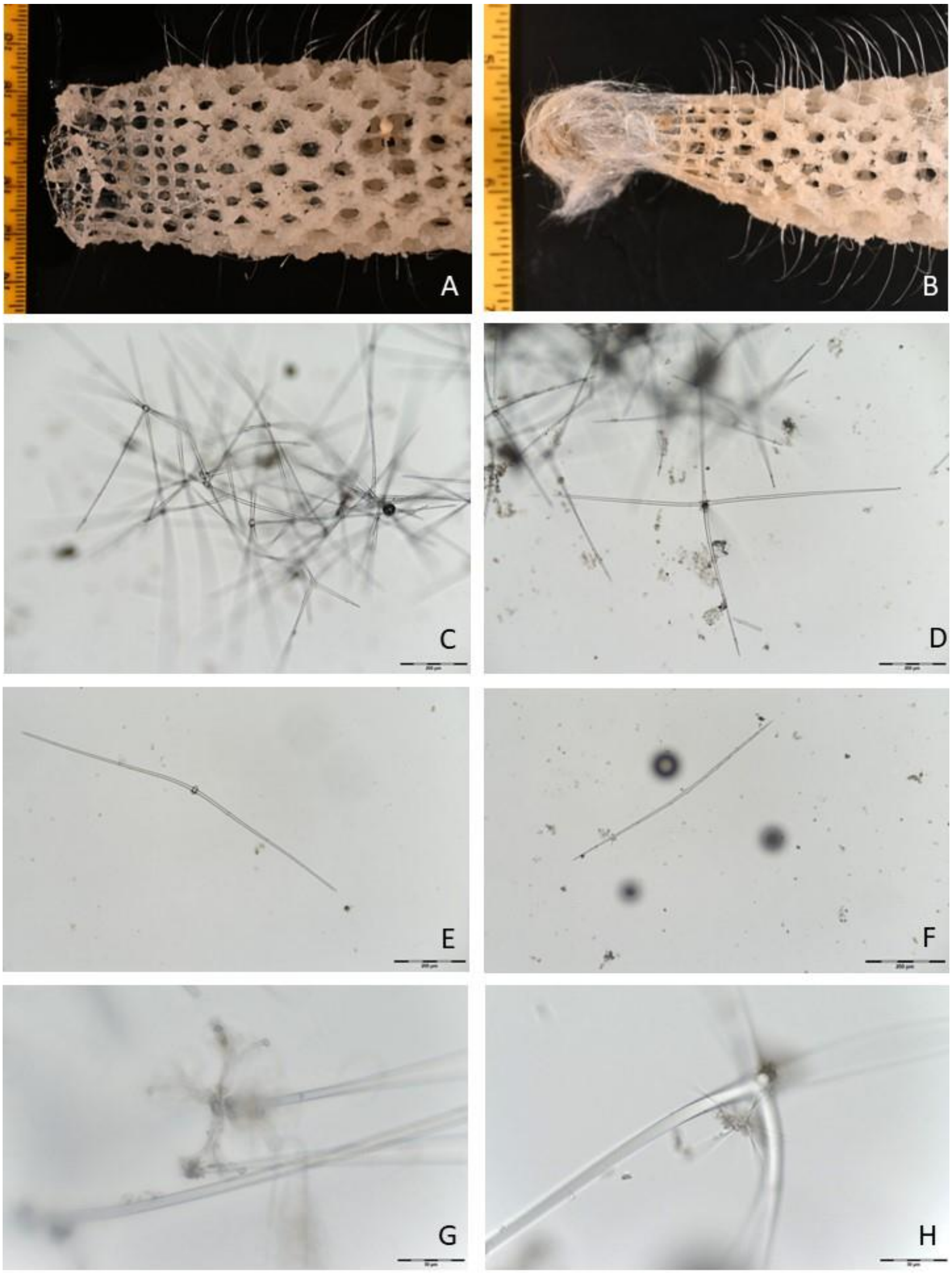


Figure 96 *Euplectella cf. suberea ex situ* A. upper view showing the top sieve-plate; B. basal view showing tuft of basalia; spicules. C. Hexactines; D. Pentactine; E. diactine type 1; F. diactine type 2; G. floricome; H. oxyhexaster laying over a pentactine.

**Habitat and distribution:** Bellow 1,500 m. Inhabits deep bathyal areas of the MAR ridges and seamounts.

### Subfamily Corbitellinae

### *Regadrella* spec. nov.

### AphiaID

**Material examined:** C10874, Local: Great Meteor at 906 m, Expedition ATHENA M151, ROV MARUM-SQUID (Sample GEOB23429 #7).

### Morphological description

**External morphology:** Corbitellinae of 'venus flower basket' form. An euplectelloid barrel-shaped tube. Body is saccular with numerous lateral oscula and with colander-like sieve-plate or with radically directed beams of prostralia oscula. Attached directly by its basal part (basiphytose). Body length is approximately 140 mm and wall thickness vary between 1-2 mm at thinner areas and 4-6 mm in thicker wall zones. Sieve plate diameter is about 45 mm type. Sieve plate mesh has triangular, polygonal and oval meshes. Parietal oscula are irregular with a variable diameter (Figure 97).

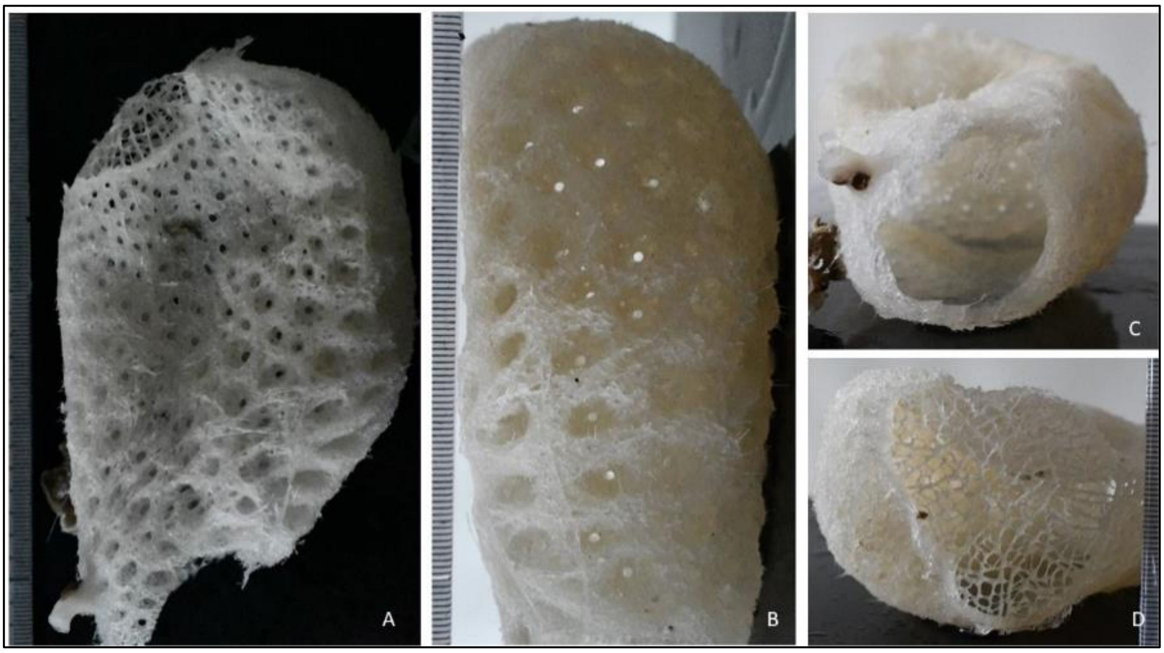

**Figure 97** *Regadrella* spec. nov. *ex-situ* External morphology. A. Specimen C10874 – Great Meteor (906 m depth). Entire specimen body shape and size; B. Parietal oscula; C. Basal disc; D. Sieve plate.

**Spicules:** Primary spicules are large and thick choanosomal hexactines, atrial pentactins and central and sieve part with diactines (see descriptions in Reiswig and Kelly, 2018; Tabachnick, 2002).

Different ray ends tips (rough, smooth or sharp), shapes and width/lengths were observed. Choanosomal spicules are predominately diactines with additional hexactines and other hexactine derivatives. Prostalia lateralia, if present, are giant hexactines. Dermalia are hexactines. Atrialia are pentactines. Microscleres are floricomes, onychohexasters, hexasters or staurasters and thick hemionychohexasters. No graphiocomes were noticed (Figure 98,Figure 99).

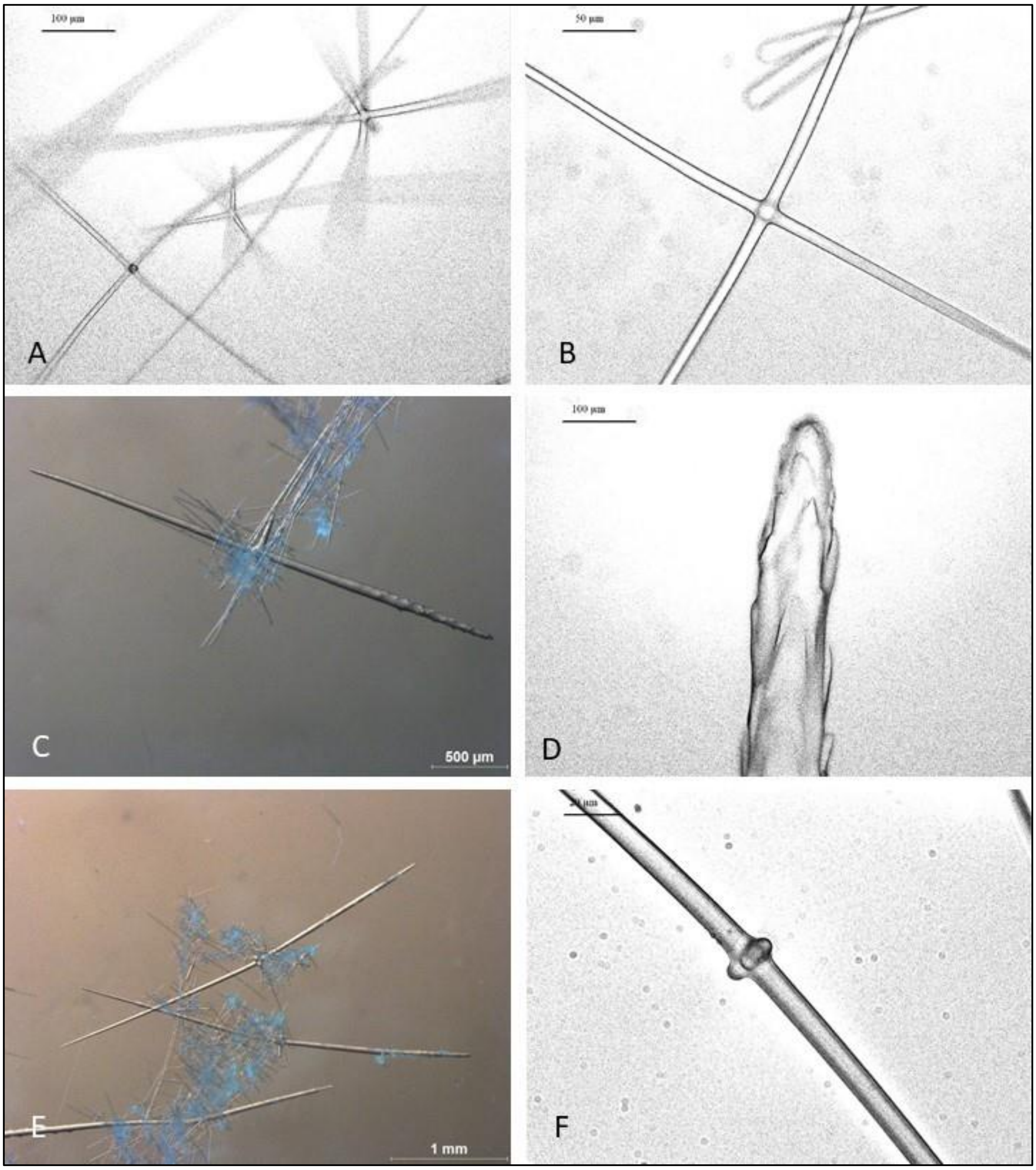


Figure 98 *Regadrella* spec. nov. Spicules. A. Hexactins; B. Pentactin; C. Pinular Hexactin; D. Pinular Hexactin outer end; E. Diactins; F. Diactin enlarged cross center.

Remarks: Microscleres are onycohexasters and floricomes. They are both rare. Floricomes primary rays have sigmoid shape. Hemionycohexasters (onychaster) rays thickness are thicker (Figure 99 D) than the ones described in Tabachnick, 2002. This feature might be representative of a new species (Domingos, *et al.* 2023 *in prep*). More preparations should be made to address this question. No measurements of rays thickness was taken by Tabachnick, 2002 and Boury Esnault, 1994 neither by Reiswig and Kelly, 2018. However, none of these authors have documented such a thick and stout hemionycohexaster on their *Regadrella spp.* descriptions. Absence of graphiocomes is also a distinguishable feature.

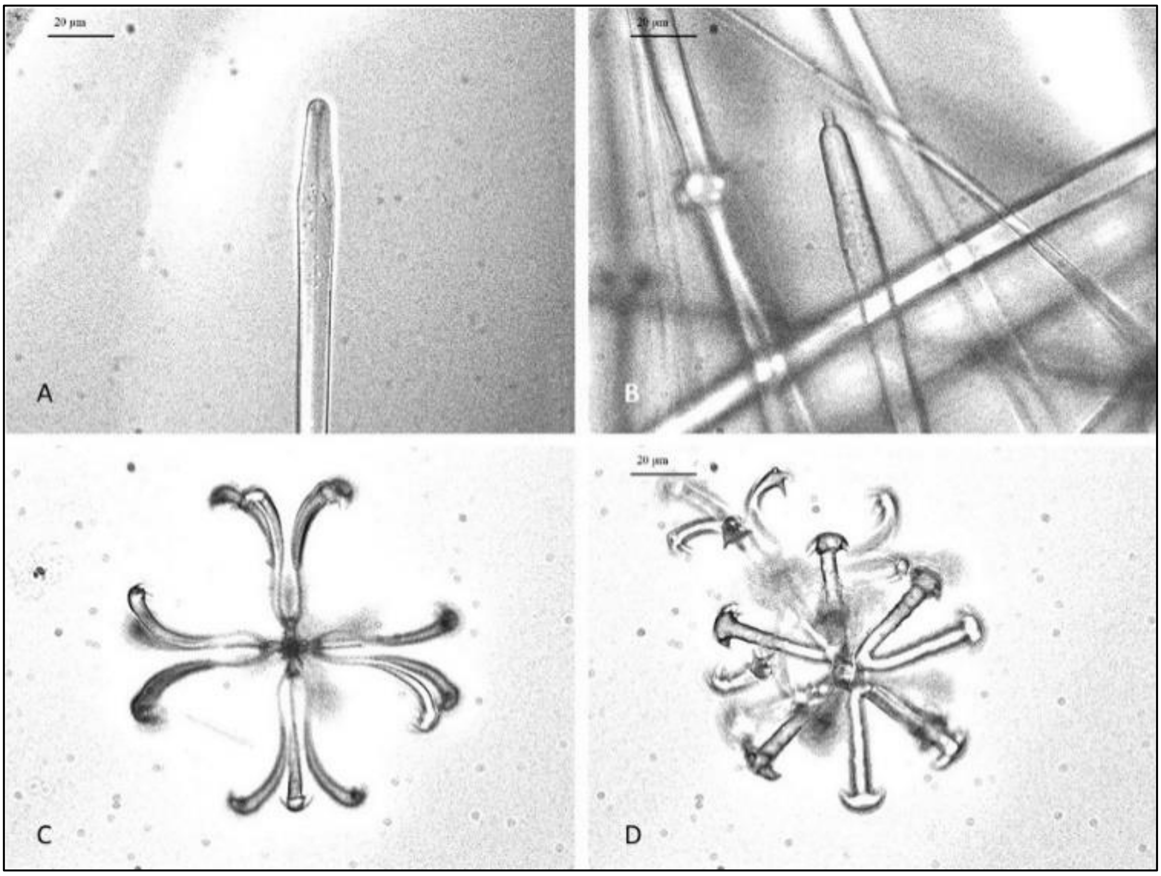


**Figure 99**. *Regadrella spec. nov. Spicules.* A. and B. Outer ends of Choanosomal Diactins; C. Floricome; D. Thick hemionychohexaster.

**Habitat and distribution:** *Regradella phoenix* is found attached to hard substrate at depths 352 –3200 m. Cosmopolitan (Boury-Esnault, *et al.* 1994; Tabachnick, 2002). However, the *Regadrella* new *sp.* examined in this work shows that many times that attributing identifications of "wide distributed" and "cosmopolitan" species might be misunderstood, generating biased data.

*Family Farreidae*

*Farrea occa* Bowerbank, 1862

AphiaID 134391

**Material examined:** C10013 - Expedition BlueAzores 2018 (18ST.03.03.02), ROV Dive 02, Local: NP6 (03.06.18).

Morphological description

**External morphology:** Small stock of branching tubes in one large fragment. Texture rigid, color white. Fine longitudinal lines from reticulate skeleton visible at upper edges of branches otherwise covered with tissue (Figure 100 B). Choanosomal skeleton is a dictyonal framework of one mesh; mesh is square or rectangular, but also triangular (Figure 100).

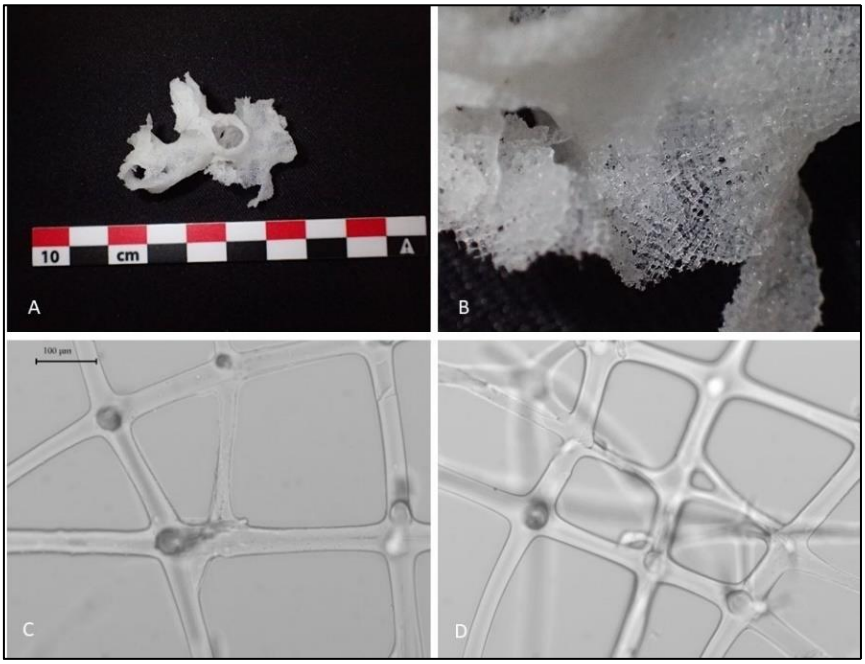


Figure 100 *Farrea occa ex situ*. External morphology: A. Specimen after collection; B. Zoom image of the dictyonal framework of the same specimen; Internal morphology: C and D. Dictyonal framework, smooth beams and spur.

Spicules: Ectosomal skeleton is a reticulation of pentactine megascleres with overlapping tangential rays in the surface planes; clavules radiate head-outwards along the pentactin proximal rays; pointed tips of uncinates project vertically from the surfaces; microscleres are located in or just below the surface tissues. Megascleres are pentactins, pileate and anchorate clavules and uncinates. Microscleres are oxyhexasters. Discohexasters were not observed. Anchorate and pileate forms differ slightly from Lopes *et al.* 2011 revision concerning to the presence of some spines bellow the sat the hooked anchorate forms (Anchorate clavule type 1, Figure 101 A and B) which are similar to *F. aculeata*. The anchorate Type 2 show a cusped tip and some spines ornamentation bellow the head seems this type does not have any representative in literature. The pileate forms Type 2 also differ slightly showing a cusped tip. Pentactines present two types, Type 1 with smooth spination and Type 2 with coarse spination. Uncinates vary in thickness and length, but usually have long barbs. Oxyhexasters also present two types, one with the same size of rays (Figure 101 K) and other with long primary rays (Figure 101 L and M). However, more spicules preparations should be made to address possible differences (cryptic species *Farrea occa* complex) between ornamentation of clavule heads, discohexasters absence and size variation of primary and secondary ray length ratio (Figure 101).

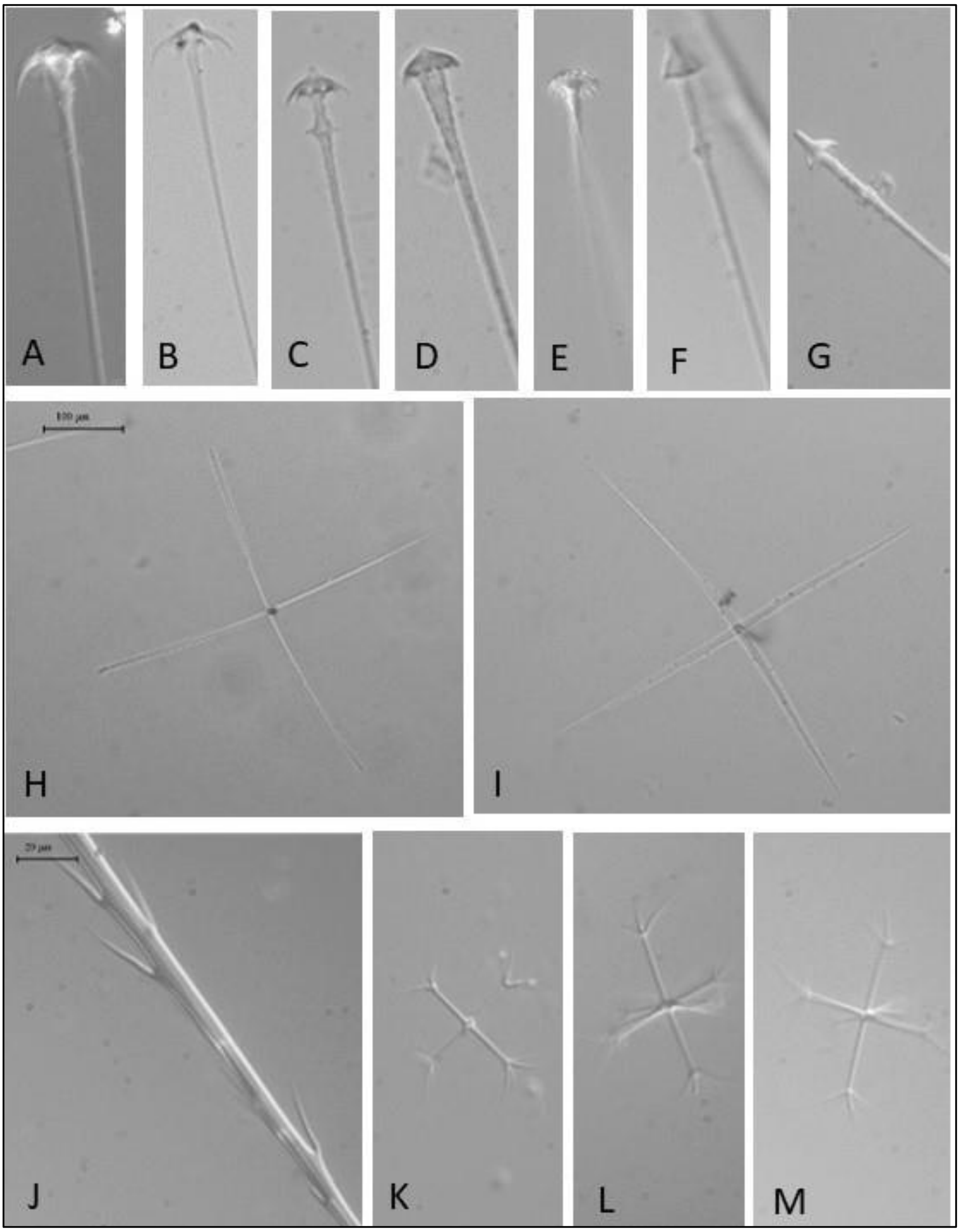


**Figure 101** *Farrea occa* spicules. Megascleres. A. and B, Upper part of anchorate clavule Type 1; C. Upper part of anchorate clavule Type 2; C. Anchorate clavule Type 2; D and E, Upper parts of pileate clavule Type 1; F and G, Upper parts of Pileate clavule Type; H and I Pentactins; J. Uncinate zoomed part with spines; Microscleres: K, L and M. Oxyhexasters.

**Habitat and distribution:** Attached to hard substrate, muddy sediments, coral rubble. Depth range at Azores Region: *Farrea occa occa* – Cosmopolitan: Northeastern Atlantic (Azores, Portugal, Ibero-Moroccan Gulf, Madeira, Canary Islands), West Indies (US Virgin Islands), southwestern Atlantic (Rio de Janeiro), northwestern Pacific (Japan), northeastern Pacific (British Columbia, Washington, California), mid-Pacific (Hawaii), southwestern Pacific (Kermadec Islands, Philippines), western Indian Ocean (Comores), mid-Indian Ocean (Bay of Bengal, Andaman Islands, Sri Lanka, Sumatra), Indonesia, southwestern Australia, Antarctica; 523–3018 m (see Lopes*, et al.* 2011; Reiswig and Kelly, 2011).

*Farrea laminaris* Topsent, 1904

AphiaID 134390

**Material examined:** C11756 - M128 Meteor (Station 810, ROV DIVE 403, Sample 03) at Rift of Princesa Alice Bank (38º11.845' N; 29º33.644') at 2414 m.

Morphological description

**External morphology:** Blade like sponge with folded lateral margins. Type species was described by Topsent in 1904 and re-described in 1928. Lately, Reid (1958) found it in fossil sponge. During MARECO Expedition, Tabachnick and Collins (2008) found several small and poor-quality fragments of a sponge that they have described similar to *F. laminaris* but with some differences (Figure 102, Figure 103).

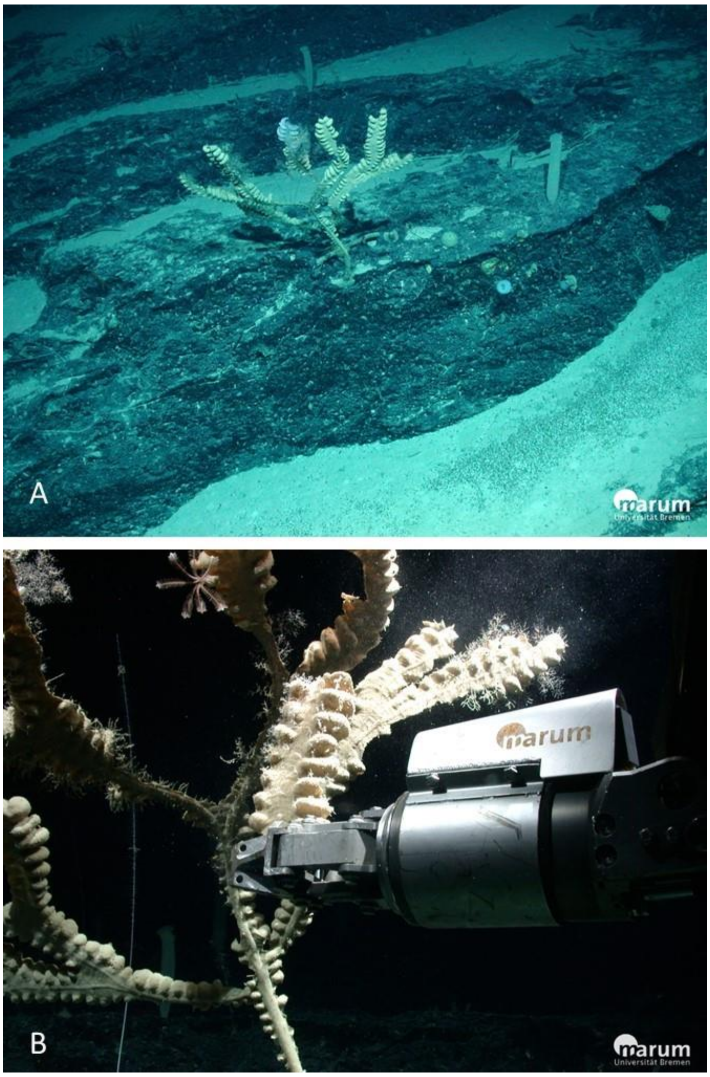


**Figure 102** *Farrea laminaris in situ* external morphology. A. Specimen C11756; B. Sampling event close-up.

**Spicules:** The analysed material resembles Topsent description. The pentactins are thick and strongly curved below, ornamented with small spines to bigger ones at the edge. Straight clavules with a disc bordered with small teeth (Figure 104).


**Figure 103** *Farrea laminaris ex situ external morphology.* A. Specimen C11756; B. and C. Zoom image of the dictyonal framework of the same specimen.

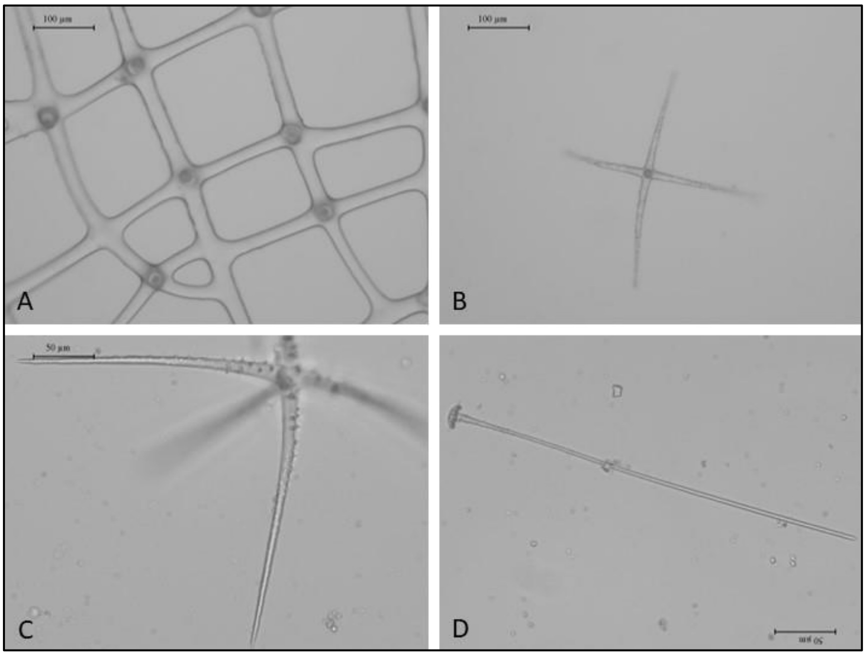


**Figure 104** *Farrea laminaris* spicules. A. Dictyonal framework; B. Dermal pentactin; C. Dermal pentactin detail; C. Clavule.

**Remarks:** At the original description, unequal uncinates with barbs and two types of discohexasters (rare) were noticed. However, in our preparations the two types of discohexasters and uncinates were not observed. Replication of observations should be attempted to address this question.

**Habitat and distribution:** Volcanic vase sable. Abyssal. It is known only one specimen (original description) caught at 3018 m depth (campaign 1902, St. 1318, Lat: 38º06 N, Lon: 26º13'45 W) by the Hirondelle (Topsent, 1904). As Tabachnick and Collins (2008) found only a few fragments and they assumed it might be a new sub-species based on the differences found. The specimen analysed in this work is the second record caught in the Azores at 2414 m.

### Farreidae *sp1 "*lacking sceptrules"

### AphiaID 131689

**Material examined:** Specimen USNM 1674029 collected during Expedition EX2206 (ROV Dive D09, Station 04B) at Cachalote Seamount (39.9706 N; -31.9706 W), 1498.53 m depth.

### Morphological description

**External morphology:** Intact material observed during the ROV dive is a lamelate sponge with marginal undulation blades. Colour white, in alcohol beige (Figure 105,Figure 106).


**Figure 105** Farreidae sp1 *in situ.* External morphology. A. Specimen USNM 1674029 collected during Expedition EX2206 (ROV Dive D09 Sample 04B) at Cachalote Seamount, 1498.53 m depth; B. and C. Zoom images of external shape; D. ex situ image of the specimen after collection.

**Spicules:** The primary framework is a typical farreoid one-layer, two-dimensional mesh of smooth beams. Blade thickness increases gradually toward the axis by addition of layers, some in regular others in irregular arrangement. Channelization is absent. The species has both low diversity and density of loose spicules. Megascleres consist of large pentactins and long thin unciantes. Pentactins present heavy spination on outer and lateral surfaces. The only microsclere type is a relatively scarce oxyhexaster. Farreid without sceptrules (clavules, scopules, aspidoscopules and sarules) (Figure 106).

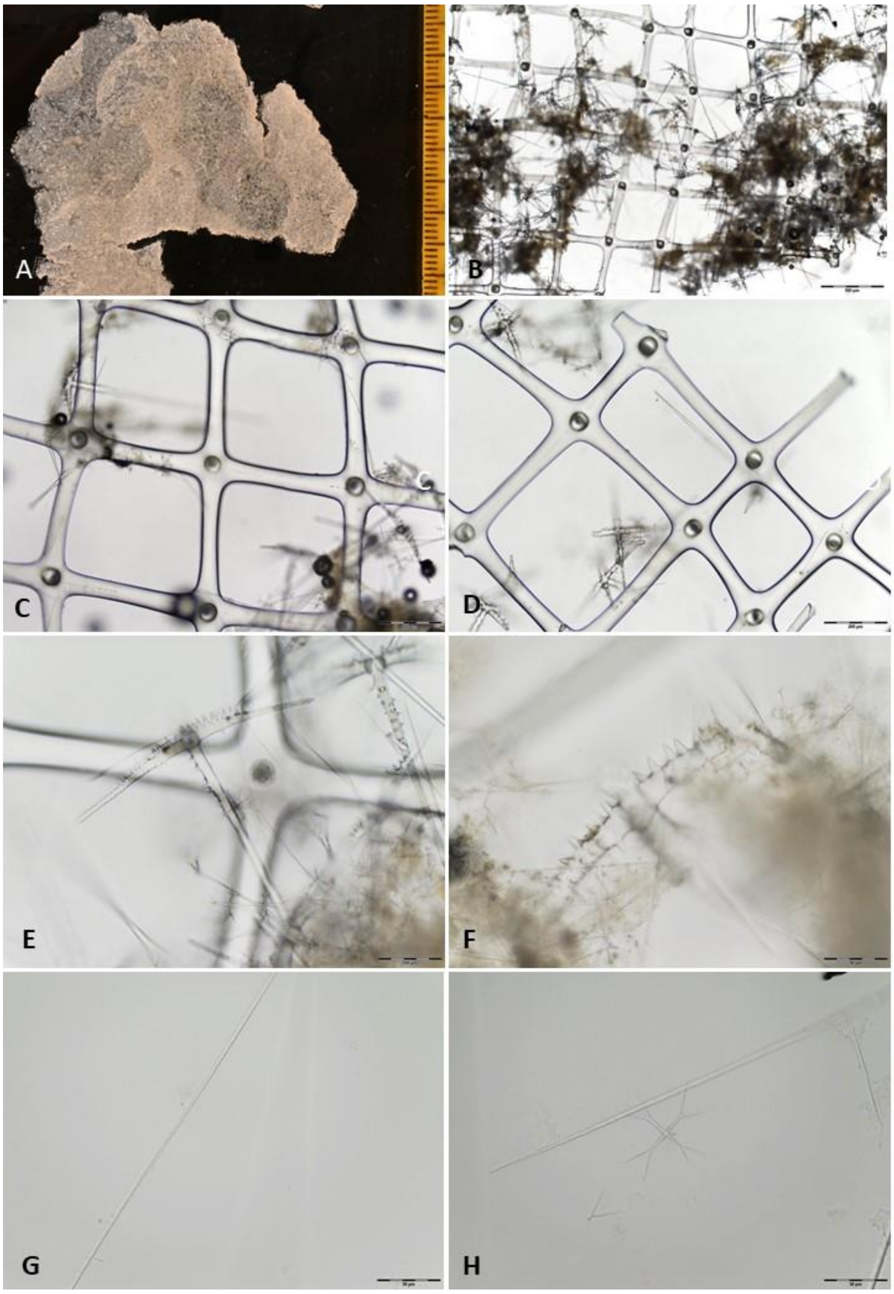


**Figure 106** *Farreidae sp1. A.* Fragment of specimen USNM 1674029 showing surface. Spicules: B. Frontal view of single-layer primary framework showing regular arrangement; C. framework close-up showing smooth beams; D. framework showing irregular arrangement; E. surface pentactins; F. close-up of pentactins showing coarse tubercules or spines; thin uncinate; H. oxyhexaster.

Remarks: Duplessis and Reiswig (2004) have erected a new genus *Asceptrulum* in the Farreidae family, with only one species recorded so far, *Asceptrulum axialis* collected at 2387 m on the Juan de Fuca Ridge (mid Indian Ocean). In this work they document the complete absence of sceptrules and one-layered farreoid framework. Regarding this the diagnosis of Farreidae was emended to encompass the new genus. The only difference is the presence of oxyhexasters in the Azores specimen instead of discohexasters in the *A. axialis* (see Duplessis and Reiswig, 2004). More work should be done to be sure that the material observed in this work belongs to the same genus regarding the geographical distance. However, until this moment, it seems plausible that this is the only genus where we can accommodate this species, but without complete certainty we provisional assign it to Farreidae sp1.

Habitat and distribution: Nearly at 1,500 m. Inhabits deep bathyal areas of the MAR ridges and seamounts.

*Family Leucopsacidae*

***Oopsacas cf. minuta***

AphiaID 134408

Material examined: Specimen USNM 1673615 collected during Expedition EX2206 (ROV Dive D01, Station 05B) at João Valadão Ridge (38.16 N; -26.2364 W), 2046.78 m depth.

Morphological description

External morphology: Oopsacas with a saccular body form. Ovoide in shape with smooth surface and rather thicker walls. Single oscula. Texture soft and delicate. Colour is white I live conditions and after preservation in alcohol (Figure 107,Figure 108).

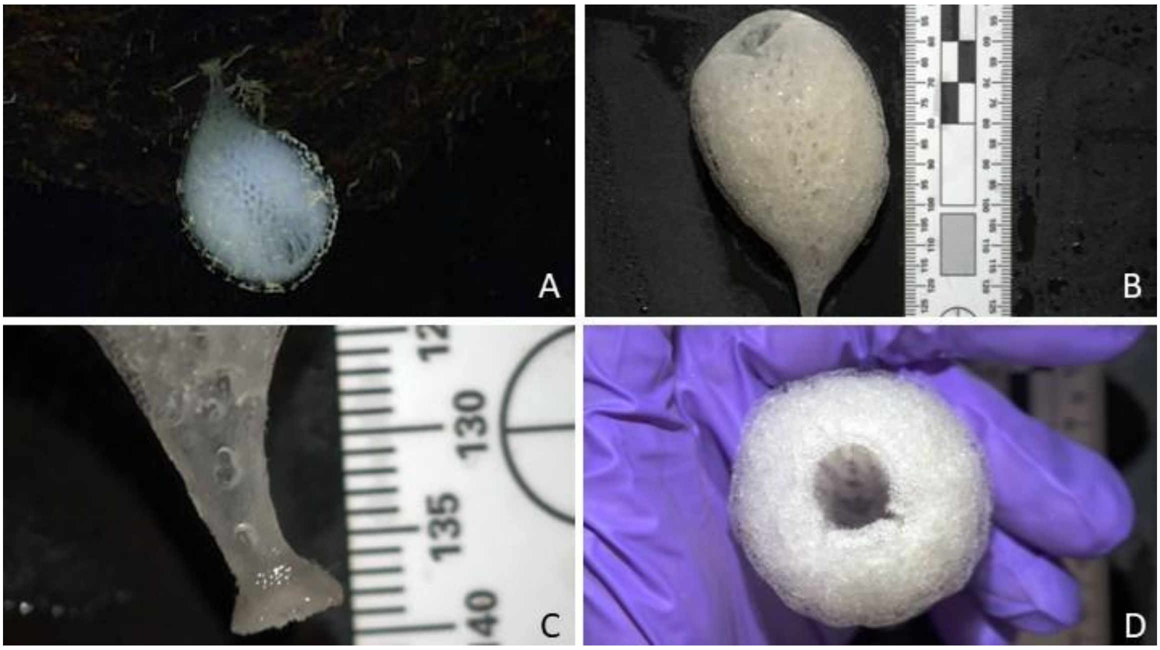


**Figure 107** *Oopsacas cf. minuta in situ.* External morphology. A. Specimen USNM 1673615 collected during Expedition EX2206 (ROV Dive D01 Sample 05B) at João Valadão Ridge, 2046.78 m depth. B., C. and D. *ex situ* after collection*:* B. upper saccular shape; C. basal part showing peduncle for attachment to substrate; D. top view showing oscule.

**Spicules:** Choanossomal skeleton is mainly formed by hexactins whose rays are slightly rugose. Dermalia with smooth pentactins. Presence of diactins. Microscleres are spherical thin onychohexasters only (Figure 108Figure 108).

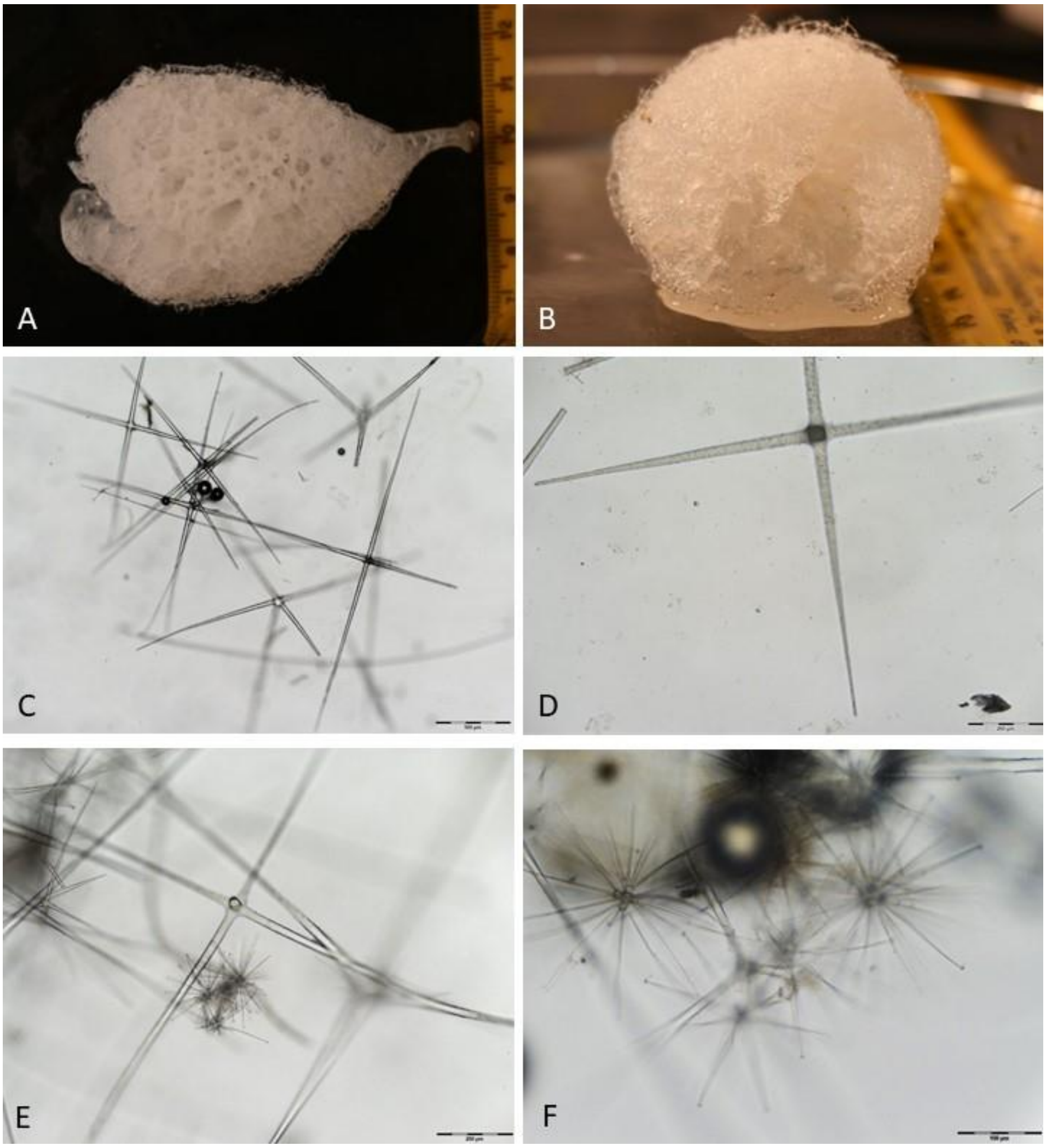


Figure 108 *Oopsacas cf. minuta.* Specimen USNM 1673615 *ex situ,* after preservation in alcohol. A. lateral view showing apertures or inhalant/exhalant canals; B. oscula view; Spicules: C. Choanosomal hexactins, pentactins and stauractins; D. rugged stauractin; E. hexactins and onychohexasters; F. thin onychohexasters close showing terminal rays.

**Remarks:** The only recorded species from *Oopsacas* genus determined at the Atlantic is *O. minuta* Topsent, 1927. The material observed in this study matches the spicules types of *O. minuta*. However, Topsent (1928) documented a much smaller specimen with 5 mm, whereas in marine caves in the Mediterranean where foun with nearly 70 mm (Pansini, et al. 2011). To confirm the specimen collected at 2046 me at the João Valadão Ridge, measurements and molecular analysis should be assessed. Although, this represents the deepest and largest specimen of Oopsacas genus found in the Atlantic lower bathyal ecosystems.

**Habitat and distribution:** *Oospecies minuta* is Atlanto-Mediterranean and can live from caves at 30 m to bathyal areas, with deepest records at 2913 m.

*Massive sponges - Class Demospongiae*

Subclass Heteroscleromorpha

*Order Tetractinellida*

Suborder Astrophorina

Family Geodidae

*Geodia* spec. nov.

Aphia Id 132005

Material examined: C2184 collected at Graciosa between 651-700 m with Arquipelago and C10034 collected at Pico during Blue Azores Expedition 2018.

### Morphological description

External morphology: Thickly encrusting, massive or globular Geodiidae with a well-developed double-layered cortex. Ectocortical microscleres are oxyasters, oxyspherasters or spherasters, commonly with cortical oxeas. Endocortical microscleres are spheroidal or ellipsoidal sterrasters. Megascleres are oxeas and medium to long-shafted orthotriaenes, plagiotriaenes, dichotriaenes, anatriaenes and protriaenes. Triaenes radiate relatively strictly from the choanosome with the cladome positioned perpendicular to the base of the cortex, and/or just below the surface, and may also extend beyond the surface. Choanosomal microscleres are oxyasters (modified from Sollas, 1888; Cárdenas *et al.*, 2010) (Figure 109,Figure 110).

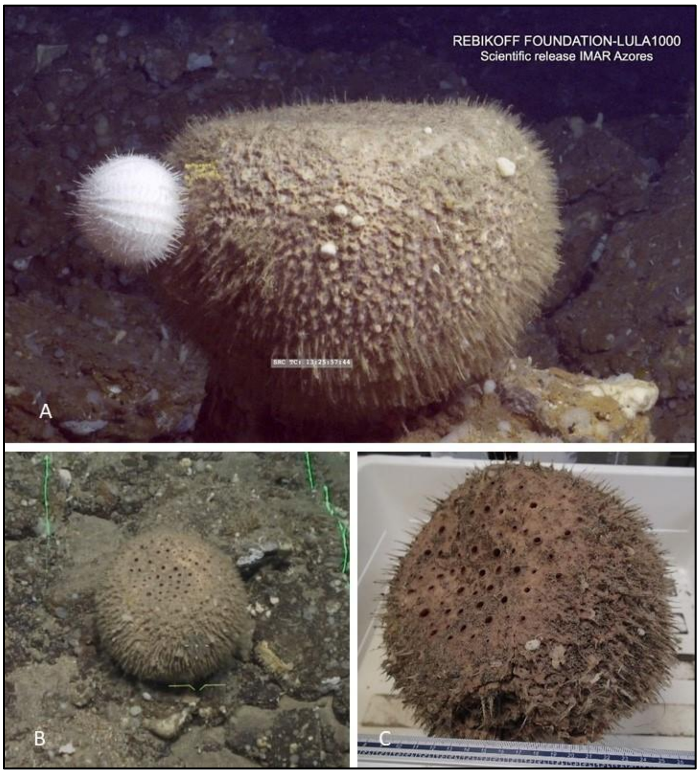


**Figure 109** *Geodia* spec. nov. *in situ*, A. Image taken by Rebikoff Foundation during a Lula submersible dive; B. Specimen 10034, *in situ* image, collected at 615 m depth (BAz Exp. 2018, Luso ROV Dive 5); C. Specimen 10034 *ex-situ,* image on-board.


**Figure 110** *Geodia* spec. nov. *ex situ* external morphology. A. Specimen 2184 collected with *by-catch* at Graciosa Island at 651 m depth, during "Demersal Cruise 2007" Expedition with R/V Arquipélago; B. Cut section; C. Oscules; D. Oxeas.

Specimens are massive-globose, very large varying from subspherical to spherical. The specimen 10034 has nearly 16 cm in diameter; however, specimen 2184 has a much larger dimension, nearly 50 cm in diameter. Consistency is firm. Colour *in situ* and *ex-situ* is brown and beige internally. It has more than 50 oscules (inhalant) on the top surface (diameter approx. 0.5-1 cm), or cribriporal pores (exhalant) all over the rest of surface (diameter approx. 0.5 cm). The surface is highly hispid with abundant and very large bundles of oxeas and styles.

Spicules: There is a three-layered cortical skeleton. Dense radially disposed bundles of large oxeas cross the entire cortex, masking the presence of cortical styles, which are protruding beyond the surface of the sponge. The upper layer is formed by these great amounts of cortical bundles of large oxeas and styles and is characterized by intense brown pigmentation. The other two layers are intermediate. The cortical skeleton is very densely packed by sterrasters underlying the choanosome. This dense crust is about 5-6 mm thick layer decreasing in density towards the interior. Large amounts of oxyasters are found among the sterrasters below the thick sterrasters layer, together with orthotriaenes radially arranged supporting the whole cortex and the rahbdome deeply inserted in the choanosome. The choanosomal skeleton is formed by large amounts of densely packed oxeas, radially or confusedly distributed. Although, scarce anatriaenes are present.

Megascleres: Cortical styles extremely slender or variably robust. Cortical oxeas very large and robust. Subcortical large orthotriaenes. Cortical sterrasters. Choanosomal oxeas (4127-4778 x 61-65 μm). Extremely variable in shape and size, slender or robust; straight, variably bent or sinuous. Occasionally styles (3297 x 35 μm), styloids or strongyloxeas (Figure 111).

Sterrasters are large, subspherical but also sometimes rounded (175-226 X 141-194 μm), spiny or rounded rosettes development forms can be present (immature, euaster stage). Hilum with nearly 10 μm in diameter. Mature sterraster rosettes are smooth and can present successive development forms too (Figure 112Figure 113Figure 114Figure 115).

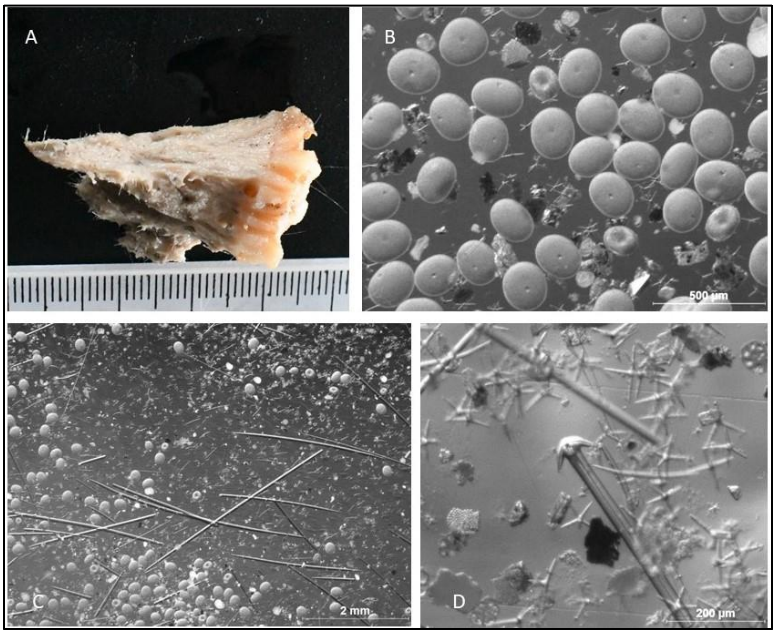


Figure 111 *Geodia* spec. nov. Specimen 10034. A. Fragment showing a thick section with the cortex measuring nearly 0.5 mm; Stereo microscope images showing: B. Sterrasters, Oxyasters and Microxeas; C. Oxeas Type I and II, Styles and Sterrasters; D. Anatriaene and oxyasters.

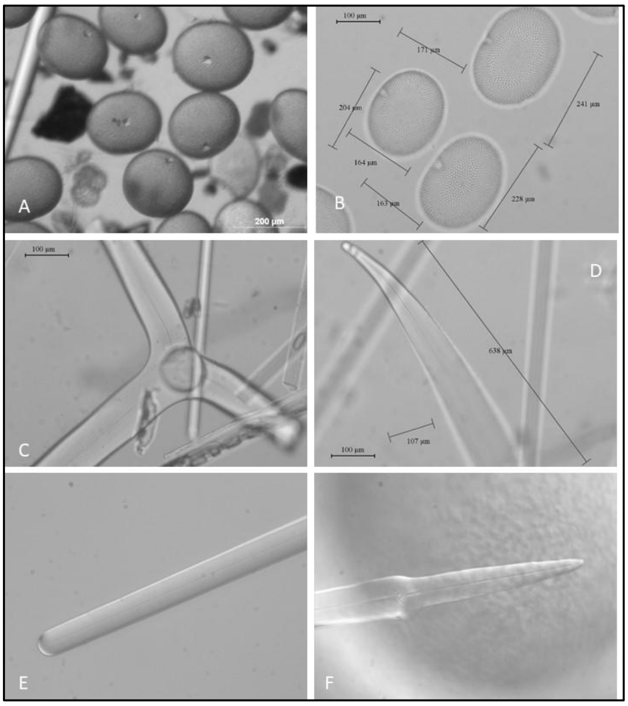


**Figure 112** Geodia spec. nov. spicules. Specimen 10034. A. Sterrasters shapes spherical/subspherical; B. Sterrasters length/width of the most abundat type (subspherical); C. Orthotriaene cladome, D. Orthotriaene deuteroclad length; E Style round top tip; F. Style sharp tip end.

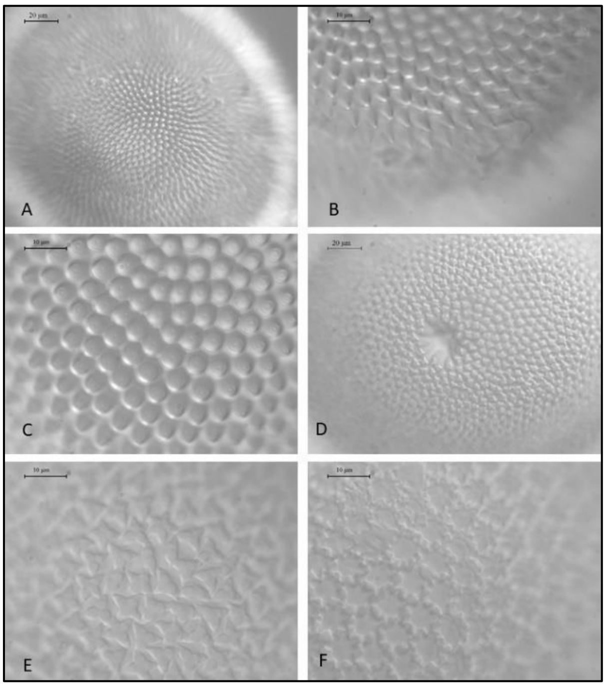


**Figure 113** Geodia spec. nov. spicules. Specimen 10034. Surface of sterraster rosettes: A. Immature spined rosettes; B. detail of immature sterraster at euaster stage with spined rosettes; C. Detail of rounded immature rosettes; D. Mature sterraster with smooth rosettes, close-up showing the central hilum; E. Mature sterraster with smooth rosettes early-stage; F. Mature sterraster with smooth rosettes late-stage.

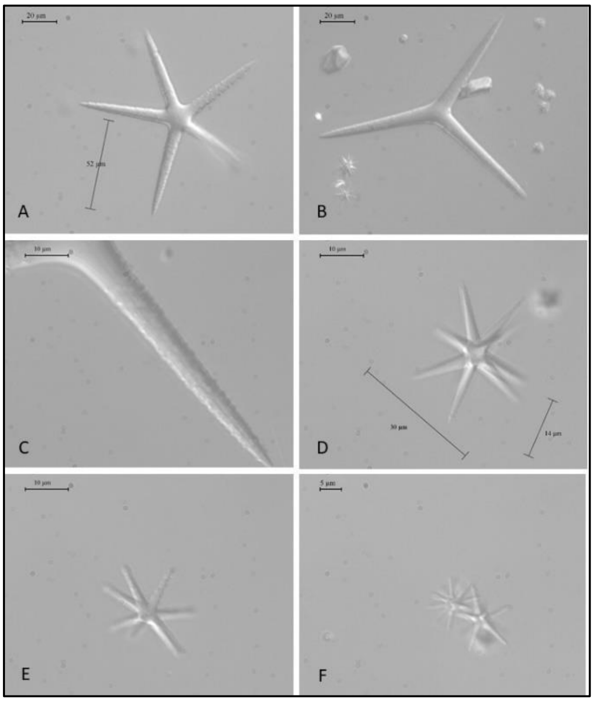


**Figure 114** *Geodia spec. nov.* spicules. Specimen 10034. A. Oxyaster I with 5-6 actines; B. Oxyaster I with 3-4 actines; C. Oxyaster I actine close-up roughed; D. Oxyaster II with 9-10 smooth actines; E. Strongylaster with 8-9 roughed actines; F. Oxyasters III (same as Strongylasters but smaller?).

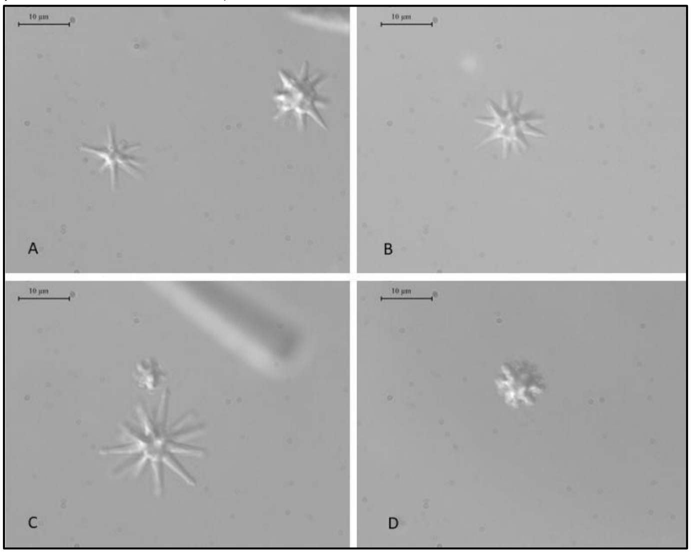


**Figure 115** Geodia spec. nov. spicules Specimen 10034. A. Oxyaster III and Oxyspheraster; B. Oxyspheraster; C. Strongylaster; D. Strongylospheraster.

**Remarks:** It was previously (ROV video assessments, data before 2023) misunderstood with other species with the same external morphological characteristics, such as *Tetilla (Craniella) longipillis*, because it is brown globular and “hairy”, as it is described in Topsent (1904). However, only with spicules we could determine the genus *Geodia sp*.. The presence of sterrasters is the genus most important diagnostic character. The same spicules types from specimen 10034 were observed on the specimen 2184. At this point we have only described the spicules types found in the two collected specimens, for a complete description more preparations should be made to access the bigger spicules and take more measurements. Most of the megascleres (Styles, Oxeas

Type I and Orthotriaenes) were found broken at first "instant" preparations. Once we know the existent spicules types, a deeper study should be conducted to properly describe this species.

Comparing *Geodia* spp. for the North Atlantic spicules complement types to the specimens 10034 and 2184 analysed in this study, the most similar is *Geodia megastrella,* regarding the possession of Oxyasters Type I (see Carter, 1876; Topsent, 1911; Cárdenas, 2015 and 2019). However, new questions arise regarding the presence of very large Oxeas Type I and Styles. Notwithstanding, the presence of spherasters (oxyspherasters and strongylospherasters) are considered very important for diagnostic characters in the genus species differentiation (see diagnostic key in Sim-Smith and Kelly, 2015, for New Zealand *Geodia spp.*).

More work should be done to complete the description. This study is an opportunity to revise the *Geodia spp.* of the Azores. Compare with *Geodia megastrella*, which is considered a species complex (Xavier, *pers. comm.*). We should stress here that specimens without spherasters and/or large oxyasters can be confirmed to be the same species as happens with *G. nodastrella (*Cárdenas, et al. 2015). A genetic study should be accomplished together with other comparative material (*G. megastrella* holotype and other type locations). We have found that differences in external morphology and spicules arrangement are distinguishable from other all other *Geodia spp.* recorded at the Azores.

**Habitat and distribution:** It is frequently in a sparse distribution. Usually associated with hard grounds, but it was observed in soft bottoms as well. It is massive, so other taxa (hydroids, urchins, etc) can use it as substrate to attach. It is very common once it has been recorded (see video imagery datasets) all over the Azores Region bathyal slopes.

### *Family Pachastrellidae*

*Characella pachastrelloides* (Carter, 1876)

Aphia ID 170240

**Material examined:** C9568 specimen collected at Atlantis Smt. At 500 m depth, with R/V Arquipélago; C10129 and 10130, specimen collected at Gigante Bank at 476 m and 464 m depth respectively (St. 50, ROV Luso, Exp. Blue Azores, 2018).

#### Morphological description

**External morphology:** The variability of the body form and texture of the individuals is remarkable. They range from columnar cylinders (spec. 10129, Fig. 32. A.) to arborescent (spec. 10130, Fig. 32. C), but also massive shapes such as crateriform (not sampled in this study). The pattern of hispidity also varies from strongly hirsute to smooth (Figure 116).


**Figure 116** *Characella pachastrelloides* external morphology. A. specimen 10129, "tubular" shape; B. specimen 10129 fragment showing the skeletal architecture of the cortex and choanosome; C. specimen 10130, "arborescent" shape; D. specimen 10130 fragments thick sections showing cortex and choanosome.

**Spicules:** In *C. pachastrelloides* the spicule set consists of large Oxeas with fusiform shape (2063 x 59 **μ**m), dichotriaenes (?), short-shafted orthotriaenes, microxeas in two sizes (Type I: 151-207 x 5-7 **μ**m; Type II: 32-43 x 3-4 **μ**m) and amphiasters. Smaller microxeas can be styles and uniformly spiny. Anatriaenes were absent at the observed material (Figure 117,Figure 118).

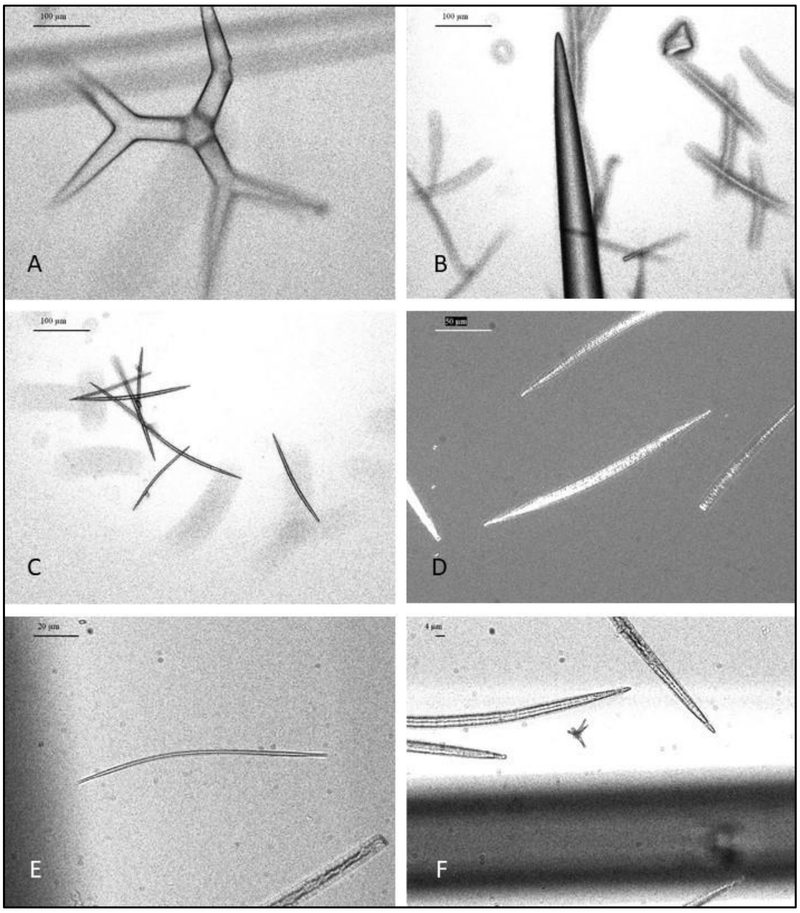


Figure 117 *Characella pachastrelloides* spicules. Specimen 10129. A. Dichotriaene; B. Oxea; C. and D. Microxeas Type I; E. Microxea Type II; F. Amphiaster.

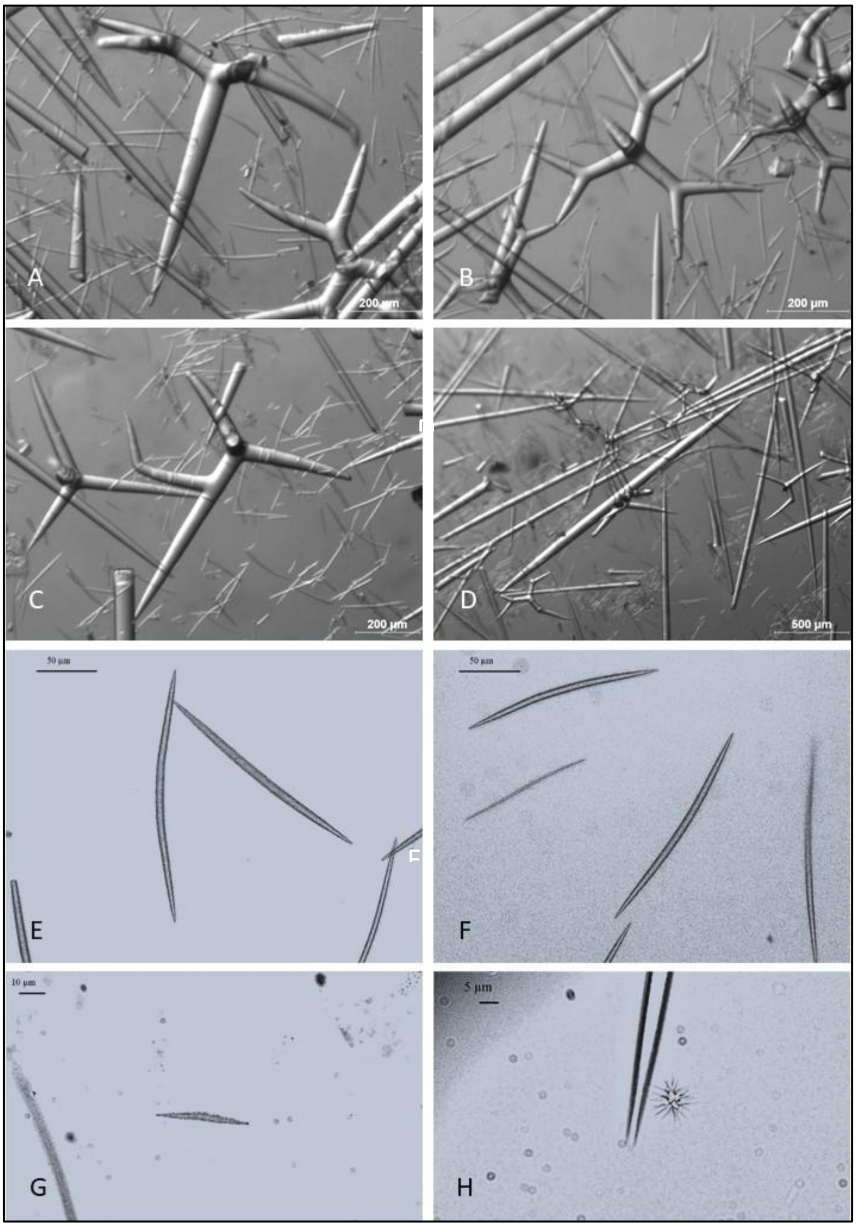


**Figure 118** *Characella pachastrelloides* spicules. Specimen 10130. A. Dichotriaene rhabdome; B. Dichotriaene cladome; C. Dichotriaene mal-formed and Orthotriaene; D. Oxeas; E. Microxeas Type I; F. Microxea Type II; G. Small microxea; H. Amphiaster.

**Remarks:** Citing Maldonado (1996): "there is a significant variability in some morphological features of this species as well as in the composition of its tetraxonid spicule set. On the one hand, this could suggest that this taxon is actually a species complex but, on the other, microscleres are notably homogenous in shape and size. Variation in morphology is traditionally assumed to be a result of environmental variation. As for the variation in the tetraxonid set of spicules, the occasional presence of short-shafted dichotriaenes in some specimens has been traditionally considered as a result of the morphological variability inherent to calthrops-pseudocalthrops, and therefore lacking any taxonomic value". In Maldonado (2002) the presence/absence of dichotriaenes is subject to population variability. However, Dias *et al* (2019) creates statement differences between *Characella* species using presence/absence of dichotriaenes and/or orthotriaenes. Dias, *et al* 2019, also defines other characteristics, such as: presence of only one type of oxeas and the presence of plesiasters in other species of

*Characella spp*. This creates a controversy at genus primary assumptions (see the identification key to genera Maldonado, 2002) that differentiates from genus *Poecillastra sp.*. Once the actual state-of-art studies, using comparative morphological data and spicules discrimination for this species group revealed to be limited. Cardenas *et al.* (2012) has verified intra-specific variability of spicules and inferred about the validity of *C. tripodaria*. There is a substantial overlap of diagnostic features, which are not useful to validate the distinction of the Northeast Atlantic species of *Characella spp*. (e.g. *C. tripodaria, C. connectens and C. pachastrelloides*). More specimens and genetic data with methods involving molecular markers (DNA sequences of *C. tripodaria* and *C. connectens* are missing at GenBank) of the studied material should be used. This would facilitate the correct determination of specimens, including polymorphic or cryptic species.

Cardenas *et al.* (2012) has sequenced *C. pachastrelloides* from Norway/Scontland and Portugal/Spain, and besides some spicules differences (absence of anatriaenes), the genetic difference between north and south specimens is so small that does not justify the spitting of *C. pachastrelloides*, showing that this species might be cryptic.

**Habitat and distribution:** Bathyal seamounts slopes. Northeast Atlantic (Azores, Lusitanian, Canaries and Mauritanian); depth range 140-1804 m.

***Characella cf. tripodaria*** **(Schmidt, 1868)**

**Aphia ID 134066**

**Material examined:** C10018, specimen collected at Pico at 522 m (St. 07, ROV Luso, Exp. Blue Azores, 2018).

**Morphological description**


Figure 119 *Characella cf. tripodaria* external morphology. A. In situ image of *C. tripodaria* specimen 10018 (ROV Luso, BAz Expedition); B. Specimen 10018 on deck.

**Spicules:** Megascleres are Oxeas (1944-2307 X 19-32). Orthotriaenes (rhabdom 662-204 X 21-6 **μ**m, actine 516-58 X 26-5 **μ**m). Dichotriaenes were not found in this specimen. Presence of anatriaenes with blunt cladomes suggest similarity with Maldonado (1996) specimens found at Mar de Alboran. Orthotriaenes are found with abnormalities. Microxeas are of at least two types oxeote type and style type (Figure 120).

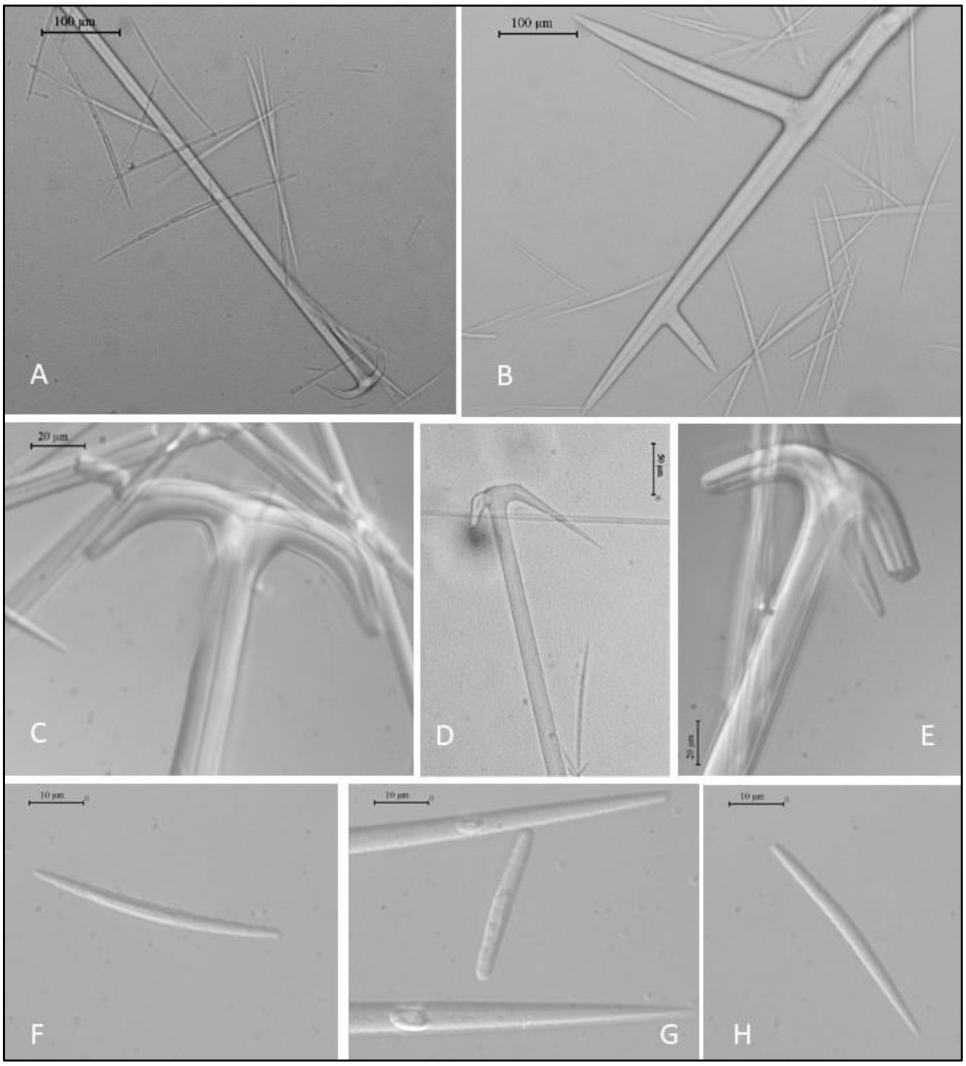


Figure 120 Characella tripodaria spicules. Specimen 10018. A. Anatriaene; B. Calthrop mal-formation. C., D. and E. Anatriaenes cladome types; F. Microxea Type I, G. Microxea Type II microstrongyle and H. Microxeas micro-style.

Habitat and distribution: Atlantic-Mediterranean region. Algeria (holotype).

*Characella connectens* (Schmidt, 1870)

Aphia ID 170236

Material examined: C9982, specimen collected at Ormonde Seamount at 1114 m depth ROV Liropus - Exp. Medwaves, 2016). (St. 146, Dive 16).

Morphological description

External morphology: Papillate flat masses (spec. 9982, Fig. 37. C and D) with highly hispid surface (Figure 121).

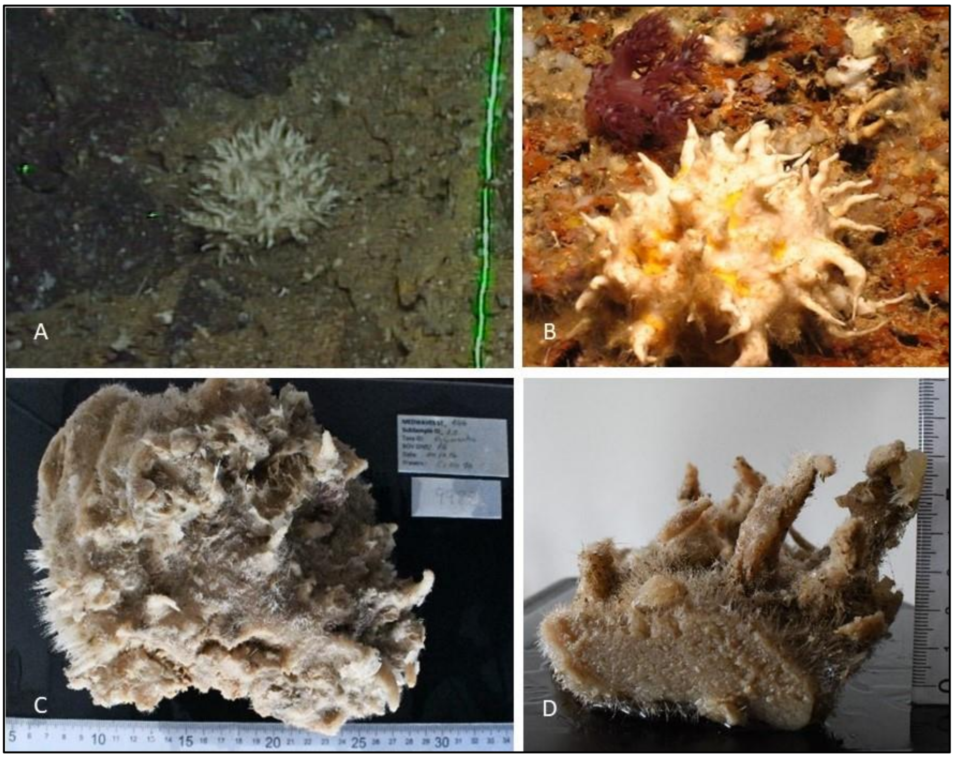


Figure 121 *Characella connectens in situ.* A. In situ image of identical morphotype specimen observed at Azores bathyal slope areas. B. Close up, orange encrusting sponge Cf. *Hexadella dedritifera*. Specimen collected at MedWaves (in situ image missing?). *Characella connectens ex situ.* C. Specimen collected at Ormonde Seamount during MEDWAVES cruise. Top view of papillae and hispid (with large Oxeas) surface; B. Cross section view of thick mass with papillae.

**Spicules:** The spicule set consists of one type of large oxeas (≃ 3840-125 **μ**m), short-shafted orthotriaenes, and anatriaenes. Microscleres in three types and sizes. The Type I has an oxeote form (336-196-110 X 4-6 **μ**m), the Type II are microstrongyles showing a range of rugged forms (with or without) centrotylote and typical curved forms varying in size which might be related with transitional stages (35-24-19 X 4-2 **μ**m), and Type III is a smaller and thinner oxeote form (29-2 **μ**m). Amphiasters are characterizes by a straight central axis with nearly 10 actines (Figure 122Figure 123).

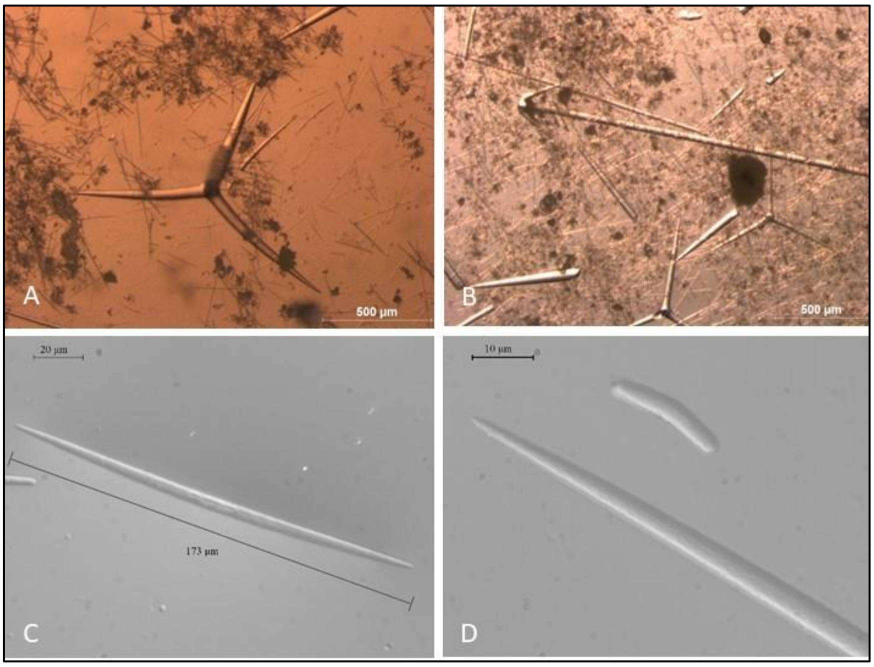


Figure 122 *Characella connectens* spicules. A. Short-shafted triaene; B. Anatriaenes; C. Microxeas I; D. Microxea I and II; E. Microxeas II type 1; F. Microxeas II type 1 and 2.

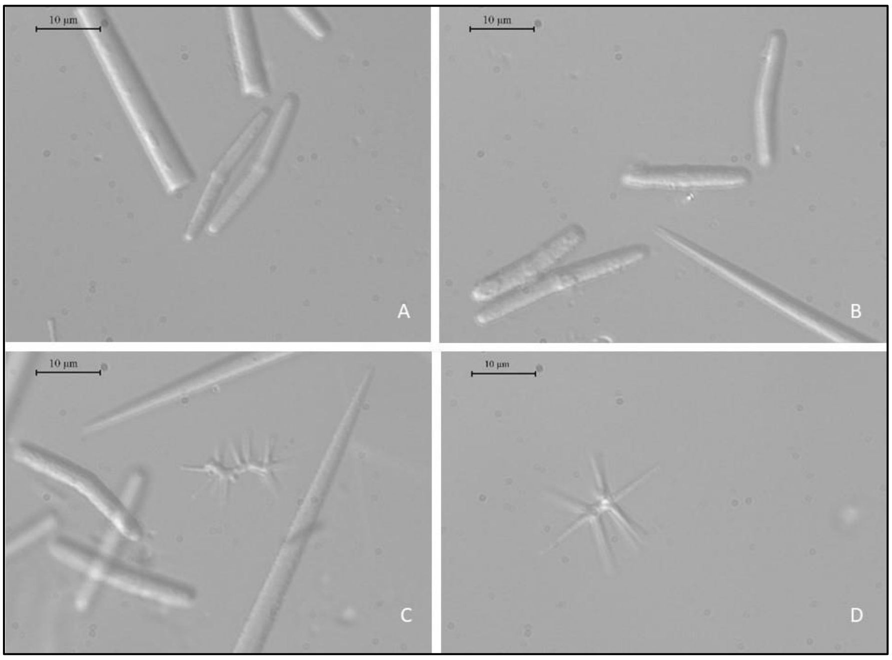


Figure 123 *Characella connectens* spicules. A. and B. Microxeas II type 1 and 3; C. Sanidaster; D. Amphiaster.

Remarks: *Characella connectens* can be clearly distinguished from *C. pachastrelloides* by the absence of dichotriaenes and from *C. tripodaria* (and all other species in the genus) because the larger microxeas are strongyles.

Habitat and distribution: Found at 1,300 m depth. First record on Florida (holotype).

*Nethea amygdaloides* (Carter, 1876)

Aphia 183627

Material examined: Specimen C12951 and C12960 collected at Princess Alice Bank, during Ocean X 2023 Expedition, ROV and Submersible dives, 645 and 730 m depth, respectively.

Morphological description

External morphology: Papillate flat masses, similar morphology to *Characella connectens* described before. However, does not have a hispid surface. Colour whitish beige alive and in alcohol (Figure 124).

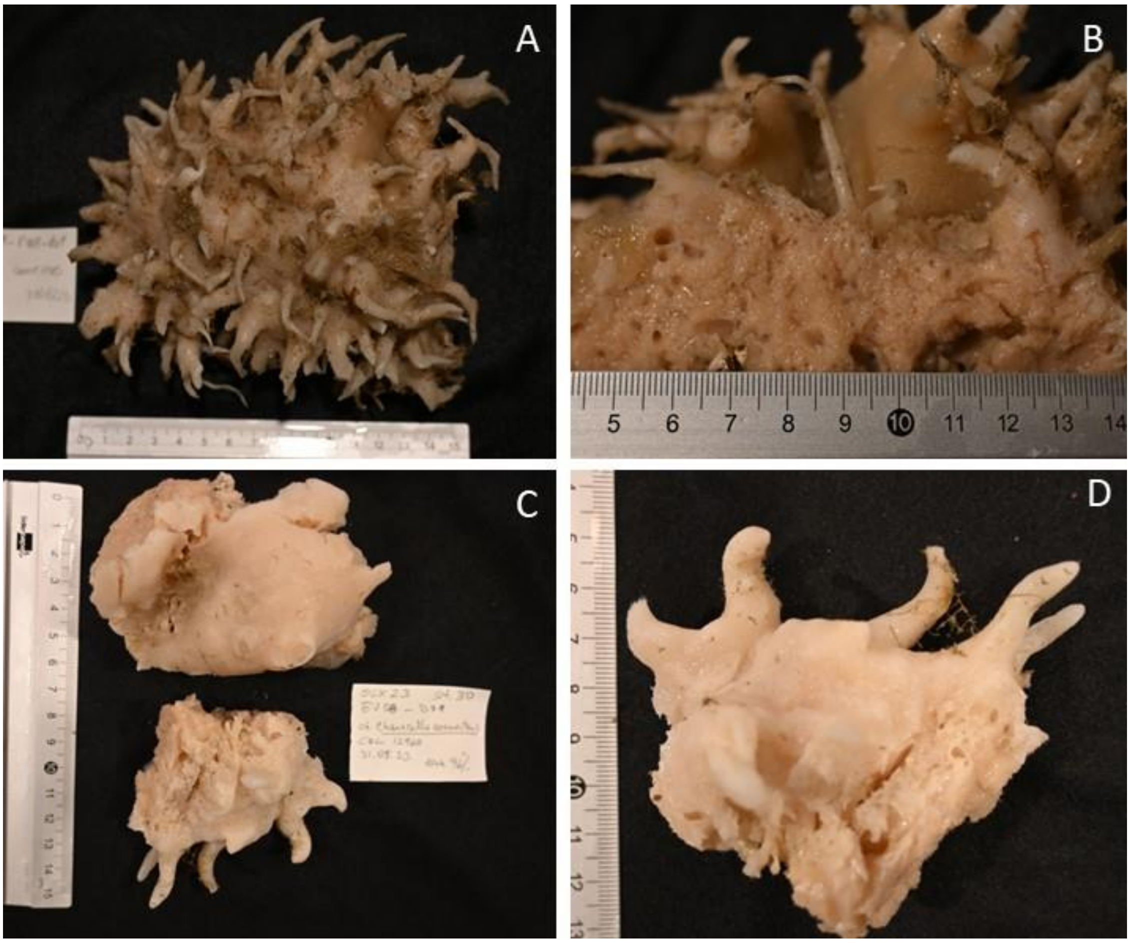


Figure 124 Nethea amygdaloides ex situ. Specimen 12951; C. and D. Specimen 12960 (OceanX 2023 Expedition).

Spicules: Megascleres are large but thin Calthrops and Oxeas slender slightly curved. Microscleres: presence of microxeas (90 to 100 µm) centrotylotous and slender spirasters. Absence of microstrongyles (see Cardenas, 2012 key) (Figure 125).

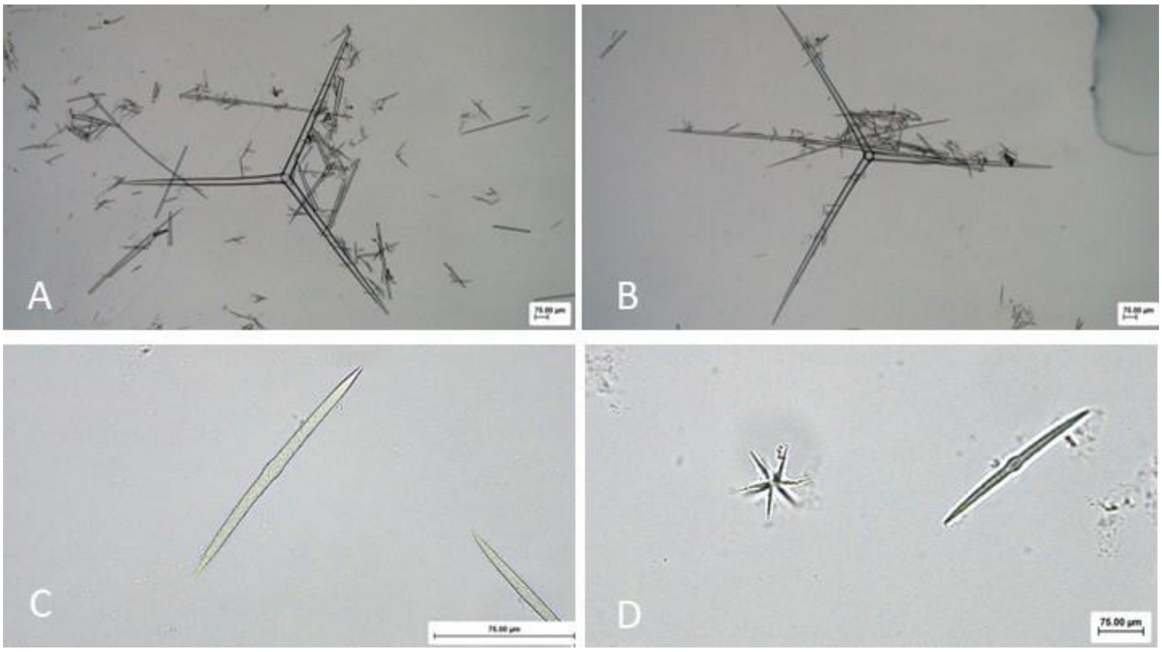

Figure 125 Nethea amygdaloides spicules. A. and B. Calthrops and Oxeas; C. Microxea size I; D. Microxea size II and spiraster.

Remarks: It was identified by Topsent 1892 as *Pachastrella debilis* (later synonymised with *Nethea amygdalodes*). The description matches with our results (for comparison see Topsent, 1892 Plate VIII, Fig. 8.) showing the same calthrops, microxeas types and spirasters.

Habitat and distribution: It was recorded in the Azores between 300-750 m depth, at hard substrates. Despite of the few images of this species it was found at the European Continental shelf (Cantabria, Cadiz) and the Mediterranean Sea. It has an Atlanto-Mediterranean distribution in bathyal environments.

Family Vulcanellidae

Poecillastra compressa (Bowerbank, 1866)

AphiaID 134083

Material examined: Morph 1. Lamellate white. C10065 – Specimen collected at Gigante Bank at 682 m depth, Expedition BlueAzores (2018), ROV Luso. Morph 2. Flabellate “Ear-shape”. Specimen USNM 1674014 collected during Expedition EX2205 (ROV Dive D05, Station 10B) at Zenith (42.3409 N; -29.1483 W), 1011.16 m depth.

Morphological description

External morphology:

Specimen C10065 has a lamellar or fan-shaped (morphology 1). Specimen USNM 1674014 has a flabellate or ear-shaped (morphology 2), whitish but covered with a brown biofilm. Specimens are compressible, surface is regular and slightly hispid. Uniporal oscules (0.5-1.2 mm) (for comparison see description in Cardenas, *et al.* 2012) (Figure 126,Figure 127).

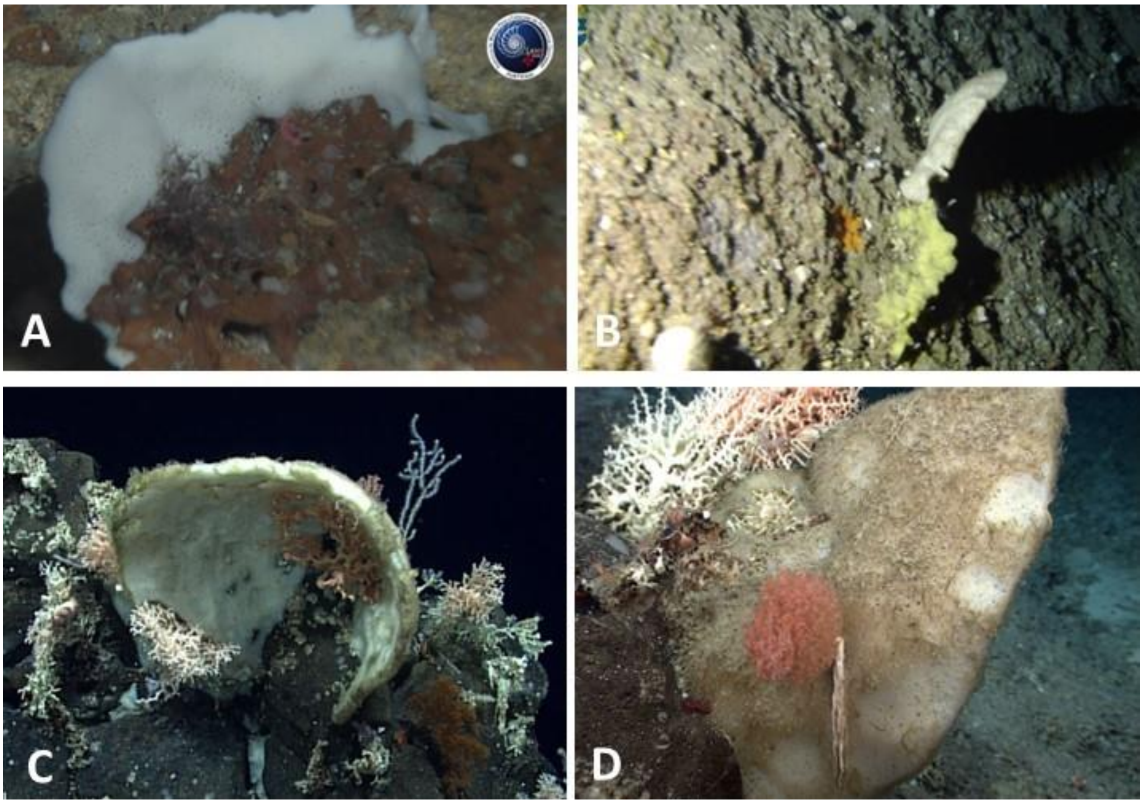


Figure 126 *Poecillastra compressa* Morph. 1 external morphology. *A.* C10065 *in situ* image collected during Expedition BlueAzores (2018), ROV Luso; B. Other *in situ* image lateral side view; Morph. 2. C. Specimen USNM 1674014 collected during Exp EX2205 with ROV; D. Specimen USNM 1674014 image lateral side view.

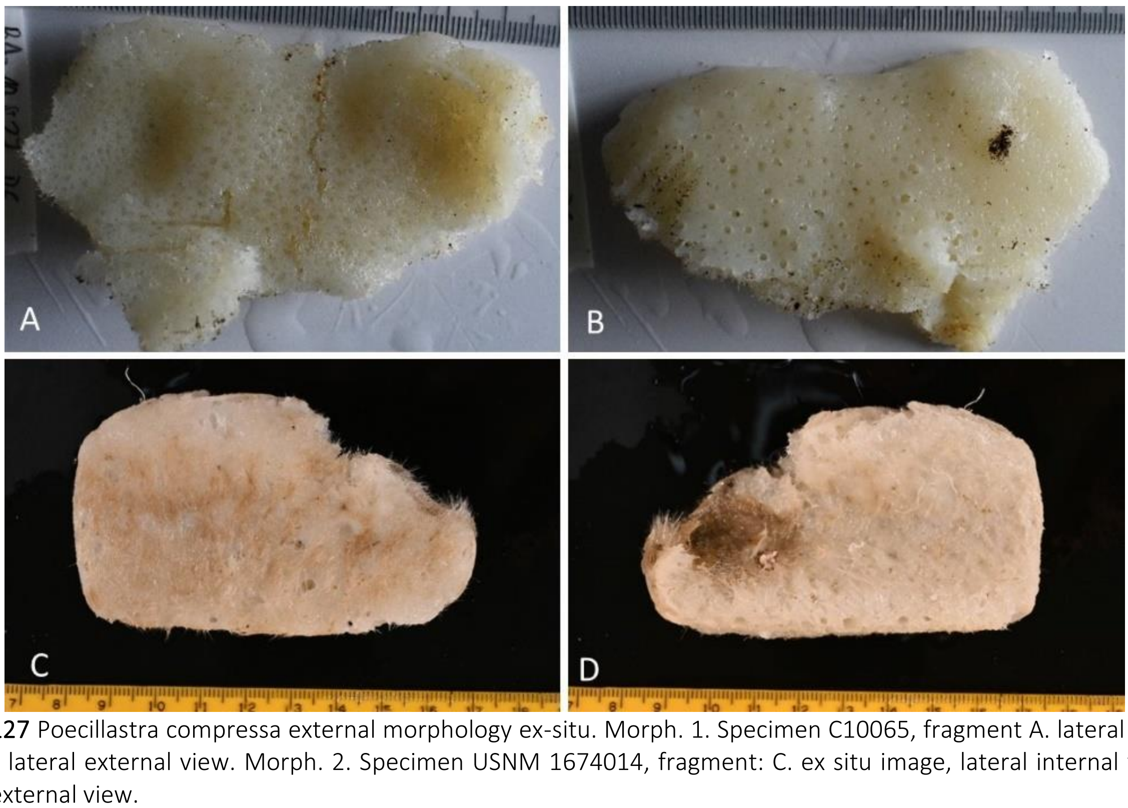


Figure 127 Poecillastra compressa external morphology ex-situ. Morph. 1. Specimen C10065, fragment A. lateral internal view. B. lateral external view. Morph. 2. Specimen USNM 1674014, fragment: C. ex situ image, lateral internal view. D. lateral external view.

Spicules: Oxeas stout, most are slightly curved, sometimes modified to styles. It differs from material from Norway (Cardenas *et al.* 2012) in the absence of a second type of Oxeas.

Short-shafted Triaenes or calthrops, often irregular with deformities. Microxeas in high numbers microspiny. Abundant plesiasters, spirasters and metasters (Figure 128).

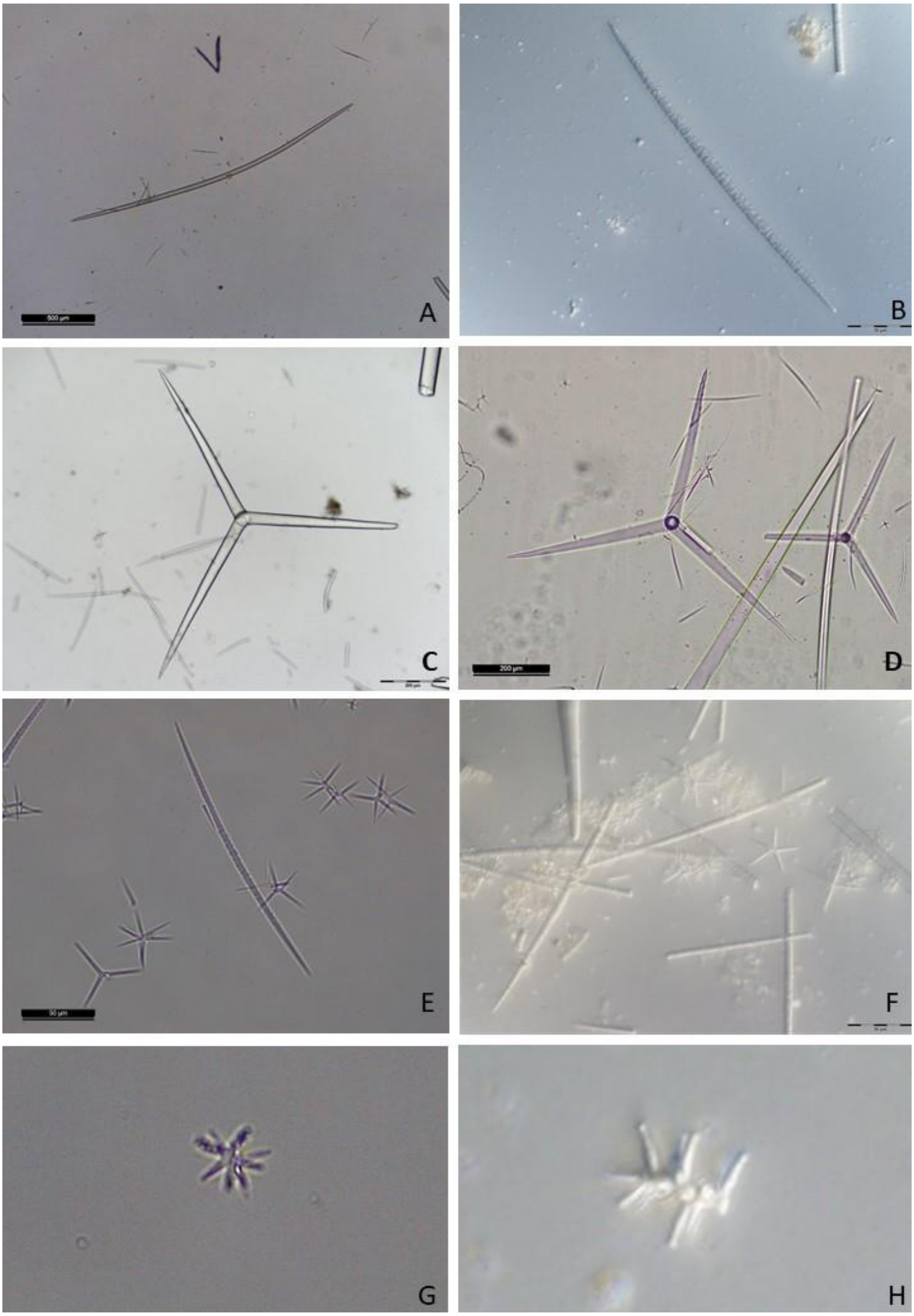


**Figure 128** Poecillastra compressa spicules. A.; Oxea; B. Microxea Specimen USNM 1674014, C. Calthrop; D. Calthrop; E. Microxea and Plesiasters; F. Microxeas and Plesiasters; G. Spiraster; H. Spiraster.

**Habitat and distribution:** Occupies rocky substrates. Morphological variations might exist from lamellar to cup-shaped and incrusting. Bi-colored specimens exist and are documented in some parts of the Mediterranean. Northern Atlantic specimens (Scotland to Norway) are more whitish, Mediterranean can vary from white to yellow and orange.

Both Azores specimens collected in this study present same spicules. *P. compressa* has been considered widely distributed over the Atlantic and Mediterranean, at also a wide depth range that goes from intertidal to depths of 3,500 m (in Maldonado, 2002). Specimens analysed in this study match with Maldonado (2002) holotype having identical spicules types, they might be different only slightly in the relative sizes of these. Therefore, the material from the Azores has high similarity with the specimens occurring at the NE Atlantic and Mediterranean Regions.

### *Family Phloeodictyidae*

***Siphonodictyon viridiscens*** **(Schmidt, 1880)**

**AphiaID 821735**

**Material examined:** Two specimens collected during mission M128, onboard Meteor, C11856 on the Cone Southeast od D. João de Castro Bank (TGB Grab Station 744) at 429.2 m depth and C11908 on the Ridge N Flank Hirondelle Basin (TGB Grab - Station 798) at 414 m depth.

**Morphological description**

**External morphology:** Thin tubular (fistules) sponge attached to hard substrate. Nearly 5.5 cm high and 1 cm diameter. Color transparent white. Firmly attached to substrate (Figure 129).

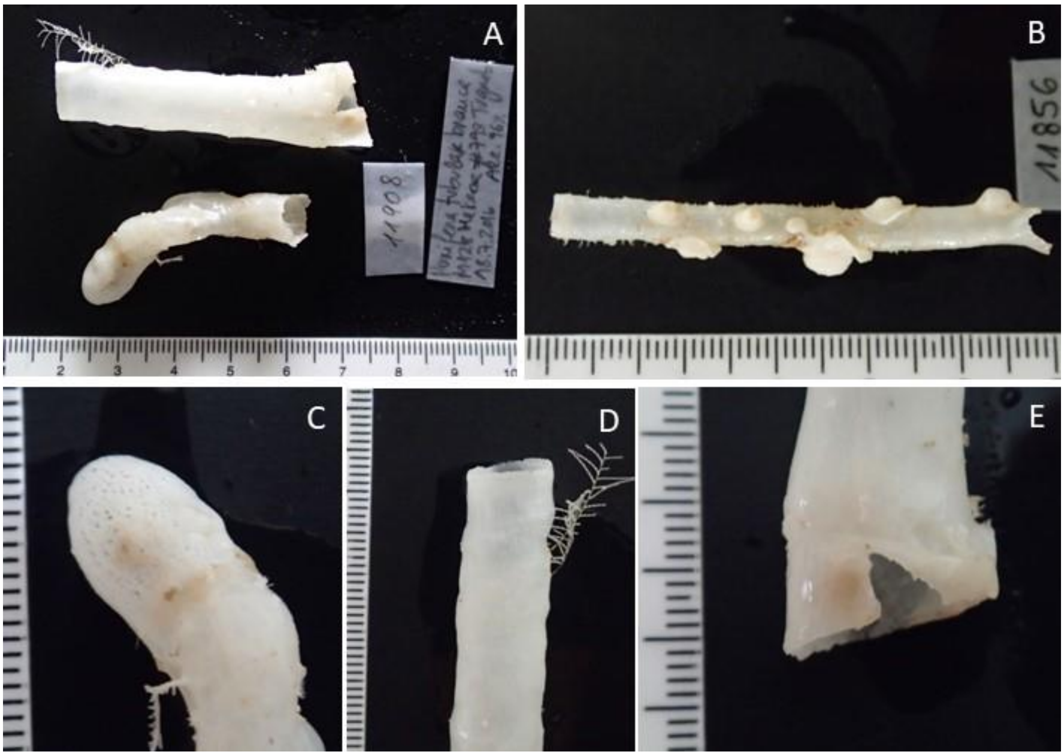


Figure 129 *Siphonodictyon viridiscens* (Schmidt, 1880) *ex situ.* A. Specimen 11908; B Specimen C11856. C. Anterior side of the tube in one specimen which is closed; D. anterior side of the tube in one specimen with open aperture; E. basal part view.

Spicules: Tight-meshed reticulation of spicule bundles. Spicules are thick abruptly pointed oxeas. Measurements allowed to compare that Azores specimens has shorter oxeas (down 200 µm) than van Soest 2014 observations (225-245 x 18-19 µm) (Figure 130).

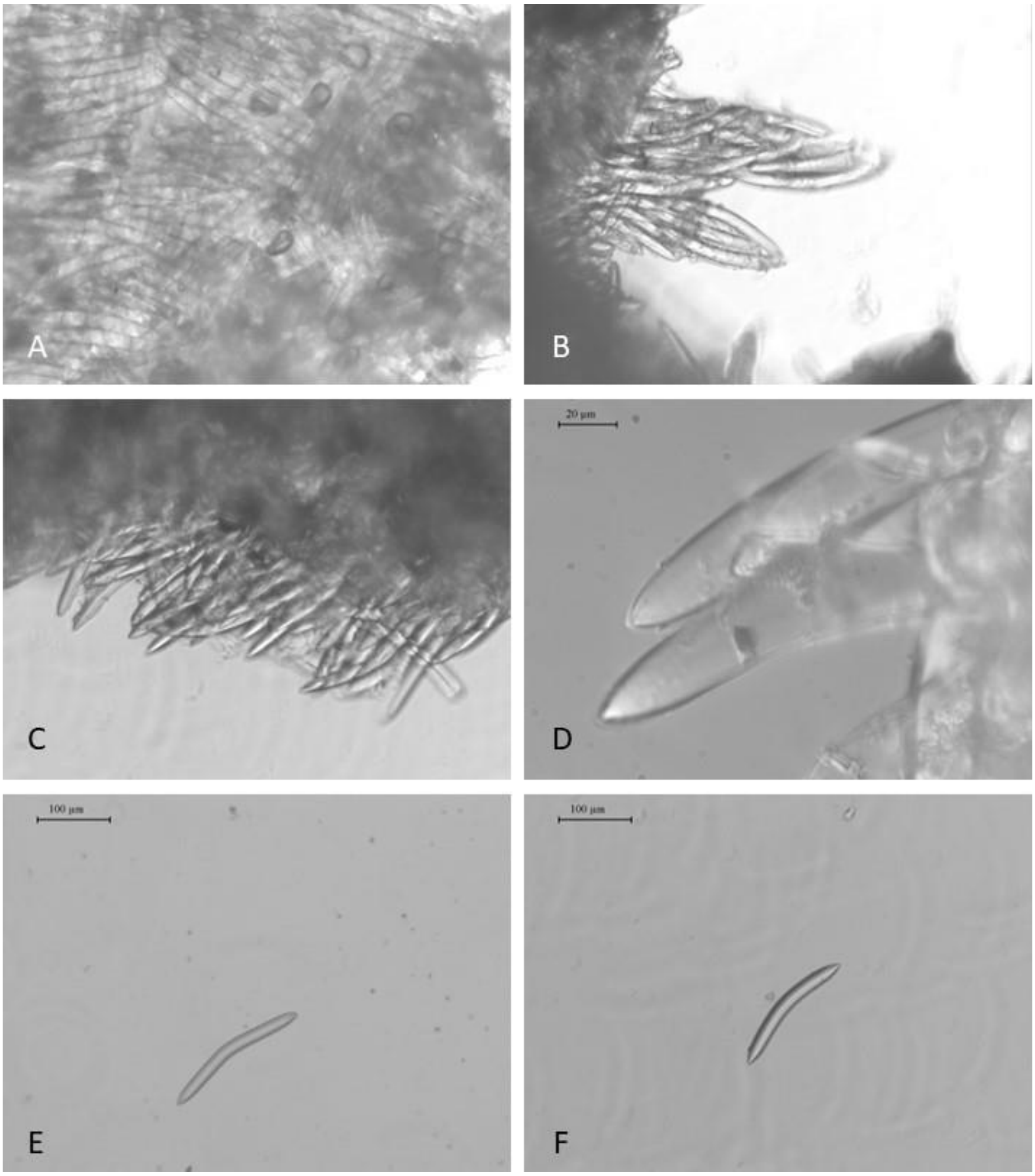


**Figure 130** Siphonodictyon viridiscens (Schmidt, 1880) spicules. A. mesh structure of Oxeas; B. and C. bundles of Oxeas; D. Oxeas tips; E. and F. small oxeas.

**Remarks:**

**Habitat and distribution:** This is the first time this species is recorded for the Azores region.

*Family Chanilidae*

***Haliclona (Soestella) implexa*** **(Schmidt, 1868)**

**Aphia ID 166642**

**Material examined:** Specimen C10139 (morphotype yellow) and Specimen C10163 (morphotype white), collected at Gigante Bank with LUSO ROV, Dives 10 and 14 (Blue Azores Expedition, 2018), respectively.

### Morphological description

**External morphology:** Arborescent with ramose bushes consisting of dichotomously branching and frequently anastomosing osculiferous tubes; total size up to 10 cm in diameter; consistency limp, fragile. Peduncular attachment to substrate. Colour pale white or dirty yellow (Figure 131).


**Figure 131** *Haliclona (Soestella) implexa* (Schmidt, 1868) external morphology: A. in situ image showing two different (yellow and white) morphotypes coexisting. Specimens collected at Gigante Bank (Luso ROV, Dives 12 and 14 during BAz, 2018); B. Morphotype yellow, Specimen C10139; C. Morphotype White, Specimen C10163.

**Spicules:** Spicules are Oxeas Type I and II (see Fig. 48. Oxeas at Specimens 10139 and 10163). Both morphotypes has the same Oxea types. Measurements were not done due to time restraints at this study stage and because this species were already studied by Pereira (2013). According to the spicules images and scale, the studied material is according Pereira (2013). Megascleres are Oxeas slightly curved but with sharp tips: 228,1 - 204,9 - 137 µm x 9,2 - 7,3 - 2,6 µm (Figure 132).

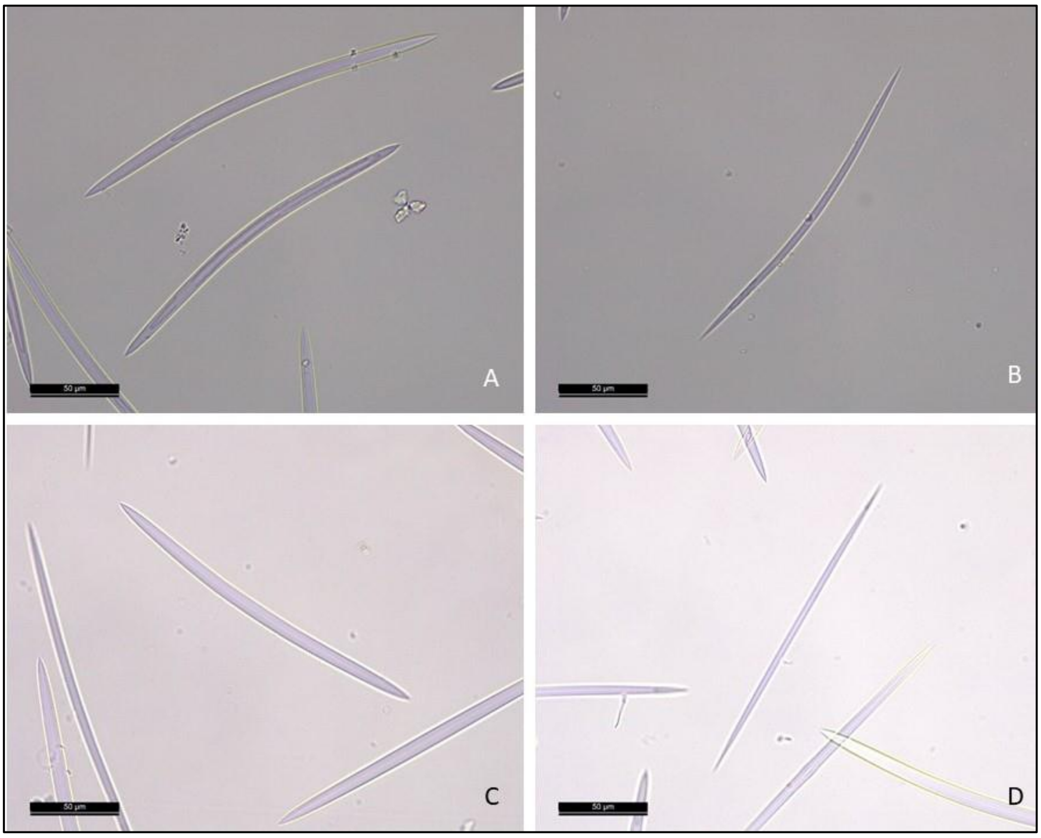


Figure 132 *Haliclona implexa* (Topsent, 1890) Spicules. Morphotype yellow, Specimen 10139 – A. Oxea I; B. Oxea Type II; Morphotype White, Specimen 10163 – C. Oxea I; D. Oxea Type II.

**Remarks:** see discussion in De Weerdt and Van Soest (1986)

**Habitat and distribution:** Atlanto-Mediterranean. It was found in the Azores (Pico and Terceira) between 200 and 900 m depth (Topsent, 1904).

### *Haliclona filholi* (Topsent, 1890)

### Aphia ID 850418

**Material examined:** Specimen D9374 collected at Azores Bank with by-catch (unknown precise position and depth, ARQDAÇO-38-P12); Specimen C10012 collected at North Pico at 736 m depth (BAz Exp., ROV Dive 2) and specimen 10084 Gigante Bank at 663 m depth (BAz Exp., ROV Dive 5).

#### Morphological description

**External morphology:** Globular shape or sub-cylindrique, small sponge. Colour yellowish or grey, friable, with a big central osculum and a fragile skeleton of an isodictyal reticulation of curved acanthoses strongyles (Kelly et al. 2015) (Figure 133).

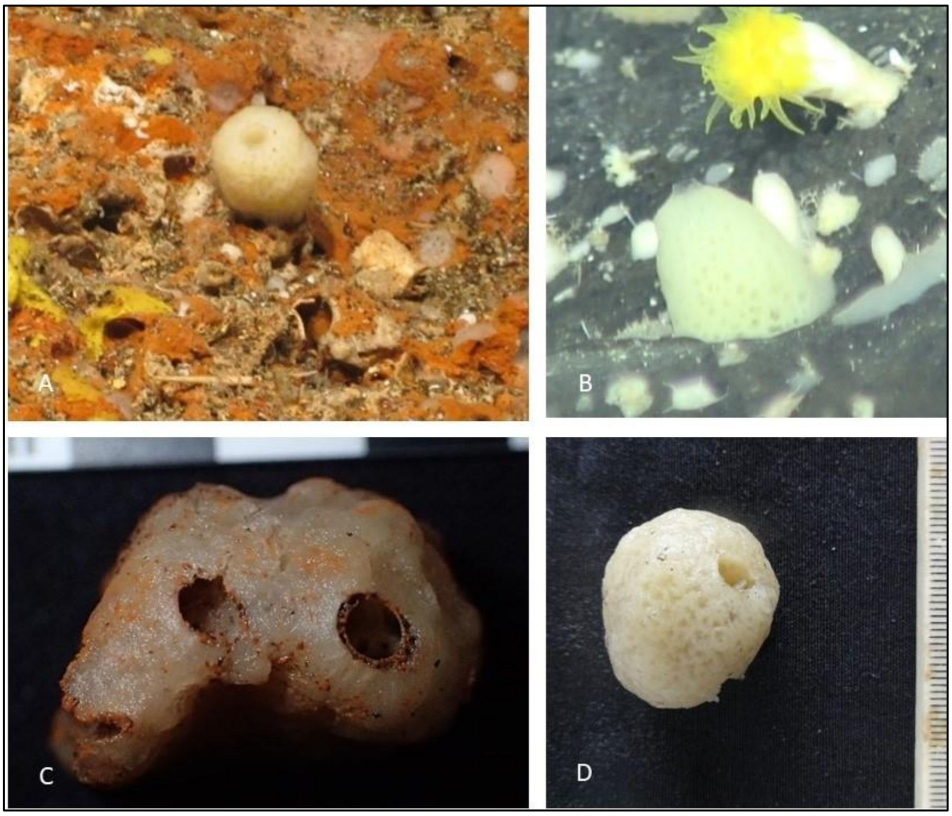


**Figure 133** *Haliclona filholi* (Topsent, 1890) external morphology. A and B *in situ* images; C. specimen 10084 collected at Gigante Bank; C. specimen 9374 collected at Azores Bank.

**Spicules:** Spicules are slightly spined acanthostrongyles. We have found centrotylote strongyles that are acanthoses. Our results corroborate with the latest description or review discussion of Kelly *et al.* (2015), saying that "occasionally centrotylote strongyles that are acanthoses or roughened in their entirety". However, to our knowledge, there are no images of these unique spicules, until the present study (Figure 134).

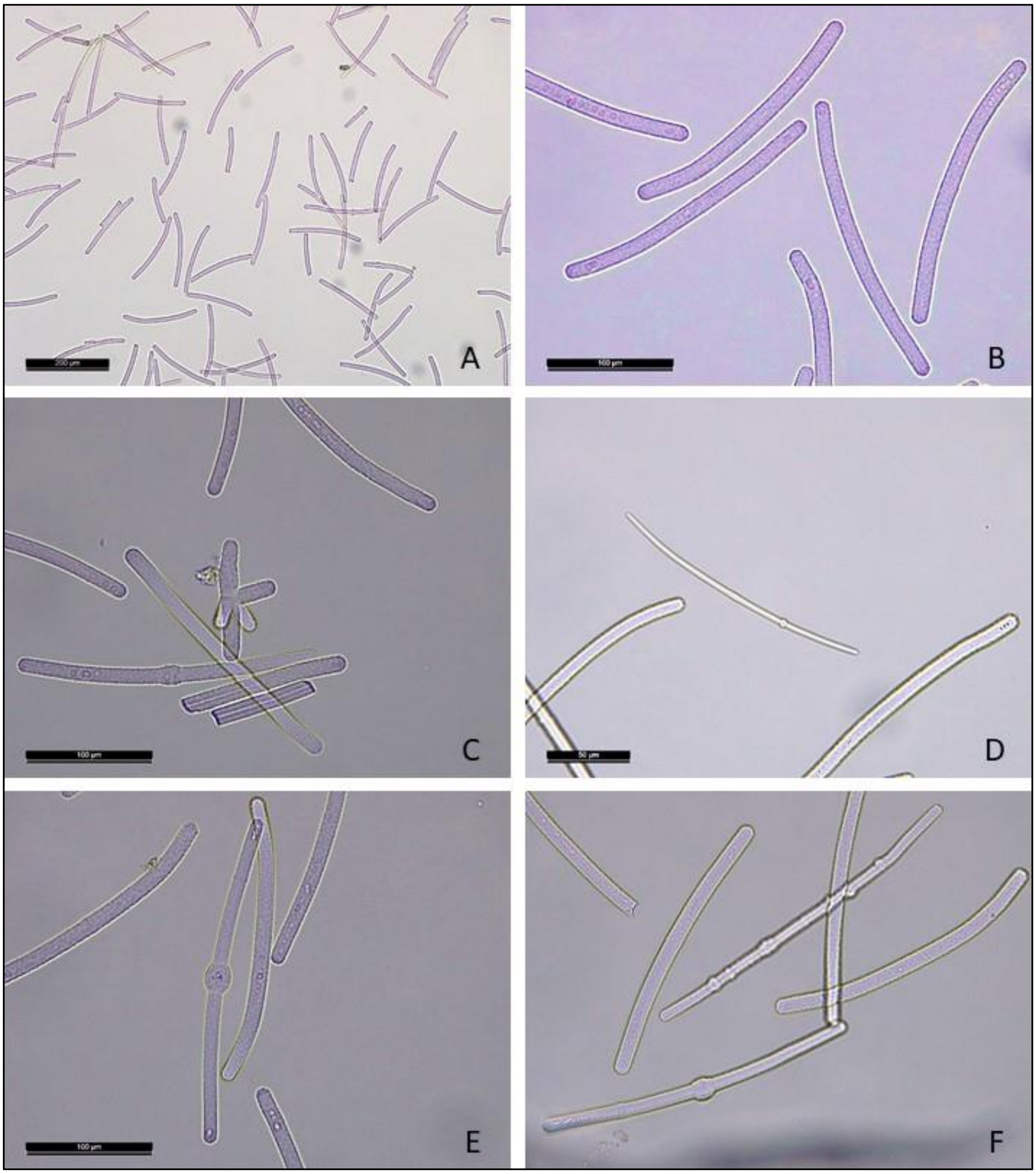


Figure 134 *Haliclona filholi*, spicules. Specimen 10012 A. Acanthose strongyles; B. Acanthostrongyles slightly rugged; C. Acanthostrongyle mal-formation (?); D. Acanthostrongyle very thin shape with a centrotylote; E. Centrotylote acanthostrongyle; F. Variations of Centrotylotes acanthostrongyles.

**Remarks:** Topsent (1904) has recollected this species several times in several locations around the Azores region (South Pico, around Terceira, South Princess Alice Bank). At Gigante Bank is found at hard substrate, volcanic boulders, in high densities.

**Habitat and distribution:** Azorean Region. Depth 200 - 927 m.

## *Haliclona (Halichoclona) magna* (Vacelet, 1969)

### Aphia ID 166581

**Material examined:** Specimen USNM 1673996 collected during Expedition EX2206 (ROV Dive D01, Station 06B) at MARNA Shallow (43.9536 N; -28.5283 W), 579.75 m depth; Specimen C13011, collected during Ocean X 2023 Expedition.

### Morphological description

**External morphology:** Copious amounts of mucous were expelled when specimen was examined fresh. Consistency very friable (Figure 135).

Original description by Vacelet (1969) has documented *H. magna* as a very large sponge made up of several tubes (generally three or four) rising from a common base. These tubes have thick walls and can reach several tens of centimeters and approximately 10 cm diameter, they are traversed by a central canal of 2 to 3 cm in diameter, which ends in an osculum of same size, surrounded by a thin and fragile membrane. The consistency is very crumbly and white in colour (alive and in alcohol). This description is consistent with our findings. Also, the photograph shown in Vacelet (1969) work (Plate II, Fig. 2 and 3) is identical to the specimens documented in the present study.

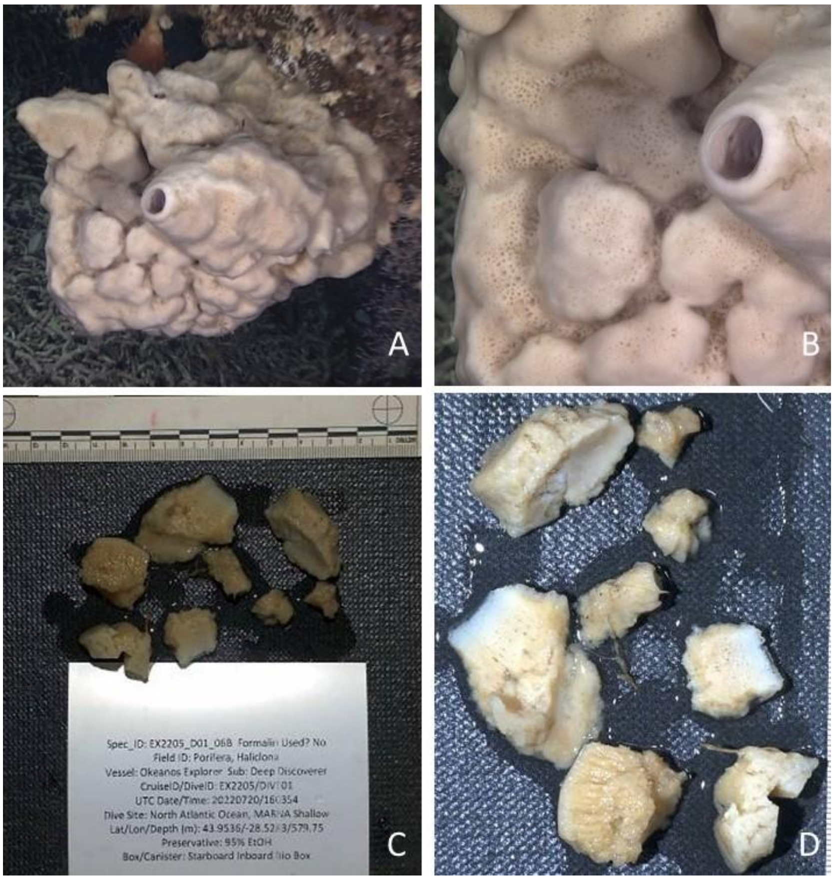


**Figure 135** *Haliclona* (*Halichoclona*) *magna* (Vacelet, 1969). in situ. A. and B. Specimen collected during Expedition EX2206 (ROV Dive D01 Station 06B) at MARNA Shallow, 579.75 m depth. C. and D. ex situ External morphology. A. Specimen after collection; B. Zoom image of the internal morphology of the same specimen.

Spicules: Only oxeas were found. Oxeas are gently curved. Several sizes (some smaller and thinner) are probably result of development (Figure 136).

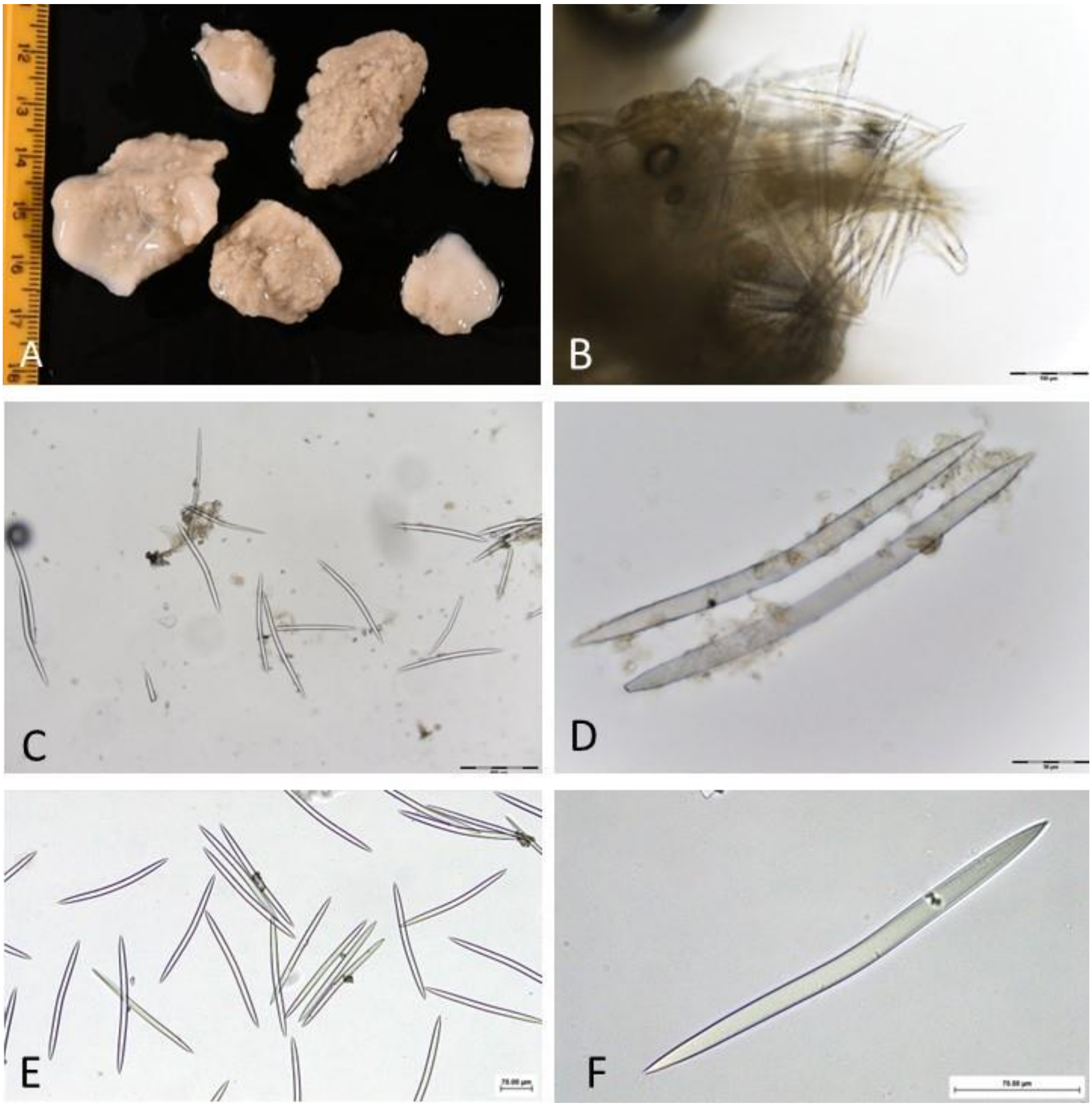


Figure 136 *Haliclona (Halichoclona) magna* (Vacelet, 1969). A. Specimen USNM 1673996 fragments, also showing the mucous; B. spicules bundles; C. Specimen USNM 1673996 Oxeas general view; D. Specimen USNM 1673996 Oxeas close up showing curved shape; Specimen C13011 Oxeas general view; Specimen C13011 Oxea close up showing curved shape.

Remarks: Presently, genus *Haliclona* needs a taxonomic revision. It is very complicated taxonomically to infer about the Chalinidae family and their species complex groups due to the paucity, simplicity and high variability of its taxonomic characters (de Weerdt 1989, 2000; Silva, 2015).

Habitat and distribution: New record for the Azores Region. Before our findings, *Haliclona magna* was recorded only for the Mediterranean Sea (Vacelet, 1969).

*Xestospongia friabilis* (Topsent, 1892)

Aphia ID 132927

Material examined: C12935 OceanX 2023 Expedition (St026, EV4, B01). Princess Alice Bank, (38.0551 N; -29.3052 W), at 779 m depth.

Morphological description

External morphology: Massive, robust, barrel- or chimney-shaped with a large oscula. The surface has lobular projections, depressions, and a rough texture. Large specimens can achieve more than 50 cm. Colour white. Consistency soft, fragile, brittle and mucous. Ectosomal skeleton tangential, unispicular, isotropic, very regular and continuous reticulation. Choanosomal skeleton consisting of a delicate, regular, unispicular, isotropic reticulation (Figure 137Figure 138).

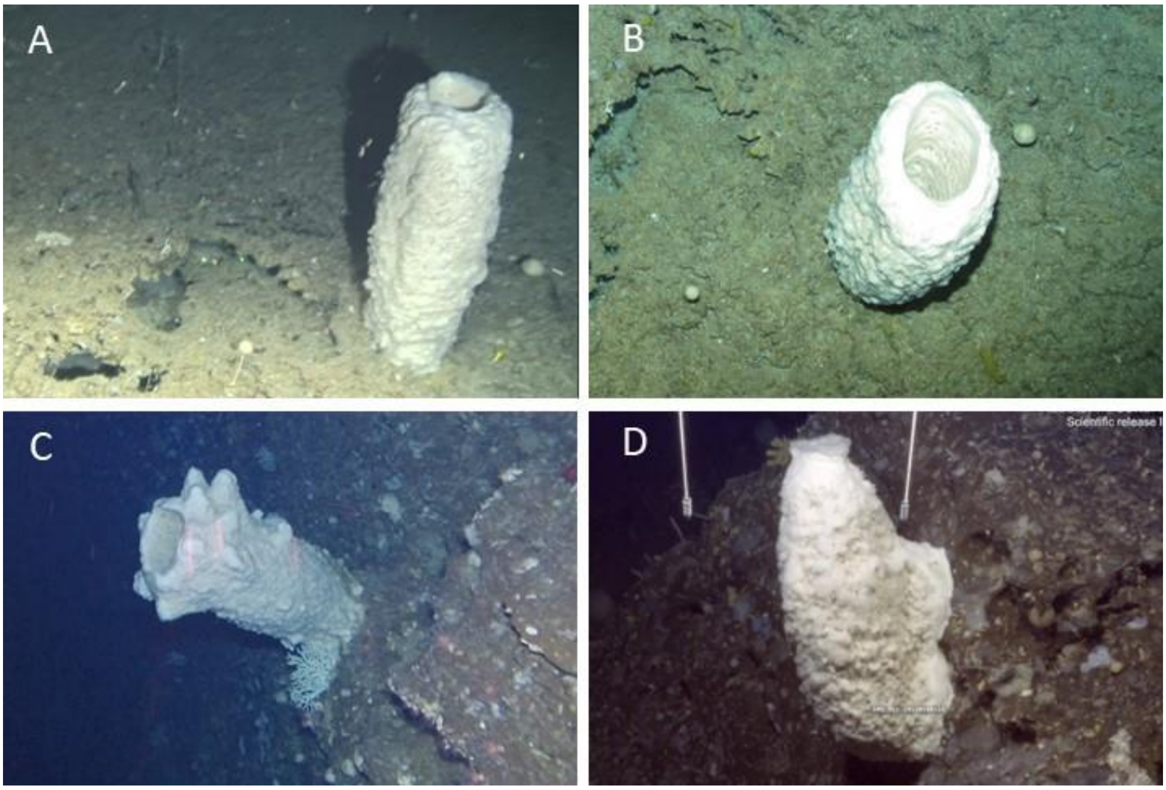


Figure 137 *Xestospongia friabilis* (Topsent, 1892) in situ. Several images of barrel-shaped specimens (from MapGes, Rebikof-Foundation images).

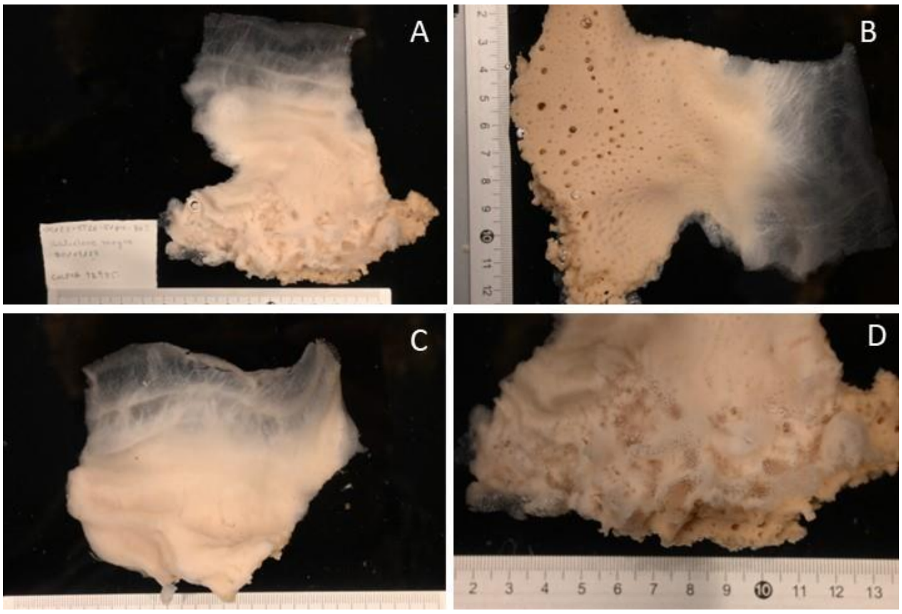


Figure 138 *Xestospongia friabilis* (Topsent, 1892) ex situ.

**Spicules:** Megascleres smooth oxeas of moderate length (80–250 µm) and thickness (5–10 µm) with acerate ends. Oxeas 170-185 X 5-7.5 **µ**m (in Vacelet, 1969); 220-240 X 10 **µ**m (in Levi and Vacelet, 1958); Oxea I: 210 **µ**m Oxea II: 116–165–204/2–4.7–7 **µ**m (in Carvalho, *et al.* 2016) (Figure 139).

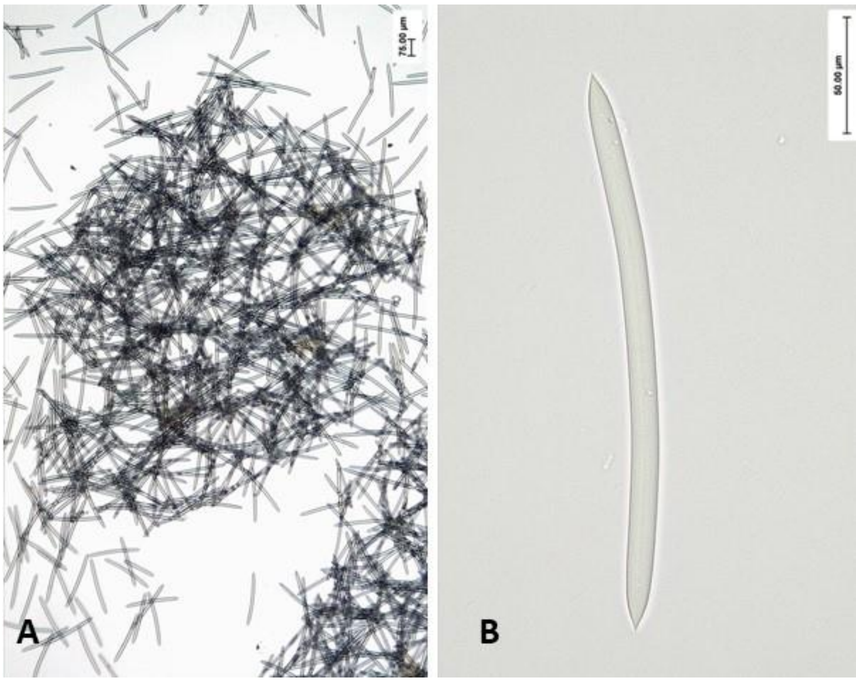


Figure 139 *Xestospongia friabilis* (Topsent, 1892) spicules. A. Ectosomal skeleton showing general spicules arrangement; B. Oxea.

**Remarks:** Because of its friable nature the shape of the sponge was never demonstrated once it always arrived destroyed by the fisheries arts (longline bycatch).

**Habitat and distribution:** Documented by Topsent (1892), before *Petrosia friabilis*, as very common in the Azores. Depth range: 130 to 927 m.

Cf. *Xestospongia* sp1

Aphia ID 131849

**Material examined:** Specimen USNM 1673617 collected during Expedition EX2206 (ROV Dive D02, Station 02B) at East of Formigas Rift (37.3544 N; -24.3813 W), 838.11 m depth.

Morphological description

**External morphology:** Multiple pieces of the sample, dead hydroids attached. Massive barrel sponge, deep atrial cavity, very rugose on external wall. Extremely crumbly or friable. External colour white, internal beige. In alcohol is dark beige. Abundant internal canals (Figure 140Figure 141).

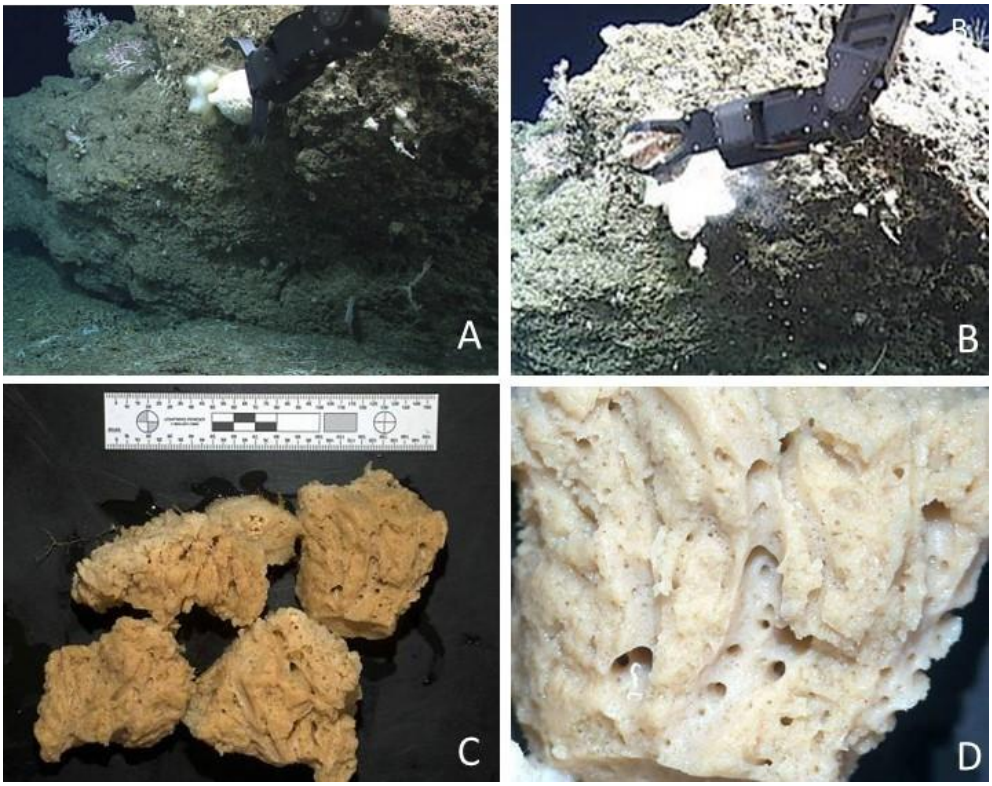


**Figure 140** *Xestospongia sp.*1 *ex situ.* A. and B. Specimen collected during Expedition EX2206 (ROV Dive D02 Station 02B) at East of Formigas Rift, 838.11 m depth. C. and D. *ex situ* External morphology. A. Specimen after collection; B. Zoom image of the internal morphology of the same specimen.

**Spicules:** Oxeas (Type I and II) and styles or stylotes (Figure 141).

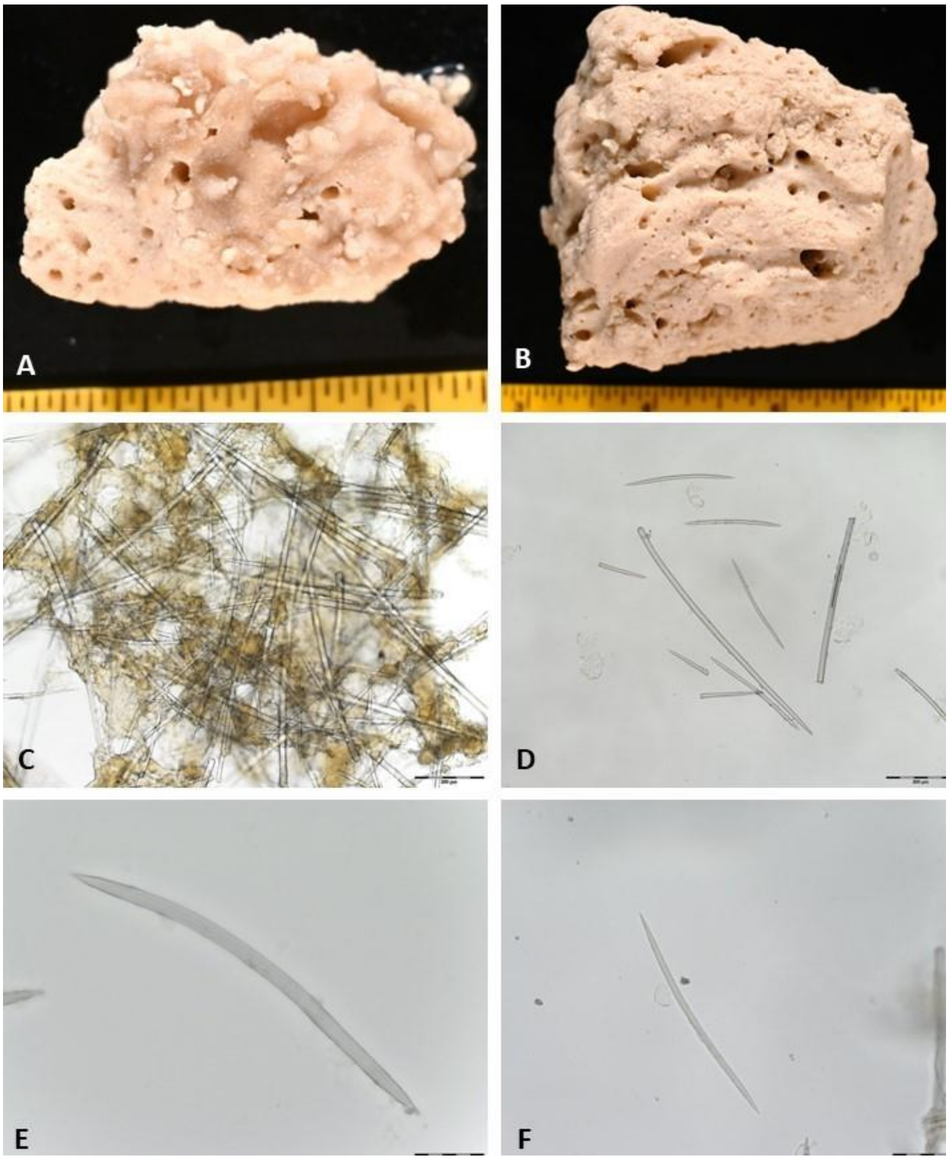


Figure 141 *Xestospongia* sp.1 ex situ Specimen USNM 1673617 oxeas and styles. A. B. Spicules. C. General spicules view; D. Styles; E. Oxea large and slightly curved (Type II); F. Oxea small thin (Type I).

**Remarks:** Only seven species of *Xestospongia* were known to occur deeper than 100 m: *X. clavata*, *X. coralloides*, *X. diprosopia*, *X. hispida*, *X. friabilis* and *X. kapne* (Carvalho, et al. 2016). Looking at the comparative material in Carvalho, *et al.* (2016) the specimen USNM 1673617 analyzed in this study has a different spicule set. At this point, we could not assign species level.

**Habitat and distribution:** Azores bathyal areas of seamount slopes (800 m depth).

*Order Suberitida*

*Family Halichondriidae*

*Spongosorites sp.*

Aphia ID 131818

**Material examined:** Specimen USNM 1673621 collected during Expedition EX2206 (ROV Dive D02, Station 08B) at East Formigas Rift (37.3538 N; -24.3776 W), 609.2 m depth.

## Morphological description

**External morphology:** Massive amorphous. Surface smooth. Consistency firm but friable. Colour intense yellow (Figure 142).

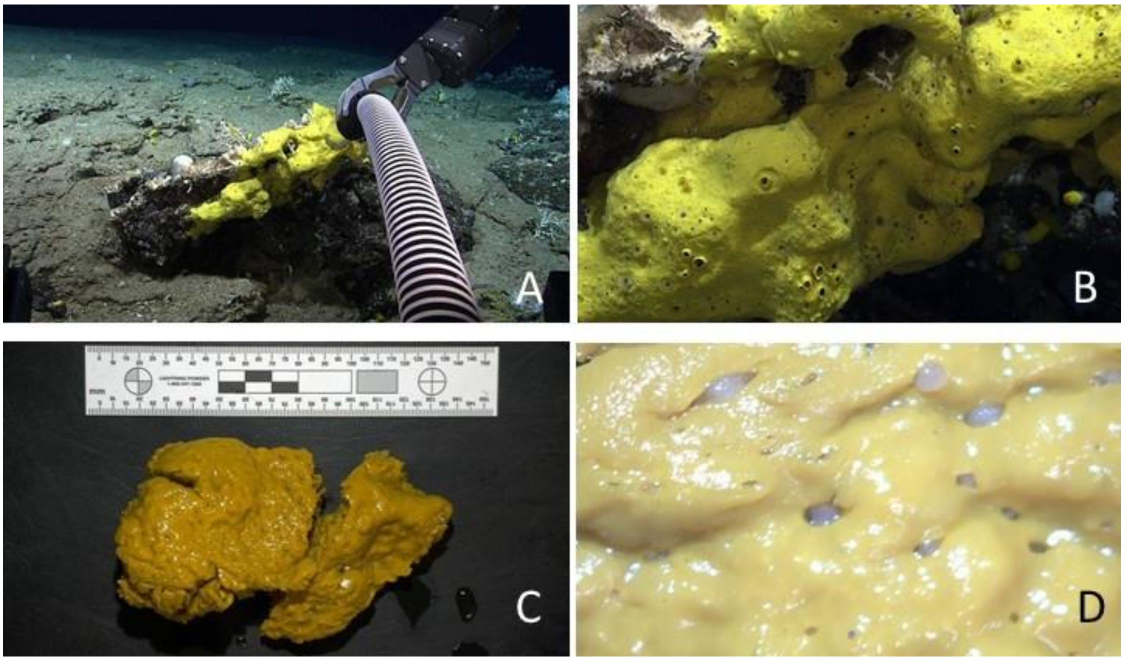


**Figure 142** *Spongosorites* sp. *ex situ*. A. and B. Specimen 1673621 collected during Expedition EX2206 (ROV Dive D02 Station 08B) at East of Formigas Rift, 609.2 m depth. C. and D. *ex situ* External morphology. A. Specimen after collection; B. Zoom image of the internal morphology of the same specimen.

**Spicules:** Ectosomal skeleton is a dense mass of spicules arranged in all directions. Megascleres are oxeas of various sizes, sometimes with their points modified to strongyles or styloides, often centrangulate (Figure 143).

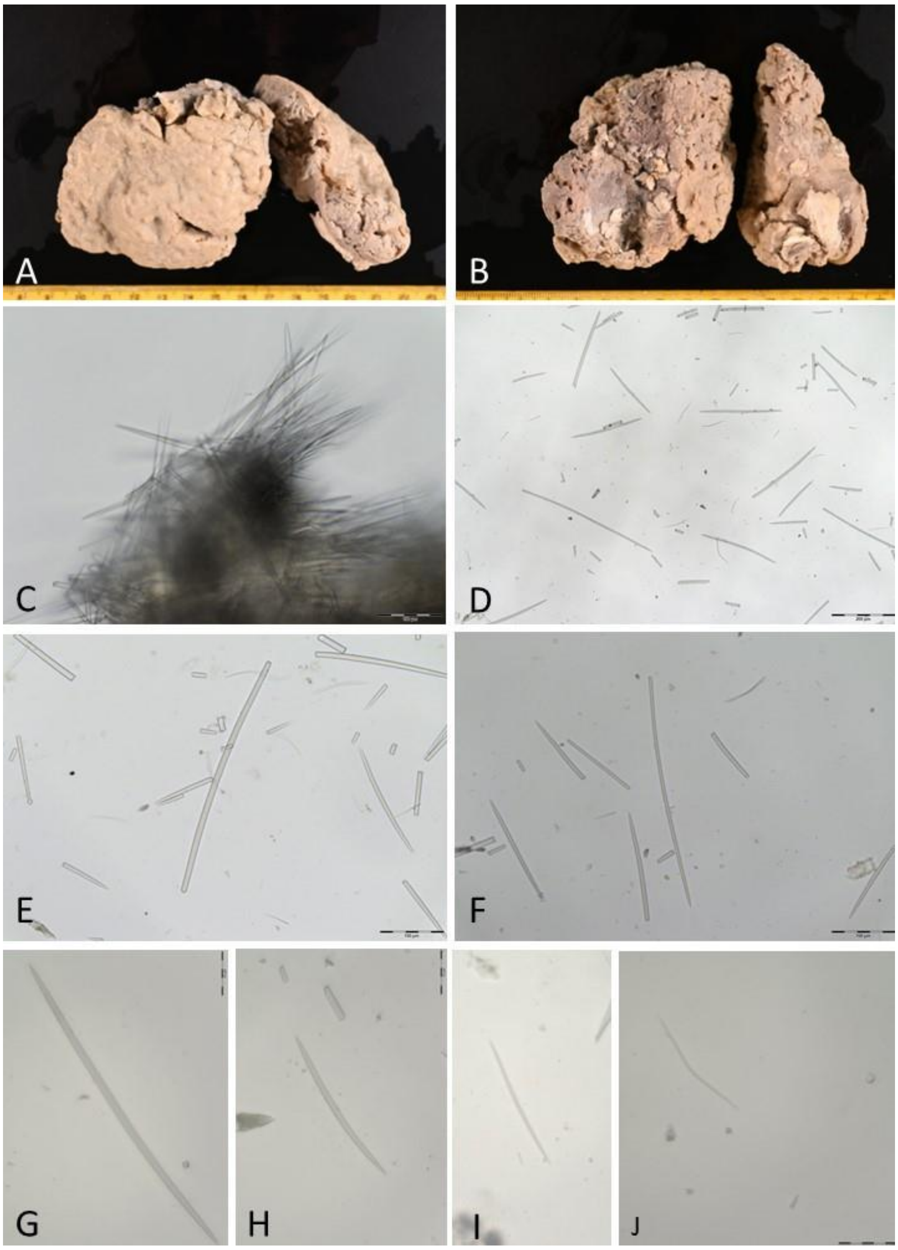


Figure 143 *Spongosorites* sp. A. Specimen fragment, B. showing internal side; C. spicules bundles; D. General view of oxeas types and sizes; E. E. and F. strongyles; G. Style; H., I. Oxeas small size, J. Oxea centrangulate.

**Remarks:** *Spongosorites placenta* Topsent, 1896 was described for the Azores (Topsent, 1928, Erpenbeck and van Soest, 2002), however measurements should be done to compare with all species from the genus (e.g. *S. coralliophaga*, *S. flavens*).

**Habitat and distribution:** In the Azores, *Spongosorites sp.* was observed at upper bathyal of seamounts.

*Order Haplosclerida*

*Family Petrosiidae*

*Petrosia (Strongylophora) vansoesti* Boury Esnault, Pansini & Uriz, 1994

Aphia ID 166878

**Material examined:** Specimen 11934 collected during mission M128, onboard Meteor, TGB Grab - Station 820 on cone W of Capelinhos (38º 37.102' N, 28º53.505' W) at 427 m depth.

Morphological description

**External morphology:** Tubular sponge with the base attached to the substrate. Oscula at the apical region of 5 mm in diameter. White/beige color both in-situ and ex-situ, beige/ochre after fixation (Figure 144).

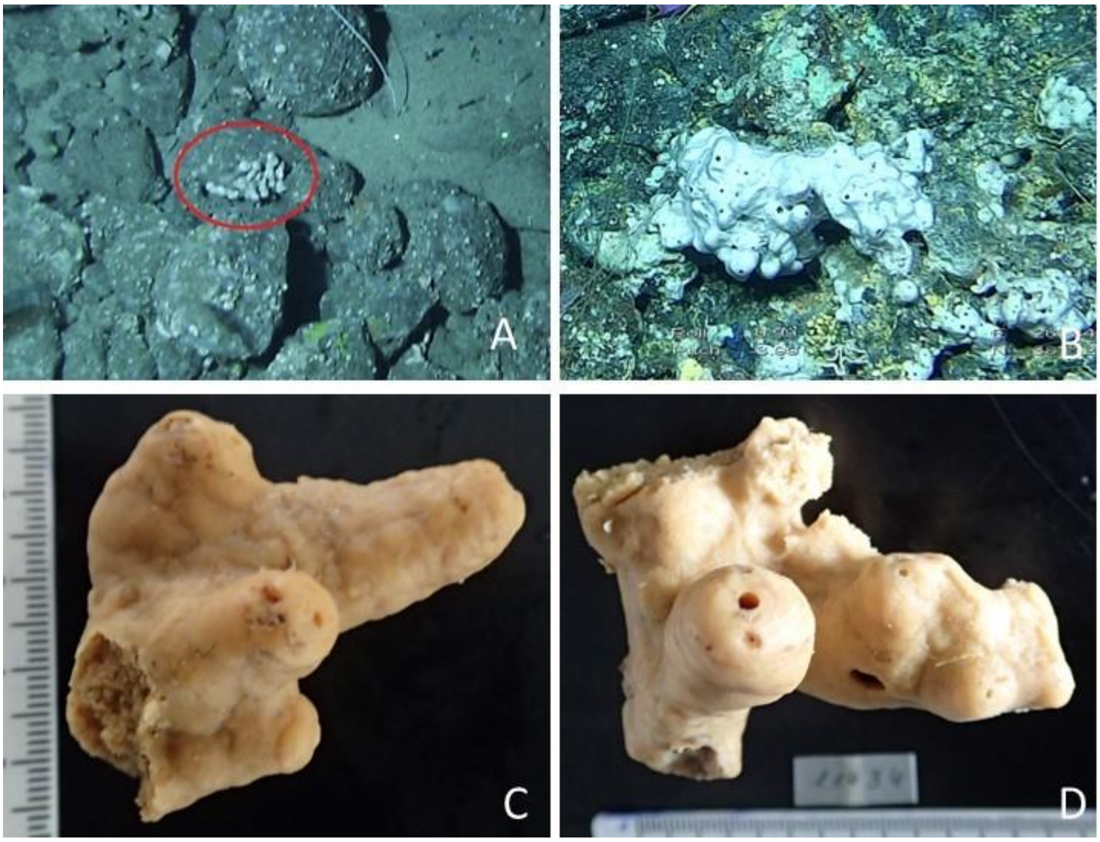


Figure 144 *Petrosia vansoesti* external morphology. Specimen 11934, ex situ lateral and top view, showing the oscula aperture.

**Spicules:** Megascleres are: a) strongyles of two categories: I – big and slightly curved; II – small and more curved than the former; b) oxeas of two categories: I – big and robust and slightly curved and II – small, thin and acerated (Figure 145).

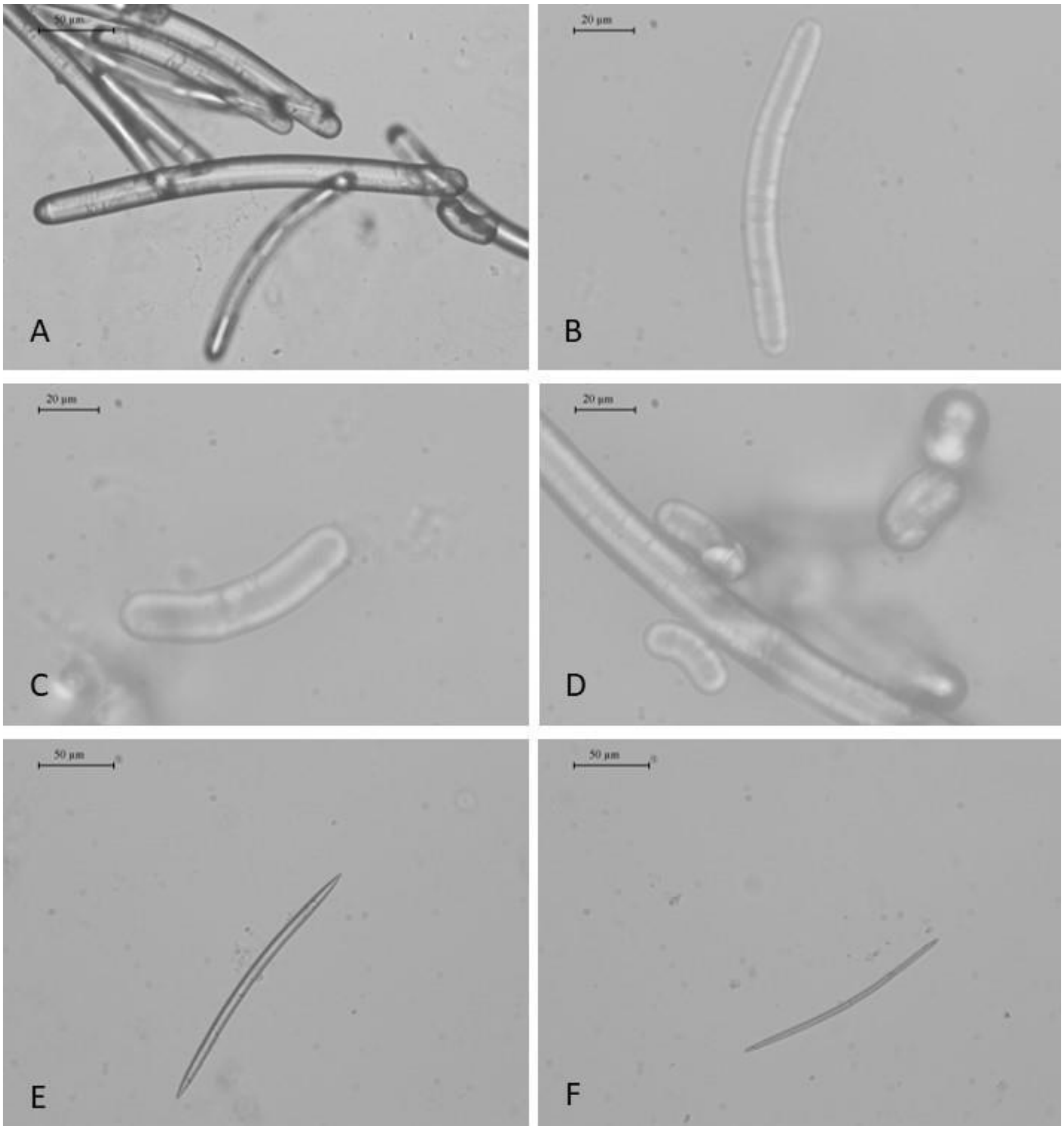

**Figure 145** *Petrosia (Strongylophora) vansoesti* Boury-Easnault, Pansini and Uriz, 1994 spicules. Specimen 11934. A. Strongyle category I; B., C. and D. Strongyles category II with three sizes. E. Oxea category I; F. Oxea category II.

**Remarks:** see discussion in Boury-Esnault, 1994.

**Habitat and distribution:** Very common and abundant species observed by ROVs and drift cameras occupying the upper slope strata, together with other Petrosiids (*Petrosia crassa*), astrophorids (*Characella spp*., etc) lithistids (*Leiodermatium spp*., *Macandrewia sp.*, etc). This species was first time recorded for the Azores region in Pereira (2013 Master Thesis manuscript, unpublished). Before it was known only for the Mediterranean (Boury-Esnault, 1994; Gerovasileiou, *et al.* 2012; Diaz *et al,* 2021). Depth range in the Mediterranean 285-362 m.

### *Family Phloeodictyidae*

**_Oceanapia coriacea_ (Topsent, 1904)**

Aphia ID 132936

**Material examined:** C10010 specimen collected at Pico, specimen collected at 522 m depth (St. 07, Dive 2 ROV Luso, Exp. Blue Azores, 2018).

## Morphological description

**External morphology:** Sponge massive globular shape, beige colour with nearly more than 20 fistules (Figure 146).

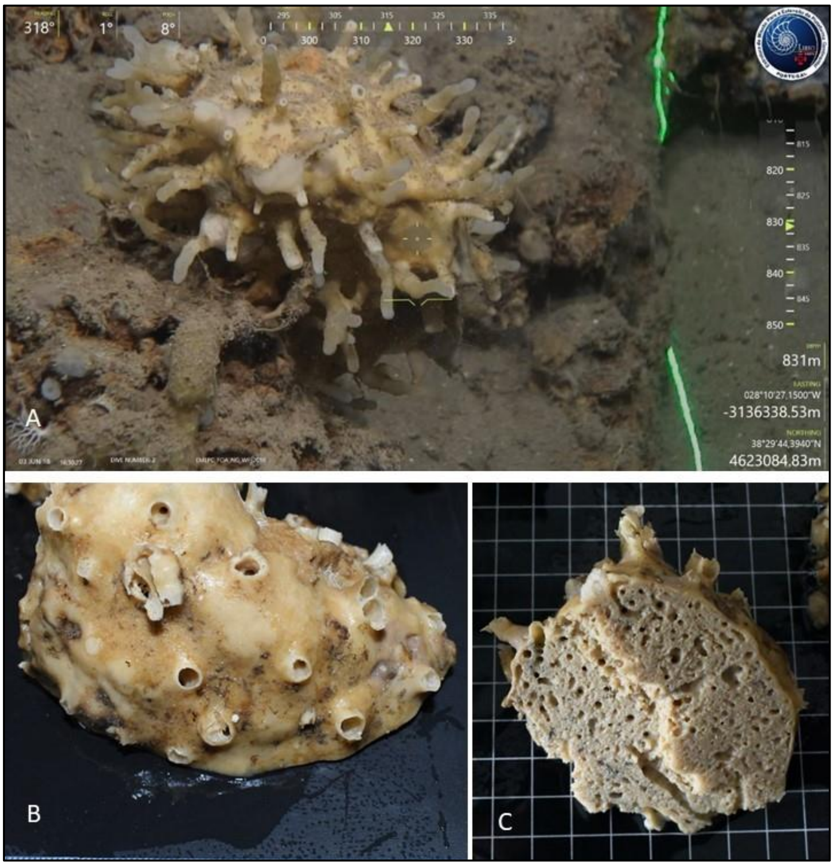


**Figure 146** *Oceanapia coriacea* external (Topsent, 1904) morphology. Specimen 10010 showing external morphology. A. External morphology of the specimen, *in situ* image with ROV Luso (BAç Exp. 2018), B. Specimen after preservation; C. Cross-section of the same specimen showing the ectosomal layer and choanosome.

**Spicules:** The spicules are two types of Oxeas. Type I: 228-280 X 10-20 **µ**m (Av. 253 X 15 **µ**m) and Type II: 160-241 X 5-7 **µ**m (Av. 212 x 6 **µ**m). Measurements taken at the collected specimen in the present study differs from Topsent (1904 and 1928) and Levi and Vacelet (1958), which are slightly smaller (max. 250 **µ**m in height, according to Princess Alice Bank specimen) than our material. Neto, *et al.* 2018 review has considered only one of Topsent stations. However, Oxea type I looks quite similar, with mucronate ends. Oxea type II was not documented by authors descriptions of *O. coriacea*, and it might not represent a true different Oxea type, but instead the variability related with Oxeas development stages (Figure 147).

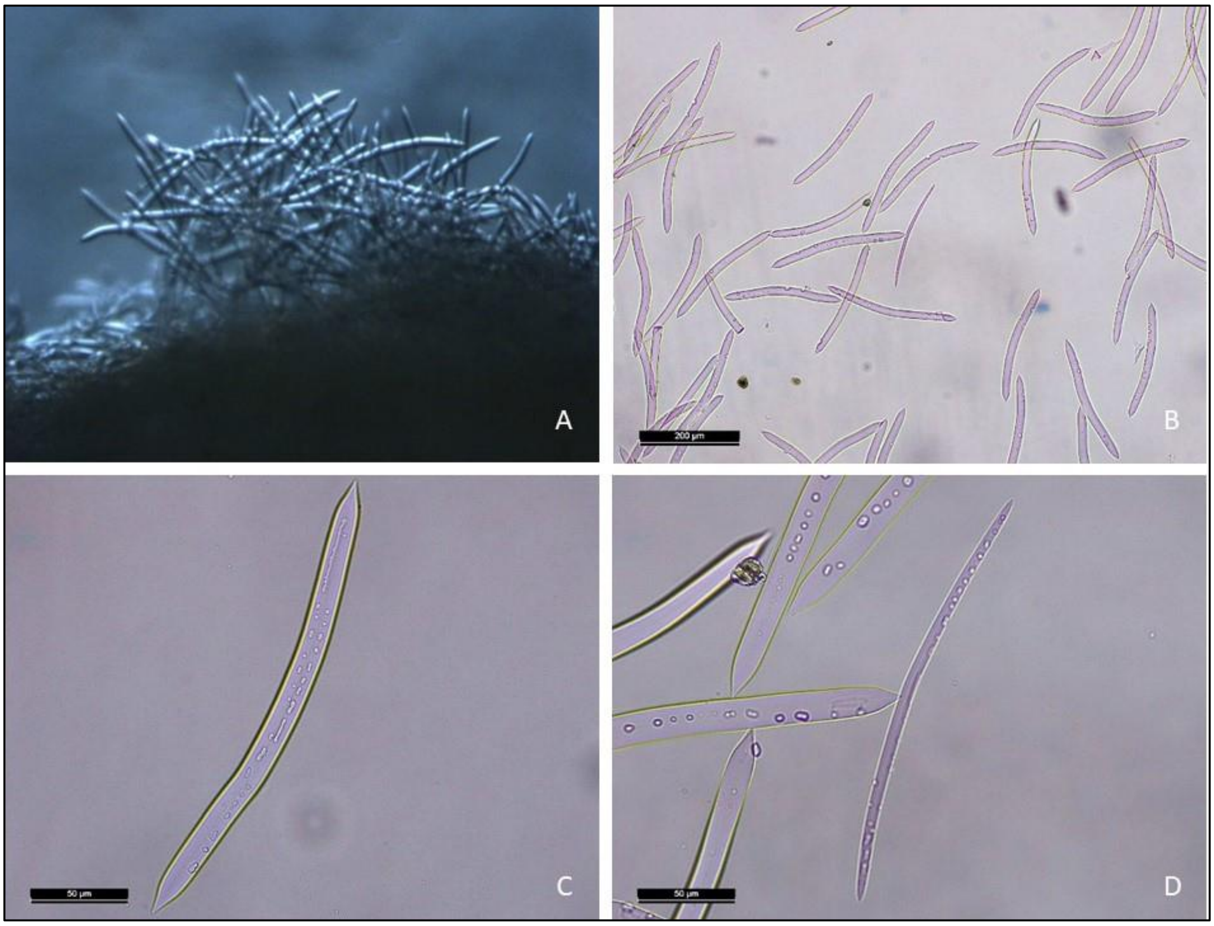


Figure 147 *Oceanapia coriacea* (Topsent, 1904) external morphology. Specimen C10010 showing external morphology. A. External morphology of the specimen, *in situ* image with ROV Luso (BAç Exp. 2018), B. Specimen after preservation; C. Cross-section of the same specimen showing the ectosomal layer and choanosome.

Remarks: See *Oceanapia spp.* review Table 1 in Neto et al. (2018).

Habitat and distribution: Rocky bottoms in Azores at 919 - 1229 m. The specimen collected in this study is also from a hard bottom but at a shallower bathyal area (522 m). The specimen observed by Burton (1956) was collected at a much shallower zone at infralittoral of Freetown (17 m depth, West Africa continental shelf). It was found for first time at West of Flores Island (Atlantic, Azores), but also at African West coast at shallow waters (doubtful record, pers. comm.).

*Oceanapia* cf. *azorensis* van Soest & Hooper, 2020

AphiaID 1423858

Material examined: Specimen C10881, Jose Gaspar Bank at 533 m (Mission Meteor/ATHENA Expedition, MARUM ROV Squid).

## Morphological description

**External morphology:** Several morphotypes were observed during expeditions with ROVs and drop-down cameras. This species morphology is always as it is shown in Fig. 64. The collected specimen is lost, or unknown location once the collected material at ATHENA Exp. is shared between different teams. Presently, it was already possible to extract a small fragment because species associations (e.g. hydroids) were removed together with sponge scraps. So, a small fragment of the sponge sturdy fistule or main cylinder was enough to check the spicules composition. Externally, the sponge cylinder bifurcates at the top and it is inserted at a base of an unknown material. Comparing with all *Oceanapia spp.*, *O. (fistulosa) azorensis* Van Soest & Hooper, 2020 (sensu Topsent 1904), there are some similarities regarding the fistules descriptions in height (≃11 cm) but not in diameter (≃12 mm) which in our material looks larger (≃20 mm). The globular formation at the base, observed by Topsent (1904 and 1928), it is not perceived in the in-situ and the collected material available images (Figure 148).

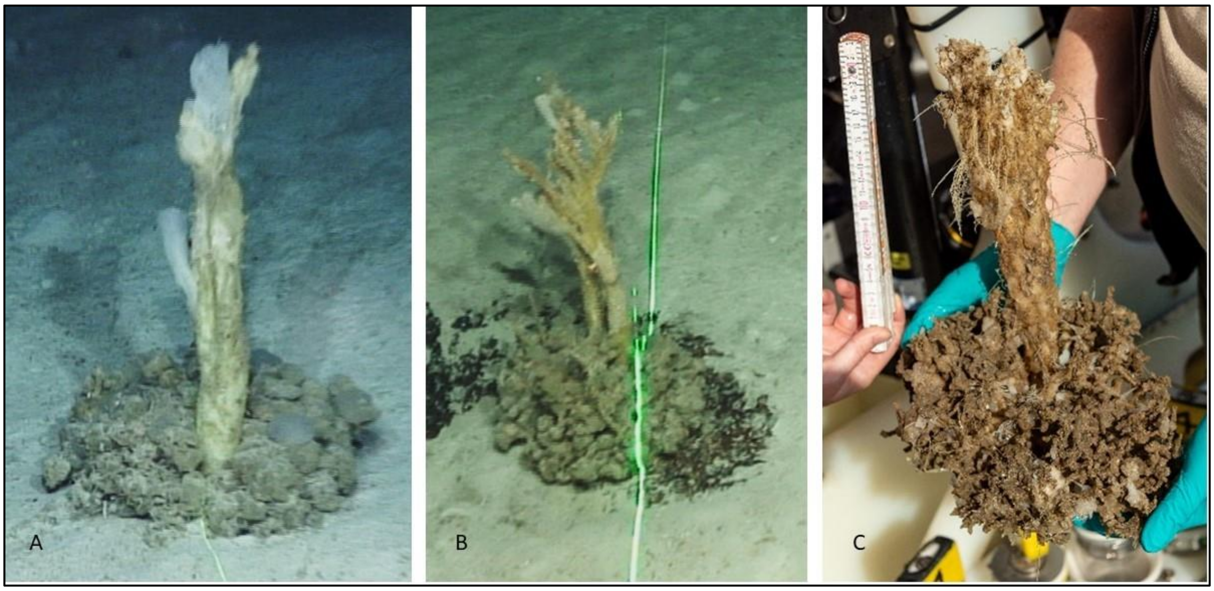


**Figure 148** *Oceanapia* cf. *azorensis* van Soest & Hooper, 2020. A. and B. in situ images at Irving Seamount, during BIOMETORE Exp.; C. specimen 10881 collected at Jose Gaspar Bank during ATHENA Exp.

**Spicules:** Regarding spicules shape and measurements of *Oceanapia azorensis* (sensu Topsent 1904) and Levi and Vacelet (1958). Oxeas height do agree with *O. azorensis*, however microxeas do not have correspondence in width (Figure 149).

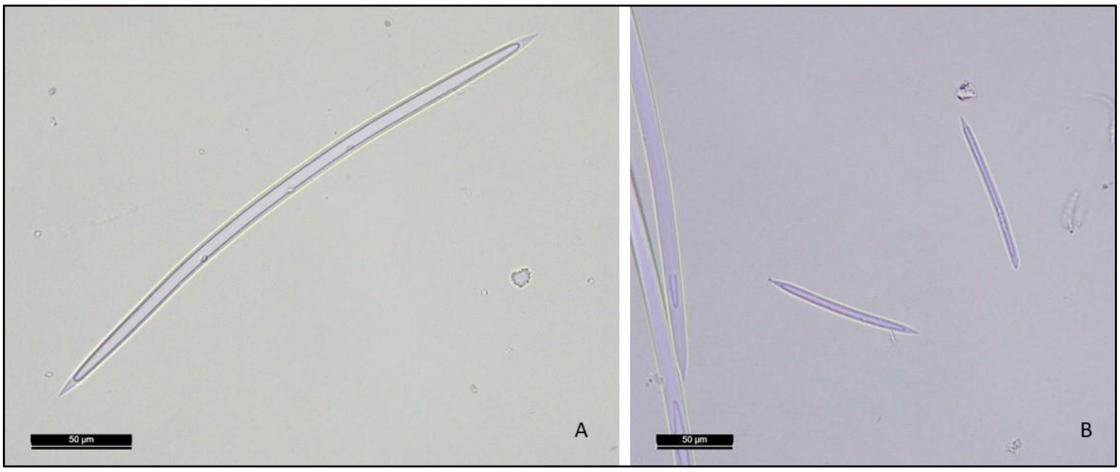


**Figure 149** Oceanapia cf. azorensis. spicules. Specimen 10881. A. Large Oxea; B. Microxea.

**Remarks:** Drawings made by Topsent (1928) suggests two types of acerate Oxeas, slightly mucronate, which does not look like the Oxeas shape of specimen 10881 at the present study. It was also documented the presence of spherules in former descriptions of *O. azorensis*.

**Habitat and distribution:** It was always observed at soft bottoms. At the Azores *O. azorensis* (sensu Topsent 1904) is distributed at the upper bathyal of the islands of Graciosa, North of Pico, Princess Alice Bank between 200-454 m depth and at mid/lower bathyal at West Flores Island were found between 650-1229 m. The material collected South the Azores was found at 533 m but in situ images revealed the distribution is extended to the South Azores Seamounts Complex (Atlantis Meteor Complex) at deeper areas (1200 m).

*Family Phymaraphiniidae*

***Exsuperantia arquipelagus*** **Carvalho & Pisera, 2019**

**Aphia ID 1349574**

**Material examined:** Specimens "white morph": C10195 collected in Gigante Bank (38.7089 N; -30.222 W), transect between 440-589 m depth (ROV Luso Dive 15 St57); and 10059 collected in Bank 127 (38.7156 N; -30.0136 W) at 546 m depth (ROV Luso Dive 6 ST20) during the Blue Azores 2018; Specimen "yellow morph" C11594 collected at M128 Expedition (sample 4, Dive 389), D. João de Castro Bank (38.2102 N; -26.5749 W) at 256 m depth.

**Morphological description**

**External morphology:** Columnar sponge. Small 5 to 7 cm tall and 2 to 3 cm thick attached to the substrate by the entire base. Surface is smooth. Oscules or pores are not visible to the naked eye. In literature the documented colour is beige to whitish in ethanol (Carvalho and Pisera, 2019). This study brings new information about the coloration type of this species. Anteriorly, we were identifying the yellow morph a different sponge species. Although, the deposited material of the M128 provided, in -situ imagery of the sample C11594, which was later confirmed to be the same species due to the same specular arrangement. This has allowed us to merge two morphotypes (Porifera digitate sp1 and Porifera digitate yellow) into the endemic lithistid *Exsuperantia archipelagus* Carvalho and Pisera, 2019 (Figure 150Figure 151).

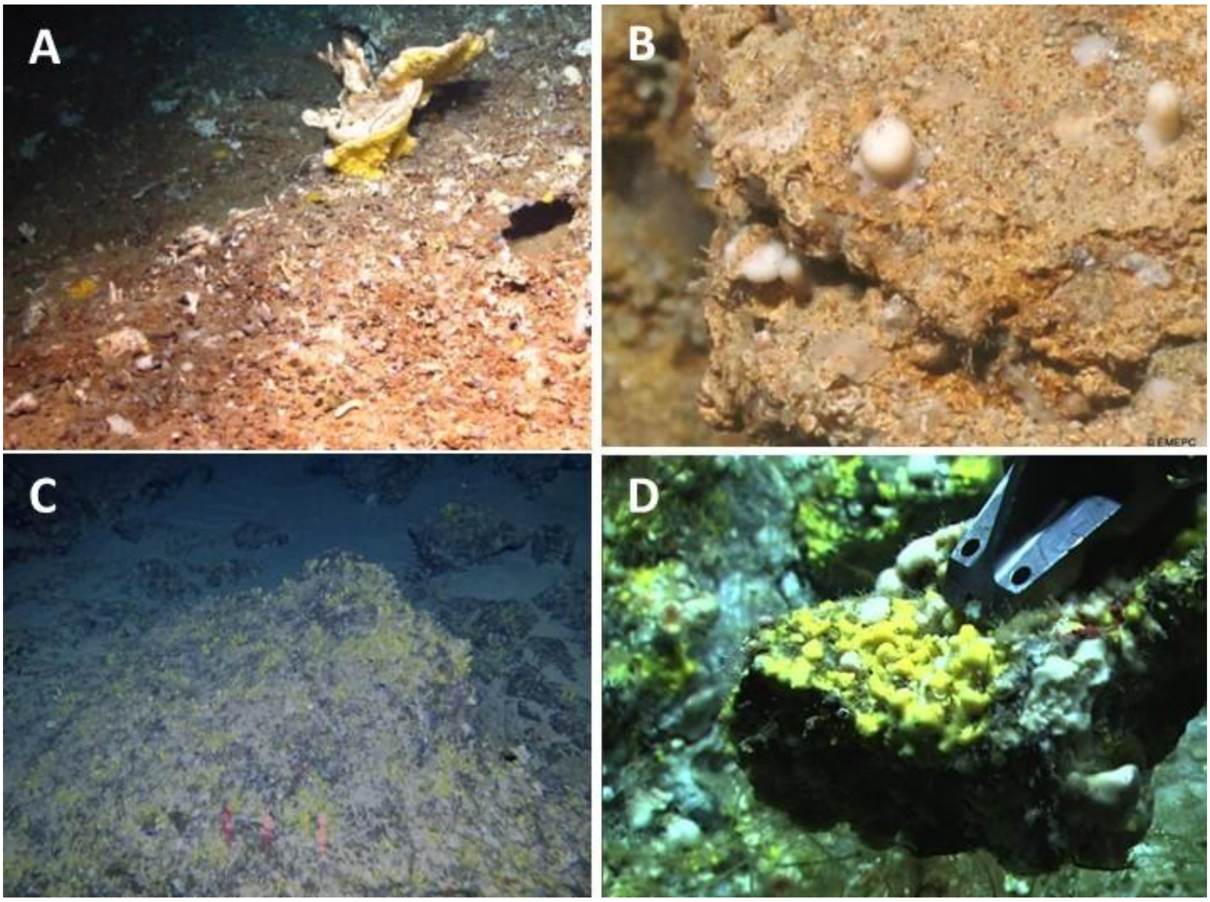


**Figure 150** *Exsuperantia archipelagus* Carvalho and Pisera, 2019. In situ. A. White Morph meadow; B. White morph close up; C. yellow morph meadow; D. yellow morph close up, ROV MARUM sampling specimen C11594.

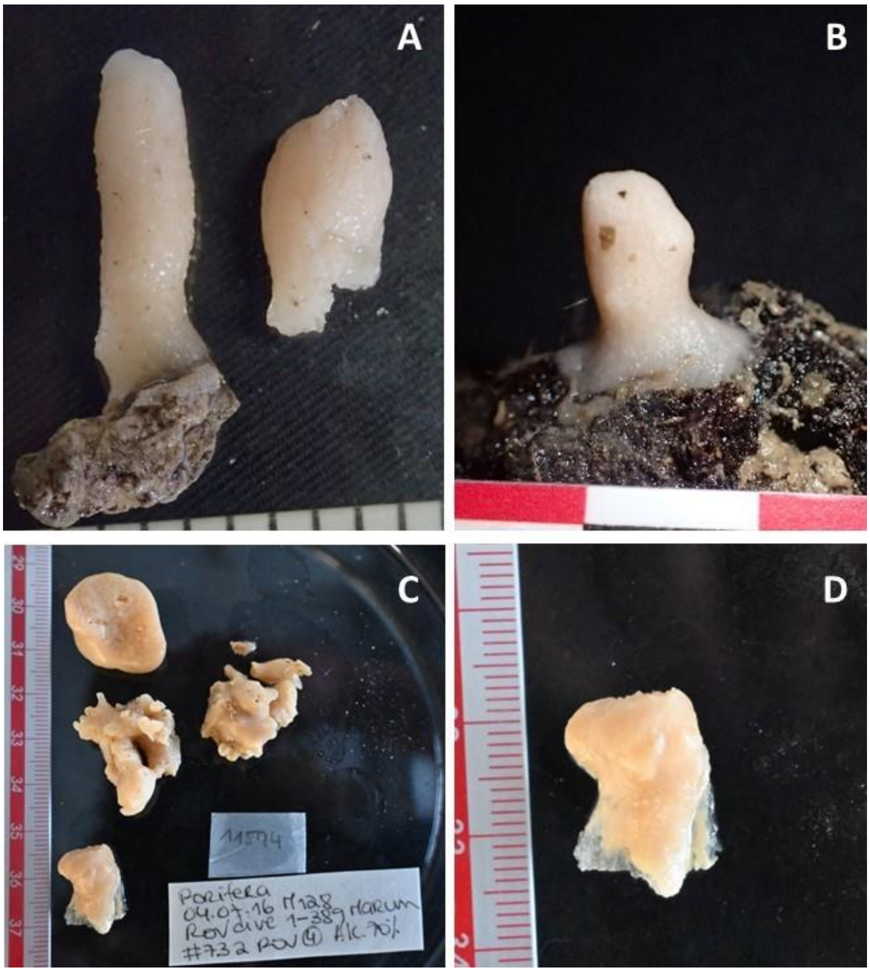


Figure 151 *Exsuperantia archipelagus* Carvalho and Pisera, 2019. external morphology. A. Specimen C10195: B. Specimen C10059. C. Specimens sample C10059.

Spicules: The skeleton is composed by a layer of overlapped phyllotriaenes, numerous acanthomicroxeas and acanthorhabds and some (rare) amphiasters. Description matches entirely the work of Carvalho and Pisera (2019). Phyllotriaenes cladome is smooth with long clads, rhabdome has a conical shape with rounded tip. Tylotes and subtylostyles are smooth often curved very variable in shape and size. Acanthomicroxeas thin with sharp tips. Acanthorhabds robust fully covered with spines (Fig. 68 E). Amphiasters regular with several spinous arms (Figure 152).

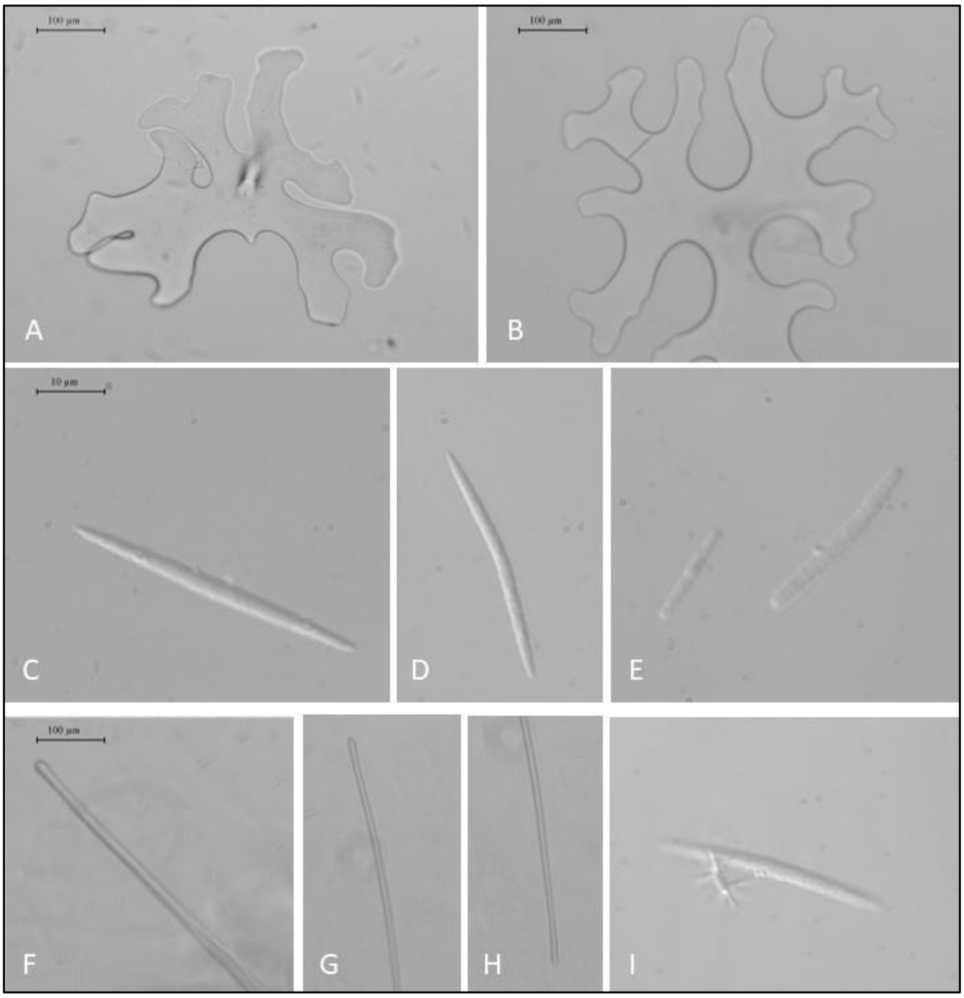


Figure 152 *Exsuperantia archipelagus* Carvalho & Pisera, 2019 spicules. A. and B. Phyllotriaenes; C. and D. Acanthomicroxeas; E. Acanthorhabds; F., G. and H. Tylotes; I. Microxea and Amphiaster.

**Remarks:** See full description and discussion of *Exsuperantia archipelagus* in Carvalho and Pisera (2019).

**Habitat and distribution:** It was observed using ROV video imagery (Dives at Gigante Bank) in very high abundances and densities attached to rocks. This species is known from its type locality (Azores 168-770 m depth) and also from other Macaronesian islands (Madeira 563 m depth and Canaries, 403 m depth).

### *Family Corallistidae*

#### *Neoschrammeniella sp.*

**Material examined:** Specimen 1673623 collected during Expedition *EX2206* (ROV Dive *D02 Station 12B)* at East of Formigas Rift, 627.37 m depth.

#### Morphological description

**External morphology:** Large sponge, hard consistency. Massive, flattened with thick walls. Attached to substrate in the basal part. white colour in live conditions and after preservation in alcohol. The surfaces of the sponge are smooth (Figure 153).


Figure 153 *Neoschrammeniella* sp. A. Specimen 1673623 collected during Expedition EX2206 (ROV Dive D02 Station 12B) at East of Formigas Rift, 627.37 m depth. B. ex situ External morphology, ear shaped and hard consistency, creamy white color. C. Specimen after collection, D. Specimen surface zoom.

**Spicules:** Ectosomal skeleton composed of smooth dichotriaenes of variable shape. Smooth cladome. Choanosomal skeleton is made of an irregular and loose network of dicranoclone desmas. Spirasters short and thick arms (Figure 154).

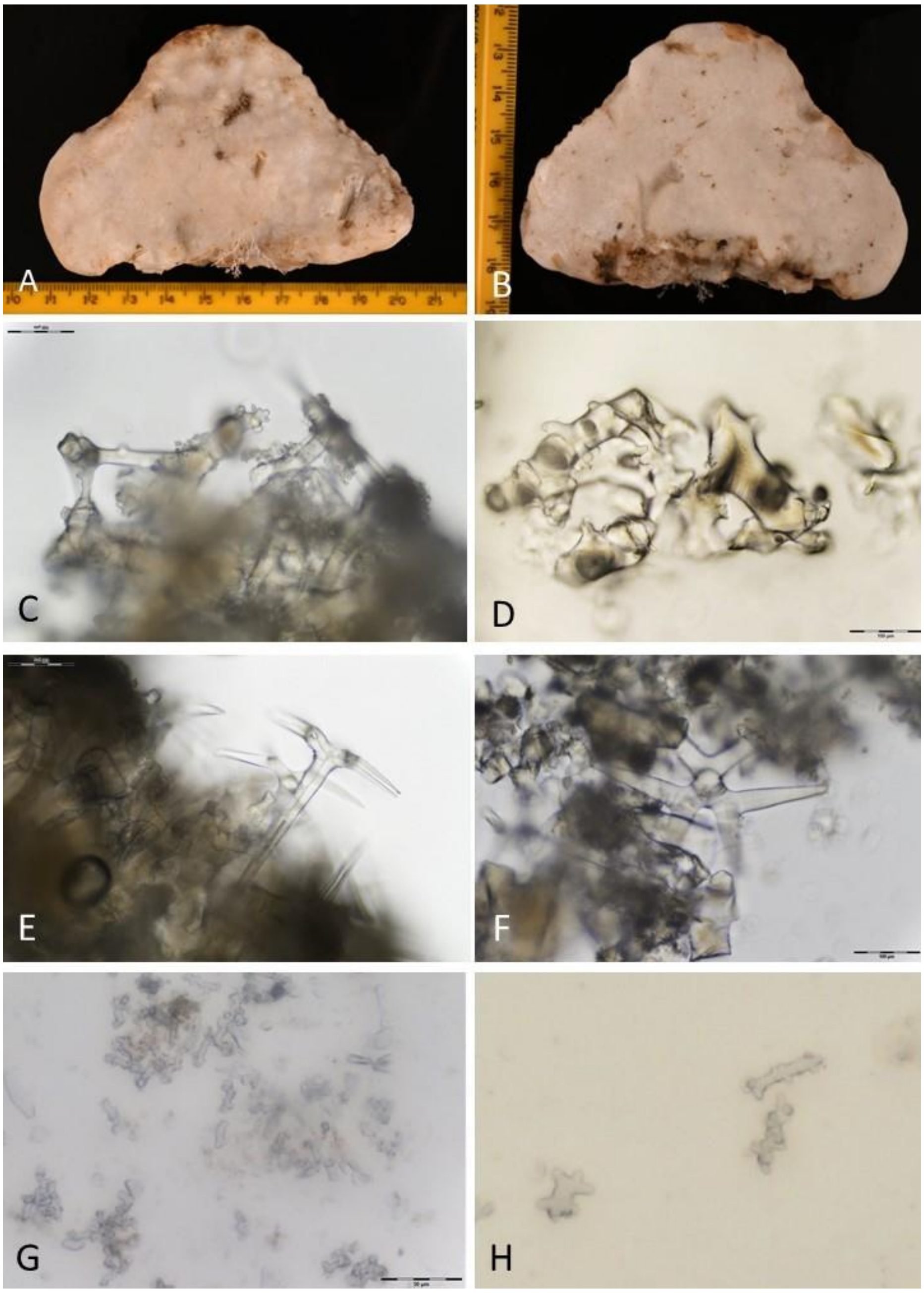


Figure 154 *Neoschrammeniella* sp. Specimen 1673623 A. top view; B. bottom view; spicules: C. D. E. Dichotriaenes lateral view; F. Dichotriaenes top view; G. Spirasters; H. Spirasters close up, two types.

**Remarks:** More preparations should be made to take measurements and compare with other species from *Neoschrammeniella* sp. determined for the Atlantic Seamounts and Mediterranean (Pisera and Vacelet, 2011; Carvalho, et al. 2014 and 2020). Recently Rios has documented N. aff. bowerbankii for the Cantabrian Sea.

**Habitat and distribution:** This preliminary assessment of this specimen is the first record of the genus *Neoschrammeniella sp.* for the Azores Region EEZ.

*Order Poecilosclerida*

*Family Mycalidae*

*Phlyctaenopora (Phlyctaenopora) bitorquis* Topsent, 1904

Aphia ID 168705

**Material examined:** Specimen 10061, collected at Bank 127 (38.7156 N; -30.0136 W) at 546 m depth (BAz Exp. 2018).

## Morphological description

**External morphology:** Mycalidae with a megasclere complement of oxeas and strongyles in combination with a microsclere complement which include anisochelae and sigmas. Convex crust torn at the underside (forcibly removed from the substratum). Cream-coloured. Surface shiny-smooth, bearing numerous unequal papillae of about 5 mm high. One large elevated oscule, with exhalant canals leading up to it (Figure 155).

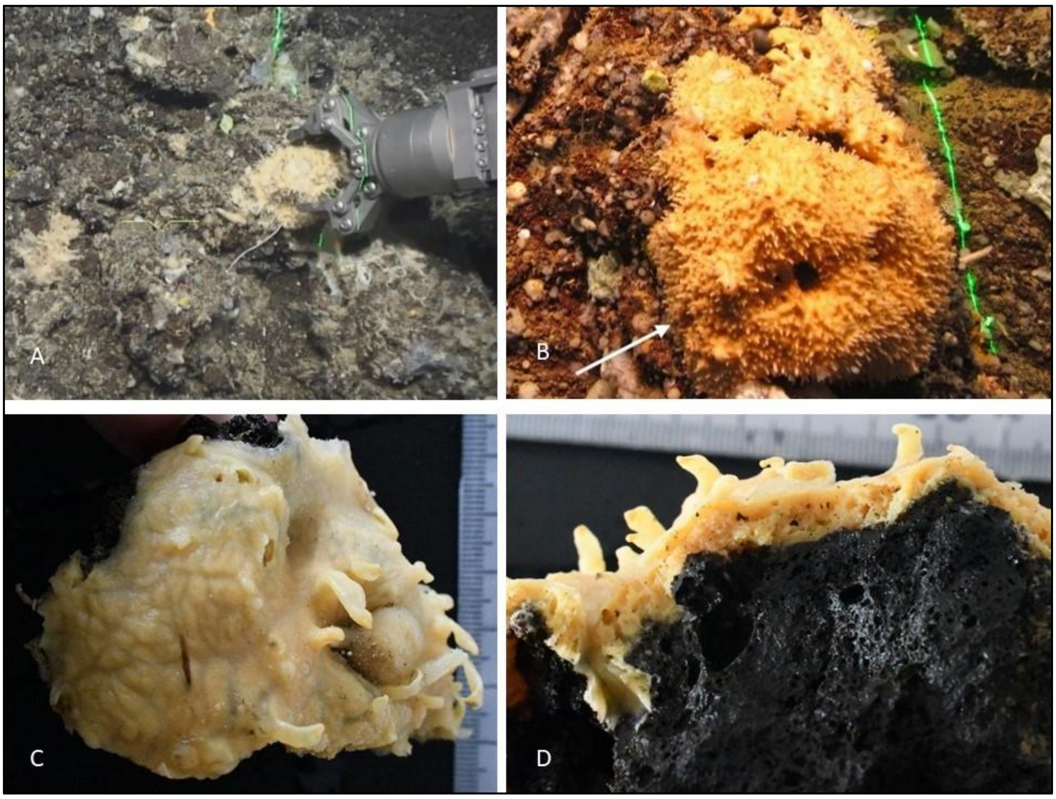


**Figure 155** *Phlyctaenopora (Phlyctaenopora) bitorquis* Topsent, 1904 external morphology. *A.* Specimen 10061 *in situ* image collected during Exp. BAz 2018 with ROV Luso; B. Other *in situ* image of a similar morphotype; C. Specimen 10061 covering a boulder, top view (colour after preservation in ethanol 96%); D. Spec. 10061 cross section, showing papillae and cortex.

**Spicules:** Massive, smooth or with erect fistules; confused compact choanosomal skeleton of smooth oxeas and scattered bundles of isolated strongyles; ectosomal skeleton a crust of smooth strongyles; microscleres include palmate anisochelae which may be basally spurred and sigmas.

Ectosomal crust firm, made up of a tightly massed tangential spicule skeleton. Most ectosomal spicules are oxeas. Choanosomal skeleton largely confused, with strongyles tending to form ill-defined tracts, whereas oxeas are intercrossing at all angles. In the walls of the papillae the strongyles are arranged parallel to the axis of the papilla. Megascleres oxeas, angularly curved twice, 300 X 10–12 µm; strongyles slightly curved, slightly thinner at the rounded ends, 360X12 µm. Microscleres anisochelae, usually spurred, 20–27 µm; sigmas, abundant, 38 µm (Van Soest and Hadju, 2002) (Figure 156).

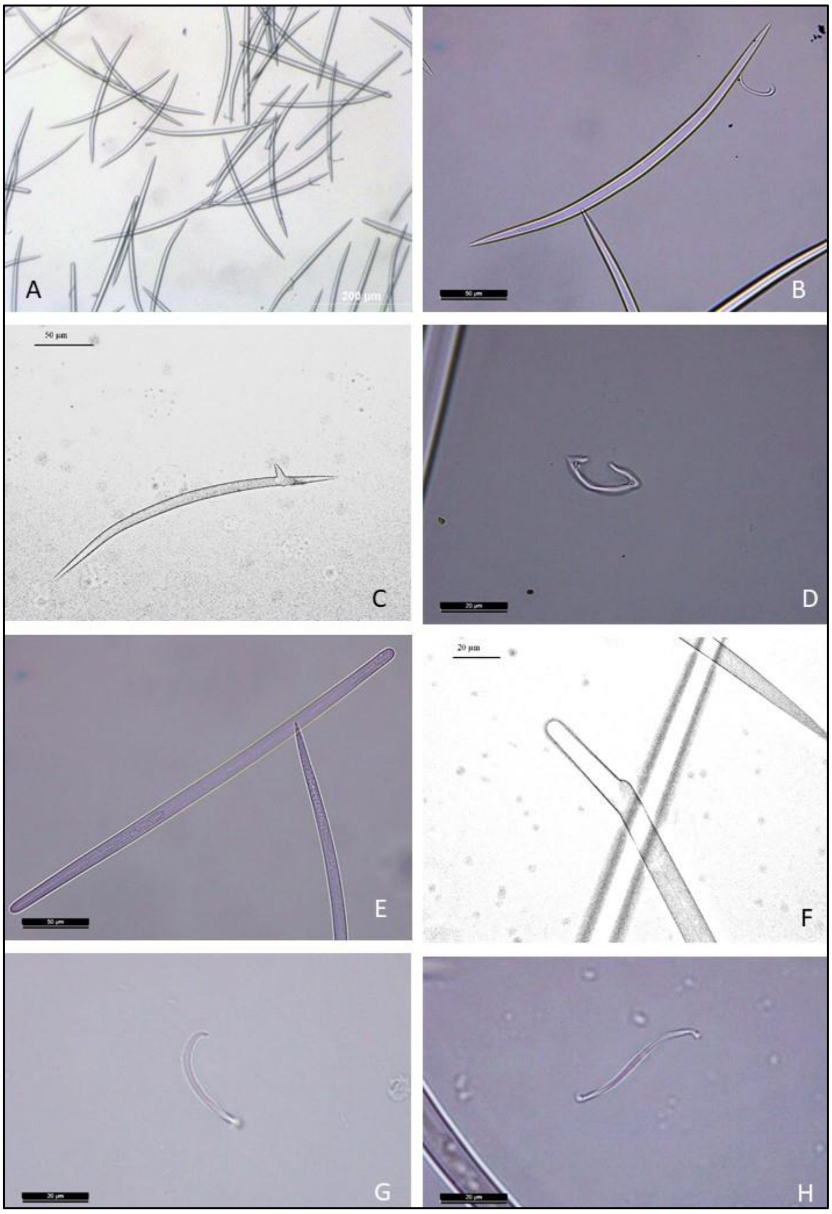


**Figure 156** *Phlyctaenopora (Phlyctaenopora) bitorquis* Topsent, 1904 spicules. A. Oxeas; B. Oxea angularly curved twice; B. Oxea mal-formation; C. Anisochelae. E. Strongyles; F. Strongyle mal-formation; G. Sigma; H. Sigma in S.

**Habitat and distribution:** Also some remarks from Van Soest and Hadju (2002): *"The habit and ectosomal reinforcement indicate that the sponge probably lives buried in the sediment with the papillae and oscules raised above it."* Although, the present material was found attached to rock, never in sediments. The same morphotype was observed covering volcanic rocks (boulders) in Gigante Seamount Complex. Azores, upper bathyal (≃550 – 600 m).

### Flabellate yellow morphotype

*Family Desmacellidae*

*Desmacella grimaldii* (Topsent 1890)

Aphia ID 168302

**Material examined:** Specimen 10090 collected at Gigante Bank at 645 m depth with ROV Luso (Dive 10) during blue Azores Expedition, 2018.

### Morphological description

**External morphology:** Specimens during dives where always in flabellate shape, coloured in yellow when alive in natural habitat. After preservation colour became dark beige. Pores and oscules confined into definite and separate areas. Topsent (1890) description of *Desmacella grimaldii* documented also different shapes, such as globular (Figure 157).


Figure 157 *Desmacella grimaldii* (Topsent 1890) external morphology. Specimen 10090. A. and B. *in situ* image showing a flabetate form, colour yellow in live specimens. C. Collected material, showing oscules distribution and a dark beige colour after storing in ethanol; C. Oscules size and hispidity details.

**Spicules:** The examined material has three sizes of Tylostyles, differing from first *Desmacella grimaldii* descriptions. Tylostyles of *D. grimaldii* are larger in literature. However, this study adds a third Tylostyle, of a smaller category 107- 287.2 X 2.2 – 7.1 (Av. 212.3 X 5.4). It was noticed the presence of Tylostrongyles, never documented before. In this regard, we do not know if they represent different development stages and even if tylostrongyles are mal-formations. It was also noticed the presence of microxeas and one different sigma type (Figure 158). Although rare, tylostyles have variations in their bases too. More measurements are necessary to check if these differences are consistent.

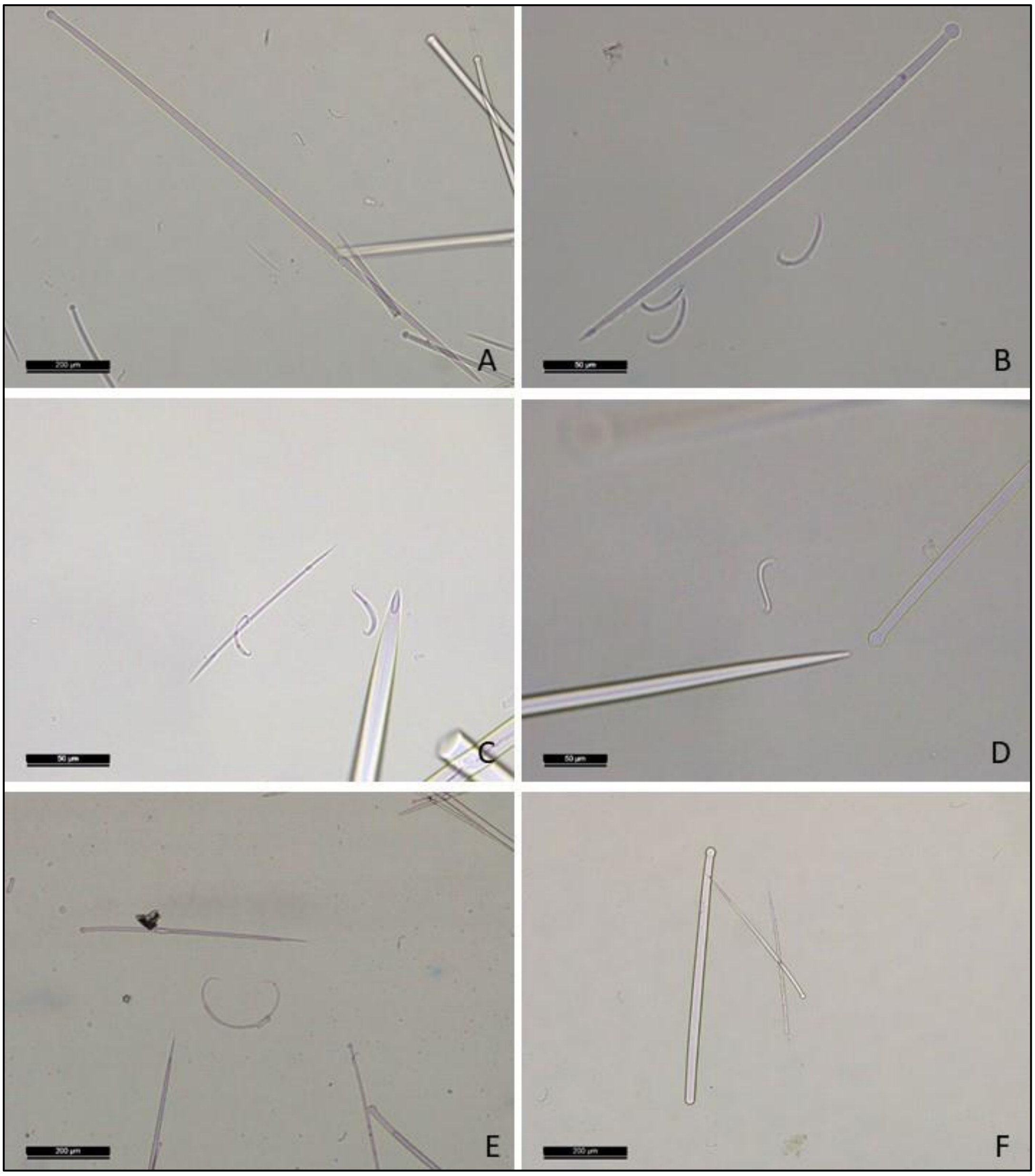


**Figure 158** *Desmacella grimaldii* (Topsent 1890) spicules. Specimen 10090. A. Tylostyle I; B. Tylostyle III and sigmas Type I; C. Microxea and sigmas Type Ia and Ib; D. Sygma type Ib (S shape); E. Sigma type II; F. Tylostrongyle and Tylostyles III.

**Remarks:** Due to high variability of Tylostyles, presence of tylostrongla, microxeas and two different types of sigmas, we propose a revision of Desmacellids from the Azores, or *Desmacella grimaldii* re-description. Molecular studies are necessary to understand the real differences between species and determine which traditional morphological characters (such as spicule morphology, skeletal architecture, and quantity of spongin) might have more importance to differentiate them. Cruz (2002) has signed that there are not enough specific differences between four Atlantic species.

**Habitat and distribution:** Specimens observed in Banco 123 and Gigante Bank Complex where always seen in flabellate form attached to rocks at the upper bathyal. Azores, North-western Portuguese continental platform, Canary Islands, Cape Vert and African occidental coast.

*Order Bubarida*

*Family Bubaridae*

**Phakellia ventilabrum (Linnaeus, 1767)**

**AphiaID 132511**

**Material examined:** C11649 - M128 Meteor (Station 764 ROV 394, Sample 09) at North Flank Terceira Basin (39.2908 N; 27.5806 W) at 1204 m.

**Morphological description**

**External morphology:** This specimen in an atypical shape of *Phakellia ventilabrum*, very small and in leaf-like morphology (Figure 159).


Figure 159 *Phakellia ventilabrum* (Linnaeus, 1767) in situ. A. Aggregations of small *Phakellia ventilabrum*.


Figure 160 *Phakellia ventilabrum* (Linnaeus, 1767) ex situ. A. Specimen ventral side; B. Specimen external side; C. close-up of upper part showing apertures; C. close-up of basal part showing.

**Spicules:** Flexible strongyles, styles curved (Figure 161).

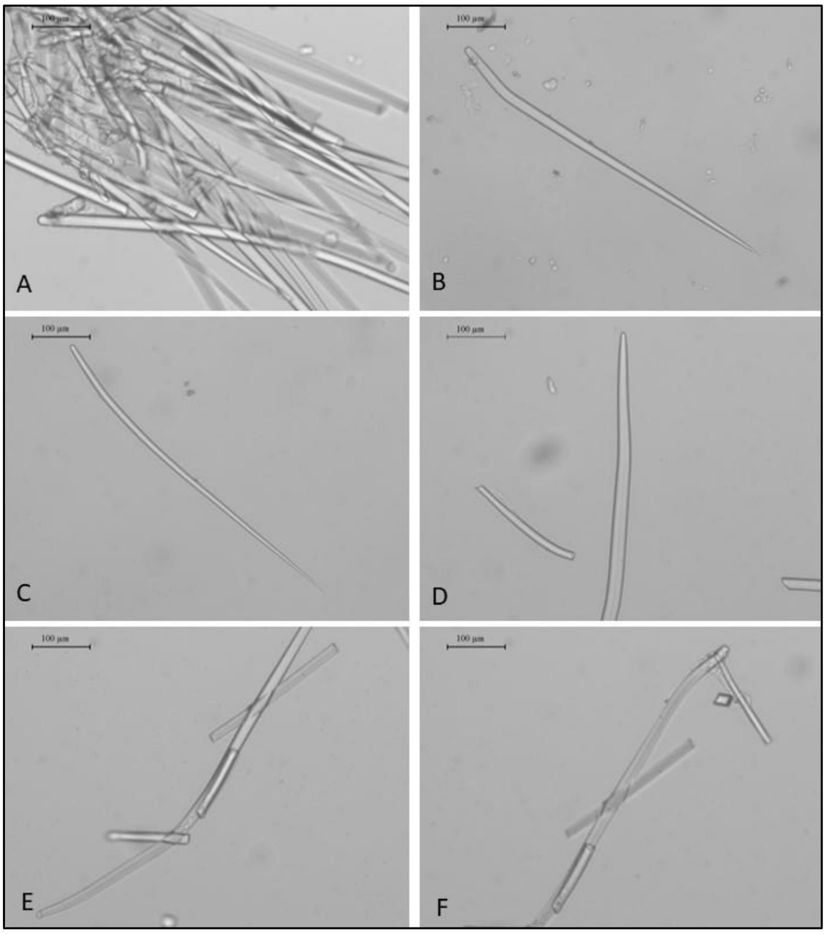


Figure 161 *Phakellia ventilabrum* (Linnaeus, 1767) spicules. A. Styles bundles; B. and C. Styles; D. Strongyle tip; E. Strongyle upper part; F. Strongyle lower part.

**Remarks:** This morphotype has represented a problem in video identification because we have never been completely sure of this identification unless with a specimen to prove it. The well-known *P. ventilabrum* are much larger and with a typical pedunculate shape.

**Habitat and distribution:** Recorded for the Azores Region around the island of Pico and S. Miguel, at 219 m depth (Levi and Vacelet, 1958). Other regions: all Atlantic from the Artic to South America, the Azores and Mediterrean from 10 to 1863 m depth (Boury-Esnault, *et al.* 1994).

*Order Axinellida*

*Family Raspaillidae*

***Raspailia (Parasyringella) falcífera*** **Topsent 1980**

**Aphia ID 168124**

**Material examined:** Specimen 2581, collected in 2002 at Sedlo Bank Seamount FISHOR (trawl by-catch, Pakura), (40.3480 N, -26.8380 W), depth 1069-1156 m.

## Morphological description

**External morphology:** Branched species with branches connected by transverse anastomoses, typically clathrate morphology (Boury-Esnault, 1997) (Figure 162).

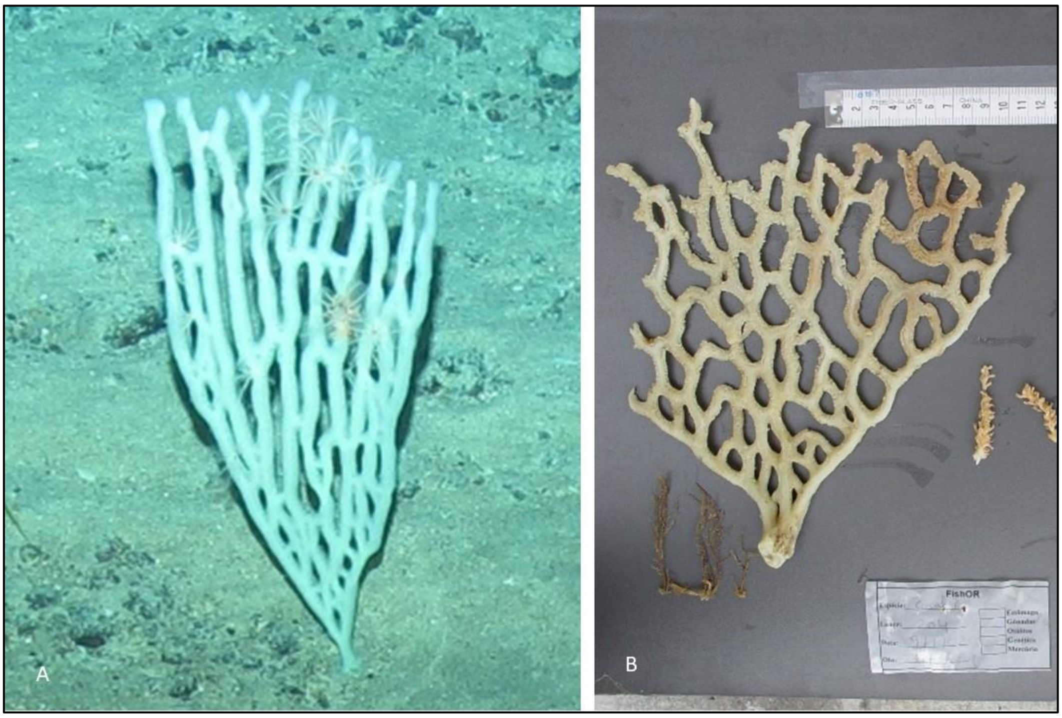


**Figure 162** *Raspailia (Parasyringella) falcifera* Topsent, 1980 external morfology. A. In situ image, video image (ROV Liropus) observed in Formigas (MEDWAVES Exp.); B. Specimen 2581 collected by trawl by-catch in Sedlo Seamount.

**Spicules:** It has two types of megascleres and lacks microscleres. Styles arranged in bundles or palissade and large oxeas with strongly curved tips (Figure 163). This character seems specific of the species *R. falc*ifera diagnose, different from other species of the genus.

Tylostyles present very high variation in size (large and small) and in their heads morphologies which can be truncated, mucronate or smooth. Measurements for each spicule category are under preparation.

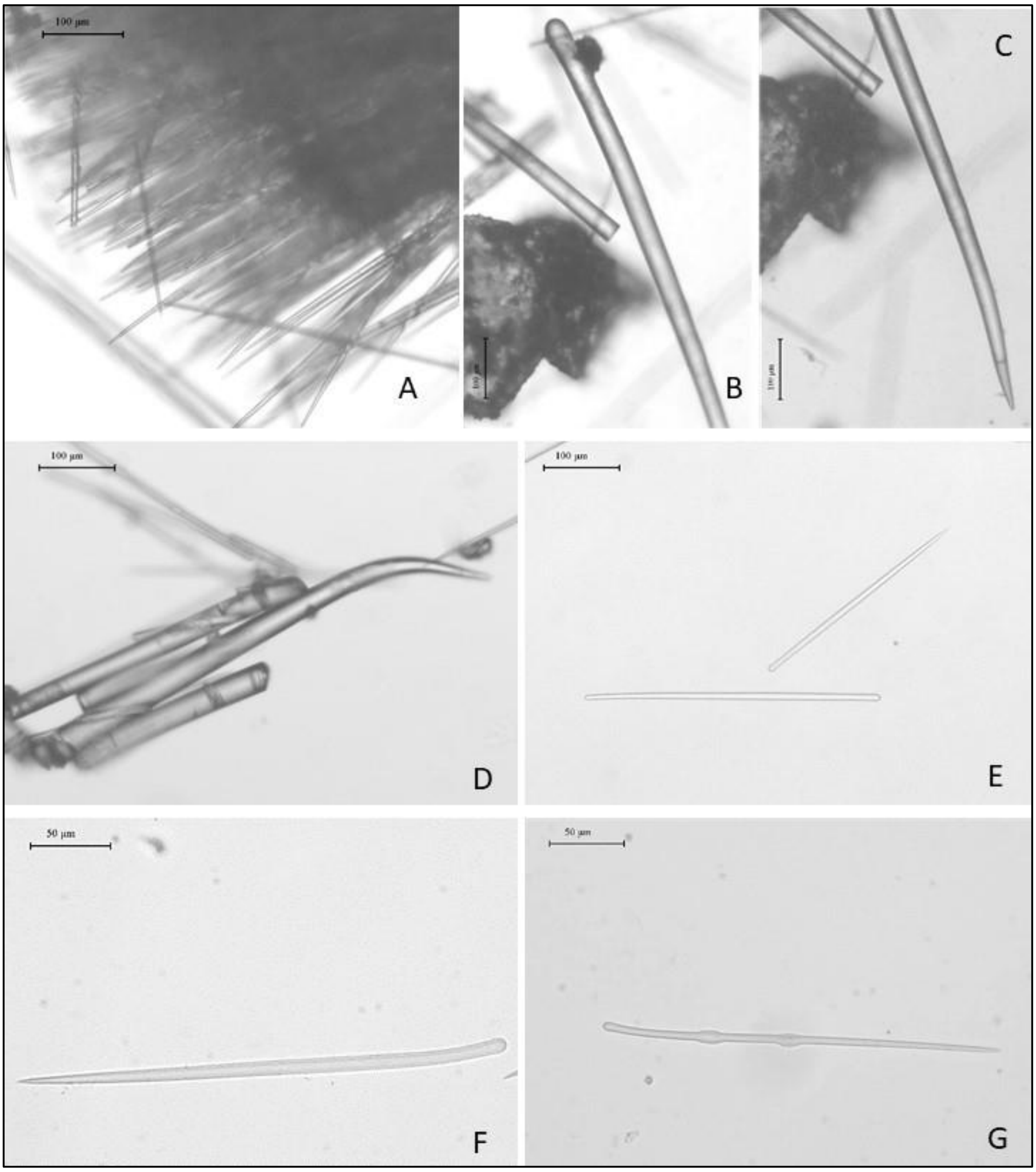


Figure 163 *Raspailia (Parasyringella) falcifera* Topsent, 1980 spicules. A. Bundles of Tylostyles; B. Tylostyle head; C. Tylostyle tip; D. Style or Oxea with curved tip; E. Small Tylostyles; F. and G. Small thin Tylostyles.

**Remarks:** Topsent 1892 has described this species with only one specimen collected between Pico and S. Jorge at 1300 m depth in soft bottom (vase and sable). The specimen external morphology corresponds with the video image (Fig. 78. A.) and the specimen collected in this study by bycatch (Fig. 78. B).

**Habitat and distribution:** Described in soft sedimentary areas with consolidated sediment where can attach. Found only in Azores, not documented for other localities. Topsent found one specimen in the channel S. Jorge – Pico. Video images from Formigas (MEDWAVES Exp.) observed 2 individuals and Sedlo Bank.

*Order Poecilosclerida*

*Family Coelosphaeridae*

*Lissodendoryx (Ectyodoryx) foliata* (Fristedt, 1887)

AphiaID 395137

Material examined: C13007 Ocean X 2023 Expedition, at Pico Island - Lajes South (38.3395 N; -28.2470 W) at 1060 m depth.

Morphological description

External morphology: Leaf-shaped. Surface even and smooth. Oscules numerous, small. Consistency fragile, soft. Colour white (Figure 164).

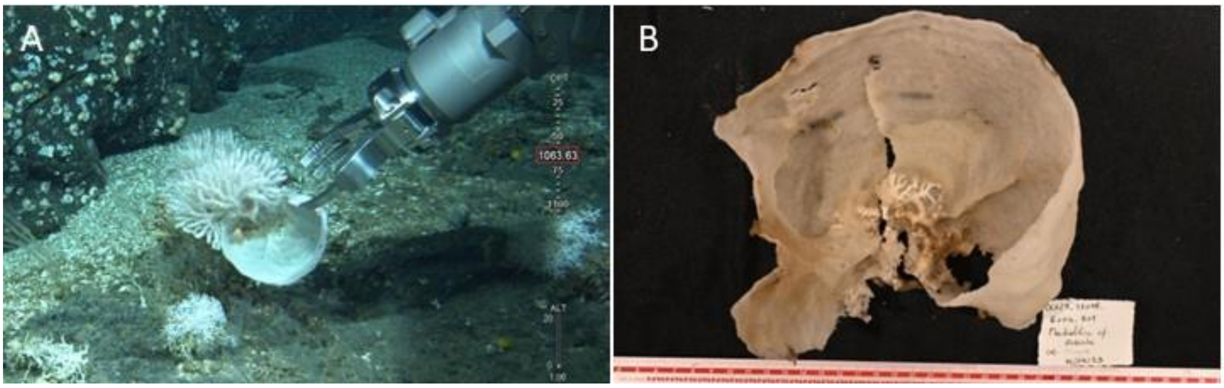


Figure 164 *Lissodendoryx (Ectyodoryx) foliata* A. Specimen C13007 in situ. B. Specimen C13007 freshly collected, close-up.

Spicules: This species is distinguished by its spicule characteristics including two size classes of acanthostyles and one size class each of tornotes, arcuate isochelae and two types of sigmas (S and C-shapes) (Figure 165).

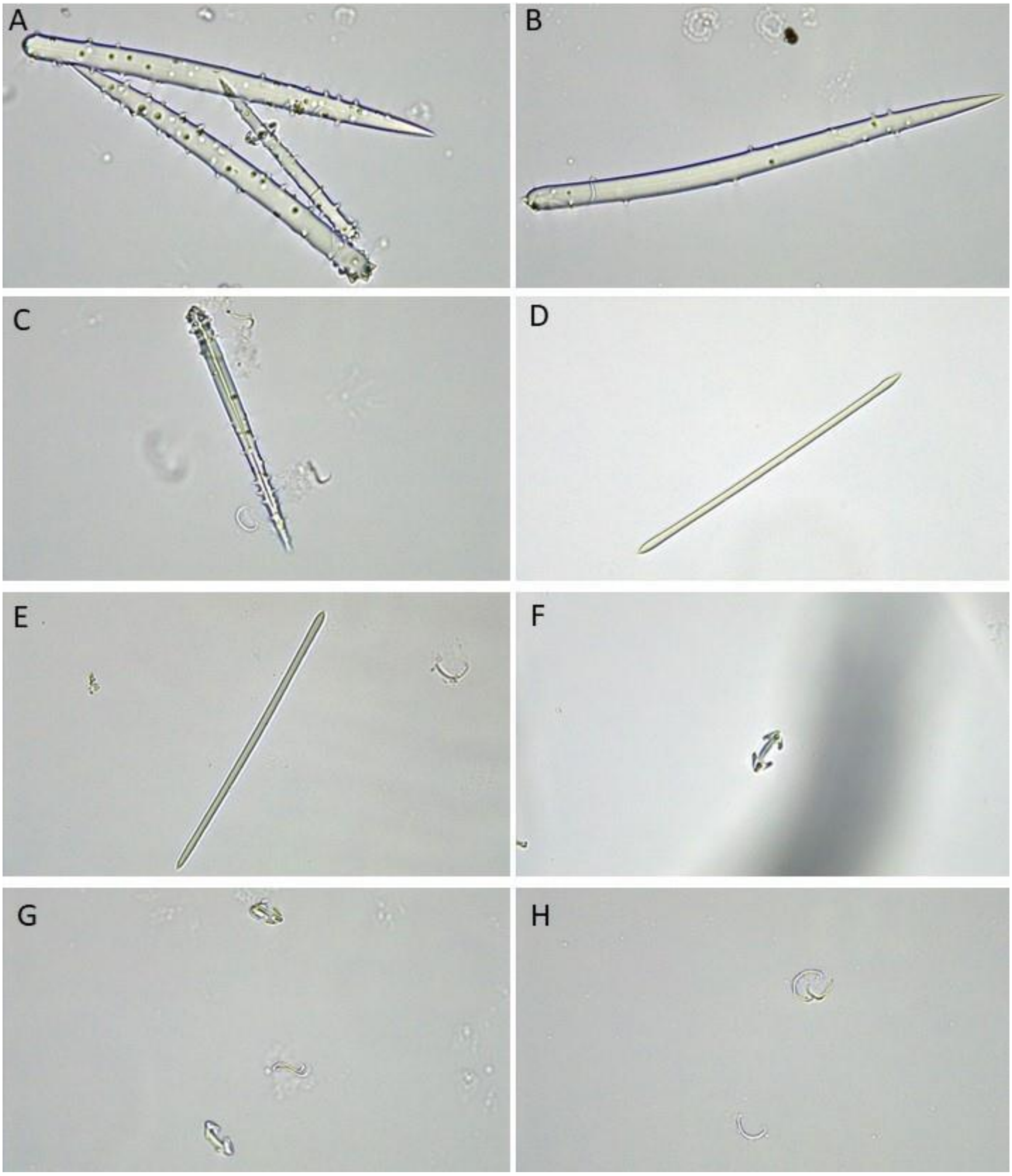


Figure 165 *Lissodendoryx (Ectyodoryx) foliata* spicules. A. Acanthostyles; B. Large Acathostyle; C. small Acanthostyle; E. tornote; D. Arcuate chelae; G. Chelae and sigma type I in S-shape; H. Sigmas types in C-shape.

Remarks: *Lissodendoryx (Ectyodoryx) foliata* was originally described by Fristedt (1887) as *Hastatus foliata*, and later transferred to the genus *Ectyodoryx* before assigning it to the genus *Lissodendoryx* while keeping *Ectyodoryx* as the subgenus. The type specimen collected from the east coast of Greenland is described as a small leaf-shaped sponge 3.5 cm long and only 3 mm thick. Topsent (1928) describes a thin encrusting sponge not more than 1 mm thick with a matching spicule complement and identified it as *Ectyodoryx foliatus.* However, the megasclere lengths reported by Topsent are considerably longer than those reported by Fristedt (260-315 by 3-8 µm vs. 200 µm for tornotes and 420-490 by 14-15 µm vs. 247-321 by 11-19 µm for large acanthostyles). The small acanthostyles were 135-160 and up to 190 µm. For miscroscleres Topsent measured arcuate isochelae 32-35 µm long and sigmas 16-20 µm. The larger tylote and large acanthostyle measurements given for Topsent's specimen cast doubt on whether Topsent's *Ectyodoryx foliatus* is the same as Fristedt's type specimen.

**Habitat and distribution:** From Greenland to Azores**.** Depth range 539-707 m (Tompkins, *et al.* 2017).

*Family Phellodermidae*

*Echynostylinos reticulatus* Topsent, 1927

AphiaID 133335

**Material examined:** C12936, Ocean X

**Morphological description**

**External morphology:** Clathrate mass of thin twisted anastomosed branches with hispid surface. Branches 1.5 mm in diameter. Colour white in alcohol (Figure 166).

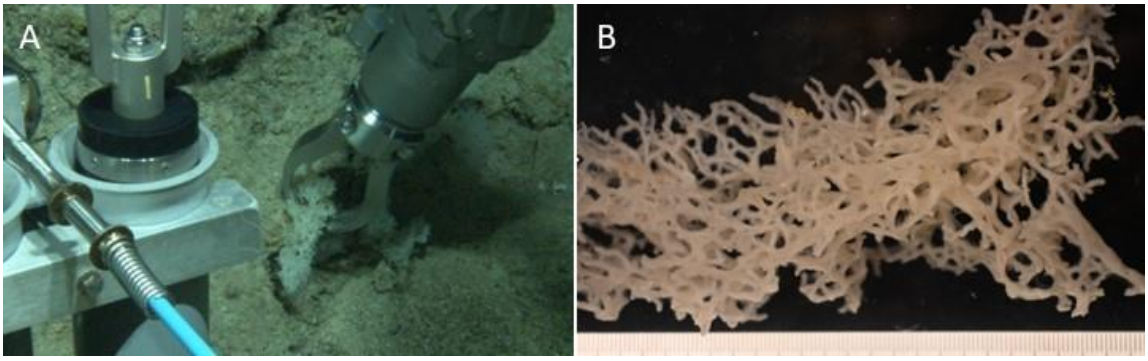


**Figure 166** *Echynostylinos reticulatus* Topsent, 1927. A. Specimen C12936 being collected during Ocean X 2023 Expedition. B. Specimen C12936 freshly collected, close up.

**Spicules:** The branches contain an axis of aligned thick styles. The ectosomal skeleton contains a loose arrangement of bundles of thin subtylostyles and solitary subtylostyles. Subtylostyles, smooth, straight, largely isodiametric, with a short point 245-280 x 4-4 um. Styles robust, smooth, somewhat curved (500-560 x 26-30 um). Microsclere, arcuate chelae, with thick curved shaft and short teeth. Sigmas of normal shape 15-22 um, in two size/form categories (Figure 167).

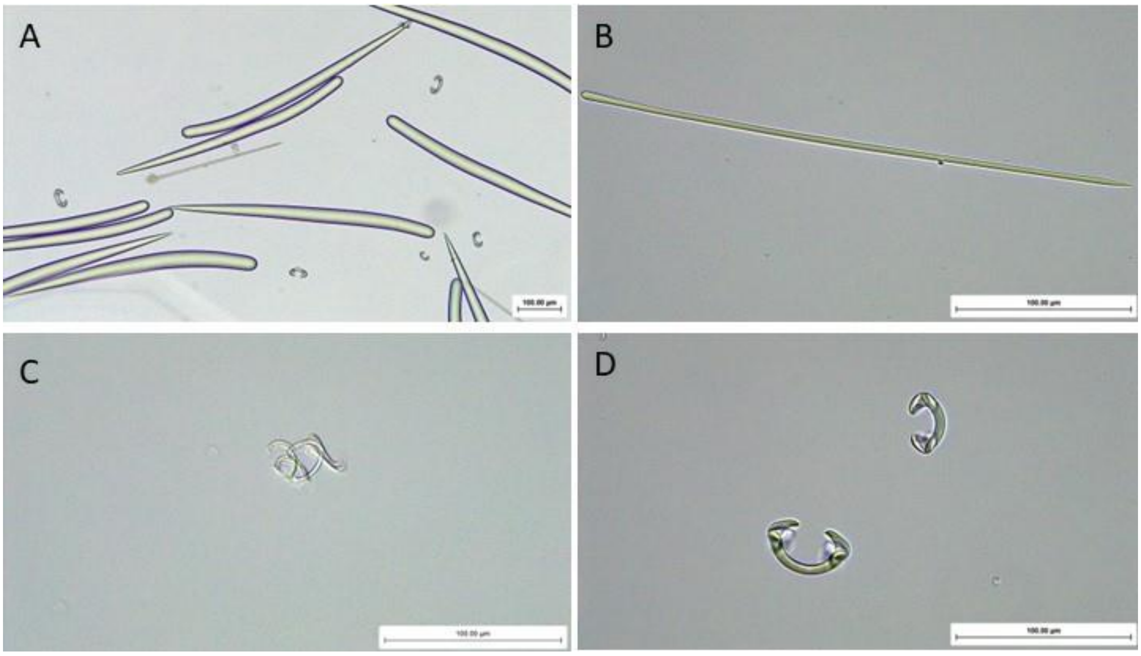


**Figure 167** *Echynostylinos reticulatus* Topsent, 1927 spicules. A. Styles, curved; B. Subtylostyles; C. Sigmas of two categories; D. Arcuate chelae.

**Remarks:** See original description by Topsent, 1929. Collected material in New Zealand shows similar spicule sizes and for that reason was assigned to *E. reticulatus* (Bergquist and Fromont, 1988). However, the shape is more lamellate or lobately ramose, different from thin branches in the North Atlantic specimens. The large geographic separation indicates that are different at species level (see discussion in Van Soest and Hajdu, 2002). Then, Carvalho, et al. 2016 has assigned it to a different species (*E. patriciae* nom.nov.).

**Habitat and distribution:** The specimens collected and observed here are probably restricted, possibly an endemism, to the Azores Region. Azores deep water, 900 m.

### *Family Myxillidae*

#### *Melonanchora cf. elliptica* Carter, 1874

**AphiaID**

**Material examined:** Specimen USNM 1674019 collected during Expedition EX2206 (ROV Dive D06, Station 09B) at Kurchatov Ridge (40.6638 N; -29.3873 W), 1663.83 m depth.

**Morphological description**

**External morphology:** From encrusting to massive-globular growth form, with paper-like, easily detachable thin ectosome, bearing fistular processes (Figure 168).


**Figure 168** *Melonanchora* cf. *elliptica* Carter, 1874 in situ. A. Specimen 1674019 in situ image, collected during Expedition EX2206 (ROV Dive D06 Station 09B) at Kurchatov Ridge, 1663.83 m depth. B. ex situ External morphology, Specimen after collection.

**Spicules:** Ectosomal skeleton composed of smooth strongyles to tylotes with somewhat asymmetrical ends, whereas the choanosome is mainly composed of smooth strongyles or styles. Microscleres include typically two categories of anchorate isochelae, rarely three, and spherancorae (amended from van Soest, 2002 in Santin, *et al.* 2021) (Figure 169Figure 169).

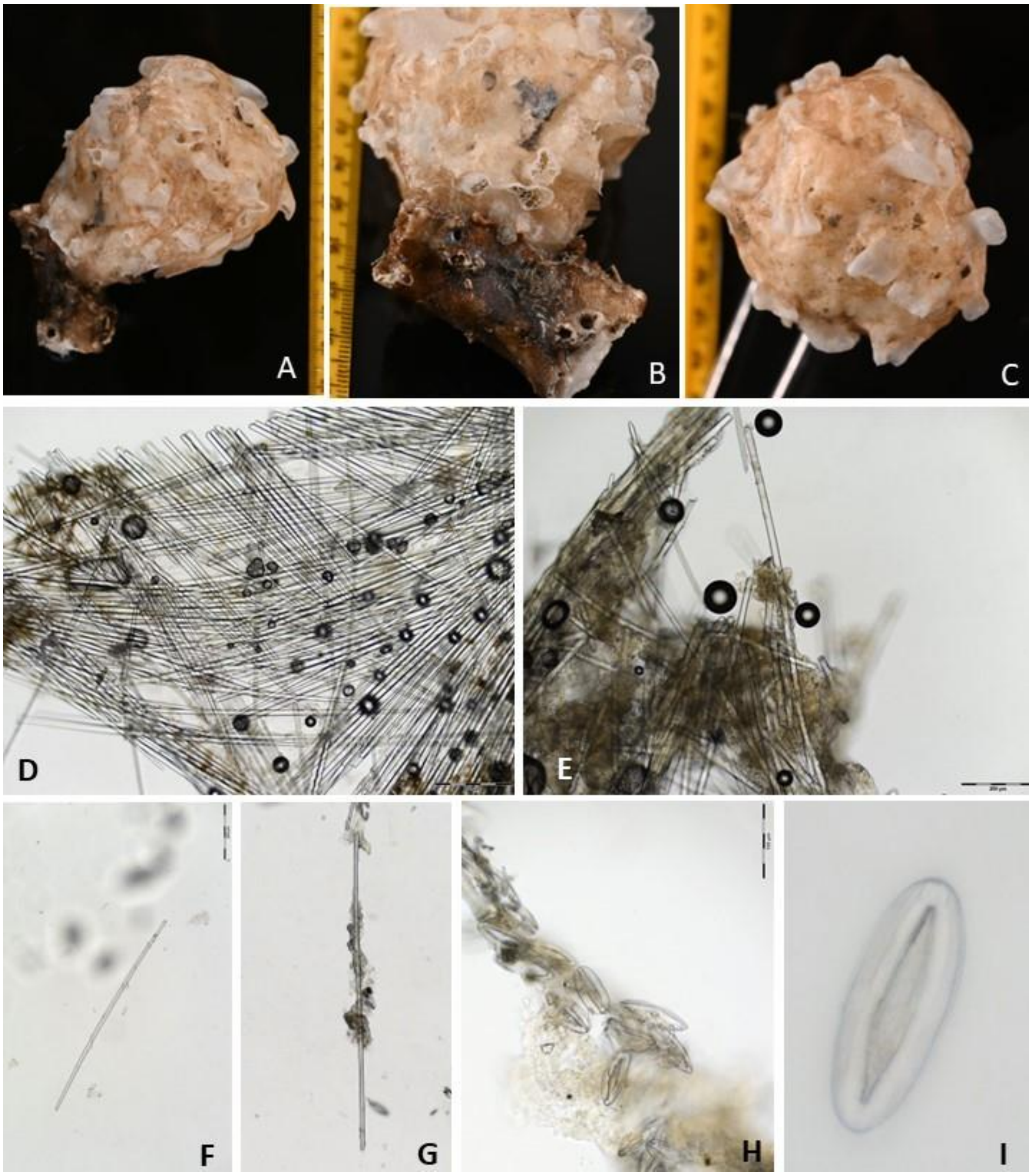


Figure 169 *Melonanchora* cf. *elliptica* spicules. A. Specimen ex situ after preservation in alcohol; B. specimen basal view attached to a scleractinian coral fragment; C. upper view showing oscula; D. View of the characteristic criss-cross like pattern of the ectosome, E. view of general spicules; F. Choanosomal tylostrongyle; G. Choanosomal style; H. Isochelae and spherancorae covering choanosomal tracts; I. spherancorae.

**Remarks:** See genus discussion and species description in Santin, *et al.* (2019) saying: Topsent's individuals form the Azores are insufficiently described and were not available. While it is clear that they belong to Melonanchora, it is impossible to ascertain based on Topsent's descriptions if they unequivocally belong to M. elliptica or to any other North Atlantic *Melonanchora* species. Although, the material analysed in the present work matches *M. elliptica* description by Santin, *et al.* (2019) measurements and sample replication should be attempted for a more accurate comparison.

**Habitat:** commonly found on sponge grounds (Santin, 2019).

**Distribution:** In the Azores archipelago (Topsent, 1892, 1904, 1928). Other regions: Greenland and Iceland; the Galician coast, and the area within the Labrador Peninsula and the Newfound Land Seas, from 80 to 1,554 m depth (see Santin, 2019).

Table. Porifera specimens analysed in this study.

| Fig. Nr | COLETA/Ref .Nr. | Species (to be confirmed) | Class | Local | Lat | Lon | Depth | Exp. year | Sample code | Img |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2517 | *Aphrocallistes sp.* | Hexactinellida | Fora do Aeroporto, Faial | 38,5180 | -28,7160 | 457 | Geralda, 1980 | na | na |
| | 9906 | *Aphrocallistes sp.* | Hexactinellida | Menez Gwen | na | na | na | DeepFun 2012 | na | na |
| | 2442 | *Asconema sp.* | Hexactinellida | Atlantis | 34,2400 | -30,3400 | 843 | Arquipélago, 2007 | ATLANTISP-2-V07 | na |
| | 10074 | *Asconema sp.* | Hexactinellida | Banco Gigante | 38,9844 | -29,8297 | 665 | Blue Azores 2018 | BAz18.ST36.02.01 | na |
| | 11187 | *Asconema sp.* | Hexactinellida | Banco Açores | 38,2432 | -29,0706 | 673 | Manuel de Arriaga, SPONGES, 2017 | RSB/18/MDA/17 | na |

| Fig. Nr | COLETA/Ref .Nr. | Species (to be confirmed) | Class | Local | Lat | Lon | Depth | Exp. year | Sample code | Img |
|---|---|---|---|---|---|---|---|---|---|---|
| | 11101 | *Asconema sp.* | Hexactinellida | Banco Açores | 38,2420 | -29,0695 | 645 | Manuel de Arriaga, SPONGES, 2017 | RSB/9/MDA/17 | na |
| | 12935 | *Cf. Xestospongia friabilis* | Demospongiae | Banco Princesa Alice | 38,0551 | -29,3052 | 779 | OceanX 2023 | OceanX_2023_St026_Ev4_B01. | Sub |
| | 13011 | *Cf. Haliclona (Halichoclona) magna* | Demospongiae | Pico S Lajes | 38.3443 | -28.2443 | 848 | OceanX 2023 | OceanX_2023_St045_Ev6_B01. | ROV |
| | USNM 1673996 | *Cf. Haliclona (Halichoclona) magna* | Demospongiae | MARNA Shallow | 43,9536 | -28,5283 | 580 | EX2206 | St. 06B, ROV Dive D01 | na |
| | 9982 | *Characella cf. connectens* | Demospongiae | Ormonde | 36,7930 | -10,9639 | 1114 | MEDWAVES, 2016 | ROV16.ST146 | Liropus, ROV 16 |

| Fig. Nr | COLETA/Ref .Nr. | Species (to be confirmed) | Class | Local | Lat | Lon | Depth | Exp. year | Sample code | Img |
|---|---|---|---|---|---|---|---|---|---|---|
| | 9568 | *Characella cf. pachastrelloides* | Demospongiae | Atlantis | 34,1380 | -30,0125 | 500 | Arquipelago Biometore, 2015 | ArqBiometore-43-V15 | na |
| | 10018 | *Characella cf. tripodaria* | Demospongiae | Pico | 38,4983 | -28,1931 | 522 | Blue Azores 2018 | BAz18.ST07.02.01 | Luso, ROV 3 |
| | 10130 | *Characella pachastrelloides* | Demospongiae | Banco Gigante | 38,9756 | -29,8517 | 464 | Blue Azores 2018 | BAz18.ST50.05.01 | Luso, ROV 12 |
| | 10129 | *Characella pachastreloides* | Demospongiae | Banco Gigante | 38,9753 | -29,8517 | 476 | Blue Azores 2018 | BAz18.ST50.04 | Luso, ROV 12 |
| | 11755 | *Chonelasma ijimai* | Hexactinellida | Rift of Princesa Alice | 38,4181 | -29,7289 | 2414 | M128 Meteor | Station 810, ROV DIVE 403, Sample 03 | Marum ROV QUEST 4000 |

| Fig. Nr | COLETA/Ref .Nr. | Species (to be confirmed) | Class | Local | Lat | Lon | Depth | Exp. year | Sample code | Img |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10090 | *Desmacella grimaldii* | Demospongiae | Banco Gigante | 38,7453 | -30,0442 | 645 | Blue Azores 2018 | BAz18.ST43.01.01 | Luso, ROV10 |
| | 12936 | *Echynostylinos reticulatus* | Demospongiae | Banco Princesa Alice | 38,0541 | -29,3078 | 732 | Ocean X 2023 | OceanX_2023_St026_Ev5_B01. Clathrate | Sub |
| | USNM 1673614 | *Euplectella cf. suberea* | Hexactinellida | João Valadão Ridge | 38,1587 | -26,2364 | 2121 | EX2206 | St. 03B, ROV Dive D01 | na |
| | USNM 1673638 | Euretidae gen. new | Hexactinellida | East of Formigas Rift | 37,3550 | -24,3799 | 714 | EX2206 | St. 03B, ROV Dive D02, Sample A01 | na |
| | 10059 | *Exsuperantia archipelagus* | Demospongiae | Banco 127 | 38,7156 | -30,0136 | 546 | Blue Azores 2018 | BAz18.ST20.03,05 | Luso, ROV 6 |
| | 10195 | *Exsuperantia archipelagus* | Demospongiae | Banco Gigante | 38,7089 | -30,2222 | 440-589 | Blue Azores 2018 | BAz18.ST57.Extra.03 | Luso, ROV 15 |

| Fig. Nr | COLETA/Ref .Nr. | Species (to be confirmed) | Class | Local | Lat | Lon | Depth | Exp. year | Sample code | Img |
|---|---|---|---|---|---|---|---|---|---|---|
| | 11594 | *Exsuperantia arquipelagus* | Demospongiae | Banco D. João de Castro | 38,2103 | -26,5749 | 256 | M128 | sample 4, Dive 389 | ROV |
| | 11756 | *Farrea laminaris* | Hexactinellida | Rift of Princesa Alice | 38,4181 | -29,7289 | 2414 | M128 Meteor | Station 810, ROV DIVE 403, Sample 03 | Marum ROV QUEST 4000 |
| | 10013 | *Farrea sp.* | Hexactinellida | Pico | 38,4947 | -28,1747 | 736 | Blue Azores 2018 | BAz18.ST03.03 | ROV Luso, EMEPC |
| | USNM 1674029 | *Farreidae sp1* | Hexactinellida | Cachalote Seamount | 39,9706 | -31,9706 | 1499 | EX2206 | St. 04B, ROV Dive D09 | na |
| | 2184 | *Geodia sp.* | Demospongiae | Graciosa | 39,1400 | -28,1500 | 651-700 | ARQDAÇO-27-P07 | #1, 2GRA(2)P07 | na |

| Fig. Nr | COLETA/Ref .Nr. | Species (to be confirmed) | Class | Local | Lat | Lon | Depth | Exp. year | Sample code | Img |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10034 | *Geodia sp.* | Demospongiae | Pico | 38,3503 | -28,2781 | 615 | Blue Azores 2018 | BAz18.ST17.06.01 | Luso, ROV 5 |
| | 10012 | *Haliclona filholi* | Demospongiae | Norte Pico | 38,4947 | -28,1747 | 736 | Blue Azores 2018 | BAz18.ST03.03.01 | Luso, ROV 2 |
| | 10084 | *Haliclona filholi* | Demospongiae | Banco Gigante | 38,9844 | -29,8325 | 663 | Blue Azores 2018 | BAz18.ST36.R1.03 | Luso, ROV 8 |
| | 9374 | *Haliclona filholi* | Demospongiae | Banco Açores | na | na | na | ARQDAÇO-38-2012 | 1AÇO(1)P12 | na |
| | 10163 | *Haliclona implexa (white morph)* | Demospongiae | Banco Gigante | 38,9750 | -29,9206 | 402 | Blue Azores 2018 | BAz18.ST54.09.04.03 | Luso, ROV14 |
| | 10139 | *Haliclona implexa (yellow morph)* | Demospongiae | Banco Gigante | 38,9772 | -29,8681 | 352 | Blue Azores 2018 | BAz18.ST50.08.01 | Luso, ROV12 |

| Fig. Nr | COLETA/Ref .Nr. | Species (to be confirmed) | Class | Local | Lat | Lon | Depth | Exp. year | Sample code | Img |
|---|---|---|---|---|---|---|---|---|---|---|
| | USNM 1674018 | *Hertwigia sp. "white morph" spec. nov.* | Hexactinellida | Kurchatov Ridge | 40,6627 | -29,3861 | 1689 | EX2206 | St. 08B, ROV Dive D06 | na |
| | 13007 | *Lissodendoryx (Ectyodoryx) foliata* | Demospongiae | Pico, Sul Lajes | 38,3395 | -28,2470 | 1060 | Ocean X 2023 | OceanX_2023_St045_Ev04_B01. | ROV |
| | USNM 1674019 | *Melonanchora cf. elliptica* | Demospongiae | Kurchatov Ridge | 40,6638 | -29,3873 | 1664 | EX2206 | St. 09B, ROV Dive D06 | na |
| | USNM 1673623 | *Neoschrammeniella sp.* | Demospongiae | East Formigas Rift | | | 627 | EX2206 | St. 12B, ROV Dive D02 | na |
| | 12951 | *Nethea amygdaloides* | Demospongiae | Banco Princesa Alice | 38,0236 | -29,4132 | 645 | OceanX 2023 | OceanX_2023_St031_Ev5_B01. | ROV |
| | 12960 | *Nethea amygdaloides* | Demospongiae | Banco Princesa Alice | 38,0218 | -29,4115 | 730 | OceanX 2023 | OceanX_2023_St030_Ev8_B01. | Sub |

| Fig. Nr | COLETA/Ref .Nr. | Species (to be confirmed) | Class | Local | Lat | Lon | Depth | Exp. year | Sample code | Img |
|---|---|---|---|---|---|---|---|---|---|---|
| | USNM 1673617 | *Xestospongia sp.1* | Demospongiae | East of Formigas Rift | 37,3544 | -24,3813 | 838 | EX2206 | St. 02B, ROV Dive D02 | na |
| | 10881 | *Oceanapia cf. azoriensis* | Demospongiae | José Gaspar | 37,6706 | -25,7134 | 533 | METEOR, ATHENA, 2018 | GEOB23172_2 | MARUM-SQUID |
| | 10010 | *Oceanapia coriacea* | Demospongiae | Pico | 38,4956 | -28,1742 | 830 | Blue Azores 2018 | BAz18.ST03.01 | Luso, ROV 2 |
| | USNM 1673615 | *Oopsacas cf. minuta* | Demospongiae | João Valadão Ridge | 38,1600 | -26,2364 | 2047 | EX2206 | St. 05B, ROV Dive D01 | na |
| | 11934 | *Petrosia (Strongylophora) vansoesti* | Demospongiae | Cone Eastern Capelinhos | 38,6057 | -28,8645 | 146 | M128 Meteor | TV Grab, St. 820 | TV Grab (TGB) |

| Fig. Nr | COLETA/Ref .Nr. | Species (to be confirmed) | Class | Local | Lat | Lon | Depth | Exp. year | Sample code | Img |
|---|---|---|---|---|---|---|---|---|---|---|
| | 11649 | *Phakellia ventilabrum* | Demospongiae | N Flank Terceira BAsin | 39,2908 | -27,5806 | 1204 | M128 Meteor | St. 764 ROV 394, Sample 09 | Marum ROV QUEST 4000 |
| | 10061 | *Phlyctaenopora (Phlyctaenopora) bitorquis* | Demospongiae | Banco 127 | 38,7156 | -30,0136 | 546 | Blue Azores 2018 | BAz18.ST20.03.07 | Luso, ROV 6 |
| | 10065 | *Poecillastra compressa* | Demospongiae | Banco Gigante | 38,9847 | -29,8294 | 682 | Blue Azores 2018 | BAz18.ST27.01 | Luso, ROV 7 |
| | USNM 1674014 | *Poecillastra compressa* | Demospongiae | Zenith | 42,3409 | -29,1483 | 1011 | EX2205 | St. 10B, ROV Dive D05 | na |
| | 2581 | *Raspailia (Parasyringella) falcifera* | Demospongiae | Sedlo | 40,3480 | -26,8380 | 1069-1156 | FISHOR | 204 | Trawl Pakura |

| Fig. Nr | COLETA/Ref .Nr. | Species (to be confirmed) | Class | Local | Lat | Lon | Depth | Exp. year | Sample code | Img |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10874 | *Regadrella sp.* | Hexactinellida | Great Meteor | 30,0862 | -28,0000 | 906 | Athena M151 - 2018, R/V METEOR | GEOB23429_1. Sample #7 | ROV MARUM - SQUID |
| | 11856 | *Siphonodictyon viridicens* | Demospongiae | Cone South East D. João de Castro | 38,2043 | -26,5570 | 429 | M128 Meteor | TV Grab, St. 744 | TV Grab (TGB) |
| | 11908 | *Siphonodictyon viridicens* | Demospongiae | Ridge on the N Flank Hirondelle Basin | 38,2287 | -26,2203 | 414 | M128 Meteor | TV Grab, St. 798 | TV Grab (TGB) |
| | USNM 1673621 | *Spongosorites sp.* | Demospongiae | East Formigas Rift | 37,3538 | -24,3776 | 609 | EX2206 | St. 08B, ROV Dive D02 | na |

## *8.5 Known occurrences and spatial distributions of deep-sea biodiversity, including VME indicator species*

The list of representative taxa proposed to ICES in 2020, was updated to include new indicator taxa based on information collected during recent field campaigns (Table 19, Table 20, and Table 21). The newly proposed indicator taxa were evaluated against the criteria for VME indicator taxa by the ADSR group, and will be brought to the next WGDEC meeting in 2024 for a formal proposal of inclusion on the ICES VME indicator taxa list for the NE Atlantic.

Moreover, given that the importance of certain VME indicator species may vary geographically, with marked differences in the abundances of some taxa across large spatial extents, their assessment can be driven by local perceptions, which could also differ depending on the background of the experts. Therefore, some VME indicator species originality included for higher latitudes in the North Atlantic, were reassessed according to their specificities in the Azores. As a result of this exercise, some representative taxa of cup-coral fields (e.g. *Caryophyllia*) and several soft coral taxa (e.g. *Gersemia*, *Anthomastus/Pseudoanthomastus*) were excluded for the VME indicator taxa list due to its low structural complexity and inferred low vulnerability to anthropogenic impacts. Sean pens and ceriantharia were also excluded due to its low abundance and limited ecological importance based on the best available knowledge at the time that the present report was produced. Information collected during future surveys may change this perception.

For the VME indicator taxa assessment, there was generally limited information to evaluate the life history and functional significance of all species due to knowledge gaps on species reproductive cycles, growth and longevity, larvae biology and dispersal and their role in the functioning of the ecosystems, such as nursery areas, as well as nutrient regeneration, and carbon remineralization and sequestration. When available, information on closely related species was used to infer decisions against these criteria. In some cases, there was also limited information on the potential for recovery of the species after impact, but this was judged on the basis on their life history traits, such as slow growth and high longevity. Under these circumstances, it was assumed that recovery for these deep-sea species is at high risk for significant adverse impacts by bottom-contact fishing, and the precautionary approach should be applied.

### Cold-water corals

The occurrence of cold-water corals in the Azores was first documented during major oceanographic expeditions during the late nineteenth century and throughout the 1900s (e.g., Josephine, Challenger, Talisman, campaigns of the Prince Albert I of Monaco – PAM, Biaçores and Bartlett) (Tixier-Durivault & D'Hondt, 1974; Studer, 1901; Thomson, 1927; Porteiro 2009; Braga-Henriques *et al.* 2013). Since then, the taxonomic inventory of cold-water coral fauna has been growing resulting from a combination of historical oceanographic expeditions and other published sources, visits to museum collections, unpublished data from bottom longline by-catch curated at COLETA (Braga-Henriques *et al.*, 2013; Sampaio *et al.*, 2019a,b), together with an extensive scientific research supported by multiple projects (e.g. Hermione, CoralFISH, 2020, ATLAS, SponGES, MapGES). Results of these projects have contributed to the identification of the Azores as a cold-water coral hotspot in the NE Atlantic, with 186 species identified to date comprising species of the anthozoan subclass Octocorallia, orders Antipatharia and Scleractinia and of the hydrozoan family Stylasteridae (Braga-Henriques *et al.*, 2013; Sampaio *et al.*, 2019a,b). Over recent years, several new species of Anthozoa have been described for the Azores including one species of black coral (de Matos *et al.*, 2014b) and five species of zoantharia (Carreiro-Silva *et al.*, 2017). The reassessment of the total diversity of cold-water corals in the Azores based on the new information generated here, accounts for 191 species with further 4 new putative new species to Science for the Azores. The spatial distribution of the known records of Cnidaria, including cold-water corals in the COLETA database and in other publicly available databases are shown in Figure 170.

**Table 19** Assessment of representative taxa the criteria for defining what constitutes a Vulnerable Marine Ecosystem (FAO, 2009) in the Azores. 'X' means direct evidence fitting to the criteria, '(X)' is inferred from the literature on other species; '?' means no information available; and blank cell means that the criterion was not met. Several species were assessed by the WGDEC in 2020 (Table 7.3 of ICES, 2020a). New representative species proposed by the ADSR are marked with *.

| VME habitat sub-type | VME representative taxa | Uniqueness | Functional significance | Fragility | Life History | Structural complexity |
|---|---|---|---|---|---|---|
| **Cold-water coral reef** | *Lophelia pertusa* | | X | X | X | X |
| | *Madrepora oculata* | | X | X | X | X |
| **Hard bottom coral garden:** Colonial scleractinians on rocky outcrops | *Solenosmilia variabilis* | | X | X | X | X |
| **Hard bottom coral garden:** Hard bottom gorgonian and black coral gardens | PARAMURICEIDAE | | | | | |
| | *Acanthogorgia armata*. | | (X) | X | ? | X |
| | *Acanthogorgia hirsuta* | | (X) | X | ? | X |
| | *Dentomuricea* | X§ | X | X | X | X |
| | *Paramuricea* spp. | | (X) | X | (X) | X |
| | *Placogorgia* spp.* | | (X) | X | (X) | X |
| | CORALLIIDAE | | | | | |
| | *Paragorgia johnsoni* | | (X) | X | (X) | X |
| | *Hemicorallium niobe* | | (X) | X | (X) | X |
| | *Hemicorallium tricolor* | | | | | |
| | *Pleurocorallium johnsoni* | | (X) | X | (X) | X |
| | ELLISELLIDAE | | | | | |
| | *Viminella flagellum* | | X | X | X | X |
| | PRIMNOIDAE | | | | | |
| | *Paracalyptrophora josephinae* | | X | X | (X) | X |
| | *Narella bellissima* | | (X) | X | ? | X |
| | *Narella versluysi* | | (X) | X | ? | X |
| | *Eunicella modesta* | | (X) | X | (X) | X |
| | *Candidella imbricata* | | (X) | X | (X) | X |
| | CHRYSOGORGIIDAE | | | | | |
| | *Chrysogorgia* spp. | | X | (X) | X | X |
| | *Iridogorgia* spp. | | X | (X) | (X) | X |
| | *Metallogorgia* spp. | | X | (X) | (X) | X |
| | KERATOISIDIDAE | | | | | |
| | *Acanella arbuscula* | | X | (X) | X | X |
| | Keratoisididae clades *J1, D2* | | X | (X) | X | X |
| Black corals | ANTIPATHARIA | | | | | |
| | *Antipathella wollastoni** | X | X | X | X | X |
| | *Antipathella subpinnata** | X | X | X | X | X |
| | *Bathypathes* spp. | X | X | X | X | X |
| | *Dendrobatypathes* sp.* | X | X | X | X | X |
| | *Elatopathes abietina** | X | X | X | X | X |
| | *Leiopathes* spp. | X | X | X | X | X |
| | *Phanopathes erinaceus ** | X | X | X | X | X |
| | *Parantipathes hirondellae* | X | X | X | X | X |
| | *Stauropathes punctata** | X | X | X | X | X |
| | *Stychopathes gravieri* | X | X | X | X | X |
| | *Tanacetipathes squamosa** | X | X | X | X | X |
| | *Tylopathes* sp.* | X | X | X | X | X |
| **Hard bottom coral garden:** Non-reefal scleractinian aggregations | DENDROPHYLLIIDAE | | | | | |
| | *Dendrophyllia cornigera* | | X | X | ? | X |
| | *Dendrophyllia ramea* | | X | X | X | X |
| | *Dendrophyllia alternata** | | X | X | ? | X |
| | *Enallopsammia rostrata* | | X | X | ? | X |
| **Soft bottom coral garden:** Non-reefal scleractinian aggregations | DENDROPHYLLIIDAE | | | | | |
| | *Eguchipsammia* sp. | | (X) | X | ? | X |
| **Hard bottom coral garden:** Stylasterid corals on hard substrata | STYLASTERIDAE | | | | | |
| | *Errina dabneyi* | X | (X) | X | X | X |
| | *Errina atlantica** | | | | | |

§ Presence only confirmed in the Great Meteor complex and in the Azores (Grasshoff, 1977; Braga-Henriques *et al.*, 2013) but suspected in the Canary Islands.

Table 20 Assessment of proposed representative taxa of sponge aggregation habitats against the criteria for defining what constitutes a vulnerable marine ecosystem (FAO, 2009). 'x' means direct evidence fitting to the criteria, '(x)' means criterion was inferred from the literature on other species; '?' means no information available and blank cell means that the criterion was not met. Several species in table were assessed during the WGDEC meeting in 2020 (based on Table 7.4 of ICES, 2020a). New proposed representative species by ADSR are marked with *.

| VME representative taxa | | Uniqueness | Functional significance | Fragility | Life History | Structural complexity |
|---|---|---|---|---|---|---|
| **DEMOSPONGIAE** | | | | | | |
| GEODIIDAE | *Geodia phlegraei* | | X | (X) | (X) | X |
| | *Geodia hentscheli* | | X | X | (X) | X |
| | *Geodia parva* | | X | X | (X) | X |
| | *Geodia megastrella** | | X | (X) | X | X |
| PACHASTRELLIDAE | *Characella* spp* | | X | (X) | X | X |
| | *Pachastrella* spp* | | X | (X) | X | X |
| AZORICIDAE | *Leiodermatium* spp. | | X | X | | X |
| CORALLISTIDAE | *Neophrissospongia nolitangere* | | X | X | (X) | X |
| | *Neoschrammeniella* spp. | | X | X | (X) | X |
| MACANDREWIIDAE | *Macandrewia* spp. | | | X | (X) | X |
| TETILLIDAE | *Tetilla longipilis* | | | X | | X |
| BUBARIDAE | *Phakellia* spp. | | X | X | | X |
| PETROSIIDAE | *Petrosia* spp. | | X | X | | X |
| CHALINIDAE | *Haliclona* spp.* | X | X | X | (X) | X |
| **HEXACTINELLIDA** | | | | | | |
| HYALONEMATIDAE | *Hyalonema* spp. | X | | X | (X) | X |
| EUPLECTELLIDAE | *Regadrella* spp.* | (X) | X | X | X | X |
| EURETIDAE | *Chonelasma* spp.* | X | X | X | X | X |
| ROSSELLIDAE | *Asconema setubalense* | X | | X | (X) | X |
| | *Asconema foliatum* | X | | X | (X) | X |
| | *Asconema fristedti** | | X | X | (X) | X |
| PHERONEMATIDAE | *Pheronema carpenteri* | *X* | X | X | (X) | X |

Table 21 Assessment of proposed representative taxa of other habitat types of importance in the Azores against the criteria for defining what constitutes a vulnerable marine ecosystem (FAO, 2009). 'X' means direct evidence fitting to the criteria, '(X)' means criterion was inferred from the literature on other species; '?' means no information available and blank cell means that the criterion was not met. Xenophyophore aggregations were assessed during the WGDEC meeting in 2020 (based on Table A5.5 4 of ICES, 2020a). New representative species proposed by ADSR are marked with *.

| VME representative taxa | | Uniqueness | Functional significance | Fragility | Life History | Structural complexity |
|---|---|---|---|---|---|---|
| **Xenophyophore aggregations** | | | | | | |
| SYRINGAMMINIDAE | *Syringammina fragilissima* | | X | X | ? | X |
| **Living fossil community** | | | | | | |
| CRINOIDEA (HOLOPODIDAE) | *Cyathidium foresti** | X | | | | |
| OSTREOIDEA (GRYPHAEIDAE) | *Neopycnodonte zibrowii** | X | X | | X | X |
| **Hydroid gardens** | | | | | | |
| HYDROZOA (LEPTHOTHECA) | *Polyplumaria flabellata** | | X | | | X |
| | *Lytocarpia myriophyllum** | | X | | | X |

*Scleractinia*

The Scleractinia in the Azores are composed of 58 species (10 families) of solitary (cup corals) and colonial scleractinians (stony corals) (see Appendix A in Braga-Henriques *et al.*, 2013). From the total species recorded, eight species were classified as VME indicator species for the Azores (Table 19), with the most common species recorded in the Azores being represented stony corals *Eguchipsammia cornucopia*, *Madrepora oculata* and *Lophelia pertusa*, based on COLETA records (Figure 171).

The stony corals *Lophelia pertusa* and *Madrepora oculata*, although considered one of the main VME indicator species in the North Atlantic, due to the formation of large reef structures and high associated biodiversity, is less abundant in the Azores. They are frequently found as isolated colonies as part of coral gardens while forming reefs in only a few locations, e.g., in the Menez Gwen hydrothermal vent field (Tempera *et al.*, 2013), and were recently documented in the Capelinhos area during the OceanX campaign (se RM2). More recently, a non-reefal scleractinian coral, *Eguchipsammia cornucopia,* was documented in the Azores (Tempera *et al.*, 2015). *Eguchipsammia* has an amphi-Atlantic distribution but is presently only known to form extensive aggregations in the Azores (Tempera *et al.*, 2015). Corals of the genus *Eguchipsammia* are free-lying on the seabed (Zibrowius, 1980; Cairns, 2000) forming a semi-rigid network of inter-twined coral branches over soft sediments (< 1 m in height) that provide a wide variety of microhabitats to epi- and endofauna (Morato *et al.*, 2019d). In some areas, *Eguchipsammia* forms reef-like structures although these are smaller in extent and height than traditional cold-water coral reefs and were therefore classified under the habitat category “Soft bottom coral garden: Non-reefal scleractinian aggregations” by ICES VME list (ICES, 2020) (Table 19). Specimens of *Eguchipsammia* were recently examined to confirm the taxonomic identity. Although diagnosing morphological characters suggest that the species in the Azores is *Eguchipsammia cornucopia*, molecular markers were inconclusive of the species identity due to the polyphyletic nature of the genus, and further studies are necessary to fully confirm the species identity.

The spatial distribution of the known records of Scleractinia in the COLETA database and in other publicly available databases are shown in Figure 172. The cup coral *Caryophyllia* spp., although included in the ICES VME indicator list, do not form extensive fields in the Azores as observed in the Wyville-Thomson Ridge (Northeast Atlantic, UK waters) (ICES, 2020a). *Caryophyllia* spp. are mostly observed as an epizoan on damaged branches of other corals (mainly *Leiopathes* spp.) or solitarily fixed to bottom rock crusts (Sampaio *et al.*, 2012) instead of forming structuring habitats, and were therefore not included as a VME indicator taxa for the Azores (Table 19). There were additionally 23 species of scleractinian corals that are currently not included in the VME indicator list (Table 22), including many species of cup corals that do not form tridimensional complex habitats such as *Flabellum* spp., *Desmophyllum dianthus*, *Leptopsammia formosa*, but that may be abundant in certain areas.

The assessment of these different cup coral species against the VME criteria revealed that because of their small size, low structural complexity, low susceptibility to bottom-contact fishing gear, relatively high growth and settlement rate based observed colonization of relatively new lost fishing cables and buoys, it was reasonable to exclude them from the VME indicator taxa list for the Azores.

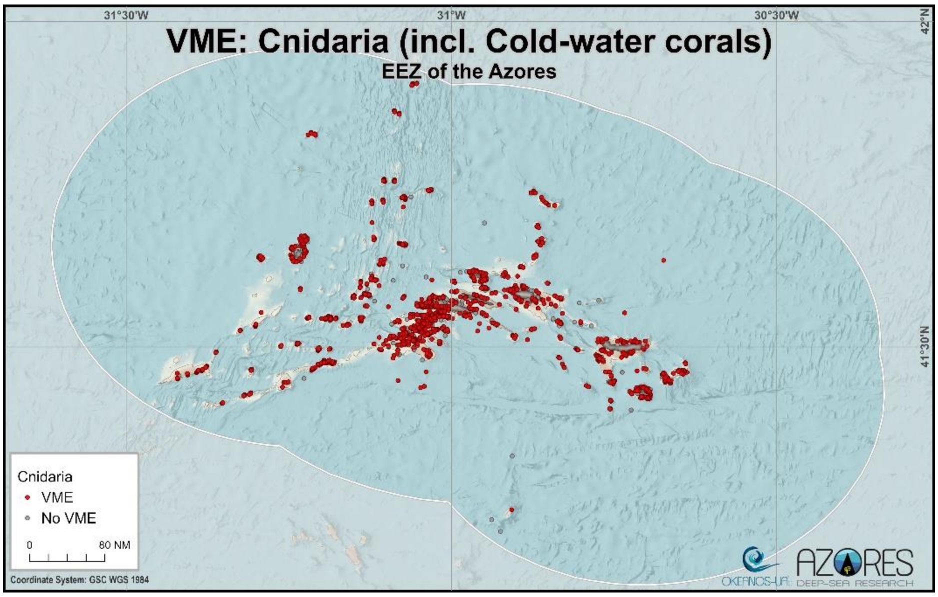


Figure 170 Geographical distribution of VME indicator Cnidaria records, inside the Azores EEZ, contained in the final version of the georeferenced database on the biodiversity of the deep sea of the Azores (BD2), on 1st November 2023.

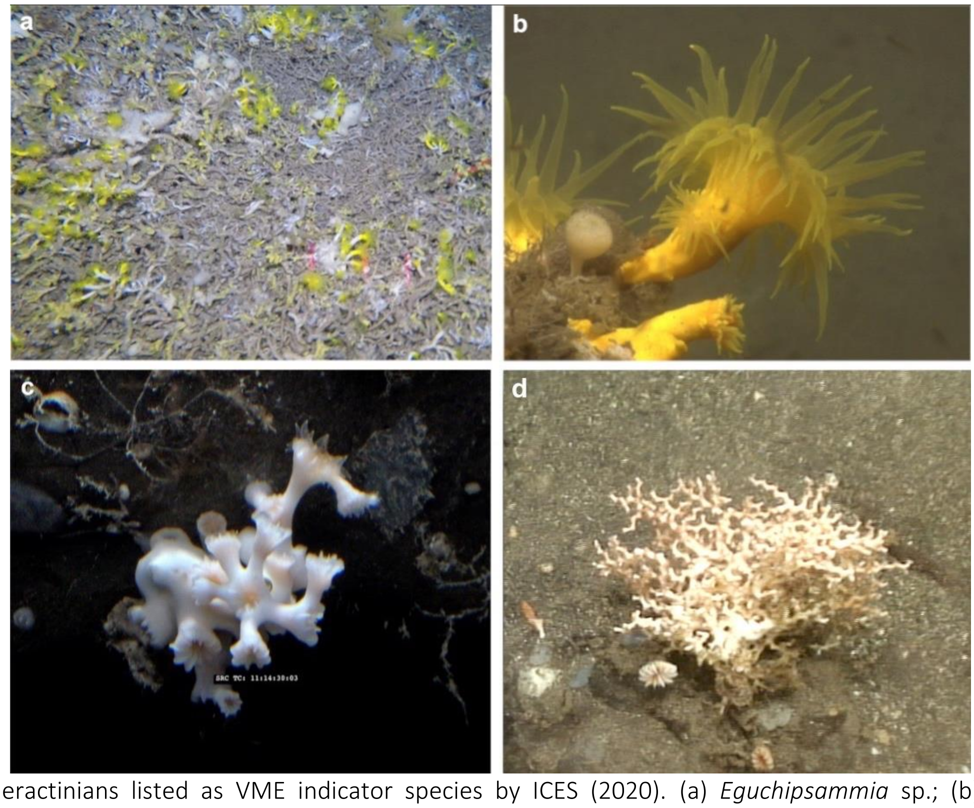


Figure 171 Scleractinians listed as VME indicator species by ICES (2020). (a) *Eguchipsammia* sp.; (b) *Dendrophyllia cornigera*; (c) *Lophelia pertusa*; (d) *Madrepora oculata.* Image credits: (a) IMAR/Okeanos-UAz, Azor drift-cam; (b,c) LULA1000, Fundação Ribekoff-Niggeler; (d) ROV Luso, EMEPC.

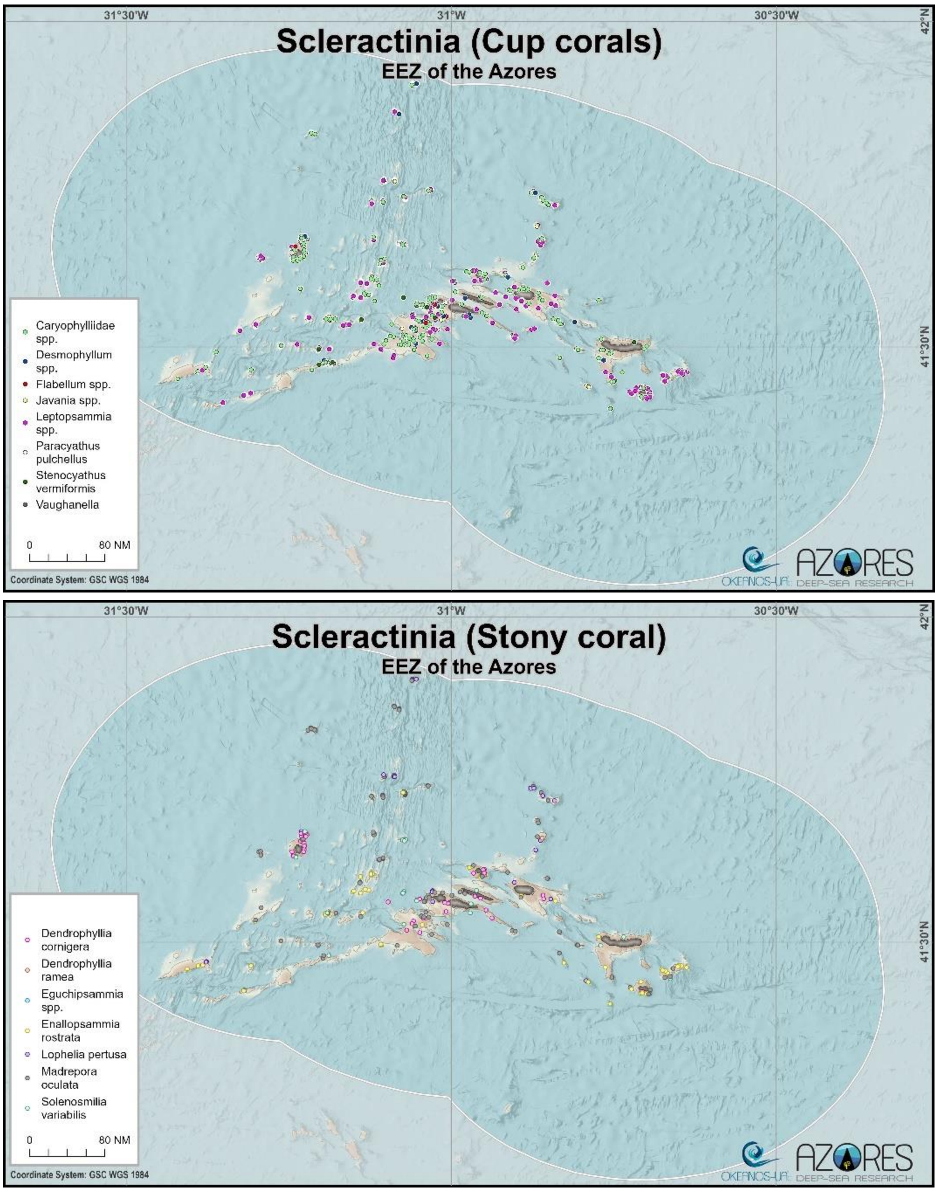


Figure 172 Two maps showing the geographical distribution of the Scleractinia records, inside the Azores EEZ, contained in the final version of the georeferenced database on the biodiversity of the deep sea of the Azores (BD2), on 1st November 2023.

*Octocorallia*

A large proportion of CWCs in the Azores belong to Octocorallia, including gorgonians, soft corals, and sea-pens, with 101 species identified (24 families) (Braga-Henriques *et al.*, 2013; Sampaio *et al.*, 2019b). From these, 27 species were classified as VME indicator species for the Azores (Table 19, ICES, 2020a), with the most common species recorded in the Azores being *Viminella flagellum*, *Callogorgia verticillata*, *Dentomuricea* aff. *meteor*, *Acanthogorgia* spp. based on historical and COLETA records.

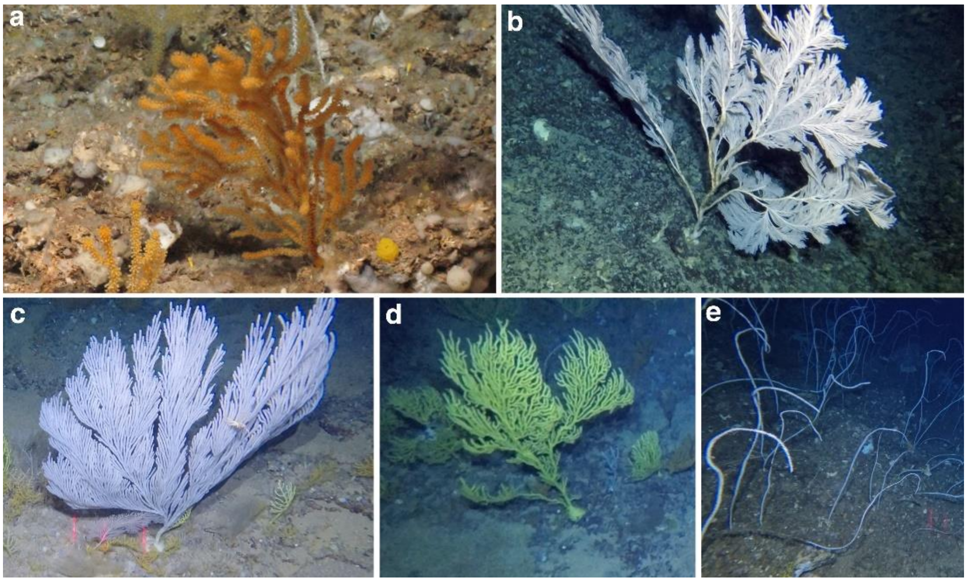


**Figure 173** Octocorals listed as VME indicator species by ICES (2020). (a) *Acanthogorgia armata* (b) *Callogorgia verticillata*; (c) *Paracalyptrophora josephinae* (d) *Dentomuricea* aff. *meteor*; (e) *Viminella flagellum*; Image credits: (a) ROV Luso/EMEPC/2018 Oceano Azul Expedition; (b, c, d, e) IMAR/Okeanos-UAz, Azor drift-cam.

Octocorals listed as VME indicator species, comprises species that due to their large size and/or complex 3-dimensional morphologies makes them more easily accidentally captured (bycatch) by long-line fisheries, such as the above mentioned species, and other species such as *Paracalyptrophora josephinae* (Sampaio *et al.*, 2012).The octocoral *Paragorgia johnsoni* can also form dense and structurally complex communities at depths of 500-700 m in some areas of the MAR (Morato *et al.*, 2021), but are not as commonly captured as bycatch likely because they are easily breakable with fishing gear contact. Smaller-sized octocorals such as *Narella bellissima* and *Narella versluysi*, *Pleucorallium johnsonii*, *Hemicorallium niobe* have less complex 2D morphologies but are also important components of cold-water communities at depths of 600-800 m depth. The primoid octocoral *Candidella imbricata*, was not listed as a VME indicator by ICES (ICES 2020), but because it forms dense, and often mono-specific, aggregations with high associated diversity at depths 200-1000 m, it was also evaluated by the ADSR against the criteria that define VME indicator taxa (Table 19). The spatial distribution of the known records of all types of Octocorallia VME indicators in the COLETA database and in other publicly available databases are shown in Figure 174.

Based on the evaluation made against the VME criteria (Table 19), these species were considered to meet the fragility, structural complexity and functional significance criteria as they are vulnerable to fishing impacts, form structurally complex habitat that provide shelter and serves as important spawning, nursery, breeding and feeding areas for a multitude of fishes and invertebrates (Pham *et al.*, 2015; Gomes-Pereira *et al.*, 2017; Porteiro *et al.*, 2013).

There is less information on the life history of these species. However, studies on age and growth estimates as part of the present report, indicate that large structuring octocorals such as *Callogorgia verticillata*, have slow growth rates (<1 cm/year) and can attain ages of 500 years old, while the whip coral *Viminella flagellum* grows relatively fast (5 cm/year based on transplantation experiments, MERCES project), with 2 m tall colonies with estimated ages of less than 50 years. Although there are no estimates of age/growth of *Hemicorallium* and *Pleurocoralium* species in the Azores, ages estimates of *Corallium* spp. from other geographic regions indicate longevities between 70-200 years old (*Corallium* sp. and *Corallium secundum*: Andrews et al., 2005; Roark et al., 2006). *Paragorgia* can also attain ages of several decades to centuries (Sherwood & Edinger, 2009). In addition to their particular growth/age characteristics, many cold-water corals species have low reproductive outputs and low recruitment success that impairs their population recovery from impact (Waller et al., 2023). This is the case for example *for Viminella flagellum* and *Dentomuricea* aff. *meteor* in the Azores (Rakka et al., 2021).

Bamboo corals of the family Keratoisididae, including *Acanella arbuscula* and other recently redefined clases of species (e.g., Keratoisididae clades J3, B1) form structuring habitats in the Azores mainly below 1,000 m. Bamboo corals often occur together with other octocorals of the family Chrysogorgidae (*Chrysogorgia* sp, *Iridogorgia* cf. *pourtalesii* and *Metallogorgia melanotrichos*). These species occur mainly below the depth limit for long line fishing in the Azores and, as such are not as vulnerable to fishing impacts, but have high intrinsic vulnerability due to their slow growth and high longevity (< 1 $cm \cdot y^{-1}$; > 400 years for the bamboo coral *Keratoisis* sp.: Thresher *et al.*, 2009 and 500 years for *Chrysogorgia* sp.: Prouty et al., 2016) and potentially low recovery from human impacts. Therefore, these species are listed in the VME indicator taxa list for the Azores (Table 19).

Several species of the family Paramuriceidae (e.g., *Paramuricea*, *Placogorgia*) are important components of deep-sea benthic communities at depths of 200-2000 m in the Azores, but are difficult to identify based on video images, and have until recently been referred by their morphotype e.g. white or purple plexaurid. As part of this project, we examined several specimens of Paramuriceidae deposited in COLETA, as well as during our visit to the NMNH in the USA. As a result of our morphological and genetic analyses, we can now distinguish between the two genera, *Paramuricea* and *Placogorgia*, based on specimens but it is still not possible to distinguish them based on video images. Therefore, for the purposes of habitat characterization these two species should be referred as a *Paramuricea/Placogorgia* species complex.

When assessed against the VME criteria (Table 19), considerably more published information is available for *Paramuricea* than for *Placogorgia*, which likely reflects *Paramuricea* wider distribution. However, taxonomic misidentification between the two genus may also contribute to this bias (see Taboada et al 2019). Both *Paramuricea* and *Placogorgia* are documented to form structurally complex habitats for associated species in the North Atlantic (de Clipelle 2019; Taboada et al 2019). However, information on life history traits could only be found for *Paramuricea*. Age and growth estimates are on the scale of several decades to centuries (70-660 years old Sherwood and Owen 2009; Prouty et al. 2016), with very slow growth rates (<1mm/year).

Reproductive studies show low fecundity and high age at first maturity for the related species *Paramuricea placomus* (21-37 years old: Fountain et al 2019) indicating slow recovery after disturbance.

The ICES VME indicator taxa list (ICES, 2020) only included *Paramuricea* spp. However, based on our observations and taxonomic examination, we propose *Placogorgia* spp. as a new VME indicator taxa for the Azores.

In the Azores, sea pens (order Pennatulacea) are composed by 13 known species (8 families) based on historical records (Sampaio *et al.*, 2019b). These species mostly occur below 1,000 m, have been observed by video in only a few occasions (Sampaio *et al.*, 2019b) and have seldom been sampled. Based on studies in the NW Atlantic and Mediterranean, these species can form dense aggregations and provide habitat for fish, and have slow growth, and high longevity (Baillon *et al.*, 2012; Ruiz-Pico *et al.*, 2017; Murillo *et al.*, 2018). Recent analyses of video images confirm that so far, sea pens occur in low abundances mostly at depths below 1200 m, and do not form aggregations. Based on this information, it was decided not to include them in the VME indicator list for the Azores. However, information collected in future survey may provide new evidence of their ecological importance in the region.

Several species of soft corals were included in the ICES VME indicator list (ICES, 2020). The species *Anthomastus/Pseudoanthomastus* and *Gersemia* sp. can occur in dense aggregations in seamounts of the MAR at depths of 200-800 m. Other species, such as *Alcyonium* sp. can also form dense aggregations at shallower depths of 100-180 m in the Capelinhos area. When considered against the FAO criteria, studies on life history traits indicate low reproductive output with the release of few, fairly large planulae from the parent colony (internal brooding) for *Gersemia* (Sun et al 2010, 2011), whereas some *Anthomastus* species have high fecundity and larval competency periods lasting up to several months (e.g. Cordes et al., 2001). In terms of their fragility against physical contact, laboratory studies on planulae of *Gersemia* suggest that when fertile colonies are damaged or torn by anthropogenic activities (e.g., bottom trawling), planulae that become free may grow into viable offspring (Henry et al., 2003; Sun et al., 2011). Gilkinson et al. (2004) found no significant immediate effect of dredging on *Gersemia* abundance in an area of the Scotian Shelf, southeastern Atlantic Canada, or any long-term declines. Studies on the impacts of trawling on benthic communities in New Zealand have observed *Antomasthus* in disturbed environments, suggesting that the reproductive characteristics of *Anthomasthus* might enable populations to persist in areas impacted by fishing (Goode et al. 2020). Given their low structural complexity and life history traits that may give them some resilience to anthropogenic impacts, it was decided not to include these taxa in the VME indicator list for the Azores. However, information collected in future surveys may provide new evidence of their ecological importance in the region.

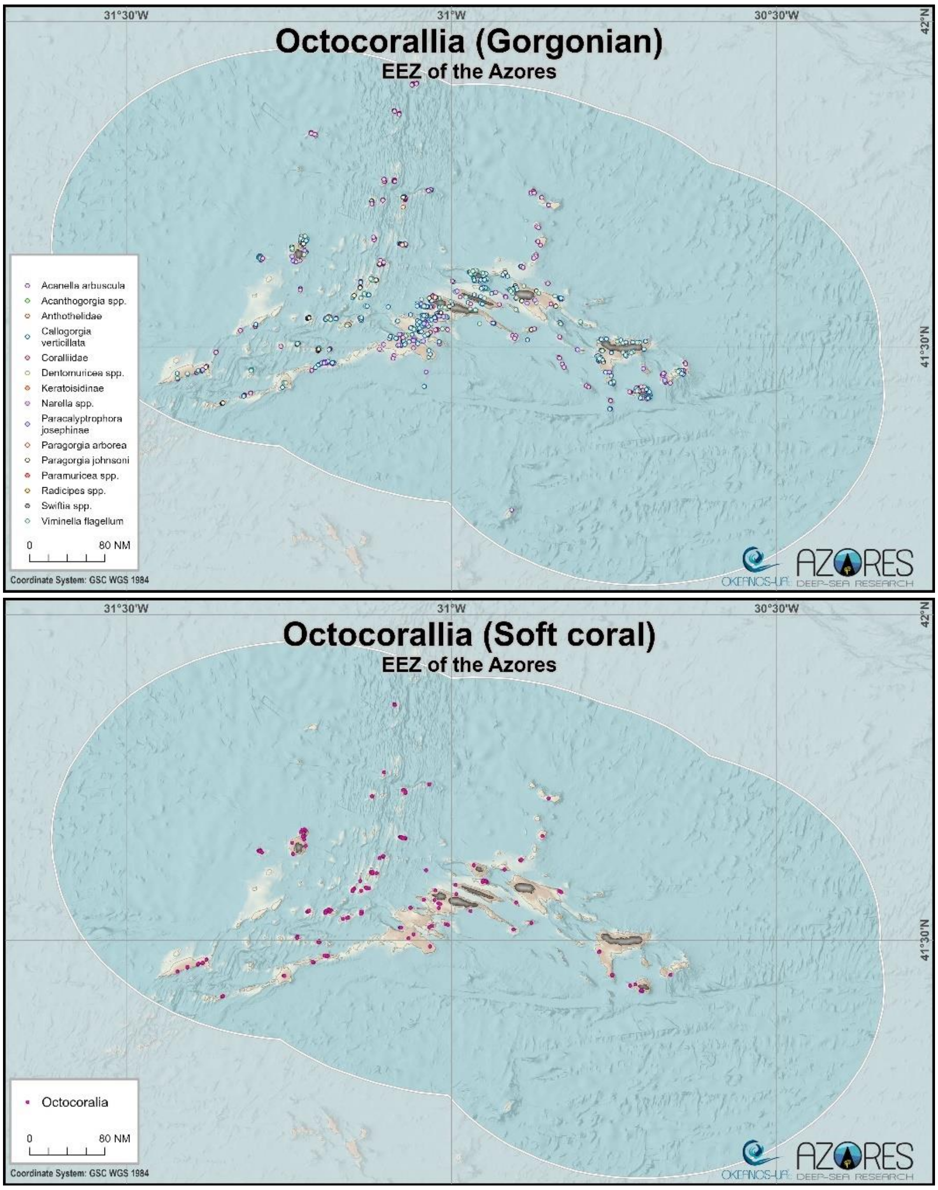


**Figure 174** Two maps showing the geographical distribution of the Octocorallia records, inside the Azores EEZ, contained in the final version of the georeferenced database on the biodiversity of the deep sea of the Azores (BD2), on 1st November 2023.

*Antipatharia*

The diversity of black corals (Antipatharia) in the Azores comprises 18 species (5 families) based on the species inventory provided by Braga-Henriques *et al.*, (2013), but several species still require taxonomic revision. Six of these species are listed as VME indicators by ICES (2020) and the ADSR has list an additional eight species that are important components of benthic communities in the Azores (Table 19). Some of these species occur above 200 m, and thus are not strictly considered deep-sea species (e.g., *Antipathella wollastoni*, *Antipathella subpinnata*, *Tanacetipathes* sp.) but have bathymetric ranges that extends to deep-sea environments (Braga-Henriques et al. 2013). Other black corals occur at depths below 600 m, with the species *Stichopathes gravieri*, *Bathypathes* spp. and *Parantipathes* spp., often forming mixed communities with octocorals and sponges (Figure 175). The black corals *Leiopathes* spp. due its large size (>2 m tall) and arborescent morphology, are considered some of the most important bioengineering species, creating structurally complex habitats for a high diversity of associated species (DeepWalls, unpublished data). However, because of their complex 3D structure, they are also highly vulnerable to long-line fishing (Sampaio *et al.*, 2012). Dense black coral communities composed of large individuals can still be found on the MAR and on vertical walls on island slopes where fishing pressure is low, but large *Leiopathes* colonies are rarely observed in at long-line fishing depths in seamounts around the islands in video surveys.

Other species, e.g., *Elatopathes* sp., *Phanopathes* sp, *Antipathes* spp., may occur in lower densities, but are found as part of mixed coral communities or may attain very large sizes (e.g., *Tylopathes* sp.), and may play an important ecological role for associated species.

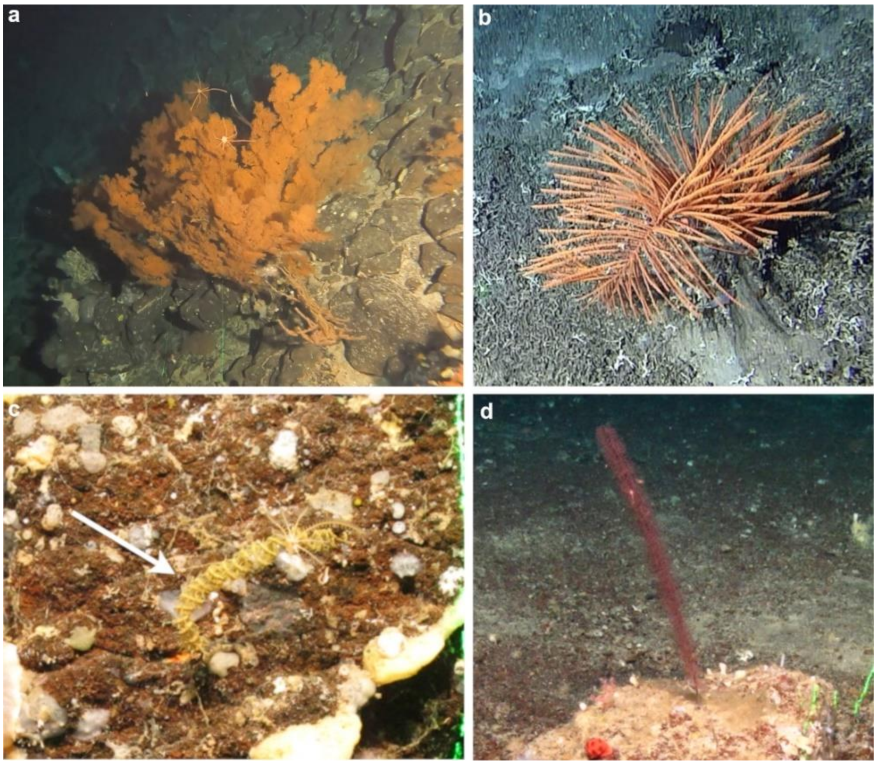


**Figure 175** Black corals listed as VME indicator species by ICES (2020). (a) *Leiopathes* sp.; (b) *Bathypathes* sp.; (c) *Sticopathes gravieri*; (d) *Parantipathes hirondelle;* Image credits: (a,b) Eurofleets+ iMAR cruise, IMAR/Okeanos-UAz; (c,d) ROV Luso / EMEPC / 2018 Oceano Azul Expedition, organized by Oceano Azul Foundation & partners.

Black corals fit several of the VME criteria, as they form highly structurally complex communities that function as refuge and nursery areas for associated species (Bo *et al.*, 2015), and are particularly vulnerable to fishing. Their life history traits, such as slow growth rates and high life spans of hundreds (*Bathypathes patula*: Marriot *et al.* 2020), to thousands of years (*Leiopathes* sp.; Roark *et al.*, 2009; Carreiro-Silva *et al.*, 2013) makes their recovery extremely slow. This means that if removed from the seabed, these species, and the communities they form can take centuries to millennia to recover from human impacts. Due to its fragility, black corals are listed under Appendix II of the CITES convention. The spatial distribution of the known records of VME indicator black corals in the COLETA database and in other publicly available databases are shown in Figure 176. Given their high intrinsic vulnerability due to very slow growth and high longevity, all black coral species occurring in deep areas in the Azores should be considered fragile with low recovery capacity after disturbance, and thus have been included as VME indicator species (Table 19).

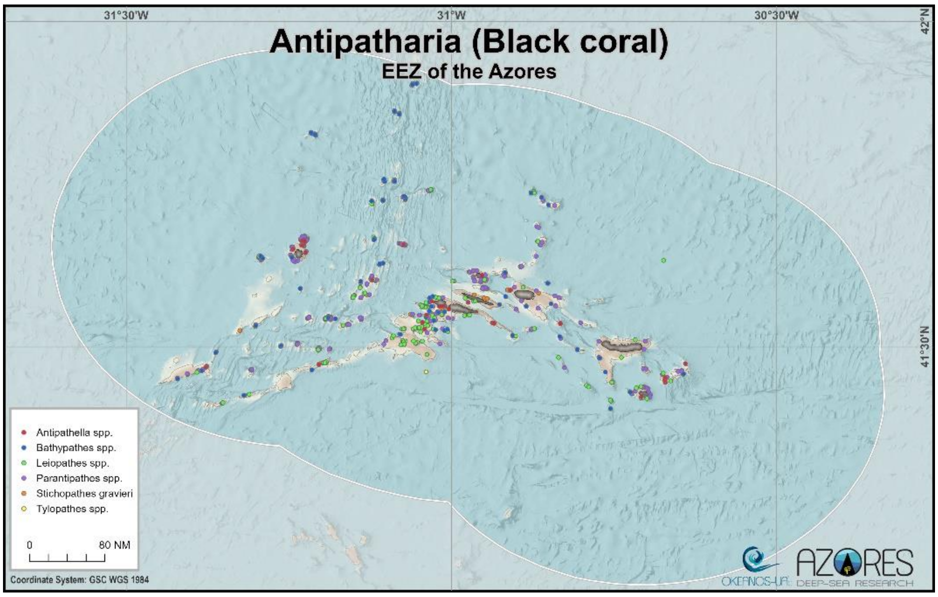


Figure 176 Geographical distribution of the Antipatharia records, inside the Azores EEZ, contained in the final version of the georeferenced database on the biodiversity of the deep sea of the Azores (BD2), on 1st November 2023.

*Hydrozoa, Familiy Stylasteridae*

Stylasterids, commonly known as lace corals, are colonial hydrozoans of the Family Stylasteridae (Order Anthoathecata) that can produce a calcium carbonate skeleton, similar to scleractinians (Cairns, 2011). In the Azores, there are nine species of stylasterids based on historical record and COLETA (Braga-Henriques *et al.* 2013), of which two species are listed as VME indicators for the Azores (Table 19). The species *Errina dabneyi* was listed during the WGDEC assessment in 2020 (ICES 2020). The lace coral *Errina atlantica* was added to the VME indicator list by the ADSR based on evidence collected during recent field surveys.

The lace coral *Errina dabneyi,* although forming restricted patches, can be particularly abundant in the Azores, forming dense aggregations generally close to island slopes (Figure 177). This species fits most of the VME criteria. It is an endemic coral species from the Azores and listed in CITES appendix II. Due to its very fragile brittle skeleton, *E. dabneyi* particularly is vulnerable to fishing gear impact and forms a great proportion of long-line fisheries bycatch (Sampaio *et al.*, 2012). It is characterized by slow growth (4-6 mm/year: Wisshak *et al.*, 2009a) which makes their recovery from disturbance very slow. The species *Errina atlantica* has a medium size (5-30 cm) and has been observed to occur together with *Lophelia pertusa* in reef-like communities in the Capelinhos area during the OceanX cruise and also forming agregations of isolated colonies, mostly in seamounts of the central group.

The other stylasterid species listed as VME indicators by ICES (2020), *Pliobothrus* spp. and *Stylaster* spp., are quite small in size (3-5 cm) in the Azores and do not form large aggregations (Figure 177). Therefore, they were not included in the VME indicator taxa list for the Azores (Table 19). The spatial distribution of the known records of VME indicator sylasterids in the COLETA database and in other publicly available databases are shown in Figure 178.


**Figure 177** Stylasterids and xenophyophores listed as VME indicator species by ICES (2020). (a) Stylasterid *Errina dabneyi*; (b) living fossil community; (c) xenophyophore *Syringammina fragilissima*; Image credits: (a) IMAR/Okeanos-UAz, Azor drift-cam; (b) LULA1000, Fundação Ribekoff-Niggeler; (c) ROV Luso/EMEPC/2018 Oceano Azul Expedition, organized by Oceano Azul Foundation & partners.

Among the five species of stylasterids occurring in the Azores but that are not listed by ICES (Table 22), the stylasterid *Crypthelia* sp. (likely *C. vascomarquesi)* can cover extensive areas in the Menez Gwen (Tempera *et al.*, 2013) but has small size (i.e., low structural complexity) and little is known about its functional significance or life history traits. The analyses of video images from previous and future surveys will help determine their ecological importance and whether they should be considered as VME indicator species in the Azores.

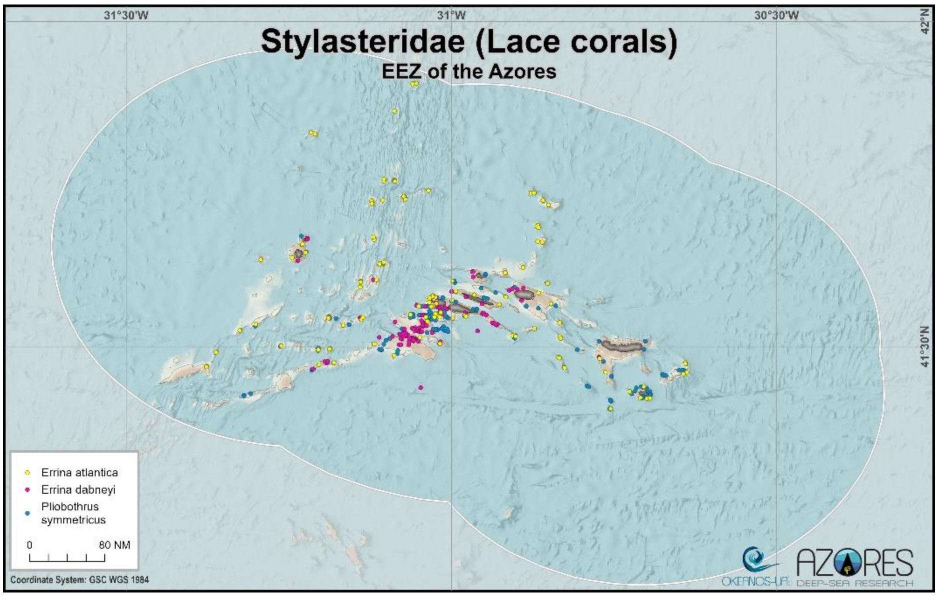


**Figure 178** Geographical distribution of the Stlylasteridae records, inside the Azores EEZ, contained in the final version of the georeferenced database on the biodiversity of the deep sea of the Azores (BD2), on 1st November 2023.

*Hydrozoa, Order Lepthotheca*

Marine hydroids of the Order Lepthotheca have high diversity in the Azores, with more than 30 potential species recorded in COLETA. Most of these species have small sizes (<5 cm in height) and occur as epiphytes to other species, growing on the bare skeletons of damaged or broken colonies of octocorals and antipatharians, collected during long-line fishing as secondary by-catch (e.g., *Sertularia* spp., *Lafoea* spp.). A few species can grow to larger sizes (> 15 cm height), e.g., *Nemertesia* spp., *Polyplumaria flabellata* and *Lytocarpia myriophyllum*, some of which are part of benthic communities dominated by octocorals, especially on seamount summits (200-400 m depth).

Large hydroids can form complex three-dimensional habitats in some areas in the Azores and elsewhere in the Atlantic and Mediterranean, and support high diversity of associated species (Gomes-Pereira & Tempera, 2016; Gomes-Pereira *et al.*, 2017; Di Camillo et al 2017). So far, hydroids have not been considered as VME indicator taxa due to their faster growth rates and shorter life spans, as compared to other deep-sea species (Hughes, 1986) and presumably faster recovery from human disturbance. Nevertheless, hydroid aggregations release planulae, medusoids, or medusae in the surrounding environment that are used as food for other organisms, contributing to benthopelagic coupling and affecting biogeochemical cycles (Gili et al. 1998; Rossi et al. 2012; Di Camillo et al 2017). When evaluated against the VME criteria, the hydroids species *Polyplumaria flabellata* and *Lytocarpia myriophyllum* were considered to meet the structural complexity and functional significance criteria, and include them in the VME indicator taxa list for the Azores (Table 21).

### Anemones

Anemones *sensu lato* include benthic cnidarians of the orders Actiniaria, Ceriantharia, Corallimorpharia, and Zoantharia. In the Azores, the species diversity within these groups has only recently started to be described. Zoantharians are a particular diverse but poorly studied group of cnidarians associated to cold-water corals. Carreiro-Silva *et al.* (2011, 2017) described five new species of zoantharians associated to stylasterids, antipatharians and octocorals in the Azores. The diversity of deep-sea Actinaria and Corallimorpharia is also suspected to the high, but there are currently no studies.

WGDEC (ICES, 2020) reviewed Zoantharia against the FAO VME criteria and found that the species from this order are not considered to be unique or rare. They have been reported from almost all marine regions of the world and are sometimes parasitic on other corals (Carreiro-Silva *et al.*, 2017). There is also very limited evidence and knowledge on their life history traits and vulnerability, partly due to uncertainties in their taxonomy limiting research. Therefore, zoantharians we excluded from the VME indicator species list for the Azores.

Tube dwelling anemones, or cerianthids, are the only anemones listed as VME indicators by ICES (ICES, 2020), but have seldom been observed in video surveys, and have never been collected in the Azores. These cnidarians have been suggested to enhance local species diversity and abundance in featureless soft-bottom areas, providing structural complexity and habitat for fish and invertebrates in the Northwestern Atlantic (e.g., Auster *et al.*, 2003). During recent surveys, tube dwelling anemones were seldom observed, and when present, occurred as isolated individuals and not as aggregations. As such, cerianthids were not included as VME indicator taxa for the Azores.

### Sponges

The diversity of sponges in the Azores is reported to be high (about 458 species, Van Soest, 2012), where more than 330 species are bathyal and abyssal (World Porifera Database, Neele *et al.*, 2015). However, the sponges that inhabit remote areas of the Mid-Atlantic Ridge, adjacent seamounts as well as the slopes of the island bathyal platform, included in the Azores EEZ, are little studied. Much of the existing knowledge is due to material collected (Demospongiae and Hexactinellida) during historical expeditions in the 19th century by Prince Albert of Monaco, in which sponges were sampled by dredging (campaigns "Princesse Alice" and "Hirondelle"). During this period, a great effort at identification, as well as the description of species new to science, was mainly made by Émile Topsent (e.g., Topsent, 1892, 1898, 1904, 1913 and 1928). Currently, some taxonomists have devoted effort to identifying specimens from more recent oceanographic missions (e.g., Cárdenas & Rapp, 2015) as well as "by-catch" in demersal fishing campaigns (Pereira 2013; Xavier *et al.*, 2021).

Sponges in the Azores are known to form important structural habitat based on video surveys and are frequently accidentally captured as bycatch during long line fisheries. The reference collection (COLETA) harbour dozens of specimens of sponges but many still need taxonomic confirmation. The difficulty in its taxonomy is due to a high morphological plasticity in this group (polymorphism) or absence of evident external characters in certain species. For this reason, until recently, sponges observed in images were classified based on morphological characters (for example, shape: arborescent, globular, massive, encrusting, etc.) and coloration. The opportunity to compare the species visualized *in situ* by video image with the specimens collected during scientific missions within the scope of this project, allowed us to assign species that were previously only known by their shape, i.e., like (morpho)species. The spatial distribution of the existing records of VME indicator sponges in the COLETA and OBIS databases are shown in Figure 179.

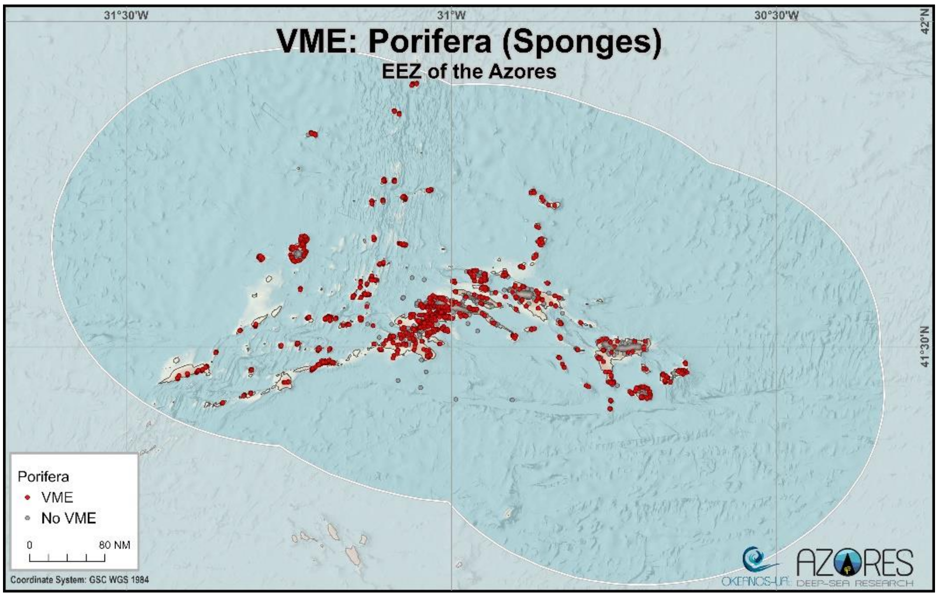


**Figure 179** Geographical distribution of VME indicator Porifera records, inside the Azores EEZ, contained in the final version of the georeferenced database on the biodiversity of the deep sea of the Azores (BD2), on 1st November 2023.

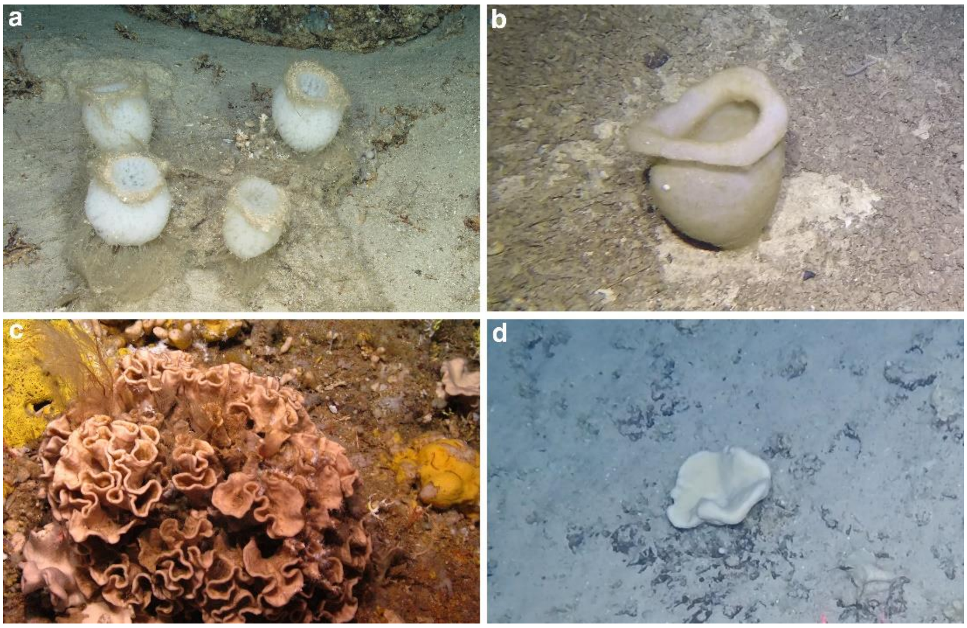


**Figure 180** Habitat forming deep-sea sponges in the Azores. Glass sponges (a) Pheronema carpenteri; (b) Asconema sp.; demosponges (c) Leiodermatium lynceus; (d) Macandrewia azorica. Image credits: (a) Medwaves, ATLAS project; (b, Azor drift cam, IMAR/Okeanos UAç; (c) ROV Luso/EMEPC / 2018 Oceano Azul Expedition.

Fifteen species of sponges in the Azores, including the ones mentioned below, are listed as VME indicators (Table 20) as they fit most of the VME criteria. Most of these species are large in size and form structurally complex aggregations. Although there is limited knowledge on the ecological role of sponges in the Azores, evidence form other regions suggests that sponges serve as habitat for numerous invertebrate and fish species (e.g., Hawkes *et al.*, 2019), also performing numerous functions in bentho-pelagic coupling and nutrient recycling (Cathalot *et al.*, 2015; Maldonado *et al.*, 2019; Rooks *et al.*, 2020). Although age estimates for sponge species are scarce, some studies suggest multi-centennial age spans, e.g., 220 and 440 years (Leys & Lauzon, 1998; Fallon *et al.*, 2010), whereas some sponge reefs are estimated to be up to 9,000 years old (e.g., Krautter *et al.*, 2001) and with episodic recruitment.

Given these life history characteristics it is likely that their recovery from disturbance is slow with the potential for significant adverse impacts by bottom-contact fishing and other human activities.

*Hexactinellida*

Some of the most important hexactinellids aggregations documented so far in the Azores EEZ are dense and often monospecific aggregations. The rossellid sponges *Asconema* spp., presenting a characteristic funnel-shape morphology, creates a three-dimensional structure increasing habitat complexity. In some areas, *A. fristedti* is frequently found occurring in high densities between 300 and 400 m. Similarly, to the aggregations of *A. setubalense* in the Northeast Atlantic where larger individuals can achieve 50 years old (e.g. Prado *et al.* 2019, Nestrowicz *et al.* 2021), *A. fristedti* might also be slow growing.

Aggregations of the nest sponge *Pheronema carpenteri* are important below 800 m depth at restricted areas with high silica rates. *P. carpenteri* are also long-lived, slow-growing and act as nursery areas for motile organisms. Viera *et. al.* (2020) has estimated slow recovery of this species, showing a drastic decrease in density and biomass 10 years after bottom fishing impacts.

Other vase-shape glass sponges, the euplectellids *Regadrella sp.* and euretids *Chonelasma sp.* were also added as VMEs indicators due to their large size (3D structure). Moreover, the rarity of certain species examined in the present study (*Regadrella sp.*, *Chonelasma ijimai*) proves that some of the anteriorly (and erroneously) defined as species with wider cosmopolitan distributions (e.g. *R. phoenix* and *C. choanoides*), might form conspicuous populations in the MAR context.

The stalked glass sponge *Hyalonema thomsoni* forms dense aggregations in the Azores. Hyalonematids fit the VME criteria of fragility (brittle delicate morphology), uniqueness, particularly in siliceous environments and diversity enhancers of epifaunal organisms (Beaulieu, 2001).

*Demospongiae*

Multispecific aggregations of demosponges *Leiodermatium lynceus*, *Neophrissospongia nolitangere*, *Macandrewia azorica, Characella pachastrelloides, Phakellia* sp. and *Petrosia crassa* are found between 400 m and 600 m depth.

Astrophorina are a polyphyletic group of demosponges mainly confined to deep waters. Most of the “streptaster-bearing” astrophorins (e.g. families Geodiidae, Ancorinidae, Pachastrellidae) are massive sponges. The *Characella* spp. are extremely abundant, large-sized sponges with high morphological variance (e.g. vase, tubular, digitate, lamellar). Other large sized species found frequently in the Azores seamounts slopes are *Geodia* aff. *megastrella*, where a single specimen can weight up to 15 Kg. Similarly to deep sea corals, they are characterised by low larval recruitment, once studies proved the *Geodia spp.* synchronize their gametogenesis with the influx of nutrients seasonality (Witte, 1996, Koutsouveli *et al.* 2020), allowing them to develop oocytes maximum once or twice a year, reducing probability of fast recovery after impact. Recent reviews (Cardenas *et al.* 2007, 2012, 2013) have demonstrated many Astrophorina to have conserved morphologies over the Northeast Atlantic deep-sea areas but other are found to be cryptic species complexes (e.g. *Geodia megastrella*, *Characella pachastrelloides*) formed by restricted different populations with limited gene flow patterns.

The rock-sponges commonly known as "lithistids", are an artificial group of demosponges that share the possession of a rigid skeleton (bearing articulated spicules named desmas). In the Azores, comprising members of the Spirophorina such as family Azoriicidae (*Leiodermatium pffeiferae, L. lynceus and L. tuba*) and from Astrophorina belonging to families Corallistiidae and Macandrewiidae (*Neophrissospongia nolitangere*, *Macandrewia azorica and M. robusta*), are very abundant, creating typical sponge grounds habitats representative in seamounts slopes and flanks ecosystems. Surprisingly, the present study adds also *Neoschrammeniella sp.* as a new record to the Azores EEZ and is here proposed as a new VME indicator. This species was previously reported in banks and canyons of the continental shelf (Rios et al. 2020). Accordingly, latest review on lithistids by Xavier *et al* (2021, 2023), has proclaimed the Azores region and neighbouring seamounts as a "lithistid" hotspot in the central North Atlantic.

Large sized haplosclerids, families Petrosiidae (*Petrosia crassa*) and Chalinidae (*Haliclona magna*) are also dominant large sized organisms in bathyal Azorean ecosystems, contributing to habitat complexity. These species may be heavily affected by fisheries once they are frequently caught with long-line by-catch. The Mediterranean sponges *P. vansoesti* (Boury-Esnault *et al.* 1994) and *H. magna* (Vacelet, 1969) are very frequent in upper slope and bathyal depths of the Azores, representing new records for the region, and western limit of their distribution suggesting the influence of the MOW in the Azorean ecosystems (Puerta, et al. 2022).

Flabellate sponges, members of Bubarida, such as the genus *Phakellia spp.* are highly abundant, reaching high sizes in height, are considered ecosystem engineers. On the other hand, these are also very fragile species. A recent study (Taboada *et al.* 2023) about the dispersal and connectivity of *Phakellia ventilabrum*, combining population genomics and oceanographic modelling, highlighted the potential fragility of this species due to low genetic diversity regarding their well-connected populations, demonstrating low resilience to anthropogenic threats.

Xenophyophores (Foraminifera)

Xenophyophores are large single-celled sessile protozoans (Foraminifera) inhabiting deep-sea soft-sediment environments (Tendal, 1972). They use sediment grains to build delicate agglutinated tests that are typically several centimetres in size (up to 25 cm). In the Azores, the xenophyophore *Syringammina fragilissima* is found below 800 m colonizing soft sediments close to the island slopes. Although they have often been observed in video surveys, it was only recently during the OceanX campaign that we had the opportunity to collect it and deposit at the reference collection COLETA .

Studies in other geographical regions have shown that xenophyophores provide food, habitat, and refuge for marine invertebrates, as well as entraining suspended particles and larvae, functioning as biodiversity hotspots on the sedimentary seafloor (e.g., Levin, 1991). They also play key roles in carbon cycling (Levin & Gooday, 1992). Because of their fragile, easily damaged tests, structural complexity and functional significance xenophyophores have been recognized as VME indicator taxa.

**"Living fossil community" composed of long-lived oysters and crinoids**

The Azores, hosts an unique benthic community formed by the deep-sea oyster *Neopycnodonte zibrowii* Gofas, Salas and Taviani 2009 (Wisshak et al., 2009a) and the sessile cyrtocrinid *Cyathidium foresti* Cherbonnier and Guille, 1972. Although the association of these two species is facultative, this assemblage has been described as a 'living fossil community', since both of its constituents escaped the massive extinction event of the Cretaceous and have survived to present day only in the Azores region (Wisshak et al., 2009). This community has so far only been observed living on vertical cliffs and underneath overhangs where they are encountered in clusters of up to several hundred individual.

The lifespan of *N. zibrowii* can reach 500 years, placing them among the longest- lived molluscs known to date and longest-living non-colonial animals (Whisshak et al., 2009b). *Neopycnodonte zibrowii* is distributed in the Atlantic and Mediterranean (Beuck et al., 2016), but the largest individuals were reported from the Azores (Whisshak et al., 2009b). Apart from providing the crinoid with substrate availability and/or food, the oyster also provides a suitable habitat for a diverse associated community of sponges, bryozoans, serpulid worms and large barnacles and mobile organisms and for demersal benthopelagic fishes (Beuck et al., 2016). When evaluated against the VME criteria, this species association was considered to meet the fragility, structural complexity and functional significance criteria and was therefore included in the VME indicator taxa list for the Azores (Table 21).

**Table 22** List of taxa occurring in the Azores that are not listed as VME indicator species by the ICES list of VMEs and their characteristic taxa.

| Phyllum | Taxonomic Group | VME Indicator | Taxa |
|---|---|---|---|
| **Cnidaria** | **Actinaria** | Anemones | Actiniaria |
| | | | Actinostoloidea |
| | | | Hormathiidae |
| | | | Peronanthus |
| | | | Phelliactis |
| | | | Amphianthus |
| | | | Liponema |
| | **Antipatharia** | Black coral | Antipatharia |
| | | | Antipathes |
| | | | Antipathes dichotoma |
| | | | Antipathes grayi |
| | | | Aphanipathidae |
| | | | Aphanostichopathes |
| | | | Chrysopathes |
| | | | Elatopathes |
| | | | Myriopathidae |
| | | | Phanopathes |
| | | | Plumapathes |
| | | | Stichopathes |
| | | | Stichopathes gracilis |
| | | | Tanacetipathes |
| | **Ceriantharia** | | Ceriantharia |
| | **Corallimorpharia** | Corallimorpharia | Corallimorpharia |
| | | | Corynactis |
| | | | Nectactis singularis |
| | **Hydrozoa** | Hydrozoan | Acryptolaria |
| | | | Acryptolaria conferta |
| | | | Acryptolaria crassicaulis |
| | | | Aglaophenia |
| | | | Aglaophenia lophocarpa |
| | | | Aglaophenia pluma |
| | | | Aglaophenia tubulifera |
| | | | Aglaophenopsis cartieri |
| | | | Antennella |
| | | | Antennella confusa |
| | | | Antennella secundaria |
| | | | Cryptolaria pectinata |
| | | | Diphasia |
| | | | Diphasia margareta |
| | | | Eudendrium |
| | | | Filellum |
| | | | Filellum serratum |
| | | | Haleciidae |

| Phyllum | Taxonomic Group | VME Indicator | Taxa |
|---|---|---|---|
| | | | Halecium |
| | | | Halecium sessile |
| | | | Hydrozoa |
| | | | Kirchenpaueria |
| | | | Kirchenpaueria bonnevieae |
| | | | Lafoea dumosa |
| | | | Lepidopora |
| | | | Lytocarpia |
| | | | Modeeria rotunda |
| | | | Nemertesia |
| | | | Nemertesia antennina |
| | | | Nemertesia belini |
| | | | Nemertesia norvegica |
| | | | Nemertesia ramosa |
| | | | Pennaria disticha |
| | | | Plumularia |
| | | | Plumularia setacea |
| | | | Plumulariidae |
| | | | Polyplumaria |
| | | | Salacia desmoides |
| | | | Sertularella |
| | | | Sertularella gayi |
| | | | Sertularella polyzonias |
| | | | Stegolaria geniculata |
| | | | Streptocaulus corneliusi |
| | | | Zygophylax |
| | | | Zygophylax biarmata |
| | Octocorallia | Gorgonian | Bebryce mollis |
| | | | Callistephanus pallida |
| | | | Candidella |
| | | | Candidella imbricata |
| | | | Chelidonisis |
| | | | Chelidonisis aurantiaca |
| | | | Dacrygorgia modesta |
| | | | Dendrobrachia |
| | | | Echinomuricea |
| | | | Ellisellidae |
| | | | Gorgoniidae |
| | | | Isidella |
| | | | Isidella longiflora |
| | | | Isididae |
| | | | Muriceides |
| | | | Muriceides paucituberculata |
| | | | Muriceides sceptrum |
| | | | Nicella granifera |
| | | | Plexauridae |
| | | | Primnoidae |
| | | | Thouarella |
| | | | Thouarella (Euthouarella) hilgendorfi |
| | | | Villogorgia |
| | | | Villogorgia bebrycoides |
| | | | Viminella |
| | | Sea-pen | Gyrophyllum hirondellei |
| | | | Pennatuloidea |
| | | | Umbellula |
| | | | Virgularia |
| | | Soft coral | Alcyonium |
| | | | Alcyonium bocagei |
| | | | Alcyonium burmedju |
| | | | Alcyonium coralloides |
| | | | Alcyonium maristenebrosi |
| | | | Bellonella |
| | | | Epizoanthus |
| | | | Lateothela grandiflora |
| | | | Nephtheidae |
| | | | Nidaliidae |
| | | | Parazoanthus |
| | | | Zibrowius primnoidus |
| | | Soft coral / Gorgonian | Octocorallia |
| | | Stoloniferan | Clavularia |
| | | | Malacalcyonacea |
| | | | Sarcodictyon catenatum |
| | | | Schizophytum echinatum |
| | Scleractinia | Cup coral | Caryophylliidae |
| | | | Desmophyllum |
| | | | Desmophyllum dianthus |
| | | | Flabellum (Flabellum) chunii |
| | | | Flabellum (Ulocyathus) macandrewi |
| | | | Javania |
| | | | Javania cailleti |
| | | | Leptopsammia |
| | | | Leptopsammia formosa |
| | | | Paracyathus pulchellus |
| | | | Stenocyathus vermiformis |
| | | | Vaughanella |
| | | Stony coral | Anomocora fecunda |
| | | | Coenocyathus cylindricus |
| | | | Dasmosmilia variegata |
| | | | Deltocyathus moseleyi |
| | | | Dendrophyllia |
| | | | Dendrophylliidae |
| | | | Enallopsammia |
| | | | Flabellum |
| | | | Madrepora |
| | | | Solenosmilia |
| | | Stony coral / Cup coral | Scleractinia |
| | Stylasteridae | Stylasterids | Crypthelia |
| | | | Crypthelia affinis |
| | | | Crypthelia tenuiseptata |
| | | | Errina |
| | | | Stylasteridae |
| | Zoantharia | | Antipathozoanthus macaronesicus |
| | | | Isozoanthus |
| | | | Savalia |
| | | | Zibrowius alberti |
| Porifera | Calcarea | Sponge | Clathrina lacunosa |
| | | | Leucandra aspera |
| | | | Leucosolenia variabilis |
| | | | Sycon ciliatum |
| | Demospongiae | Large Sponge | Geodia |
| | | | Geodia pachydermata |
| | | | Stryphnus |
| | | Sponge | Antho (Acarnia) elegans |
| | | | Astrophorina |
| | | | Auletta |
| | | | Auletta sessilis |
| | | | Auletta sycinularia |

| Phyllum | Taxonomic Group | VME Indicator | Taxa |
|---|---|---|---|
| | | | Axinella vasonuda |
| | | | Axinellida |
| | | | Chalinidae |
| | | | Demospongiae |
| | | | Desmacella grimaldii |
| | | | Discodermia ramifera |
| | | | Exsuperantia archipelagus |
| | | | Heteroscleromorpha |
| | | | Hymedesmia (Hymedesmia) paupertas |
| | | | Ircinia |
| | | | Ircinia polejaeffi |
| | | | Latrunculia (Biannulata) citharistae |
| | | | Nethea amygdaloides |
| | | | Oceanapia |
| | | | Oceanapia coriacea |
| | | | Phlyctaenopora (Phlyctaenopora) bitorquis |
| | | | Poecillastra |
| | | | Poecillastra compressa |
| | | | Porifera |
| | | | Pseudotrachya hystrix |
| | | | Raspailia (Parasyringella) falcifera |
| | | | Raspailia (Parasyringella) humilis |
| | | | Siphonidium |
| | | | Siphonodictyon viridescens |
| | | | Spongosorites |
| | | | Spongosorites coralliophaga |
| | | | Stylocordyla pellita |
| | | | Xestospongia variabilis |
| | | | Xestospongia variabilis crassa |
| | **Hexactinellida** | Large Sponge | Asconema |
| | | | Pheronema |
| | | Sponge | Amphidiscella |
| | | | Aphrocallistes |
| | | | Aphrocallistes beatrix |
| | | | Echinostylinos reticulatus |
| | | | Euplectella suberea |
| | | | Euretidae |
| | | | Farrea |
| | | | Farrea herdendorfi |
| | | | Farrea laminaris |
| | | | Farrea occa |
| | | | Farreidae |
| | | | Hertwigia |
| | | | Hertwigia falcifera |
| | | | Hexactinellida |
| | | | Rossellidae |
| | | | Saccocalyx |
| | | | Sympagella |
| **Foraminifera** | **Xenophyophores** | Xenophyophores | Foraminifera |
| | | | Miniacina miniacea |
| | | | Reticulammina |

* These categories followed the classification given in Morato *et al.* (2018) where "large sponge*" refers to genus: Asconema, Craniella, Chonelasma, Geodia, Pheronema, Polymastia, Stryphnus, Tetilla, Thenea,* and Vazella. All other species of sponges and records for which no information of Genus were provided were classified as "Generic Sponge."

### *8.6 Catalogue of deep-sea species of the Azores*

The information obtained during the analysis of pre-existing videos as well as those collected during the provision of services has allowed for the development of the first digital Catalogue of deep-sea species of the Azores, a digital tool that aims to foster our knowledge on deep-sea biodiversity in the region. The catalogue was created following the guidelines provided under the SMarTar-ID project (https://smartar-id.app), which has developed a protocol for the correct cataloging of the fauna observed in underwater images of the deep sea and is currently developing a reference image bank on deep-sea species, mainly from the Atlantic Ocean (Howell et al., 2021). The catalogue of deep-sea species of the Azores includes sessile (or low mobility) benthic invertebrates and benthopelagic (bottom-associated) fish observed in the images that are included in the definition of benthic megafauna, that is organisms that can be identified from images which generally have a size greater than 1-3 cm (Moleón et al., 2020). The determination of the taxonomic level for each organism varied depending on the quality of the image collected and/or the existence of biological material associated with the observation, as well as with the degree of development and/or potential limitations of the taxonomic work and review carried out by specialists. The organisms were classified into taxonomic categories called OTUs (Operational Taxonomic Units), creating specific and unique reference numbers for each taxa. Associating unique reference numbers to each morphospecies significantly improves the consistency of the annotations made on the images collected, since the reference number is maintained over time even though the taxonomic identification of the organism may change as new information is compiled or new samples are collected. The database associated with the OTUs contains various fields of information, including the reference number, the scientific name, the AphiaID number given by the World Register of Marine Species (WoRMS) and the classification according to CATAMI morphology, among others. The complete list of all the fields included in the database of the digital Catalogue of deep-sea species of the Azores for each OTU, with a brief description and a practical example is given in (Table 23). In addition to the data provided for each OTU, the digital catalogue also contains information related to each individual image that makes up the catalogue, including the scientific mission where the image was taken, the date and dive number, as well as the platform used and the depth at which it was taken. A more detailed description of how the digital Catalogue of deep-sea species of the Azores was constructed is provided in the report CD2.

At the present state of development, the digital Catalogue of deep-sea species of the Azores contains images and information for a total of 410 OTUs in its database (Table 24). The catalogue contains 22 OTUs from the Phylum Arthropoda, 32% of which have been identified down to species level, with the remaining at higher taxonomic levels (TABLE). The complete list of taxa from the phylum Arthropoda included in the catalogue is given in Table 25, with some images of the most representative taxa shown in Figure 181. Regarding the Phylum Brachiopoda, the catalogue contains only 1 OTU, which is still classified at a high taxonomic level and waiting for identification by experts. The catalogue contains 6 OTUs of the Phylum Bryozoa, all classified at high taxonomic levels. The list of Bryozoa included in the catalogue is given in Table 26. There are 82 OTUs from the Phylum Chordata already classified in the catalogue, 85% of which are identified at species level. The complete list of taxa from the phylum Chordata included in the catalogue is given in Table 27, with some images of the most representative species shown in Figure 183. The catalogue also contains 147 OTUs from the Phylum Cnidaria, of which 63% are currently classified down to species or genus level. The complete list of taxa from the phylum Cnidaria is given in Table 28, with some images of the most representative taxa shown in Figure 184. The catalogue contains 48 OTUs from the Phylum Echinodermata, of which 43% are classified down to species or genus level. The complete list of taxa from the phylum Echinodermata included in the catalogue is given in Table 29, with some images of the most representative species shown in Figure 185. Regarding the Phylum Mollusca, the catalogue contains 18 OTUs, of which 56% are classified at species or genus level. The complete list of taxa from the phylum Mollusca included in the catalogue is given in Table 31. List of OTUs included in the digital Catalogue of deep-sea species of the Azores  from the Phylum Mollusca. Taxa marked with * are considered indicator species for Vulnerable Marine Ecosystems (VME) in the Azores region., with some images of the most representative species shown in Figure 185. Finally, the catalogue includes 84 OTUs of the Phylum Porifera, of which 67% are classified at species or genus level. The complete list of taxa from the phylum Porifera included in the catalogue is given in Table 32. List of OTUs included in the digital Catalogue of deep-sea species of the Azores  from the Phylum Porifera. Taxa marked with * are considered indicator species for Vulnerable Marine Ecosystems (VME) in the Azores region., with some images of the most representative taxa shown in Figure 186.

**Table 23.** Information compiled for each of the OTUs included in the digital Catalog of deep-sea species of the Azores. Fields marked with * are not shown on the online version of the catalog.

| Field | Description | Example |
|---|---|---|
| OTUnum | OTU reference number. Specific number given by the database manager | 2078 |
| aphiaID | OTU identifier, based on a unique and persistent number created by the World Register of Marine Species (WoRMS, www.marinespecies.org) for each taxonomic level | 125360 |
| taxonRank* | Taxonomic level reached, automatically generated based on the AphiaID code | Species |
| scientificName | It corresponds to the lowest taxonomic level determined on the basis of the best taxonomic identification. The name is generated automatically based on the AphiaID code | Viminella flagellum |
| morphospeciesName | In cases where the species level cannot be determined, it will correspond to the taxonomic level reached (based on AphiaID) followed by a code to differentiate between different OTUs of the same taxonomic level (e.g. msp1, msp2, msp3, etc.). | White morph |
| CommonName | The name given to the OTU by the local population, in Portuguese and English, if any | Whip-like gorgonian; Coral chicote |
| identifiedBy | The name of the expert who identified the species in the image | Marina Carreiro-Silva |
| verificationStatus | Score for quality of identification. 1 = OTU identified by image, 2 = OTU identified by image but with the existence of a physical specimen collected in the region, 3 = OTU identified by image and the same physical specimen appearing in the image | 3 |
| numberSamplesCOLETA | Number of samples collected and stored in the Azores reference collection (COLETA) | 12 |
| refsCOLETA* | Reference numbers of specimens collected in the region and stored in COLETA | 10716; 10049; 10168 |
| SimilarOTU | OTUs with similar morphological characteristics that can be confused with the OTU when annotated from video images taken in the Azores | Narella versluysi |
| MorphologyCATAMI | CATAMI standardized hierarchical classification, which allows marine organisms to be classified based on their morphological characters (see Althaus et al., 2015) | Corals \| Black and Octocorals \| Unbranched \| Not Seapen |
| Distribution | Location on a georeferenced map of the areas where the OTU has been observed. Locations will be based on occurrences compiled in the Azores Species Occurrence Database. | |

**Table 24.** Taxonomic level reached for the 410 OTUs that make up the digital Catalogue of deep-sea species of the Azores at its present state of development.

| | Taxonomic level reached | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Phylum | Subphylum | Subclass | Class | Order | Suborder | Superfamily | Family | Genus | Species |
| Arthropoda | | | 3 | 1 | 7 | | 4 | | | 7 |
| Brachiopoda | 1 | | | | | | | | | |
| Bryozoa | 6 | | | | | | | | | |
| Chordata | | 2 | | | 1 | | | 6 | 3 | 70 |
| Cnidaria | | | 8 | 2 | 9 | | 5 | 30 | 35 | 58 |
| Echinodermata | | | | 22 | | | | 5 | 8 | 13 |
| Foraminifera | | | | | | | | | 1 | 1 |
| Mollusca | | | | 5 | 2 | | | 1 | 3 | 7 |
| Porifera | 20 | | | 2 | | 1 | | 5 | 18 | 38 |
| ***Total*** | ***27*** | ***2*** | ***11*** | ***32*** | ***19*** | ***1*** | ***9*** | ***47*** | ***68*** | ***194*** |

**Table 25** List of OTUs from the phylum Arthropoda included in the digital Catalogue of deep-sea species of the Azores.

| Class | Order | Family | OTU name | OTU num. | AphiaID | Level reached |
|---|---|---|---|---|---|---|
| Malacostraca | Decapoda | Aristeidae | *Aristaeopsis edwardsiana* | 6014 | 240796 | Species |
| Malacostraca | Decapoda | Cancridae | *Cancer bellianus* | 6015 | 107275 | Species |
| Malacostraca | Decapoda | Epialtidae | *Anamathia rissoana* | 6013 | 441513 | Species |
| Malacostraca | Decapoda | Geryonidae | *Chaceon affinis* | 6016 | 107369 | Species |
| Malacostraca | Decapoda | Homolidae | *Paromola cuvieri* | 6017 | 107264 | Species |
| Malacostraca | Decapoda | Polybiidae | *Bathynectes maravigna* | 6006 | 107377 | Species |
| Malacostraca | Decapoda | Sternostylidae | *Sternostylus formosus* | 6025 | 1310474 | Species |
| Malacostraca | Decapoda | | Decapoda hermit sp. 1 | 6008 | 1130 | Order |
| Malacostraca | Decapoda | | Decapoda sp. 1 | 6002 | 1130 | Order |
| Malacostraca | Decapoda | | Decapoda sp. 2 | 6005 | 1130 | Order |
| Malacostraca | Decapoda | | Decapoda sp. 3 | 6010 | 1130 | Order |
| Malacostraca | Decapoda | | Decapoda sp. 4 | 6011 | 1130 | Order |
| Malacostraca | Decapoda | | Decapoda sp. 5 | 6012 | 1130 | Order |
| Malacostraca | Decapoda | | Decapoda vent sp. 1 | 6004 | 1130 | Order |
| Malacostraca | Decapoda | | Galatheoidea sp. 1 | 6018 | 106685 | Superfamily |
| Malacostraca | Decapoda | | Galatheoidea sp. 3 | 6020 | 106685 | Superfamily |
| Malacostraca | Decapoda | | Galatheoidea sp. 4 | 6021 | 106685 | Superfamily |
| Malacostraca | Decapoda | | Galatheoidea sp. 5 | 6022 | 106685 | Superfamily |
| Pycnogonida | | | Pycnogonida sp. 1 | 6024 | 1302 | Class |
| Thecostraca | | | Cirripedia sp. 1 | 6000 | 1082 | Subclass |
| Thecostraca | | | Cirripedia sp. 2 | 6026 | 1082 | Subclass |
| Thecostraca | | | Cirripedia Vent sp. 1 | 6001 | 1082 | Subclass |

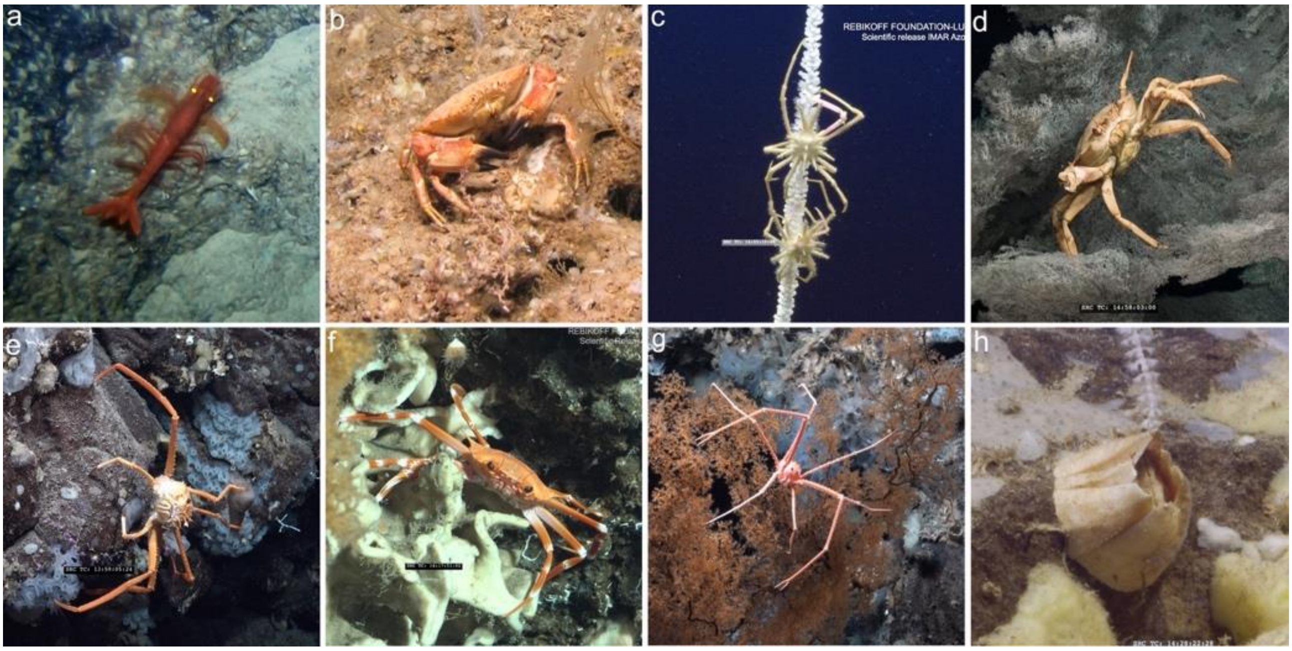


**Figure 181** Examples of arthropod species included in the digital Catalogue of deep-sea species of the Azores. (a) *Aristaeopsis edwardsiana*. (b) *Cancer bellianus*. (c) *Anamathia rissoana*. (d) *Chaceon affinis*. (e) *Paromola cuvieri*. (f) *Bathynectes maravigna*. (g) *Sternostylus formosus*. (h) Unidentified Cirripedia. (i). Image credits: (a) Azor drift-cam, Okeanos-UAç; (b,h) Luso ROV, Oceano Azul Foundation; (c,d,e,f,g) Rebikoff-Nieggler Foundation.

**Table 26** List of OTUs from the phylum Bryozoa included in the digital Catalogue of deep-sea species of the Azores.

| OTU name | OTU num. | AphiaID | Level reached |
|---|---|---|---|
| Bryozoa sp. 1 | 3000 | 146142 | Phyllum |
| Bryozoa sp. 2 | 3001 | 146142 | Phyllum |
| Bryozoa sp. 3 | 3002 | 146142 | Phyllum |
| Bryozoa sp. 4 | 3003 | 146142 | Phyllum |
| Bryozoa sp. 6 | 3005 | 146142 | Phyllum |
| Bryozoa sp. 7 | 3006 | 146142 | Phyllum |

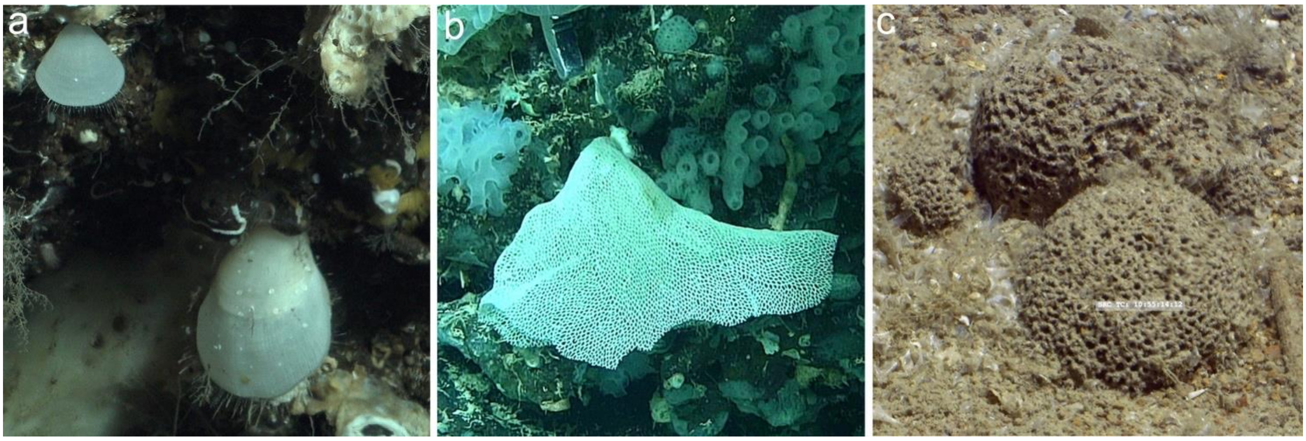

**Figure 182** Examples of brachiopod, bryozoan and foraminifera species included in the digital Catalogue of deep-sea species of the Azores. (a) Unidentified Brachiodpoda; (b) Unidentified Bryozoa; (c) *Syringammina fragilissima*. Image credits: (a,c) Fundação Rebikoff-Nieggler. (b) OceanX, Okeanos-UAç.

**Table 27.** List of OTUs from the phylum Chordata included in the digital Catalogue of deep-sea species of the Azores.

| Classe | Ordem | Familia | Nome da OTU | Num. OTU | AphiaID | Nível atingido |
|---|---|---|---|---|---|---|
| Elasmobranchii | Carcharhiniformes | Pentanchidae | *Galeus murinus* | 8066 | 105813 | Species |
| Elasmobranchii | Carcharhiniformes | Triakidae | *Galeorhinus galeus* | 8065 | 105820 | Species |
| Elasmobranchii | Hexanchiformes | Hexanchidae | *Hexanchus griseus* | 8089 | 105833 | Species |
| Elasmobranchii | Lamniformes | Alopiidae | *Alopias vulpinus* | 8099 | 105836 | Species |
| Elasmobranchii | Lamniformes | Odontaspididae | *Odontaspis ferox* | 8094 | 105844 | Species |
| Elasmobranchii | Rajiformes | Rajidae | *Dipturus intermedius* | 8076 | 711846 | Species |
| Elasmobranchii | Rajiformes | Rajidae | *Raja clavata* | 8055 | 105883 | Species |
| Elasmobranchii | Squaliformes | Centrophoridae | *Centrophorus squamosus* | 8064 | 105901 | Species |
| Elasmobranchii | Squaliformes | Centrophoridae | *Deania calceus* | 8102 | 298167 | Species |
| Elasmobranchii | Squaliformes | Centrophoridae | *Deania profundorum* | 8101 | 105905 | Species |
| Elasmobranchii | Squaliformes | Centrophoridae | *Deania profundorum* | 8067 | 105905 | Genus |
| Elasmobranchii | Squaliformes | Dalatiidae | *Dalatias licha* | 8070 | 105910 | Species |
| Elasmobranchii | Squaliformes | Etmopteridae | cf. *Etmopterus pusillus* | 8069 | 105912 | Species |
| Elasmobranchii | Squaliformes | Oxynotidae | *Oxynotus paradoxus* | 8098 | 105915 | Species |
| Elasmobranchii | Squaliformes | Somniosidae | cf. *Centroscymnus owstonii* | 8100 | 299089 | Species |
| Elasmobranchii | Torpediniformes | Torpedinidae | *Tetronarce nobiliana* | 8071 | 321911 | Species |
| Holocephali | Chimaeriformes | Chimaeridae | *Chimaera opalescens* | 8097 | 712407 | Species |
| Holocephali | Chimaeriformes | Chimaeridae | *Hydrolagus pallidus* | 8072 | 105827 | Species |
| Teleostei | Acanthuriformes | Antigoniidae | *Antigonia capros* | 8108 | 127418 | Species |
| Teleostei | Acanthuriformes | Caproidae | *Capros aper* | 8048 | 127419 | Species |
| Teleostei | Acropomatiformes | Epigonidae | *Epigonus telescopus* | 8063 | 126858 | Species |
| Teleostei | Acropomatiformes | Polyprionidae | *Polyprion americanus* | 8052 | 126998 | Species |
| Teleostei | Anguilliformes | Congridae | *Conger conger* | 8005 | 126285 | Species |
| Teleostei | Anguilliformes | Muraenidae | *Muraena helena* | 8007 | 126303 | Species |
| Teleostei | Anguilliformes | Nettastomatidae | *Nettastoma melanura* | 8103 | 299709 | Species |
| Teleostei | Anguilliformes | Nettastomatidae | *Nettastomatidae spp.* | 8000 | 125433 | Family |

| | | | | | | |
|---|---|---|---|---|---|---|
| Teleostei | Anguilliformes | Synaphobranchidae | *Simenchelys parasitica* | 8077 | 126327 | Species |
| Teleostei | Anguilliformes | Synaphobranchidae | *Synaphobranchus kaupii* | 8008 | 126328 | Species |
| Teleostei | Aulopiformes | Aulopidae | *Aulopus filamentosus* | 8010 | 126335 | Species |
| Teleostei | Aulopiformes | Chlorophthalmidae | *Chlorophthalmus agassizi* | 8011 | 126336 | Species |
| Teleostei | Aulopiformes | Chlorophthalmidae | *Chlorophthalmus* sp. 1 | 8082 | 125664 | Genus |
| Teleostei | Aulopiformes | Ipnopidae | *Bathypterois spp.* | 8009 | 125669 | Species |
| Teleostei | Beryciformes | Berycidae | *Beryx decadactylus* | 8013 | 126394 | Species |
| Teleostei | Beryciformes | Berycidae | *Beryx splendens* | 8014 | 126395 | Species |
| Teleostei | Callionymiformes | Callionymidae | cf. *Synchiropus phaeton* | 8049 | 126798 | Species |
| Teleostei | Carangiformes | Carangidae | *Trachurus picturatus* | 8090 | 126821 | Species |
| Teleostei | Eupercaria incertae sedis | Labridae | *Acantholabrus palloni* | 8046 | 126957 | Species |
| Teleostei | Eupercaria incertae sedis | Labridae | *Lappanella fasciata* | 8078 | 126969 | Species |
| Teleostei | Eupercaria incertae sedis | Sparidae | *Pagellus bogaraveo* | 8051 | 127059 | Species |
| Teleostei | Gadiformes | Lotidae | *Molva macrophthalma* | 8033 | 126460 | Species |
| Teleostei | Gadiformes | Macrouridae | *Coelorinchus caelorhincus* | 8036 | 398381 | Species |
| Teleostei | Gadiformes | Macrouridae | *Coelorinchus labiatus* | 8028 | 280299 | Species |
| Teleostei | Gadiformes | Macrouridae | *Coryphaenoides armatus* | 8029 | 158952 | Species |
| Teleostei | Gadiformes | Macrouridae | *Coryphaenoides guentheri* | 8084 | 158958 | Species |
| Teleostei | Gadiformes | Macrouridae | *Gadomus longifilis* | 8030 | 126471 | Species |
| Teleostei | Gadiformes | Macrouridae | Macrouridae sp. 1 | 8018 | 125471 | Family |
| Teleostei | Gadiformes | Macrouridae | Macrouridae sp. 3 | 8020 | 125471 | Family |
| Teleostei | Gadiformes | Macrouridae | Macrouridae sp. 5 | 8022 | 125471 | Family |
| Teleostei | Gadiformes | Macrouridae | Macrouridae sp. 6 | 8023 | 125471 | Family |
| Teleostei | Gadiformes | Moridae | *Laemonema yarrellii* | 8031 | 126492 | Species |
| Teleostei | Gadiformes | Moridae | *Lepidion eques* | 8032 | 126493 | Species |
| Teleostei | Gadiformes | Moridae | *Mora moro* | 8034 | 126497 | Species |
| Teleostei | Gadiformes | Phycidae | *Phycis blennoides* | 8035 | 126501 | Species |
| Teleostei | Gadiformes | Phycidae | *Phycis phycis* | 8075 | 126502 | Species |
| Teleostei | Lophiiformes | Chaunacidae | *Chaunax* spp. | 8037 | 125796 | Species |
| Teleostei | Lophiiformes | Lophiidae | *Lophius piscatorius* | 8039 | 126555 | Species |
| Teleostei | Lophiiformes | | *Lophiiformes* sp. 1 | 8088 | 10316 | Order |
| Teleostei | Myctophiformes | Myctophidae | *Myctophidae* | 8040 | 125498 | Family |
| Teleostei | Notacanthiformes | Halosauridae | *Aldrovandia sp.* | 8107 | 125837 | Genus |
| Teleostei | Notacanthiformes | Halosauridae | *Halosauropsis macrochir* | 8002 | 126639 | Species |
| Teleostei | Notacanthiformes | Notacanthidae | *Polyacanthonotus rissoanus* | 8041 | 126645 | Species |
| Teleostei | Ophidiiformes | Bythitidae | *Cataetyx laticeps** | 8042 | 126657 | Species |
| Teleostei | Ophidiiformes | Ophidiidae | cf. *Spectrunculus grandis* | 8043 | 126678 | Species |
| Teleostei | Perciformes | Scorpaenidae | *Pontinus kuhlii* | 8058 | 127240 | Species |
| Teleostei | Perciformes | Sebastidae | *Helicolenus dactylopterus* | 8057 | 127251 | Species |
| Teleostei | Perciformes | Sebastidae | *Trachyscorpia cristulata* | 8059 | 127256 | Species |
| Teleostei | Perciformes | Serranidae | *Anthias anthias* | 8047 | 127031 | Species |
| Teleostei | Perciformes | Serranidae | *Serranus atricauda* | 8080 | 127040 | Species |
| Teleostei | Pleuronectiformes | Bothidae | *Arnoglossus rueppelii* | 8053 | 127127 | Species |
| Teleostei | Pleuronectiformes | Scophthalmidae | *Lepidorhombus whiffiagonis* | 8054 | 127146 | Species |
| Teleostei | Scombriformes | Gempylidae | *Ruvettus pretiosus* | 8095 | 126867 | Species |
| Teleostei | Scombriformes | Trichiuridae | *Lepidopus caudatus* | 8050 | 127088 | Species |
| Teleostei | Syngnathiformes | Centriscidae | *Macroramphosus scolopax* | 8092 | 127378 | Species |
| Teleostei | Trachichthyiformes | Trachichthyidae | *Gephyroberyx darwinii* | 8015 | 126401 | Species |
| Teleostei | Trachichthyiformes | Trachichthyidae | *Hoplostethus atlanticus* | 8016 | 126402 | Species |
| Teleostei | Trachichthyiformes | Trachichthyidae | *Hoplostethus mediterraneus* | 8017 | 126404 | Species |
| Teleostei | Zeiformes | Grammicolepididae | cf. *Grammicolepis brachiusculus* | 8012 | 127420 | Species |
| Teleostei | Zeiformes | Oreosomatidae | *Neocyttus helgae* | 8061 | 127423 | Species |
| Teleostei | Zeiformes | Parazenidae | *Cyttopsis rosea* | 8060 | 127425 | Species |
| Teleostei | Zeiformes | Zeidae | *Zeus faber* | 8062 | 127427 | Species |


**Figure 183.** Examples of shark, ray and fish species included in the digital Catalogue of deep-sea species of the Azores. (a) *Helicolenus dactylopterus*; (b) *Polyprion americanus*. (c) *Beryx decadactylus*; (d) *Hoplostethus mediterraneus*. (e) *Coelorinchus caelorhincus*; (f) *Neocyttus helgae*; (g) *Dipturus intermedius*; (h) *Dalatias licha*; (i) *Chimaera opalescens*. Créditos das imagens: (a,b,d,g,h,i) Azor drift-cam, Okeanos-UAç; (c) Luso ROV, EMEPC; (e,f) Fundação Rebikoff-Niegger.

**Table 28.** List of OTUs from the phylum Cnidaria included in the digital Catalogue of deep-sea species of the Azores.

| Classe | Ordem | Familia | Nome da OTU | Num. OTU | AphiaID | Nível atingido |
|---|---|---|---|---|---|---|
| Anthozoa | Actiniaria | Actiniidae | Actiniaria sp. 4 | 2004 | 1360 | Order |
| Anthozoa | Actiniaria | Actiniidae | Actiniaria sp. 5 | 2005 | 1360 | Order |
| Anthozoa | Actiniaria | Actiniidae | Actiniaria sp. 7 | 2007 | 1360 | Order |
| Anthozoa | Actiniaria | Hormathiidae | *Phelliactis* sp. 1 | 2006 | 100762 | Genus |
| Anthozoa | Actiniaria | Hormathiidae | *Phelliactis* sp. 2 | 2151 | 100762 | Genus |
| Anthozoa | Actiniaria | Liponematidae | cf. *Liponema* sp. 1 | 2003 | 100769 | Genus |
| Anthozoa | Actiniaria | | Actiniaria sp. 1 | 2155 | 1360 | Order |
| Anthozoa | Actiniaria | | Actinostoloidea sp. 1 | 2002 | 888374 | Superfamily |

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|---|---|---|---|---|---|---|
| Anthozoa | Antipatharia | Antipathidae | *Antipathes dichotoma* | 2017 | 103309 | Species |
| Anthozoa | Antipatharia | Antipathidae | *Stichopathes gravieri** | 2023 | 472931 | Species |
| Anthozoa | Antipatharia | Antipathidae | *Stichopathes* sp. 2 | 2013 | 103308 | Genus |
| Anthozoa | Antipatharia | Aphanipathidae | Aphanipathidae sp. 1 | 2008 | 266960 | Family |
| Anthozoa | Antipatharia | Aphanipathidae | Aphanipathidae sp. 2 | 2160 | 266960 | Family |
| Anthozoa | Antipatharia | Aphanipathidae | cf. *Aphanostichopathes* sp. | 2012 | 1514479 | Genus |
| Anthozoa | Antipatharia | Aphanipathidae | cf. *Elatopathes abietina** | 2102 | 289886 | Species |
| Anthozoa | Antipatharia | Aphanipathidae | *Phanopathes erinaceus** | 2016 | 1580310 | Species |
| Anthozoa | Antipatharia | Cladopathidae | cf. *Chrysopathes* sp. | 2116 | 267316 | Genus |
| Anthozoa | Antipatharia | Leiopathidae | cf. *Leiopathes expansa** | 2019 | 103325 | Species |
| Anthozoa | Antipatharia | Leiopathidae | *Leiopathes glaberrima** | 2020 | 103326 | Species |
| Anthozoa | Antipatharia | Leiopathidae | cf. *Leiopathes montana** | 2143 | 689419 | Species |
| Anthozoa | Antipatharia | Myriopathidae | *Antipathella subpinnata** | 2014 | 289447 | Species |
| Anthozoa | Antipatharia | Schizopathidae | cf. *Bathypathes pseudoalternata** | 2142 | 1578714 | Species |
| Anthozoa | Antipatharia | Schizopathidae | *Bathypathes* sp. 1* | 2009 | 103304 | Genus |
| Anthozoa | Antipatharia | Schizopathidae | *Bathypathes* sp. 2* | 2018 | 103304 | Genus |
| Anthozoa | Antipatharia | Schizopathidae | *Bathypathes* sp. 3 | 2141 | 103304 | Genus |
| Anthozoa | Antipatharia | Schizopathidae | *Dendrobathypathes* sp. 1* | 2140 | 267372 | Genus |
| Anthozoa | Antipatharia | Schizopathidae | *Parantipathes hirondelle** | 2022 | 472932 | Species |
| Anthozoa | Antipatharia | Schizopathidae | *Parantipathes* sp.* | 2124 | 103306 | Genus |
| Anthozoa | Antipatharia | Schizopathidae | cf. *Stauropathes punctata** | 2011 | 291112 | Species |
| Anthozoa | Antipatharia | Stylopathidae | *Tylopathes* sp.* | 2133 | 267934 | Genus |
| Anthozoa | Corallimorpharia | | Corallimorpharia sp. 1 | 2025 | 1362 | Order |
| Anthozoa | Corallimorpharia | | Corallimorpharia sp. 2 | 2148 | 1362 | Order |
| Anthozoa | Malacalcyonacea | Alcyoniidae | Alcyoniidae sp. 1* | 2061 | 125269 | Family |
| Anthozoa | Malacalcyonacea | Alcyoniidae | *Alcyonium maristenebrosi** | 2125 | 517613 | Species |
| Anthozoa | Malacalcyonacea | Alcyoniidae | *Alcyonium* sp. 1* | 2060 | 125284 | Genus |
| Anthozoa | Malacalcyonacea | Alcyoniidae | *Alcyonium* sp. 2* | 2126 | 125284 | Genus |
| Anthozoa | Malacalcyonacea | Alcyoniidae | *Anthothela grandiflora** | 2028 | 125414 | Species |
| Anthozoa | Malacalcyonacea | Alcyoniidae | *Bellonella* sp. 1 | 2058 | 267263 | Genus |
| Anthozoa | Malacalcyonacea | Alcyoniidae | *Gersemia* sp.* | 2056 | 146953 | Genus |
| Anthozoa | Malacalcyonacea | Alcyoniidae | *Lateothela grandiflora* | 2103 | 1045586 | Species |
| Anthozoa | Malacalcyonacea | Clavulariidae | *Clavularia* sp. 1 | 2057 | 125286 | Genus |
| Anthozoa | Malacalcyonacea | Eunicellidae | *Eunicella modesta** | 2149 | 1608978 | Species |
| Anthozoa | Malacalcyonacea | Gorgoniidae | Gorgoniidae Pale Yellow | 2154 | 125275 | Family |
| Anthozoa | Malacalcyonacea | Gorgoniidae | Gorgoniidae Red | 2153 | 125275 | Family |
| Anthozoa | Malacalcyonacea | Paramuriceidae | *Acanthogorgia armata** | 2088 | 125348 | Species |
| Anthozoa | Malacalcyonacea | Paramuriceidae | *Acanthogorgia hirsuta** | 2089 | 125349 | Species |
| Anthozoa | Malacalcyonacea | Paramuriceidae | *Acanthogorgia* sp. 1 | 2084 | 125293 | Genus |
| Anthozoa | Malacalcyonacea | Paramuriceidae | *Dentomuricea aff. meteor** | 2091 | 125381 | Species |
| Anthozoa | Malacalcyonacea | Paramuriceidae | *Muriceides paucituberculata* | 2083 | 125384 | Species |
| Anthozoa | Malacalcyonacea | Paramuriceidae | *Paramuricea* sp. 2* | 2081 | 125311 | Genus |
| Anthozoa | Malacalcyonacea | Paramuriceidae | *Paramuriceidae* sp. 1* | 2085 | 151540 | Family |
| Anthozoa | Malacalcyonacea | Paramuriceidae | *Paramuriceidae* sp. 2* | 2119 | 151540 | Family |
| Anthozoa | Malacalcyonacea | Paramuriceidae | *Placogorgia terceira* | 2092 | 125396 | Species |
| Anthozoa | Malacalcyonacea | Paramuriceidae | *Villogorgia bebrycoides* | 2121 | 125404 | Species |
| Anthozoa | Malacalcyonacea | Plexauridae | Plexauridae orange sp. 1 | 2079 | 125277 | Family |
| Anthozoa | Malacalcyonacea | Plexauridae | Plexauridae orange sp. 3 | 2128 | 125277 | Family |
| Anthozoa | Malacalcyonacea | Plexauridae | Plexauridae sp. 1 | 2113 | 125277 | Family |
| Anthozoa | Malacalcyonacea | Plexauridae | Plexauridae sp. 2 | 2114 | 125277 | Family |
| Anthozoa | Malacalcyonacea | Plexauridae | Plexauridae sp. 3 | 2115 | 125277 | Family |
| Anthozoa | Malacalcyonacea | Plexauridae | Plexauridae white sp. 2 | 2097 | 125277 | Family |
| Anthozoa | Malacalcyonacea | Plexauridae | Plexauridae white sp. 3 | 2135 | 125277 | Family |
| Anthozoa | Malacalcyonacea | Plexauridae | Plexauridae white sp. 4 | 2159 | 125277 | Family |
| Anthozoa | Malacalcyonacea | Plexauridae | Plexauridae white sp. 5 | 2165 | 125277 | Family |
| Anthozoa | Malacalcyonacea | Plexauridae | Plexauridae yellow sp. 1 | 2118 | 125277 | Family |
| Anthozoa | Malacalcyonacea | Plexauridae | Plexauridae yellow sp. 2 | 2090 | 125277 | Family |
| Anthozoa | Malacalcyonacea | Plexauridae | Plexauridae yellow sp. 3 | 2120 | 125277 | Family |
| Anthozoa | Malacalcyonacea | Plexauridae | *Swiftia dubia** | 2080 | 125400 | Species |
| Anthozoa | Malacalcyonacea | Plexauridae | *Swiftia* sp. 1 | 2094 | 125314 | Genus |

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|---|---|---|---|---|---|---|
| Anthozoa | Scleractinia | Caryophylliidae | Caryophylliidae sp. 1 | 2027 | 135073 | Family |
| Anthozoa | Scleractinia | Caryophylliidae | Caryophylliidae sp. 2 | 2001 | 135073 | Family |
| Anthozoa | Scleractinia | Caryophylliidae | *Desmophyllum dianthus* | 2031 | 135159 | Species |
| Anthozoa | Scleractinia | Caryophylliidae | *Lophelia pertusa** | 2035 | 135161 | Species |
| Anthozoa | Scleractinia | Caryophylliidae | *Solenosmilia variabilis** | 2037 | 135168 | Species |
| Anthozoa | Scleractinia | Deltocyathidae | cf. *Deltocyathus moseleyi* | 2104 | 135157 | Species |
| Anthozoa | Scleractinia | Dendrophylliidae | cf. *Dendrophyllia alternata** | 2134 | 135184 | Species |
| Anthozoa | Scleractinia | Dendrophylliidae | *Dendrophyllia cornigera** | 2030 | 135185 | Species |
| Anthozoa | Scleractinia | Dendrophylliidae | cf. *Eguchipsammia cornucopia** | 2026 | 135188 | Species |
| Anthozoa | Scleractinia | Dendrophylliidae | *Enallopsammia rostrata** | 2032 | 135190 | Species |
| Anthozoa | Scleractinia | Dendrophylliidae | *Leptopsammia formosa* | 2034 | 135192 | Species |
| Anthozoa | Scleractinia | Flabellidae | *Flabellum* spp. | 2033 | 135114 | Genus |
| Anthozoa | Scleractinia | Flabellidae | cf. *Javania* sp. | 2146 | 135115 | Genus |
| Anthozoa | Scleractinia | Oculinidae | *Madrepora oculata** | 2036 | 135209 | Species |
| Anthozoa | Scleractinia | | *Scleractinia* sp. 1 | 2117 | 1363 | Order |
| Anthozoa | Scleractinia | | *Scleractinia* sp. 2 | 2039 | 1363 | Order |
| Anthozoa | Scleralcyonacea | Anthoptilidae | cf. *Anthoptilum murrayi** | 2100 | 128505 | Species |
| Anthozoa | Scleralcyonacea | Chelidonisididae | *Chelidonisis aurantiaca* | 2112 | 125372 | Species |
| Anthozoa | Scleralcyonacea | Chrysogorgiidae | *Chrysogorgia* sp. 1* | 2070 | 125294 | Genus |
| Anthozoa | Scleralcyonacea | Chrysogorgiidae | *Chrysogorgia* sp. 2* | 2147 | 125294 | Genus |
| Anthozoa | Scleralcyonacea | Chrysogorgiidae | *Chrysogorgia* sp. 3* | 2065 | 125294 | Genus |
| Anthozoa | Scleralcyonacea | Chrysogorgiidae | *Iridogorgia fontinalis** | 2063 | 286153 | Species |
| Anthozoa | Scleralcyonacea | Chrysogorgiidae | *Iridogorgia* spp.* | 2129 | 125295 | Genus |
| Anthozoa | Scleralcyonacea | Chrysogorgiidae | *Metallogorgia melanotrichos** | 2073 | 125355 | Species |
| Anthozoa | Scleralcyonacea | Chrysogorgiidae | cf. *Radicipes gracilis** | 2077 | 125357 | Species |
| Anthozoa | Scleralcyonacea | Coralliidae | *Hemicorallium niobe** | 2105 | 1311257 | Species |
| Anthozoa | Scleralcyonacea | Coralliidae | *Hemicorallium tricolor** | 2106 | 1311264 | Species |
| Anthozoa | Scleralcyonacea | Coralliidae | *Paragorgia johnsoni* red morph* | 2107 | 125419 | Species |
| Anthozoa | Scleralcyonacea | Coralliidae | *Paragorgia johnsoni* white morph* | 2108 | 125419 | Species |
| Anthozoa | Scleralcyonacea | Coralliidae | *Pleurocorallium johnsoni** | 2109 | 1311281 | Species |
| Anthozoa | Scleralcyonacea | Coralliidae | cf. *Pseudoanthomastus* spp.* | 2064 | 267770 | Genus |
| Anthozoa | Scleralcyonacea | Ellisellidae | cf. *Nicella granifera** | 2071 | 125359 | Species |
| Anthozoa | Scleralcyonacea | Ellisellidae | *Viminella flagellum** | 2078 | 125360 | Species |
| Anthozoa | Scleralcyonacea | Ellisellidae | *Viminella flagellum* yellow morph* | 2072 | 125360 | Species |
| Anthozoa | Scleralcyonacea | Keratoisididae | *Acanella arbuscula** | 2067 | 125371 | Species |
| Anthozoa | Scleralcyonacea | Keratoisididae | Keratoisididae Clade B1* | 2066 | 1544106 | Family |
| Anthozoa | Scleralcyonacea | Keratoisididae | Keratoisididae Clade C1* | 2158 | 1544106 | Family |
| Anthozoa | Scleralcyonacea | Keratoisididae | Keratoisididae Clade D1-D2* | 2157 | 1544106 | Family |
| Anthozoa | Scleralcyonacea | Keratoisididae | Keratoisididae Clade J3* | 2082 | 1544106 | Family |
| Anthozoa | Scleralcyonacea | Keratoisididae | Keratoisididae whip thin* | 2029 | 1544106 | Family |
| Anthozoa | Scleralcyonacea | Keratoisididae | Keratoisididae whip ultra thin* | 2130 | 1544106 | Family |
| Anthozoa | Scleralcyonacea | Primnoidae | *Callogorgia verticillata** | 2068 | 125405 | Species |
| Anthozoa | Scleralcyonacea | Primnoidae | *Candidella imbricata* | 2069 | 125406 | Species |
| Anthozoa | Scleralcyonacea | Primnoidae | *Narella bellissima** | 2074 | 177838 | Species |
| Anthozoa | Scleralcyonacea | Primnoidae | *Narella versluysi** | 2075 | 125409 | Species |
| Anthozoa | Scleralcyonacea | Primnoidae | *Paracalyptrophora josephinae** | 2076 | 125410 | Species |
| Anthozoa | Scleralcyonacea | Primnoidae | cf. *Thouarella* spp. | 2015 | 125323 | Genus |
| Anthozoa | Scleralcyonacea | Umbellulidae | *Umbellula sp.* | 2095 | 128499 | Genus |
| Anthozoa | Scleralcyonacea | | cf. *Gyrophyllum hirondellei* | 2101 | 128514 | Species |
| Anthozoa | Scleralcyonacea | | Pennatuloidea sp. 1 | 2096 | 1609360 | Superfamily |
| Anthozoa | Scleralcyonacea | | Pennatuloidea sp. 3 | 2098 | 1609360 | Superfamily |
| Anthozoa | Scleralcyonacea | | Pennatuloidea sp. 4 | 2099 | 1609360 | Superfamily |
| Anthozoa | Scleralcyonacea | | Pennatuloidea sp. 5 | 2152 | 1609360 | Superfamily |
| Anthozoa | Zoantharia | Epizoanthidae | cf. *Epizoanthus* sp. 1 | 2038 | 100790 | Genus |
| Anthozoa | Zoantharia | Parazoanthidae | Parazoanthus sp. | 2062 | 100793 | Genus |
| Anthozoa | Zoantharia | Parazoanthidae | *Zibrowius alberti* | 2010 | 992954 | Species |
| Anthozoa | Zoantharia | Parazoanthidae | *Zibrowius primnoidus* | 2040 | 992956 | Species |
| Anthozoa | | | Ceriantharia sp. 1 | 2000 | 1361 | Subclass |
| Anthozoa | | | Octocorallia sp. 1 | 2059 | 1341 | Subclass |
| Anthozoa | | | Octocorallia sp. 2 | 2093 | 1341 | Subclass |

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|---|---|---|---|---|---|---|
| Anthozoa | | | Octocorallia sp. 3 | 2122 | 1341 | Subclass |
| Anthozoa | | | Octocorallia sp. 4 | 2123 | 1341 | Subclass |
| Anthozoa | | | Octocorallia sp. 5 | 2163 | 1341 | Order |
| Anthozoa | | | Octocorallia sp. 6 | 2110 | 1341 | Subclass |
| Anthozoa | | | Octocorallia sp. 7 | 2111 | 1341 | Subclass |
| Anthozoa | | | *Octocorallia* whip coral deep | 2156 | 1341 | Subclass |
| Hydrozoa | Anthoathecata | Stylasteridae | *Crypthelia* sp. 1 | 2043 | 117241 | Genus |
| Hydrozoa | Anthoathecata | Stylasteridae | *Crypthelia* sp. 2 | 2044 | 117241 | Genus |
| Hydrozoa | Anthoathecata | Stylasteridae | *Errina atlantica** | 2041 | 117958 | Species |
| Hydrozoa | Anthoathecata | Stylasteridae | *Errina dabneyi** | 2046 | 117959 | Species |
| Hydrozoa | Anthoathecata | Stylasteridae | cf. *Lepidopora* sp. | 2052 | 117243 | Genus |
| Hydrozoa | Anthoathecata | Stylasteridae | *Pliobothrus symmetricus** | 2047 | 117962 | Species |
| Hydrozoa | Anthoathecata | Stylasteridae | Stylasteridae sp. 2 | 2042 | 22805 | Family |
| Hydrozoa | Leptothecata | Aglaopheniidae | *Lytocarpia myriophyllum** | 2048 | 117302 | Species |
| Hydrozoa | Leptothecata | Haleciidae | Haleciidae sp. 1 | 2053 | 1608 | Family |
| Hydrozoa | Leptothecata | Haleciidae | Haleciidae sp. 2 | 2150 | 1608 | Family |
| Hydrozoa | Leptothecata | Sertularellidae | cf. *Sertularella* sp. 1 | 2055 | 117233 | Genus |
| Hydrozoa | | | Hydrozoa sp. 1 | 2049 | 1337 | Class |
| Hydrozoa | | | Hydrozoa sp. 2 | 2050 | 1337 | Class |

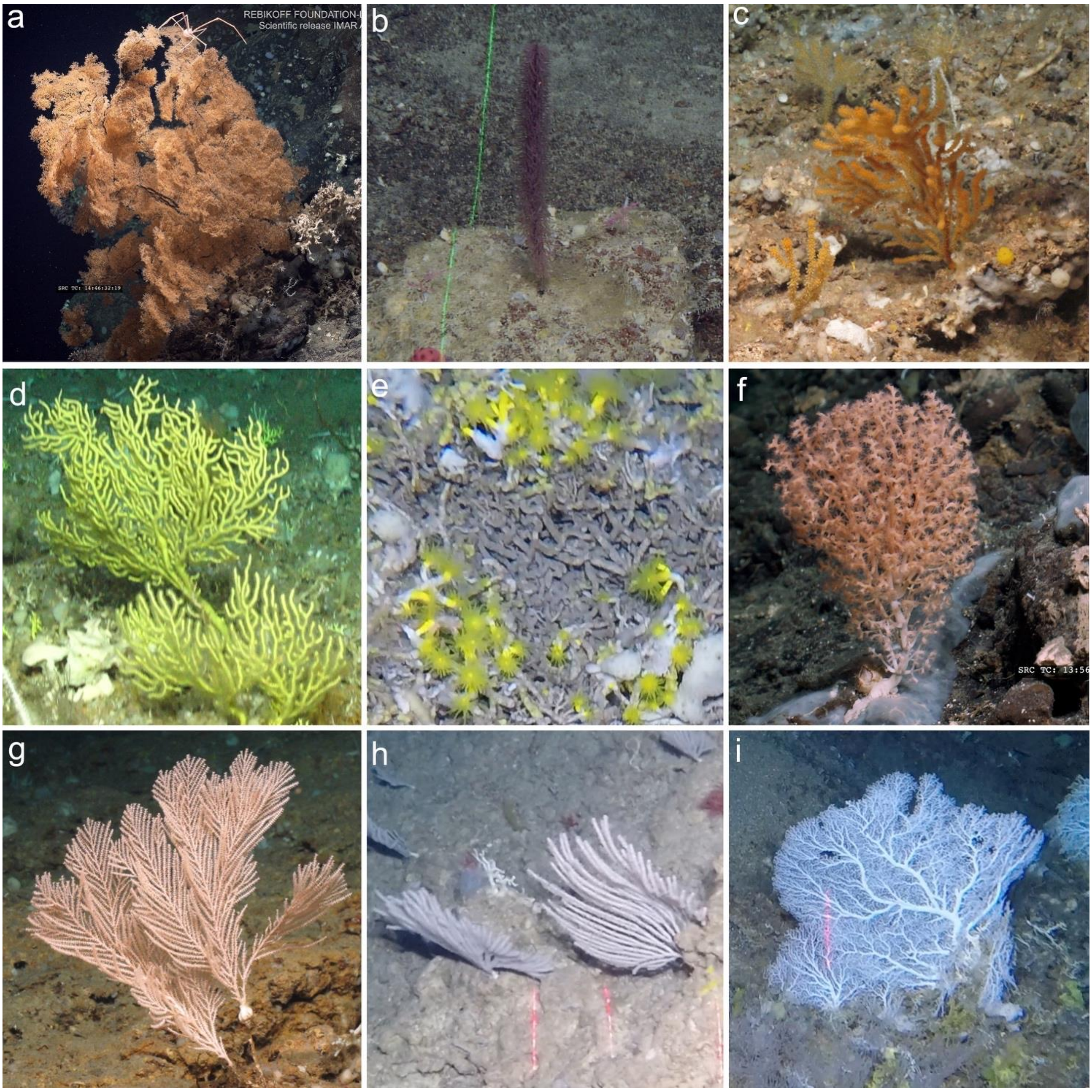


**Figure 184).** Examples of cold-water coral species included in the digital Catalogue of deep-sea species of the Azores. (a) *Leiopathes expansa*. (b) *Parantipathes hirondelle*. (c) *Acanthogorgia hirsuta*. (d) *Dentomuricea aff. meteor* (e) *Eguchipsammia cf. cornucopia*; (f) *Acanella arbuscula*. (g) *Callogorgia verticillata*. (h) *Narella bellissima*. (i) *Errina dabney*. Créditos das imagens: (a,f) Fundação Rebikoff-Nieggler; (b,c,d,g) Luso ROV, Fundação Oceano Azul; (e,h,i) Azor drift-cam, Okeanos-UAç.

**Table 29.** List of OTUs from the phylum Echinodermata included in the digital Catalogue of deep-sea species of the Azores.

| Classe | Ordem | Familia | Nome da OTU | Num. OTU | AphiaID | Nível atingido |
|---|---|---|---|---|---|---|
| Asteroidea | Brisingida | Brisingidae | *Novodinia sp.* | 7008 | 123213 | Genus |
| Asteroidea | Forcipulatida | Stichasteridae | cf. *Stichastrella* sp. 1 | 7003 | 123229 | Genus |
| Asteroidea | Forcipulatida | Zoroasteridae | cf. *Zoroaster fulgens* | 7048 | 123826 | Species |
| Asteroidea | Paxillosida | Luidiidae | *Luidia* sp. 1 | 7007 | 123260 | Genus |
| Asteroidea | Paxillosida | Pseudarchasteridae | *Pseudarchaster gracilis* | 7000 | 178133 | Species |
| Asteroidea | Spinulosida | Echinasteridae | cf. *Henricia* sp. 1 | 7002 | 123276 | Genus |
| Asteroidea | Valvatida | Goniasteridae | *Evoplosoma* sp. 1 | 7004 | 123293 | Genus |

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|---|---|---|---|---|---|---|
| Asteroidea | Valvatida | Goniasteridae | _Goniasteridae_ | 7006 | 123135 | Family |
| Asteroidea | Valvatida | Goniasteridae | _Peltaster placenta_ | 7005 | 124055 | Species |
| Asteroidea | Velatida | Pterasteridae | cf. _Hymenaster_ sp. 1 | 7042 | 123333 | Genus |
| Asteroidea | Velatida | Pterasteridae | cf. _Pteraster personatus_ | 7001 | 124150 | Species |
| Asteroidea | | | _Asteroidea_ sp. 4 | 7045 | 123080 | Class |
| Crinoidea | Cyrtocrinida | Holopodidae | _Cyathidium foresti_* | 7016 | 124245 | Species |
| Crinoidea | | | Crinoidea Long Feathers | 7039 | 123081 | Class |
| Crinoidea | | | Crinoidea Orange sp. 1 | 7009 | 123081 | Class |
| Crinoidea | | | Crinoidea Purple sp. 1 | 7010 | 123081 | Class |
| Crinoidea | | | Crinoidea Red sp. 1 | 7011 | 123081 | Class |
| Crinoidea | | | Crinoidea Small sp. 1 | 7012 | 123081 | Class |
| Crinoidea | | | Crinoidea stalked sp. 1 | 7013 | 123081 | Class |
| Crinoidea | | | Crinoidea stalked sp. 2 | 7014 | 123081 | Class |
| Crinoidea | | | Crinoidea stalked sp. 3 | 7037 | 123081 | Class |
| Crinoidea | | | Crinoidea White sp. 1 | 7015 | 123081 | Class |
| Echinoidea | Arbacioida | Arbaciidae | _Coelopleurus floridanus_ | 7021 | 513202 | Species |
| Echinoidea | Camarodonta | Echinidae | cf. _Echinus esculentus_ | 7020 | 124287 | Species |
| Echinoidea | Camarodonta | Echinidae | _Echinus melo_ | 7022 | 124294 | Species |
| Echinoidea | Camarodonta | Echinidae | _Gracilechinus affinis_ | 7017 | 532039 | Species |
| Echinoidea | Cidaroida | Cidaridae | _Cidaris cidaris_ | 7019 | 124257 | Species |
| Echinoidea | Diadematoida | Diadematidae | _Centrostephanus longispinus_ | 7050 | 124331 | Species |
| Echinoidea | Echinothurioida | Echinothuriidae | Echinothuriidae sp. 1 | 7018 | 160734 | Family |
| Echinoidea | Echinothurioida | Echinothuriidae | Echinothuriidae sp. 2 | 7038 | 160734 | Family |
| Echinoidea | Echinothurioida | Echinothuriidae | cf. _Hygrosoma petersii_ | 7023 | 124339 | Species |
| Holothuroidea | Elasipodida | Psychropotidae | _Benthodytes sp. 1_ | 7027 | 123529 | Genus |
| Holothuroidea | Holothuriida | Mesothuriidae | cf. _Mesothuria sp. 1_ | 7041 | 123465 | Genus |
| Holothuroidea | Synallactida | Synallactidae | Synallactidae sp. 1 | 7026 | 123185 | Family |
| Holothuroidea | Synallactida | Synallactidae | cf. Synallactidae sp. 2 | 7040 | 123185 | Family |
| Holothuroidea | | | Holothuroidea sp. 1 | 7024 | 123083 | Class |
| Holothuroidea | | | Holothuroidea sp. 2 | 7025 | 123083 | Class |
| Holothuroidea | | | Holothuroidea sp. 3 | 7044 | 123083 | Class |
| Holothuroidea | | | Holothuroidea sp. 4 | 7046 | 123083 | Class |
| Holothuroidea | | | Holothuroidea sp. 5 | 7051 | 123083 | Class |
| Ophiuroidea | Euryalida | Gorgonocephalidae | cf. _Gorgonocephalus caputmedusae_ | 7035 | 124967 | Species |
| Ophiuroidea | | | Ophiuroidea sp. 10 | 7043 | 123084 | Class |
| Ophiuroidea | | | Ophiuroidea sp. 11 | 7047 | 123084 | Class |
| Ophiuroidea | | | Ophiuroidea sp. 2 | 7028 | 123084 | Class |
| Ophiuroidea | | | Ophiuroidea sp. 3 | 7029 | 123084 | Class |
| Ophiuroidea | | | Ophiuroidea sp. 5 | 7031 | 123084 | Class |
| Ophiuroidea | | | Ophiuroidea sp. 6 | 7032 | 123084 | Class |
| Ophiuroidea | | | Ophiuroidea sp. 9 | 7036 | 123084 | Class |

Table 30. List of OTUs from the phylum Foraminifera included in the digital Catalogue of deep-sea species of the Azores.

| Classe | Familia | Nome da OTU | Num. OTU | AphiaID | Nível atingido |
|---|---|---|---|---|---|
| Monothalamea | Psamminidae | cf. Reticulammina sp. | 9002 | 137318 | Genus |
| Monothalamea | Psamminidae | cf. Syringammina fragilissima* | 9001 | 137339 | Species |

Table 31. List of OTUs included in the digital Catalogue of deep-sea species of the Azores from the Phylum Mollusca. Taxa marked with * are considered indicator species for Vulnerable Marine Ecosystems (VME) in the Azores region.

| Classe | Ordem | Familia | Nome da OTU | Num. OTU | AphiaID | Nível atingido |
|---|---|---|---|---|---|---|
| Bivalvia | Limida | Limidae | _Acesta excavata_ | _4002_ | 140232 | Species |
| Bivalvia | Ostreida | Gryphaeidae | _Neopycnodonte zibrowii_* | _4003_ | 379789 | Species |
| Bivalvia | | | _Bivalvia sp. 1_ | _4001_ | 105 | Class |
| Cephalopoda | Myopsida | Loliginidae | _Loligo forbesii_ | _4010_ | 140270 | Species |
| Cephalopoda | Octopoda | Enteroctopodidae | cf. _Muusoctopus sp._ | _4015_ | 527126 | Genus |
| Cephalopoda | Octopoda | Octopodidae | _Pteroctopus tetracirrhus_ | _4007_ | 140606 | Species |
| Cephalopoda | Octopoda | Octopodidae | cf. _Scaeurgus unicirrhus_ | _4009_ | 140607 | Species |

| | | | | | | |
|---|---|---|---|---|---|---|
| Cephalopoda | Octopoda | | Octopoda sp. 2 | *4008* | 11718 | Order |
| Cephalopoda | Octopoda | | Octopoda sp. 4 | *4016* | 11718 | Order |
| Cephalopoda | Oegopsida | Histioteuthidae | cf. *Histioteuthis sp.* | *4017* | 138074 | Genus |
| Cephalopoda | Oegopsida | Mastigoteuthidae | cf. *Mastigoteuthis sp. 1* | *4006* | 138168 | Genus |
| Cephalopoda | | | Cephalopoda sp. 2 | *4004* | 11707 | Class |
| Cephalopoda | | | Cephalopoda sp. 3 | *4005* | 11707 | Class |
| Cephalopoda | | | Cephalopoda sp. 5 | *4022* | 11707 | Class |
| Gastropoda | Lepetellida | Fissurellidae | Fissurellidae sp. 1 | *4018* | 111 | Family |
| Gastropoda | Neogastropoda | Pseudomelatomidae | cf. *Leucosyrinx verrillii* | *4020* | 141866 | Species |
| Gastropoda | Trochida | Calliostomatidae | *Calliostoma leptophyma* | *4019* | 141760 | Species |
| Gastropoda | | | Gastropoda sp. 4 | *4014* | 101 | Class |

**Table 32.** List of OTUs included in the digital Catalogue of deep-sea species of the Azores from the Phylum Porifera. Taxa marked with * are considered indicator species for Vulnerable Marine Ecosystems (VME) in the Azores region.

| Class | Order | Family | OTU Name | OTU number | AphiaID | Level reached |
|---|---|---|---|---|---|---|
| Demospongiae | Axinellida | Axinellidae | *Axinella vasonuda* | 1112 | 132497 | Species |
| Demospongiae | Axinellida | Raspailiidae | *Raspailia (Parasyringella) falcifera* | 1034 | 168124 | Species |
| Demospongiae | Bubarida | Bubaridae | cf. *Auletta sessilis* | 1000 | 132462 | Species |
| Demospongiae | Bubarida | Bubaridae | cf. *Phakellia ventilabrum** | 1002 | 132511 | Species |
| Demospongiae | Desmacellida | Desmacellidae | *Desmacella grimaldii* | 1022 | 168302 | Species |
| Demospongiae | Dictyoceratida | Irciniidae | cf. *Ircinia sp. 1* | 1003 | 131751 | Genus |
| Demospongiae | Haplosclerida | Chalinidae | *Chalinidae sp.* | 1006 | 131636 | Family |
| Demospongiae | Haplosclerida | Chalinidae | cf. *Haliclona (Soestella) implexa** | 1005 | 166642 | Species |
| Demospongiae | Haplosclerida | Chalinidae | *Haliclona filholi** | 1051 | 850418 | Species |
| Demospongiae | Haplosclerida | Petrosiidae | *Petrosia (Petrosia) crassa** | 1007 | 166828 | Species |
| Demospongiae | Haplosclerida | Petrosiidae | cf. *Petrosia* sp. 1* | 1004 | 131847 | Genus |
| Demospongiae | Haplosclerida | Petrosiidae | cf. *Xestospongia variabilis* | 1077 | 132930 | Phyllum |
| Demospongiae | Haplosclerida | Phloeodictyidae | *Oceanapia coriacea* | 1013 | 132936 | Species |
| Demospongiae | Haplosclerida | Phloeodictyidae | cf. *Oceanapia* sp. 1 | 1083 | 131852 | Genus |
| Demospongiae | Haplosclerida | Phloeodictyidae | *Oceanapia* sp. 2 | 1065 | 131852 | Genus |
| Demospongiae | Haplosclerida | Phloeodictyidae | cf. *Siphonodictyon viridescens* | 1082 | 821735 | Species |
| Demospongiae | Poecilosclerida | Hymedesmiidae | cf. *Hymedesmia (Hymedesmia) paupertas* | 1010 | 133621 | Species |
| Demospongiae | Poecilosclerida | Latrunculiidae | *Latrunculia (Biannulata) citharistae* | 1011 | 134177 | Species |
| Demospongiae | Poecilosclerida | Mycalidae | *Phlyctaenopora (Phlyctaenopora) bitorquis* | 1012 | 168705 | Species |
| Demospongiae | Poecilosclerida | Phellodermidae | *Echinostylinos reticulatus* | 1030 | 133335 | Species |
| Demospongiae | Polymastiida | Polymastiidae | *Polymastia corticata** | 1014 | 134197 | Species |
| Demospongiae | Polymastiida | Polymastiidae | *Pseudotrachya hystrix* | 1080 | 134261 | Species |
| Demospongiae | Suberitida | Halichondriidae | cf. *Spongosorites* sp. 1 | 1031 | 131818 | Genus |
| Demospongiae | Suberitida | Stylocordylidae | *Stylocordyla pellita* | 1015 | 185002 | Species |
| Demospongiae | Tetractinellida | Azoricidae | *Leiodermatium* blue morph* | 1024 | 132086 | Genus |
| Demospongiae | Tetractinellida | Azoricidae | *Leiodermatium tuba** | 1129 | 1430934 | Species |
| Demospongiae | Tetractinellida | Azoricidae | *Leiodermatium* white morph* | 1025 | 132086 | Genus |
| Demospongiae | Tetractinellida | Corallistidae | *Neophrissospongia nolitangere** | 1020 | 171086 | Species |
| Demospongiae | Tetractinellida | Corallistidae | cf. *Neoschrammeniella* sp. 1* | 1084 | 171087 | Genus |
| Demospongiae | Tetractinellida | Geodiidae | cf. *Geodia hentscheli** | 1063 | 449128 | Species |
| Demospongiae | Tetractinellida | Geodiidae | cf. *Geodia megastrella** | 1028 | 134034 | Species |
| Demospongiae | Tetractinellida | Geodiidae | *Geodia* sp. 2 | 1017 | 132005 | Genus |
| Demospongiae | Tetractinellida | Macandrewiidae | *Macandrewia azorica** | 1019 | 134346 | Species |
| Demospongiae | Tetractinellida | Pachastrellidae | *Characella pachastrelloides complex** | 1023 | 170240 | Species |
| Demospongiae | Tetractinellida | Pachastrellidae | cf. *Nethea amygdaloides* | 1093 | 183627 | Species |
| Demospongiae | Tetractinellida | Pachastrellidae | *Pachastrella* spp.* | 1072 | 132015 | Genus |
| Demospongiae | Tetractinellida | Phymaraphiniidae | *Exsuperantia archipelagus* | 1008 | 1349574 | Species |
| Demospongiae | Tetractinellida | Vulcanellidae | *Poecillastra compressa* | 1021 | 134083 | Species |
| Demospongiae | Tetractinellida | | *Astrophorina* sp. 1 | 1016 | 131602 | Suborder |
| Hexactinellida | Amphidiscosida | Hyalonematidae | cf. *Hyalonema (Cyliconema) infundibulum** | 1027 | 171460 | Species |
| Hexactinellida | Amphidiscosida | Hyalonematidae | cf. *Hyalonema (Cyliconema) thomsonis** | 1078 | 171475 | Species |
| Hexactinellida | Amphidiscosida | Pheronematidae | *Pheronema carpenteri** | 1045 | 134378 | Species |
| Hexactinellida | Lyssacinosida | Euplectellidae | cf. *Amphidiscella* sp. 1 | 1085 | 171849 | Species |

| | | | | | | |
|---|---|---|---|---|---|---|
| Hexactinellida | Lyssacinosida | Euplectellidae | *Amphidiscella* sp. 2 | 1075 | 171849 | Genus |
| Hexactinellida | Lyssacinosida | Euplectellidae | cf. *Euplectella suberea* | 1009 | 134401 | Species |
| Hexactinellida | Lyssacinosida | Euplectellidae | *Hertwigia falcifera* | 1043 | 134402 | Species |
| Hexactinellida | Lyssacinosida | Euplectellidae | *Hertwigia* sp. 1 | 1039 | 132115 | Genus |
| Hexactinellida | Lyssacinosida | Euplectellidae | *Regadrella phoenix** | 1041 | 134405 | Species |
| Hexactinellida | Lyssacinosida | Euplectellidae | cf. *Saccocalyx sp. 1* | 1037 | 171844 | Genus |
| Hexactinellida | Lyssacinosida | Rossellidae | *Asconema fristedti** | 1029 | 255144 | Species |
| Hexactinellida | Lyssacinosida | Rossellidae | Asconema morph 1 | 1032 | 132122 | Genus |
| Hexactinellida | Lyssacinosida | Rossellidae | Asconema morph 3 | 1081 | 132122 | Genus |
| Hexactinellida | Lyssacinosida | Rossellidae | *Rossellidae* | 1126 | 131694 | Family |
| Hexactinellida | Lyssacinosida | Rossellidae | *Sympagella* sp. 1 | 1033 | 132113 | Genus |
| Hexactinellida | Sceptrulophora | Aphrocallistidae | *Aphrocallistes beatrix* | 1042 | 134380 | Species |
| Hexactinellida | Sceptrulophora | Euretidae | cf. *Chonelasma* sp. 1* | 1109 | 132102 | Genus |
| Hexactinellida | Sceptrulophora | Euretidae | *Chonelasma* sp. 2* | 1040 | 132102 | Genus |
| Hexactinellida | Sceptrulophora | Euretidae | Euretidae sp. 1 | 1036 | 131688 | Family |
| Hexactinellida | Sceptrulophora | Euretidae | Euretidae sp. 2 | 1088 | 131688 | Family |
| Hexactinellida | Sceptrulophora | Farreidae | cf. *Farrea herdendorfi* | 1076 | 171744 | Species |
| Hexactinellida | Sceptrulophora | Farreidae | *Farrea laminaris* | 1038 | 134390 | Species |
| Hexactinellida | Sceptrulophora | Farreidae | *Farrea occa* | 1044 | 134391 | Species |
| Hexactinellida | Sceptrulophora | Farreidae | Farreidae sp. 1 | 1086 | 131689 | Family |
| Hexactinellida | | | Hexactinellida sp. 1 | 1026 | 22612 | Class |
| Hexactinellida | | | Hexactinellida sp. 2 | 1091 | 22612 | Class |
| | | | Porifera digitate sp. 2 | 1050 | 558 | Phyllum |
| | | | Porifera encrusting beige | 1053 | 558 | Phyllum |
| | | | Porifera encrusting grey | 1056 | 558 | Phyllum |
| | | | Porifera encrusting orange | 1057 | 558 | Phyllum |
| | | | Porifera encrusting red | 1059 | 558 | Phyllum |
| | | | Porifera encrusting white | 1061 | 558 | Phyllum |
| | | | Porifera encrusting yellow | 1054 | 558 | Phyllum |
| | | | Porifera fanshape sp. 1 | 1073 | 558 | Phyllum |
| | | | Porifera flabellate sp. 2 | 1087 | 558 | Phyllum |
| | | | Porifera globular sp. 2 | 1064 | 558 | Phyllum |
| | | | Porifera globular yellow | 1090 | 558 | Phyllum |
| | | | Porifera massive indet. | 1067 | 558 | Phyllum |
| | | | Porifera papilate indet. | 1104 | 558 | Phyllum |
| | | | Porifera pedunculate indet. | 1074 | 558 | Phyllum |
| | | | Porifera tubular sp. 3 | 1094 | 558 | Phyllum |
| | | | Porifera tubular sp. 5 | 1106 | 558 | Phyllum |
| | | | Porifera tubular sp. 7 | 1068 | 558 | Phyllum |
| | | | Porifera vase white | 1066 | 558 | Phyllum |
| | | | Porifera white lamellate | 1001 | 558 | Phyllum |

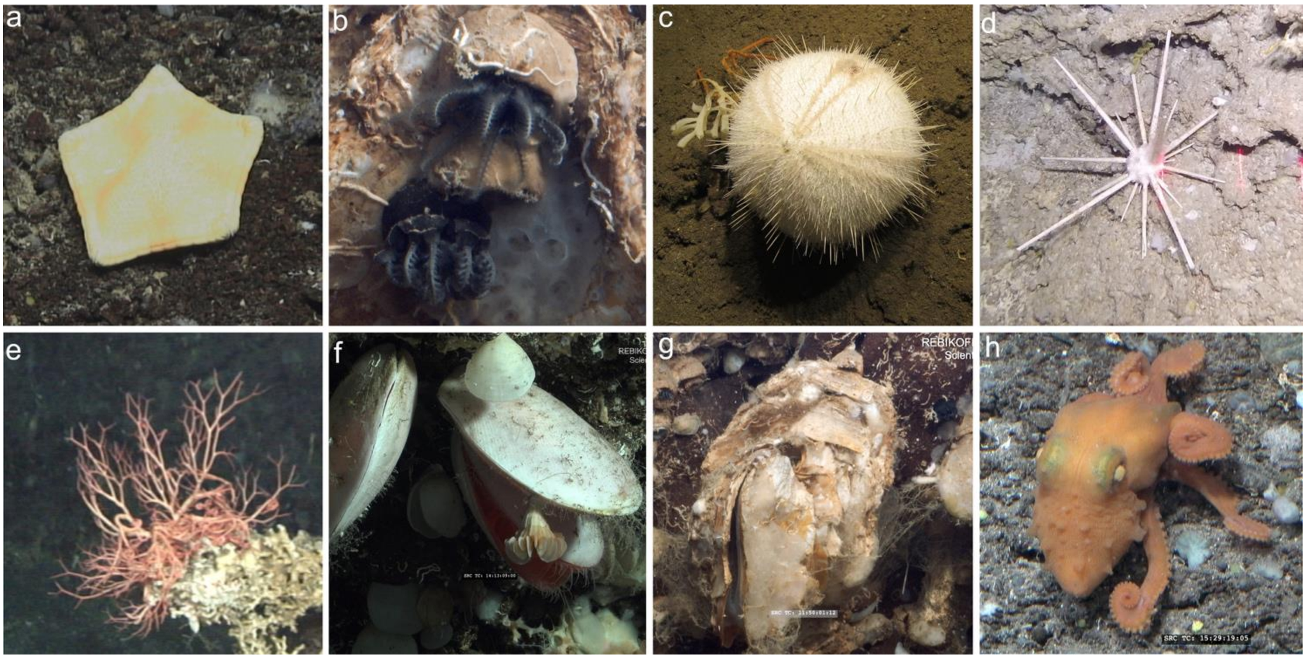



Figure 185. Examples of echinoderm and mollusk species included in the digital Catalogue of deep-sea species of the Azores. (a) *Peltaster placenta*; (b) *Cyathidium foresti*; (c) *Echinus melo*; (d) *Cidaris cidaris*; (e) *Gorgonocephalus caputmedusae*; (f) *Acesta excavata*; (g) *Neopycnodonte zibrowii*; (h) *Pteroctopus tetracirrhus*. Créditos das imagens: (a,e,h) Luso ROV, Fundação Oceano Azul; (b,c,f,g) Fundação Rebikoff-Nieggler; (d) Azor drift-cam, Okeanos-UAç.


**Figure 186**. Examples of sponge species included in the digital Catalogue of deep-sea species of the Azores. (a) *Desmacella grimaldii*; (b) *Petrosia (Petrosia) crassa*; (c) *Leiodermatium* sp.; (d) *Characella pachastrelloides*; (e) *Poecillastra compressa*; (f) *Pheronema carpenteri*; (g) *Regadrella phoenix*; (h) *Asconema fristedti*. (i) *Aphrocallistes beatrix*. Créditos das imagens: (a,c,g) Luso ROV, Fundação Oceano Azul; (b,d,e,f,h,i) Azor drift-cam, Okeanos-UAç.

The digital Catalogue of deep-sea species of the Azores is hosted on the ADSR group's website (https://deepsea.uac.pt/catalogue). The web portal has a relatively simple internal structure, with three main divisions that can be accessed from the main landing page: (1) the species catalogue, (2) the catalogue of biological communities and (3) a smaller section containing some information about the catalogue, its main contributors and how to access the data. To facilitate the navigation through the species database, the website allows the user to search and extract information from the OTUs using various 'search attributes', such as taxonomy and external morphology of the organisms following the CATAMI scheme. These features make it easier for the user to find a particular species included in the catalogue, even without knowing its scientific name or taxonomic classification, being guided solely by the morphological characteristics of the organism. After each search, the portal produces an answer for each taxa included in the catalogue (Figure 187), providing the best available images of the OTU and information about its taxonomy and morphology, as well as its spatial and depth distribution in the Azores region through the links to the occurrences data portal.

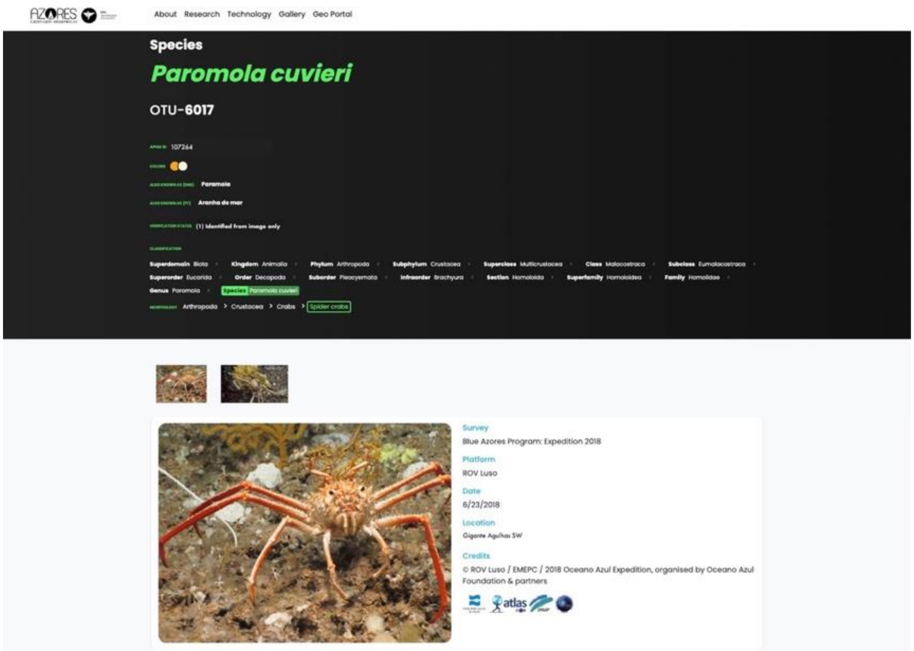



**Figure 187.** Current aspect of the web portal displaying one of the OTUs included in the digital catalogue of deep-sea species of the Azores, showing the organization of the metadata and how the images are presented.

## 9. Deep-sea benthic communities' diversity, including Vulnerable Marine Communities (VMC)

Due to the scarce knowledge that exists regarding the diversity and distribution of benthic species along large areas of the deep sea, the concept of VME indicator species has been widely used to signal the occurrence of VMEs. As previously mentioned, the sole presence of an indicator species should not be considered sufficient to classify an individual geomorphological feature as a VME, and knowledge on its abundance, and more preferably, on the spatial associations produced by benthic species, should also be incorporated in the assessments. For this reason, a comprehensive understanding of how benthic species associate in the deep sea to form stable communities is of paramount importance to effectively infer the presence of VMEs.

### *9.1 Methodologies and definitions for VME indicator communities*

The term biological community (or biocenosis) refers to characteristic associations of organisms and can be broadly defined as a "group of populations of species that interact together in space". This definition considers that the organisms that form a biological community should occur in the same place at the same time, and that are interacting among each other either on a direct or indirect way (Stroud *et al.*, 2015). Identifying benthic communities whose composition and structure is maintained stable across large areas is a challenging task, which can only be accomplished through the processing of large datasets of species occurrences, in our case, extracted from underwater video images. Once benthic communities have been identified and described, their intrinsic characteristics should be assessed to determine whether they display vulnerability towards human activities, leading to the listing of those that should be regarded as VMCommunities (*sensu* Watling and Auster, 2021). Thus, a cluster of VME indicator species most often refers to a benthic community and not an ecosystem, leaving the term VME (VMEcosystem) as a reference to a series of functionally interrelated and spatially overlapping communities that make up part of the ecosystem. VMEs, in this sense, potentially comprise one seamount or multiple seamounts, or other geomorphological features (e.g., ridge, trench).

It is of key importance that the assessment of benthic communities to identify VMCommunities should be made through a data-driven process, which should follow the five criteria for defining what constitutes a VME provided by FAO (2009). These criteria, however, should be adapted for the assessment of benthic communities in each area under study. For the specific case of the Azores, we have adapted the five FAO criteria in a similar way to that used in section 8.1:

- Rarity: the community only occurs in a restricted area of the Azores region, and if the representative species are known to be endemic, rare, threatened, or declining.
- Functionality: assessed by evaluating the biodiversity and density of associated sessile and vagile species and the degree of interspecific interactions, the community is known to create nursery areas for other species or provide ecosystem services such as nutrient cycling or carbon storage.
- Fragility: assessed according to the fragility of the representative taxa against physical contact, the height and complexity of its structure, and the capacity for recovery after human impact.
- Life-history: assessed against the longevity, fecundity, age at maturity, growth rate, and known frequency of recruitment success of the characteristic species.
- Structural complexity: assessed based on the structural habitat created, evaluated by the size and 3D complexity of the association of species, as well as the heterogeneity of the habitat and its ability to create “habitat cascades” (i.e., positive effects on focal organisms mediated by biogenic habitat formation).

### *9.2 Known deep-sea biological communities in the Azores*

The deep sea of the Azores is characterized by its complex seafloor geomorphology, home to several coral gardens, cold-water coral reefs, sponge grounds and hydrothermal vents. These habitats play a fundamental role in the stability and resilience of marine food webs, providing nursery and refuge to a set of benthic and demersal species, some of which with important socio-economic implications in the region. The amount of ecological information collected by the ADSR team regarding these habitats has increased significantly in the past years, especially with the development of the Azor drift-cam and the possibility to lead and participate in oceanographic surveys on board of vessels equipped with imaging platforms. The underwater images collected in different areas of the Azores has fostered the identification and characterization of deep-sea benthic communities found in the region down to 1000 m depth. Through visual assessments, the main associations of conspicuous epibenthic species have now been catalogued, identifying in each case the main structuring and dominant taxa (i.e., indicator species). The spatial extent of the video transects evaluated so far is large and includes several seamounts and ridges along the whole Mid-Atlantic Ridge and slopes of several islands. The images evaluated until now have provided information for a total of 39 biological communities. Most of the communities identified are coral gardens (23), cold-water coral reefs (2), followed by deep-sea sponge aggregations (9), Xenophyophores aggregations (1) and other groups (4). The complete list of biological communities identified and classified can be found in Table 33 and is summarized in the following sections.

### Coral gardens

*Octocoral-dominated communities*

Unlike other areas of the North Atlantic, the main species providing tridimensional structures to the seabed of the Azores down to 1000 m depth correspond to large gorgonian corals (Octocorallia, Alcyonacea), with many representatives of different suborders. The most conspicuous octocoral-dominated community is that characterized by the species *Viminella flagellum*, *Callogorgia verticillata, Paracalyptrophora josephinae* (Calcaxonia), *Dentomuricea* aff. *meteor* and *Acanthogorgia* spp. (Holaxonia) (Figure 188a). These cosmopolitan species generally thrive on the summits and upper slopes of shallow seamounts and island slopes across the Azores (e.g., Tempera *et al.*, 2013). Their abundance can vary from scattered colonies covering large areas to spatially restricted patches reaching very high-densities, some in excess of 5-10 col·m$^{-2}$. Their role as key components of the Azores ecosystems has not yet been fully evaluated, but it is known that these species provide shelter and refuge to a wide variety of associated species, including mobile fauna such as fish and crustaceans. The dominance in terms of abundance of one species over the others within this community is still under study, and all possible combinations have been reported so far in the Azores: from monospecific patches of one single species in high abundances to areas where all species are reported cooccurring together. Aggregations with *Viminella flagellum* and/or *Acanthogorgia spp.* tend to be the most widespread along the EEZ of the Azores (Figure 188b), although dense patches of the species *Callogorgia verticillata* and *Dentomuricea* aff. *meteor* have now been reported in several seamounts along the Mid-Atlantic Ridge and island slopes of the central group and eastern groups.

There exist other octocoral-dominated communities commonly observed throughout the region, especially in a deeper bathymetric range. A very characteristic association relates to that formed by the octocoral *Pleurocorallium johnsoni*, the soft coral cf. *Anthomastus*/*Pseudoanthomastus* and the yellow lamellate sponge *Desmacella grimaldii*, especially on the upper slopes of shallow seamounts between 500 and 700 m depth. This community is generally found on hard substrates, either of a lithogenic or a basaltic origin, although it has also been reported developing on lava balloons. Other members of the Coralliidae family (*Hemicorallium tricolor* and *H. niobe*) also form dense aggregations in the Azores, particularly along the Mid-Atlantic Ridge and on island slopes of the central group, but with much less frequency than that of the communities listed above. For this reason, the ecology of these aggregations has poorly been studied, and would require specific studies to understand the reasons behind their limited spatial prevalence. Aggregations of the bubblegum coral *Paragorgia johnsoni*, which in the Azores can attain heights above 1 m (Morato *et al.*, 2021b), have also been observed on the slopes of several seamounts of the Mid-Atlantic Ridge and island slopes of the western group, especially at depths between 600 and 800 m (Figure 188c). Several species are reported associated to these aggregations, including small soft corals (e.g., cf. *Anthomastus*/*Pseudoanthomastus*) and cup corals (e.g., *Leptopsammia formosa*). The community characterized by the association between the primnoid corals *Narella bellissima* and *Narella versluysi* is also frequently observed at those depths (600-800 m), sometimes covering very large areas that extend for hundreds of meters (Figure 188d). These two species have already been found in great abundances, with the whip coral *N. versluysi* reaching some of the highest densities for any structuring gorgonian species in the Azores, especially on the southern side of the Mid-Atlantic Ridge and on the island slopes of the eastern group. The number of species associated to this community is varied, and includes not only sessile but also mobile fauna, such as crabs and some commercially important fishes. Another less-common octocoral-dominated community corresponds to that formed by the primnoid *Candidella imbricata*, which has been observed generating highly dense patches over large rocks or boulders either in shallow or deep areas, generally displaying a very limited spatial extent. In those cases, most of the colonies observed attain great sizes and show little signs of impacts (i.e., broken branches, epiphytes). In recent surveys, a very dense coral garden formed by gorgonians of the Paramuriceidae family has been observed on some seamount slopes and summits. This species, not yet been identified to species level, produces highly structurally complex aggregations, some of which have been associated to commercially important fishes such as *Polypiron americanus*.

*Antipatharia and bamboo corals*

Some of the deepest areas explored (~1,000 m), at the base of the seamounts and island slopes, have displayed a high diversity of structurally complex habitats, playing an important role in enhancing deep-sea biodiversity at the local scale. The communities found in some of these areas are formed by dense and diverse coral gardens with antipatharians, scleractinians and bamboo corals associated with hexactinellid sponges. These coral gardens are mainly composed by large epibenthic species, with the iconic long-lived and slow-growing black coral *Leiopathes* expansa as the most conspicuous species. Isolated colonies of the scleractinian cold-water coral *Lophelia pertusa* and large plexaurids from the family Paramuriceidae are common as accompanying species, as well as hexactinellids such as *Farrea* spp.*, Aphrocallistes beatrix* and *Gymnorete* sp., these last species when the community is observed in sloping areas or vertical walls. Scleractinian corals forming reefal and non-reefal aggregations are generally observed in deep areas on the northern Mid-Atlantic Ridge, attached to outcropping rocks, especially in steep slopes. This community is composed by several stony coral species, such as *Lophelia pertusa* and *Madrepora oculata*, commonly observed alongside with lace corals from the species *Errina atlantica.* Bamboo corals are also a very diverse group within this community, with undescribed or rare species from the clades B1 and C1 of the Keratoisididae family*.* The diversity of associated antipatharians is also higher than in other depth layers, with several species have been registered so far, some of which are still very poorly studied and with little information on their life history: e.g., *Bathypathes* spp., *Tylopathes* sp., *Chrysopathes* sp. Several large cup-like hexactinellids are commonly observed within this community, such as the euplectellids *Hertwigia falcifera* and *Regadrella phoenix,* the euretid *Chonelasma* spp. and the rossellid *Asconema* spp., as well as the widely distributed *Pheronema carpenteri,* found either isolated or in small clumps. The inaccessibility of this community and the lack of samples until recently implies that there are still some gaps in the identification of many of the species observed, especially the corals belonging to the families

Paramuriceidae and Keratoisididae, and cryptic or poorly known sponges (eg., *Asconema* spp., *Farrea* spp., *Hertwigia* sp., *Chonelasma* sp.). Further efforts are still needed to fully understand the diversity of this complex coral-dominated community (much likely underestimated), and the extent of the associations between the observed species. Another frequently reported community at depths of ~1000 m corresponds to that formed by the bamboo coral *Acanella arbuscula* and the chrysogorgiids *Chrysogorgia* spp., *Iridogorgia* spp. and *Metallogorgia* sp. The fields created by *Acanella arbuscula* and *Chrysogorgia* spp. could extend for hundreds of meters, in some areas with the chrysogorgiid reaching very high densities, especially on seamounts along the Mid-Atlantic Ridge.

*Lace corals*

Besides the octocoral and antipatharia-dominated communities, other species of Cnidaria are also responsible for dense aggregations in the deep-sea of the Azores leading to the development of structurally complex communities. This is the case of the hydrozoan of the Stylasteridae family *Errina dabneyi* (Figure 188f), a (likely) endemic species of the Azores archipelago that has been observed forming highly dense patches in areas around several islands of the central group. The fauna associated to these stylasterid aggregations is similar to that found on shallow seamount summits, with the four main octocorals repoted (*V. flagellum*, *C. verticillata*, *A. hirsuta* and *D. meteor*) and several sponge species, although generally reported in lower densities. In deeper strata, the stylasterid *Errina atlantica* also forms dense aggregations, with their prevalence also low and generally associated to seamounts of the central group.

*Scleractinian corals*

The only stony coral that makes extensive aggregations in the Azores is the dendrophylliid *Eguchipsammia* cf. *cornucopia*, which has a free-living habit (Tempera *et al.*, 2015). This amphiatlantic species, scarcely recorded in previous works (Zibrowius, 1980), produces dense accumulations in shallow summits. The dead coral fragments serve as unconsolidated substrate to the alive polyps (determined by the intense yellow colour of their branches), which lay on top as unattached colonies. This community has only been seldomy observed, especially in some seamount summits, always harbouring a rich diversity of other associated taxa (e.g., crinoids, decapods, hydroids, etc).

**Cold-water coral reefs**

The reef-forming scleractinians *Madrepora oculata* and *Lophelia pertusa* are generally observed in the Azores forming solitary colonies that are part of coral gardens found at depths of 1,000-1,200 m. In only a few occasions, those two species have been observed forming actual reefs, in this case associated to the stylasterid Errina atlantoca and a wide variety of other small species, such as cup and soft corals, decapods, crinoids, and several other groups. In opposition, large accumulations of coral rubble mostly formed by dead colonies of *Madrepora oculata* and *Lophelia pertusa* are commonly found on the base and slopes of seamounts, especially along the Mid Atlantic Ridge. Radiocarbon dating of this coral rubble revealed that corals died 11,000 years ago during the last deglaciation period, when environmental conditions became unsuitable for the survival of *L.*

*pertusa* and *M. oculata* reefs. These large deposits of coral rubble, composed by broken corals and detritic fragments from other organisms, generate suitable micro-habitats for other sessile fauna, enhancing species diversity at the local scale. Unique associations of cryptic taxa, such as polychaeta, amphipods or isopods, as well as epifaunal species such as sponges, anemones, ceriantharians or alcyonaceans can be found within these patches, increasing the diversity at the local scale and playing a role in the functioning of deep-sea ecosystems.

### Sponge grounds

Several aggregations of demosponges have been recorded in the Azores, with the giant tetractinellid sponge *Characella pachastrelloides* as the most conspicuous due to its large size (with more than 50 cm) and varied morphological shapes, from vase to conical or tubular. This community is generally found in association with other large sponges, commonly known as lithistids (Xavier *et al.*, 2021) on hard substrates at bathyal depth, especially on the slopes of the seamounts. The lithistids associated to community show high diversity and is composed by the families Azoricidae (*Leiodermatium* spp.), Corallistidae (*Neophrissospongia nolitangere*) and Macandrewiidae (*Macandrewia* spp.). Other massive sponges that reach large sizes, found in mixed associations with astrophorids and/or lithistids, are the haplosclerids *Petrosia* cf. *crassa* and *Haliclona* cf. *magna*.

Areas of basaltic rocks in bathyal areas of the Azores, especially in offshore seamounts, host a huge diversity of encrusting species, which sometimes patch the available hard substrates of the rocky outcrops, vertical walls and boulders. The identification of encrusting species from underwater images is a challenging task, and most times these species are left as morphospecies (OTUs) during the annotation, with the real diversity largely underestimated. Massive globular sponges, commonly known as geodiids, are also found in this community, with several *Geodia* species inhabiting upper-bathyal areas of the seamounts (e.g., *Geodia* cf. *megastrella, G.* cf. *hentcheli*). Other important sponge grounds are those formed by lamellate and fan-shaped species that live attached to outcropping rocks, from to genus *Phakellia* and *Pachastrella*. Some of those lamellate sponges attain very large sizes, and can reach locally high densities, especially on top of large boulders or rocky outcrops.

Two hexactinellid sponges have been observed forming dense aggregations: the rossellid *Asconema* sp. and the pheronematid *Pheronema carpenteri* (Figure 188h). These species are commonly observed on soft or mixed substrates in bathyal areas, usually in seamounts slopes characterized by high rates of sediment deposition. The remaining sponge communities found in the Azores are characterized by small pedunculate sponges (*Hyalonema* spp. and *Stylocordyla pellita;* Figure 188i), which develop over soft sediments in some of the deepest areas investigated (>1,000 m). Although these aggregations are rarely observed, these small sponges can form populations with very high densities.

### Other taxa

Finally, besides the coral- and sponge-dominated communities, fauna from other phyla have also been identified as characteristic species in other benthic communities, including some aggregations of echinoderms such as sea urchins or sea stars. Especially relevant is the case of the community characterized by the deep-sea oyster cf. *Neopycnodonte zibrowii* and the crinoid cf. *Cyathidium foresti* on vertical walls (Figure 188j). This community, found always in seamounts and slopes close to the islands, is considered a ‘living-fossil community’ since it has most likely survived the Cretaceous/Palaeogene mass extinction and the whole of the Cenozoic (Wisshak *et al.*, 2009b, Levin & Rouse, 2019). Another important aggregation found in many areas of the Azores is that formed by the xenophyophore cf. *Syringammina fragilissima*, which develops in soft bottoms at the base of the seamounts. It is usually found past 1000 m depth, although it has been observed up to 700 m in the slopes of Pico Island. The densities of this foraminifera are generally low, but it extends for large areas.

**Table 33.** List of benthic communities of the megafauna identified for the Azores deep-sea down to ~1,000 m depth from the underwater video images collected.

| Code | Community name | Dominant and/or structuring species |
|---|---|---|
| *Coral gardens* | | |
| CG01 | Hard and mixed substrates of shallow summits and upper slopes with mixed coral gardens | *Viminella flagellum*, *Dentomuricea aff. meteor*, *Callogorgia verticillata*, *Acanthogorgia* spp. |
| CG02 | Hard substrates of summits and upper slopes with octocorals of the family *Paramuricidae* | *Paramuricidae* sp. |
| CG03 | Hard substrates of shallow summits with the back coral *Elatopathes abietina* | *Elatopathes abietina* |
| CG04 | Hard and mixed substrates of summitss,upper and lower slopes with the octocoral *Candidella imbricata* | *Candidella imbricata* |
| CG05 | Hard substrates of upper slopes with the bubblegum coral *Paragorgia johnsoni* | *Paragorgia johnsoni,* cf. *Pseudoanthomastus sp.* |
| CG06 | Hard substrates of upper slopes with the octocoral *Swiftia* sp. | *Swiftia sp.* |
| CG07 | Hard and mixed substrates of upper and lower slopes with *Pleurocorallium johnsoni* and *Desmacella grimaldi* | *Pleurocorallium johnsoni, Desmacella grimaldii,* cf. *Pseudoanthomastus sp.* |
| CG08 | Hard substrates of upper and lower slopes with mixed coral gardens of *Narella versluysi* and *N. bellissima* | *Narella versluysi, Narella bellissima* |
| CG09 | Hard substrates of upper and lower slopes with mixed coral gardens of *Hemicorallium niobe* and *H. tricolor* | *Hemicorallium niobe, Hemicorallium tricolor* |
| CG10 | Hard substrates of upper and lower slopes with the black coral *Parantipathes hirondelle* | *Parantipathes hirondelle* |
| CG11 | Hard and mixed substrates of the lower slopes with mixed coral gardens dominated by *Leiopathes expansa* and *Lophelia pertusa* | *Leiopathes expansa, Lophelia pertusa, Farrea occa, Errina atlantica, Placogorgia* spp. |
| CG12 | Hard and mixed substrates of the lower slopes with mixed coral gardens dominated by bamboo corals and black corals | *Keratoisididae spp., Bathypathes sp., Phanopathes erinaceus, Plexauridae* |
| CG13 | Hard and mixed substrates of the lower slopes with mixed coral gardens dominated by *Acanella arbuscula* and *Chrysogorgia* sp. | *Acanella arbuscula, Chrysogorgia* sp. |
| CG14 | Hard and mixed substrates of the lower slopes with *Antipathes dichotoma* | *Antipathes dicotoma* |
| CG15 | Mixed substrates with aggregations of the scleractinian *Eguchipsammia* cf. *cornucopia* | *Eguchipsammia cf. cornucopia* |
| CG16 | Hard substrates of the lower slopes with the scleractinian *Leptopsammia formosa* | *Leptopsammia formosa* |
| CG17 | Soft bottoms of the lower slope with the free-living scleractinian *Flabellum* spp. | *Flabellum* spp. |

| | | |
|---|---|---|
| CG18 | Hard substrates of shallow summits with soft coral aggregations | *Alcyonium sp., Polyplumularia sp.* |
| CG19 | Soft bottoms of summits and upper slopes with large hydrozoans | cf. *Lytocarpia myriophyllum* |
| CG20 | Hard substrates of shallow summits with the stylasterid *Errina dabney* | *Errina dabneyi* |
| CG21 | Hard substrates of upper and lower slopes with the stylasterid *Errina atlantica* | *Errina atlantica* |
| CG22 | Hard substrates of upper and lower slopes with *Pliobrotus* sp. | *Pliobrotus sp.* |
| CG23 | Hard substrates of upper and lower slopes with *Crypthelia* sp. | *Crypthelia sp.* |
| *Cold-water coral reefs* | | |
| CWC1 | Hard substrates of the lower slope with reefs of *Lophelia pertusa* and/or *Madrepora oculata* | *Lophelia pertusa, Madrepora oculata, Errina atlantica* |
| CWC2 | Dead coral framework and/or coral rubble | ┼Lophelia pertusa, ┼Madrepora oculata |
| *Deep-sea sponge aggregations* | | |
| DSS01 | Large Porifera (Demospongiae) on outcropping rock | *Characella spp., Macandrewia azorica, Neophrisospongia nolitangere, Leiodermatium spp.* |
| DSS02 | Encrusting and other large Porifera on basaltic rock | Encrusting sponges, *Geodia sp., Petrosia crassa, Haliclona magna* |
| DSS03 | Hard substrates of upper and lower slopes with large lamellate sponges | *Poecillastra compressa, Phakellia ventilabrum* |
| DSS04 | Hard substrates of the upper slopes with the glass sponge *Asconema fridsteti* | *Asconema fridsteti* |
| DSS05 | Mixed substrates of upper and lower slopes with the glass sponge *Pheronema carpenteri* | *Pheronema carpenteri* |
| DSS06 | Hard bottoms of the lower slopes with large hexactniellida (e.g., *Chonelasma* sp., *Hertwigia* sp.) | *Chonelasma sp., Hertwigia falcifera* |
| DSS07 | Soft bottoms of the lower slopes with the lollypop sponge *Stylacordilla pellita* | *Stylacordilla pellita* |
| DSS08 | Soft bottoms of the lower slopes with the glass sponge *Hyalonema* sp. | *Hyalonema* sp. |
| DSS09 | Mixed substrates of shallow summits with the repent sponge *Pseudotrachya hystrix* | *Pseudotrachya hystrix* |
| Xenophyophore aggregations | | |
| XA01 | Soft bottoms of the lower slopes with xenophyophores | Syringammina fragilissima, *Reticulammina sp.* |
| Other groups | | |
| OG01 | Mixed substrates of the upper slopes with seastars of the family Goniasteridae | Goniasteridae |
| OG02 | Soft bottoms of the lower slopes with the echinoid *Cidaris cidaris* | *Cidaris cidaris* |
| OG03 | Soft bottoms with aggregations of the echinoid *Centrostephanus longispinus* | *Centrostephanus longispinus* |
| OG04 | Vertical walls with the living-fossil community of *Cyathidium foresti* and *Neopycnodonte zibrowii* | *Cyathidium foresti, Neopycnodonte zibrowii, Acesta excavata, Brachipoda* |

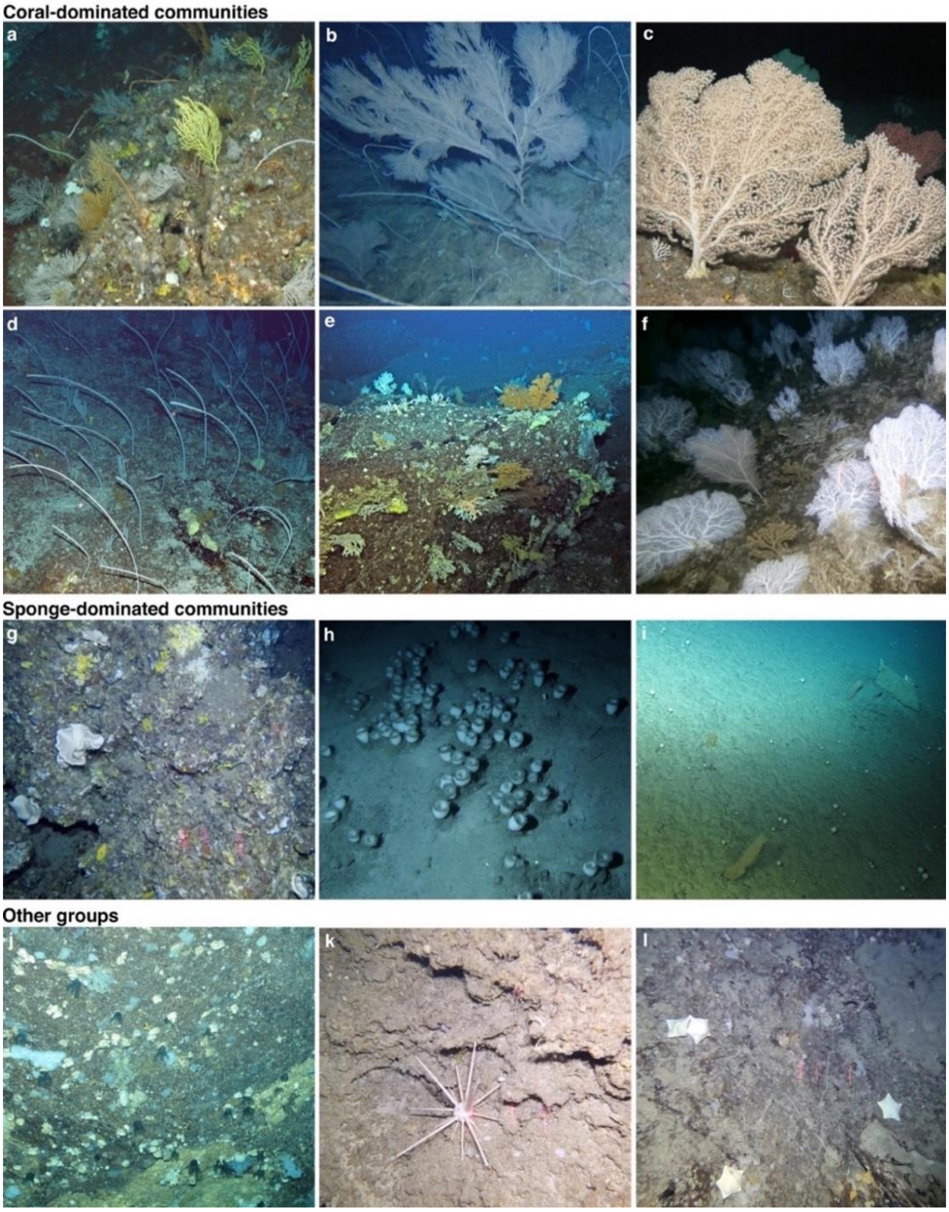



Figure 188 Some examples of benthic communities identified in the Azores deep-sea. (a) Very diverse patch on a large boulder with the octocorals *Viminella flagellum*, *Acanthogorgia* sp. and *Dentomuricea* aff. *meteor* in Gigante seamount. (b) Large colonies of *Callogorgia verticillata* and *Viminella flagellum* observed in Picoto seamount. (c) A dense aggregation of the hydroid coral *Errina dabneyi* in Capelinhos. (d) Large *Paragorgia johnsoni* colonies found on the slopes of the western ridge, in the Gigante Seamount Complex. (e) Dense aggregation of the Primnoid *Narella versluysi* with a few other corals and glass sponges in Formigas seamount. (f) Aspect of a large rocky outcrops colonized by cold-water corals, including several species of scleractinians, octocorals, black corals and bamboo corals above 1,000 m depth in Formigas seamount. (g) Some of the various species of Porifera observed on large rocky outcrops and vertical walls in Voador seamount. (h) Aggregation of the hexactinellid *Pheronema carpenteri* in Condor seamount. (i) Dense aggregation of the pedunculate sponge *Stylocordyla pellita*. (j) Ancient community found in vertical walls with cf. *Cyathidium foresti*. (k) Bare outcropping rocks with the long-spine sea urchin cf. *Cidaris cidaris* in Ferradura seamount. (l). Some sea stars of the family Goniasteridae in Oscar seamount. Credits: ROV Luso / EMEPC / 2018 Oceano Azul Expedition, organised by Oceano Azul Foundation & partners; (b,f,g,k,l) IMAR/Okenaos-UAç, Azor drift-cam; (d,e,j) MedWaves, ATLAS project: (h) Hopper tow-cam, NIOZ.

### *9.3 Evaluation against the FAO criteria*

The deep-sea benthic communities identified in the Azores deep-sea down to 1,000 m depth (listed in Table 33) were assessed against the 5 criteria for defining what constitutes a VMCommunity (VMC), using expert judgment and information extracted from the scientific literature. From the 39 benthic communities identified so far from the video images, 25 were considered to fit the criteria to be considered VMC (Table 34). These communities were generally characterized by associations of more than one large, structurally complex bioengineering species, as for example the communities dominated by large (>1 m in height) and 3D morphologies, including octocorals such as *Callogorgia verticillata, Dentomuricea aff. meteor* and *Paragorgia johnsoni*, the black coral *Leiopathes* cf. *expansa*, bamboo corals of the Keratoisididae family or large sponges such as *Pheronema carpenteri* or *Characella pachastrelloides*. Some of these species are also highly vulnerable to long-line fishing based on bycatch data collected through the years in the Azores (Sampaio *et al.* 2012; COLETA records). Habitats characterized by the presence of large hydrozoans that make aggregations on soft sediment, especially on seamount summits, were also considered to be VMC, although their inclusion could incorporate some controversy due to their fast growth, and short life span, which makes them less susceptible to the potential effects of fishing activities.

Some benthic communities classified as VMC were dominated by small or medium sized corals (following definition in Sampaio *et al.*, 2012), e.g. *Narella bellissima, Pleurocorallium johnsoni, Acanthogorgia* spp., or corals with simple whip-like morphologies (e.g. *Viminella flagellum, Narella versluysi)*, but their high densities were considered as an important factor in increasing the habitat available for associated species, and promoting interspecific interactions, and thus enhancing biodiversity. In some cases, communities were dominated by potentially endemic species to the Azores, such as the octocoral *Dentomuricea* aff. *meteor* and the stylasterid *Errina dabneyi*. The life history criterion was generally difficult to assess due to the lack of information on longevity, growth and reproduction for most species but some communities were considered particularly vulnerable due to their composition of century to millennium long-lived species such as bamboo corals and black corals (e.g., *Leiopathes* cf. *expansa*). It was also generally difficult to assess the functionality of communities, although the heterogeneity of the habitat (multiple bioengineering species) and its ability to create “habitat cascades” (i.e., positive effects on focal organisms mediated by biogenic habitat formation) was considered as a proxy for enhanced biodiversity.

**Table 34** List of benthic communities of the megafauna identified in the Azores down to 1000 m depth assessed against the 5 criteria provided by FAO for defining what constitutes a VME, to identify those communities that could be considered VMCommunities (VMC). 'X' means direct evidence fitting to the criteria, '(X)' is inferred from the literature on other indicator species of the same group; '?' means no information available; and blank cell means that the criterion was not met. Several species were assessed by the WGDEC in 2020 (Table 7.3 of ICES, 2020a).

| | FAO Criteria | | | | | |
|---|---|---|---|---|---|---|
| Community code | Uniqueness | Functional significance | Fragility | Life-history | Structural complexity | VMC |
| CG01 | X | X | X | X | X | X |
| CG02 | | (X) | X | (X) | X | X |
| CG03 | | | (X) | (X) | | |
| CG04 | | (X) | X | (X) | X | X |
| CG05 | | (X) | X | (X) | X | X |
| CG06 | | | (X) | | | |
| CG07 | | (X) | X | (X) | X | X |
| CG08 | | (X) | X | ? | X | X |
| CG09 | | (X) | X | (X) | X | X |
| CG10 | X | X | X | X | X | X |
| CG11 | X | X | X | X | X | X |
| CG12 | X | X | X | X | X | X |
| CG13 | | X | (X) | X | X | X |
| CG14 | X | | X | X | | |
| CG15 | X | (X) | X | ? | X | X |
| CG16 | | (X) | | | | |
| CG17 | | | | | | |
| CG18 | | (X) | | | X | |
| CG19 | | X | (X) | | X | X |
| CG20 | X | (X) | X | X | X | X |
| CG21 | | (X) | X | | X | X |
| CG22 | | | | | | |
| CG23 | | | (X) | | X | |
| CWC1 | X | X | X | X | X | X |
| CWC2 | | (X) | | | | |
| DSS01 | | X | X | X | X | X |
| DSS02 | | X | X | (X) | X | X |
| DSS03 | | X | X | | X | X |
| DSS04 | | X | X | (X) | X | X |
| DSS05 | | X | X | (X) | X | X |
| DSS06 | X | X | X | X | X | X |
| DSS07 | | ? | ? | | | |
| DSS08 | X | | X | (X) | | |
| DSS09 | | (X) | (X) | | (X) | X |
| XA01 | | X | X | ? | X | X |
| OG01 | | | | | | |
| OG02 | | | | | | |
| OG03 | | | | | | |
| OG04 | X | (X) | | X | (X) | X |

### *9.4 Spatial distributions of the deep-sea biological communities in the Azores*

The spatial coverage of the video recordings evaluated until now is relatively large and comprised images from different seamounts and ridges as well as island slopes. The identification of deep-sea benthic communities from the video images should be regarded as an extremely valuable resource to understand the spatial and bathymetrical distribution of the associations of species that characterize the deep sea of the Azores. Acknowledging that it would be necessary to explore a minimum area along all the bathymetric range within each seamount/ridge in order to be certain that all existing benthic communities have been identified, the images evaluated so far should be considered representative of the diversity of benthic communities in the Azores, and can provide a first indication of their prevalence and distribution in the region. The geographic occurrences of the different benthic communities representative of the Azores identified in the video images are shown in Figure 189. The database produced (communitiesDB) contains 1683 occurrence records of biological communities in the deep sea of the Azores, namely 1389 records of coral gardens, 189 of deep-sea sponge aggregations, 89 of foraminifer aggregations and 16 records of other communities. In the current version of communitiesDB, the areas with the highest number of occurrences of biological communities correspond to those located along the Mid-Atlantic Dorsal (Figure 190).

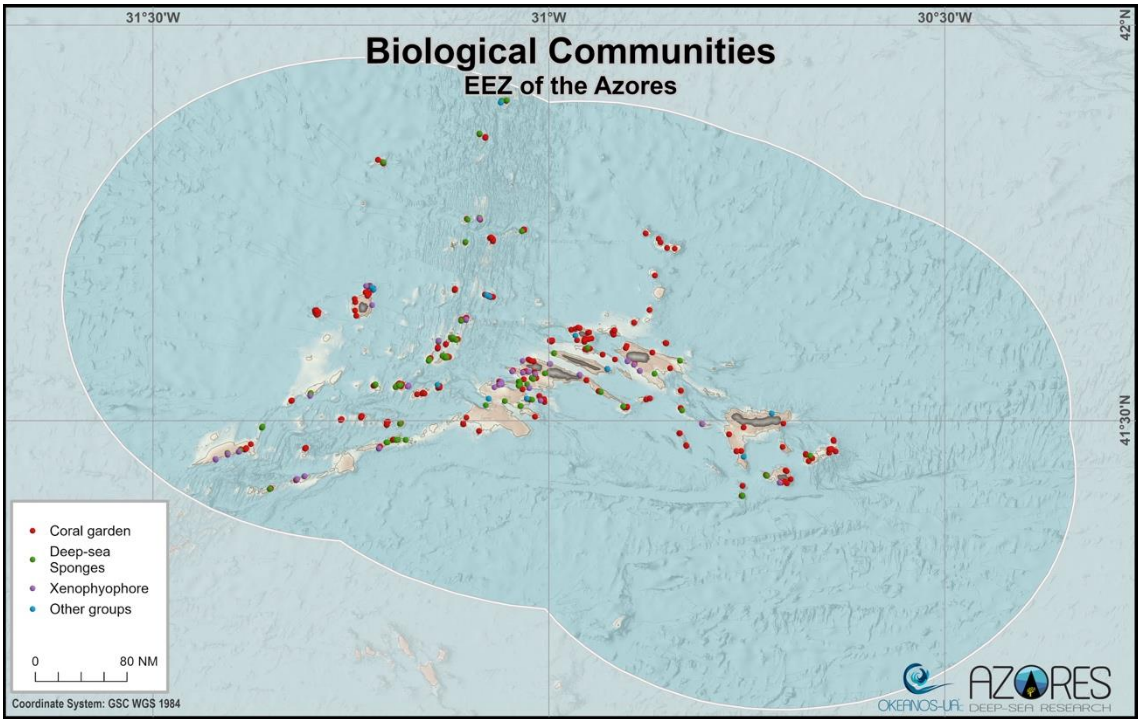



**Figure 189.** Geographical distribution of all the biological communities within the Azorean EEZ gathered in the Azorean deep-sea community database, classified by community type.

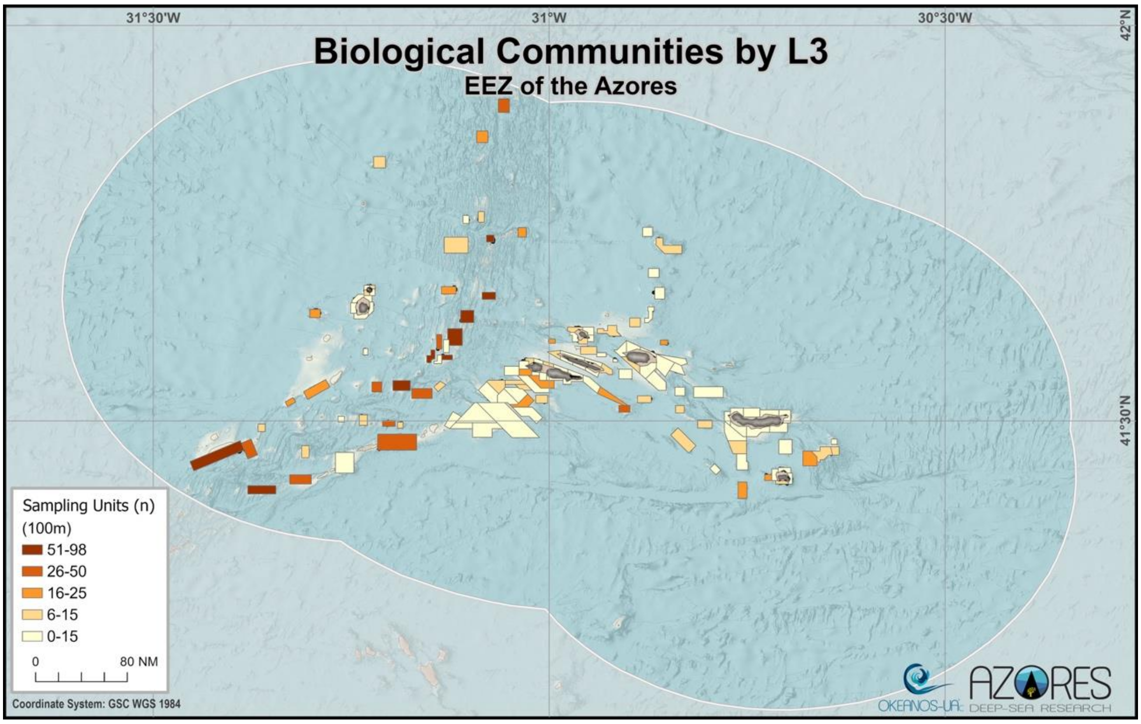



Figure 190. Number of occurrences of biological communities in the database communitiesDB for each of the L3 study areas.

## 10. Geomorphological features in the Azores

The information on the deep-sea biodiversity in the Azores, regarding VME indicators and biological communities, was used summarized for each geomorphological unit (i.e., sampling area; level 3) and to access them against the criteria that defines a VME. The compilation of the existing information identified a total of 606 video transects that have currently been annotated by the ADSR team to report the occurrence of megabenthic (morpho)species (or OTUs) in the deep sea of the Azores. The annotation of the underwater video transects has produced more than 52,000 records of megabenthic (morpho)species (OTUs) for the deep-sea of the Azores (Table 35).

Here we summarized the main findings related to the deep-sea biodiversity found in each of the 140 geomorphological unites of the Azores. This information was also used to produce individual factsheets containing descriptions of deep-sea species and biological communities identified. The digital factsheets sheets were developed as a dynamic tool (FTD2), where the collected and analysed information will be progressively added as new areas are explored or new information is produced.

Table 35 Number of occurrences of megabenthic (morpho)species or OTUs, grouped in higher taxonomic levels, inside the sampling areas evaluated using underwater video images. Occurrence data (data as of November 1th 2023) was collected in intervals of 100 m in length along all the annotated dives, attributing to each OTU an abundance value following the scale SACFOR scale.

| | | | Cnidaria | | | | | | | Porifera | | | Other groups | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| L1 | L2 | L3 | Actiniaria | Antipatharia | Ceriantharia | Hydrozoa | Octocorallia | Scleractinia | Stylasteridae | Demospongiae | Hexactinellida | Porifera | Bryozoa | Mollusca | Arthropoda | Echinodermata | Foraminifera |
| Western Group | Hard-Rock Café | | | 79 | 7 | 2 | 71 | 34 | 4 | 82 | 56 | 36 | | | 68 | 41 | |
| | Flores/Corvo | Co.NW | | 12 | 6 | 2 | 26 | 19 | 1 | 15 | 12 | 15 | 4 | 1 | 16 | 6 | 2 |
| | | Co.NE | | 23 | | 1 | 79 | 15 | 1 | 43 | 7 | 23 | 1 | 2 | 20 | 9 | |
| | | Co.SE | | 13 | 1 | | 18 | 6 | 1 | 12 | 3 | 17 | 4 | | 5 | 5 | |
| | | Co.SW | | 19 | 7 | 2 | 77 | 17 | | 56 | 11 | 40 | 2 | 2 | 25 | 28 | |
| | | Flo.NW | 1 | 25 | 6 | 1 | 48 | 17 | | 41 | 23 | 55 | 4 | 1 | 19 | 14 | 7 |
| | | Flo.NE | 2 | 17 | 5 | 2 | 34 | 15 | 5 | 24 | 20 | 45 | 2 | 2 | 22 | 16 | 4 |
| | | Flo.E | | 11 | 11 | 9 | 33 | 16 | 3 | 60 | 9 | 54 | 6 | 2 | 19 | 14 | 8 |
| | | Flo.S | | 27 | 13 | 8 | 55 | 20 | 2 | 63 | 17 | 53 | 3 | 4 | 35 | 12 | 7 |
| | | Flo.W | | 13 | 12 | | 17 | 4 | | 26 | 17 | 36 | 8 | 1 | 14 | 9 | 18 |
| | | Cachalote | | 70 | 22 | 7 | 258 | 100 | 13 | 346 | 79 | 295 | 2 | 7 | 76 | 54 | 7 |
| Northern Mid-Atlantic Ridge | S.Chaucer | Chaucer S | 5 | 91 | 2 | | 126 | 76 | 4 | 37 | 91 | 17 | 1 | | 25 | 103 | |
| | | Estrela | 5 | 71 | | 3 | 138 | 73 | 1 | 25 | 64 | 22 | | | 28 | 53 | |
| | Kurchatov | Kurch.N | 4 | 34 | 5 | 4 | 130 | 51 | 21 | 51 | 90 | 26 | | | 31 | 39 | 2 |
| | | Isolado | | 30 | 6 | | 61 | 29 | 3 | 39 | 27 | 36 | 6 | 1 | 37 | 25 | 1 |
| | | Kurch.SE | | 27 | 8 | | 88 | 38 | 6 | 54 | 30 | 65 | | | 25 | 42 | |
| | | Kurch.S | 7 | 75 | 13 | 9 | 244 | 84 | 9 | 118 | 107 | 71 | | 2 | 39 | 89 | 3 |
| | | Kurch.SW | 4 | 50 | 15 | 1 | 93 | 42 | 9 | 66 | 47 | 68 | 1 | 1 | 41 | 54 | |
| | | Ag.Corvo-Grac. | 4 | 55 | 15 | 5 | 134 | 59 | 11 | 87 | 90 | 36 | 6 | | 24 | 53 | 1 |
| | | Óscar | | 105 | 10 | 3 | 256 | 61 | | 146 | 9 | 206 | | 4 | 72 | 114 | |
| Central Mid-Atlantic Ridge | Gigante | Gig.N | 8 | 10 | 16 | 3 | 216 | 52 | 31 | 135 | 134 | 58 | 7 | | 49 | 103 | 2 |
| | | Gigante | | 76 | 4 | 35 | 332 | 36 | 1 | 442 | 61 | 290 | 3 | 2 | 61 | 77 | |
| | | Gig.Ag.NE | | 7 | 3 | | 27 | 8 | | 36 | 12 | 29 | | | 7 | 19 | |
| | | Gig.Ag.NW | 4 | 14 | 7 | 6 | 240 | 23 | 28 | 93 | 104 | 50 | 2 | | 28 | 60 | 8 |
| | | Gig.127 | 1 | 39 | | 35 | 171 | 42 | | 301 | 12 | 272 | 5 | 17 | 37 | 42 | |
| | | Gig.Ag.S | | 6 | 1 | | 26 | 5 | | 31 | 2 | 30 | | 1 | 6 | 10 | |
| | | Gig.Ag.SW | | 65 | 2 | 30 | 223 | 37 | | 227 | 7 | 212 | 1 | 10 | 54 | 47 | |
| | Cavala | Ferradura E | | 5 | 1 | 10 | 73 | 15 | 4 | 79 | 15 | 60 | 1 | | 23 | 17 | |
| | | Ferradura | | 33 | 2 | 20 | 173 | 41 | 9 | 105 | 40 | 129 | 1 | 1 | 43 | 27 | |
| | | Cavala | | 98 | 3 | 54 | 428 | 59 | 25 | 484 | 174 | 315 | 6 | 7 | 82 | 105 | 7 |
| | | Beta | | 29 | | 21 | 149 | 24 | | 118 | 38 | 88 | 2 | 2 | 21 | 21 | |
| | Picos SE Flores | D.Teive | | 7 | 14 | | 24 | 9 | | 56 | 40 | 56 | 5 | 2 | 31 | 30 | 1 |
| | | Buchanan | 2 | 5 | 4 | 11 | 91 | 14 | 2 | 208 | 128 | 162 | 9 | 2 | 52 | 43 | 27 |
| | | Cabeçote | | 2 | 1 | | 78 | 13 | 7 | 67 | 40 | 58 | 1 | 5 | 31 | 23 | 2 |
| | | Sardinha | | 5 | 1 | | 28 | 2 | 9 | 59 | 42 | 29 | | 1 | 12 | 31 | |
| | | L.Strike E | | 36 | | | 76 | 9 | | 60 | 7 | 108 | | 2 | 29 | 19 | |

| | | | Cnidaria | | | | | | | Porifera | | | Other groups | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| L1 | L2 | L3 | Actiniaria | Antipatharia | Ceriantharia | Hydrozoa | Octocorallia | Scleractinia | Stylasteridae | Demospongiae | Hexactinellida | Porifera | Bryozoa | Mollusca | Arthropoda | Echinodermata | Foraminifera |
| Southern Mid-Atlantic Ridge | Alberto do Mónaco | M.Gwen | 1 | 12 | | 12 | 85 | 13 | 11 | 22 | 27 | 31 | 1 | 1 | 41 | 20 | 5 |
| | | Picoto | | 26 | | 8 | 97 | 4 | | 91 | 7 | 81 | | 2 | 23 | 28 | |
| | | Alfa | 1 | 33 | 1 | 17 | 149 | 32 | 18 | 123 | 79 | 80 | | 1 | 29 | 41 | 5 |
| | | Alfa E | | 7 | 3 | 7 | 116 | 20 | 19 | 62 | 94 | 31 | 2 | 1 | 17 | 42 | 3 |
| | | Voador | 4 | 18 | 6 | 28 | 244 | 46 | 18 | 722 | 137 | 483 | 4 | 7 | 54 | 99 | 23 |
| | | Mte.Alto | | | 1 | | 23 | 6 | | 82 | | 80 | | | 1 | 14 | |
| | Farpas | Farpas | 4 | 14 | 3 | 1 | 131 | 33 | 19 | 104 | 163 | 102 | 1 | 5 | 37 | 25 | 37 |
| | | Espadarte | | 34 | | 19 | 188 | 8 | | 149 | 57 | 112 | | 1 | 23 | 28 | |
| | Sarda | Sarda E | 1 | 76 | 9 | 36 | 195 | 29 | 13 | 234 | 130 | 189 | | 2 | 42 | 27 | 22 |
| | | Sarda | | 45 | 16 | 13 | 159 | 36 | | 368 | 131 | 219 | | 3 | 30 | 49 | 48 |
| Northern Central Group | Sedlo | Sedlo W | 3 | 31 | 5 | 9 | 53 | 42 | 16 | 32 | 17 | 48 | 1 | 1 | 25 | 37 | 1 |
| | | Sedlo | 5 | 38 | 9 | 11 | 89 | 37 | 17 | 50 | 26 | 44 | 1 | | 29 | 35 | |
| | | Gaillard | | 4 | 1 | | 13 | 11 | 9 | 20 | 5 | 18 | | 1 | 16 | 18 | 1 |
| | | Borda | 3 | 18 | 10 | 3 | 34 | 47 | 3 | 31 | 22 | 23 | | 2 | 28 | 71 | 1 |
| | | J.Leonardes | | 2 | 3 | 1 | 25 | 13 | 1 | 29 | 18 | 35 | | 1 | 15 | 23 | |
| | | Serreta Mar | 1 | 9 | 2 | | 70 | 2 | 5 | 42 | 13 | 71 | 2 | 1 | 24 | 25 | 3 |
| | Graciosa/São Jorge | M.Fortuna | | 23 | 4 | 9 | 104 | 20 | 12 | 134 | 52 | 85 | | | 27 | 24 | |
| | | Grac.NW | | 39 | 3 | 16 | 96 | 38 | 2 | 254 | 1 | 155 | | 2 | 48 | 28 | |
| | | Grac.NE | | 5 | 1 | 4 | 25 | 10 | 3 | 114 | 9 | 74 | 1 | | 8 | 6 | 4 |
| | | Grac.SE | | 12 | 2 | 13 | 65 | 24 | | 166 | 6 | 80 | 1 | | 8 | 10 | |
| | | Grac.S | | 21 | 1 | 9 | 57 | 22 | | 150 | 12 | 79 | 1 | | 25 | 6 | 3 |
| | | Grac.SW | | 29 | 6 | 5 | 41 | 13 | 2 | 70 | 8 | 104 | 5 | 2 | 30 | 17 | 1 |
| | | P.Bartolomeu | | 5 | 16 | | 45 | 31 | 20 | 50 | 28 | 55 | 2 | | 39 | 43 | 3 |
| | | I.Azul | | 46 | 12 | 5 | 196 | 22 | 5 | 320 | 85 | 220 | 8 | 7 | 43 | 16 | 5 |
| | | I.Azul E | | | 1 | | 10 | 2 | 2 | 9 | 8 | 13 | | | 3 | 3 | 2 |
| | | I.Azul SE | | 5 | | 1 | 27 | 16 | 15 | 25 | 35 | 37 | 1 | | 17 | 19 | 1 |
| | | S.Jorge NW | | 1 | 6 | 1 | 7 | | 3 | 25 | | 23 | 2 | | 13 | 11 | |
| | | S.Jorge NE | 1 | 2 | 7 | 1 | | | 3 | 35 | 3 | 53 | 7 | | 17 | 8 | 1 |
| | | S.Jorge E | | 3 | 7 | 4 | 30 | 7 | 8 | 14 | 13 | 23 | 1 | | 8 | 21 | |
| | | S.Jorge SE | | 2 | 3 | | 7 | | 3 | 33 | | 45 | | 1 | 12 | 7 | |
| | | S.Jorge S | | | 1 | 1 | 7 | 2 | | 14 | | 6 | | | | 1 | |
| | | S.Jorge SW | | 1 | 1 | | 5 | | 3 | 27 | | 23 | | 2 | 12 | 7 | |
| | | S.Jorge W | | 4 | | 1 | 35 | 5 | 6 | 118 | 4 | 89 | 7 | 1 | 23 | 11 | 1 |
| | | J.Melo | | 3 | | 1 | 12 | 1 | | 38 | | 25 | | | 1 | 2 | |
| | Terceira | Terc.N | | 1 | 1 | | 25 | | | 23 | 4 | 21 | | | 9 | 1 | |
| | | Terc.NE | | 11 | 2 | 6 | 35 | 3 | 1 | 70 | 7 | 51 | 3 | | 13 | 7 | |
| | | Terc.E | 3 | 1 | 2 | 4 | 29 | 11 | 8 | 5 | 10 | 16 | 1 | | 13 | 7 | 1 |
| | | Terc.S | 1 | 3 | 7 | 4 | 23 | 19 | 5 | 8 | 16 | 10 | 4 | | 12 | 7 | 7 |

| | | | Cnidaria | | | | | | | Porifera | | | Other groups | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| L1 | L2 | L3 | Actiniaria | Antipatharia | Ceriantharia | Hydrozoa | Octocorallia | Scleractinia | Stylasteridae | Demospongiae | Hexactinellida | Porifera | Bryozoa | Mollusca | Arthropoda | Echinodermata | Foraminifera |
| | | Terc.SW Angra | 1 | 9 | 14 | 32 | 65 | 15 | 5 | 98 | 9 | 78 | | 1 | 13 | 17 | 27 |
| | | Terc.W Serreta | | 3 | 3 | 1 | 17 | 10 | 5 | 10 | 16 | 23 | 7 | | 11 | 7 | 1 |
| | | Maçarico | | 6 | 1 | 7 | 24 | 2 | | 45 | 9 | 50 | | 2 | 9 | 4 | |
| | | A.Martins | | 6 | 6 | 4 | 42 | 19 | 12 | 31 | 8 | 70 | 1 | | 20 | 22 | 1 |
| | | Beir.Fora | | 6 | 1 | 3 | 24 | 3 | 6 | 36 | 12 | 38 | | | 8 | 4 | |
| | | Gastromar | | 3 | 4 | 1 | 20 | 1 | 1 | 31 | 17 | 20 | 3 | | 11 | 6 | |
| | | Albatroz N | | 15 | 2 | 7 | 54 | 14 | 4 | 21 | 29 | 25 | | | 13 | 14 | |
| | Dom João de Castro | Alcatraz | | 2 | | 1 | 4 | | | 5 | | 5 | | | 2 | 1 | |
| | | D.J.Castro | | | | 2 | 9 | | 1 | 13 | | 17 | 2 | | 2 | | |
| | | Ferraria N | | 10 | 4 | 6 | 72 | 2 | 13 | 14 | 17 | 30 | | 1 | 16 | 10 | |
| | | Ferraria Mar | | 5 | 6 | 3 | 28 | | 1 | 3 | 27 | 14 | | 4 | 7 | 14 | 6 |
| | | Girard | | 2 | 1 | 4 | 69 | 5 | 27 | 20 | 59 | 43 | | 3 | 13 | 24 | |
| Southern Central Group | Faial/Pico | Faial NW | | 13 | 13 | 12 | 102 | 51 | 24 | 44 | 37 | 67 | 7 | 2 | 40 | 23 | 6 |
| | | Faial N | | 5 | 10 | 4 | 18 | 6 | 4 | 82 | 8 | 87 | 6 | | 14 | 13 | 1 |
| | | Faial-Pi.N | | | 7 | | 5 | 4 | 3 | 14 | 2 | 34 | 2 | | 9 | 20 | 9 |
| | | Pi.NW | | | 2 | | | | 1 | 3 | | 11 | | | 1 | 4 | 2 |
| | | Pi.NE | | 6 | 10 | | 16 | 5 | 9 | 97 | 23 | 91 | 8 | 1 | 37 | 22 | 8 |
| | | Pi.S | | 4 | 6 | 1 | 10 | 4 | 9 | 40 | 14 | 38 | 2 | | 9 | 4 | 4 |
| | | PiSW | | | 1 | 1 | 5 | | 2 | 2 | 17 | 6 | 2 | | 6 | 6 | 1 |
| | | Faial-Pi.S | | 4 | 5 | 11 | 37 | 9 | 7 | 119 | 11 | 125 | 5 | 3 | 20 | 18 | 3 |
| | | Faial S | | 4 | 8 | 5 | 40 | 2 | 11 | 135 | 20 | 156 | 3 | 4 | 15 | 41 | 9 |
| | | Faial F.C. | 1 | 9 | 25 | 3 | 97 | 12 | 19 | 128 | 57 | 157 | 2 | 4 | 33 | 47 | 26 |
| | | Faial W | | 1 | 3 | | 6 | 3 | 2 | 2 | 10 | 11 | 3 | | 6 | 2 | 4 |
| | | Condor | | 7 | 4 | 8 | 47 | 7 | 1 | 110 | 1 | 64 | | 1 | 8 | 7 | 2 |
| | | Baixo S.Mateus | | 17 | 37 | 15 | 125 | 12 | 17 | 583 | 122 | 331 | | 7 | 50 | 57 | 3 |
| | | Ponta Ilha N | | | | | | 4 | 4 | 35 | | 28 | | 1 | 2 | 2 | |
| | | Ponta Ilha S | | 16 | | 6 | 58 | 5 | 3 | 112 | 14 | 93 | 9 | 1 | 5 | 7 | |
| | | Albatroz Meio | | 11 | 5 | 6 | 116 | 19 | 23 | 68 | 49 | 74 | 2 | 4 | 31 | 22 | 1 |
| | Princesa Alice | Ag12 Milhas | 5 | 8 | 37 | 18 | 129 | 14 | 33 | 372 | 121 | 329 | 5 | | 99 | 51 | 17 |
| | | Condor Fora | | 4 | 5 | 3 | 51 | 6 | 18 | 224 | 44 | 147 | 6 | 1 | 10 | 19 | 3 |
| | | Ag.18 Milhas | 2 | 8 | 16 | 3 | 68 | 19 | 21 | 170 | 79 | 146 | 3 | | 37 | 37 | 25 |
| | | Bourée NE | | 3 | 19 | | 78 | 12 | 21 | 53 | 77 | 71 | 15 | 2 | 26 | 27 | 23 |
| | | Bourée E | | 2 | 5 | 1 | 13 | 4 | 6 | 7 | 20 | 17 | 4 | 4 | 6 | 7 | 2 |
| | | Açor | | 8 | 3 | 17 | 14 | 17 | 1 | 84 | 7 | 92 | 8 | 2 | 30 | 23 | |
| | | Açor S | | 2 | 3 | 2 | 5 | | 7 | 61 | 10 | 53 | | 4 | 4 | 13 | 2 |
| | | De Guerne N | 4 | 4 | 31 | 9 | 147 | 19 | 32 | 166 | 142 | 182 | 22 | 4 | 56 | 43 | 21 |

| | | | Cnidaria | | | | | | | Porifera | | | Other groups | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| L1 | L2 | L3 | Actiniaria | Antipatharia | Ceriantharia | Hydrozoa | Octocorallia | Scleractinia | Stylasteridae | Demospongiae | Hexactinellida | Porifera | Bryozoa | Mollusca | Arthropoda | Echinodermata | Foraminifera |
| | | De Guerne | | 1 | 2 | | 16 | 10 | 10 | 23 | 23 | 36 | | | 7 | 5 | 4 |
| | | S.Mateus Fora | 1 | 7 | 10 | 4 | 117 | 7 | 19 | 204 | 107 | 214 | 8 | 4 | 59 | 41 | 25 |
| | | P.Alice | | 3 | 2 | 6 | 56 | | 18 | 117 | 70 | 97 | 7 | 2 | 8 | 9 | |
| | | P.Alice W | | 2 | 1 | 5 | 23 | 9 | 6 | 70 | 25 | 77 | 1 | | 11 | 11 | 2 |
| | | P.Alice PS | | | | | 42 | 8 | 4 | 105 | 79 | 61 | | 2 | 19 | 11 | |
| | | H.Carr | 2 | | 2 | | 44 | 21 | 10 | 14 | 41 | 23 | | | 14 | 9 | 1 |
| | | P.Alice SW | | | | | 3 | 4 | 4 | 5 | 14 | 13 | | | 5 | 2 | 1 |
| Eastern Group | São Miguel | S.Mi.NW | | | | | 10 | 2 | | 8 | | 22 | | | 3 | | |
| | | S.Mi.N | | 1 | 2 | 7 | 8 | 3 | | 28 | 1 | 17 | 4 | | 8 | 7 | |
| | | S.Mi.NE | | | 2 | 3 | | 4 | | 2 | | 6 | | | 1 | 3 | |
| | | S.Mi.E | | 2 | 4 | 1 | 7 | 5 | 2 | 23 | 1 | 29 | 3 | 2 | 13 | 7 | |
| | | S.Mi.SE | | 1 | 1 | 6 | 32 | 6 | 4 | 27 | | 34 | 5 | 2 | 10 | 1 | |
| | | S.Mi.S | | | | | 4 | 5 | | 2 | | 6 | | | 8 | 1 | |
| | | S.Mi.SW | | | | 6 | 24 | 2 | | 25 | 3 | 20 | 2 | 2 | | 3 | |
| | | S.Mi.W | | 5 | 1 | 2 | 25 | 4 | 5 | 26 | 15 | 37 | | 1 | 11 | 5 | |
| | Mar da Prata | M.Prata N | 4 | 2 | 3 | 8 | 50 | 6 | 3 | 47 | 7 | 26 | 1 | | 2 | 6 | |
| | | M.Prata | | 2 | 2 | 2 | 40 | 6 | 4 | 27 | 34 | 34 | | 1 | 12 | 12 | |
| | | M.Prata S | | | 5 | 1 | 10 | 8 | 4 | 33 | 31 | 38 | 4 | | 12 | 6 | 3 |
| | | M.a Celeste | | 8 | 2 | 9 | 94 | 4 | 26 | 132 | 42 | 124 | 4 | 6 | 21 | 30 | |
| | | Sauerwein | | 3 | | 5 | 42 | 17 | 4 | 8 | 20 | 11 | | | 8 | 5 | 3 |
| | Formigas | Grd.Norte | | 2 | | 3 | 14 | 6 | | 33 | | 23 | 1 | | 5 | 7 | |
| | | Formigas | | 13 | 8 | 19 | 132 | 66 | 7 | 220 | 37 | 149 | 4 | 1 | 24 | 26 | 18 |
| | | Margrette | | 8 | 1 | 7 | 105 | 33 | 14 | 136 | 23 | 115 | 3 | 1 | 34 | 22 | |
| | | Marg.E | 2 | | 3 | 2 | 35 | 9 | 6 | 23 | 20 | 51 | 4 | | 15 | 12 | |
| | | Marg.NE | | 3 | 6 | 2 | 55 | | 15 | 25 | 22 | 34 | 4 | | 17 | 20 | |
| | Santa Maria | Sta.Maria N | 1 | 11 | 4 | 34 | 37 | 39 | 8 | 99 | 9 | 83 | 5 | | 25 | 14 | 1 |
| | | Sta.Maria E | | 4 | 3 | 27 | 62 | 35 | 8 | 81 | 16 | 110 | 6 | | 18 | 22 | 19 |
| | | Sta.Maria SW | | 8 | 11 | 24 | 52 | 38 | 16 | 87 | 31 | 83 | 14 | 2 | 19 | 19 | 5 |
| | | Sta.Maria W | | 9 | 9 | 27 | 41 | 23 | 5 | 30 | 18 | 47 | 3 | | 16 | 7 | 3 |
| | | Sta.Maria P.W | | 13 | 1 | 5 | 79 | 26 | 16 | 77 | 43 | 69 | 4 | 5 | 22 | 11 | |
| | | Total | 98 | 2 179 | 757 | 945 | 9 767 | 2 501 | 1 049 | 12 530 | 4712 | 10 608 | 363 | 213 | 3 128 | 3 270 | 577 |

### *10.1 Large area | Western Group*

The area Western Group contains 2 study areas: Hard Rock Café and Flores/Corvo islands and a total of 13 sampling areas (Figure 191). All sampling areas have been explored with the Azor drift-cam during the MapGES 2021, 2022 and 2023 surveys, and the NOAA EX2206 (2022) surveys. (Figure 191).

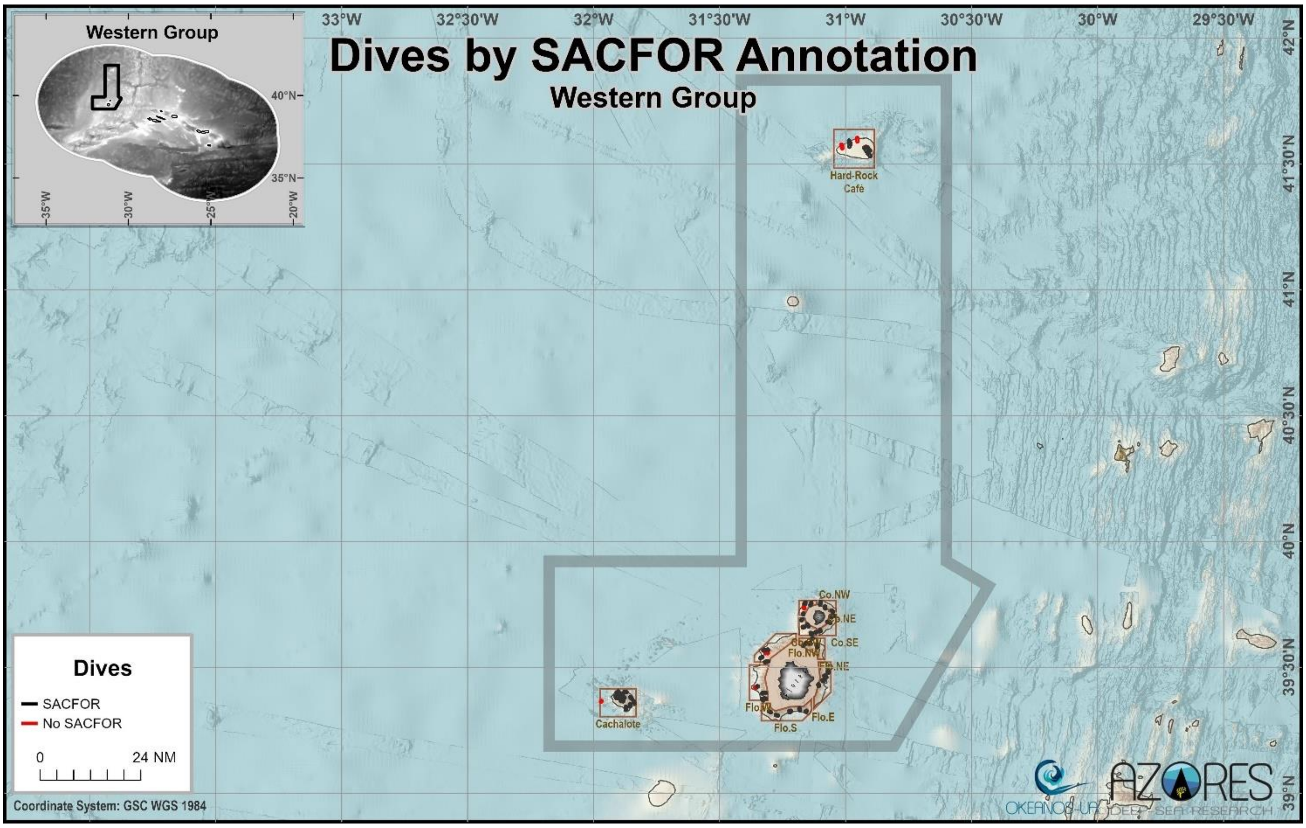



**Figure 191** Western Group sampling areas (Level 3) with or without SACFOR dive locations.

#### Study area | Hard Rock Café

*Hard Rock Café*

Exploring the Hard-Rock Café region, 8 underwater video transects were performed covering depths between 740 and 1100 m (Figure 192). Analysis of the footage revealed a total of 56 taxa, with 33 of them identified at the species level. This indicates a moderate diversity of deep-sea megabenthic species in the area. Noteworthy taxa, based on weighted occurrences, include *Desmacella grimaldii* (n= 48), *Cidaris cidaris* (n= 47), and *Acanella arbuscula* (n= 39).

Hard Rock Café seamount is located 210 nm away from Faial, 110 nm away from Corvo – at almost 13 hours of sailing. This geomorphological unit was characterized by soft bottoms with some coral rubble with generally low biodiversity and abundance of megabenthic species, and some basaltic outcrops generally with higher densities of sponges and corals. The unconsolidated substrates of the deep sector showed the typical fauna of such depths, including the bamboo corals *Acanella arbuscula* (Figure 193f), frequent in the area, and

*Chrysogorgya* sp., small and dispersed *Narella versluysi* (Figure 193d) and some aggregations of the black coral *Antipathes dichotoma* (Figure 193c). Moving further up the slope, when reaching harder substrates, different coral species were occasionally recorded, such as *Hemicorallium niobe*, *Lophelia pertusa, Leiopathes* cf. *expansa* (Figure 193b), *Bathypathes* sp. (Figure 193e), *Acanthogorgia* spp., and *Parantipathes hirondelle* (Figure 193f) and some individuals belonging to the complex cf. *Paramuricea/Placogorgia*. Sponge communities were characterized by the presence of lamellate sponges such as *Desmacella grimaldi* (Figure 193e) and both *Phakellia ventilabrum* and *P. robusta* (Figure 193f). Large demospongiae like *Characella pachastrelloides*, *Petrosia crassa and Haliclona magna* were also identified but were generally few and disperse. Likewise, glass sponges such as *Pheronema carpenteri, Regadrella phoenix* (Figure 193e). were also observed, as well as some small and scattered *Asconema* sp. (Figure 193a). aggregations. Several fishes were recorded including some large *Polyprion americanus*, *Mora moro*, numerous *Neocyttus helgae*, some eel-like fish and the rarely spotted orange roughy (*Hoplostethus atlanticus),* observed in large amount and seems to be abundant in this area. Some crabs *Chaceon affinis* and *Bathynectes mavigna* also appeared, as well as a squid cf. *Mastigoteuthis* sp.

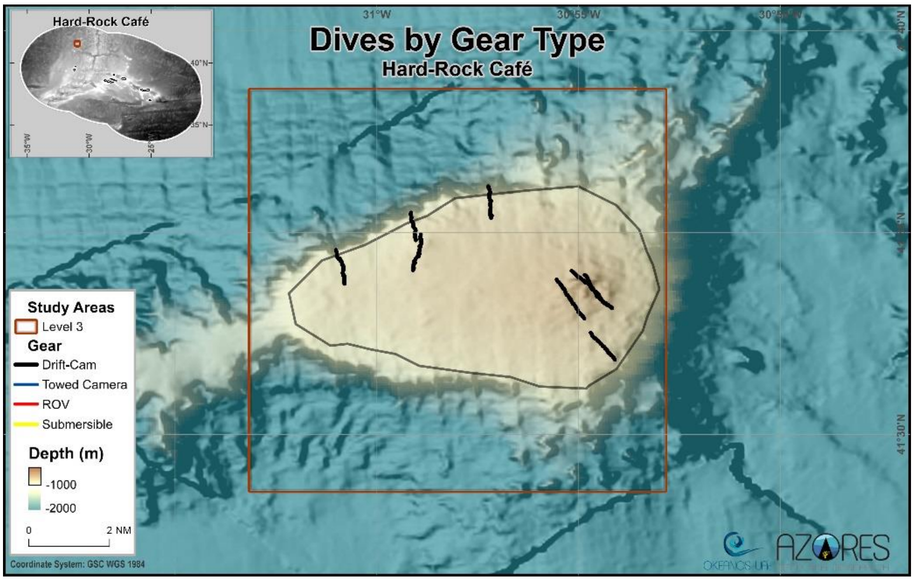



**Figure 192** Map displaying the 8 underwater dives performed in the Hard-Rock Café area between 740 and 1,100 meters depth.

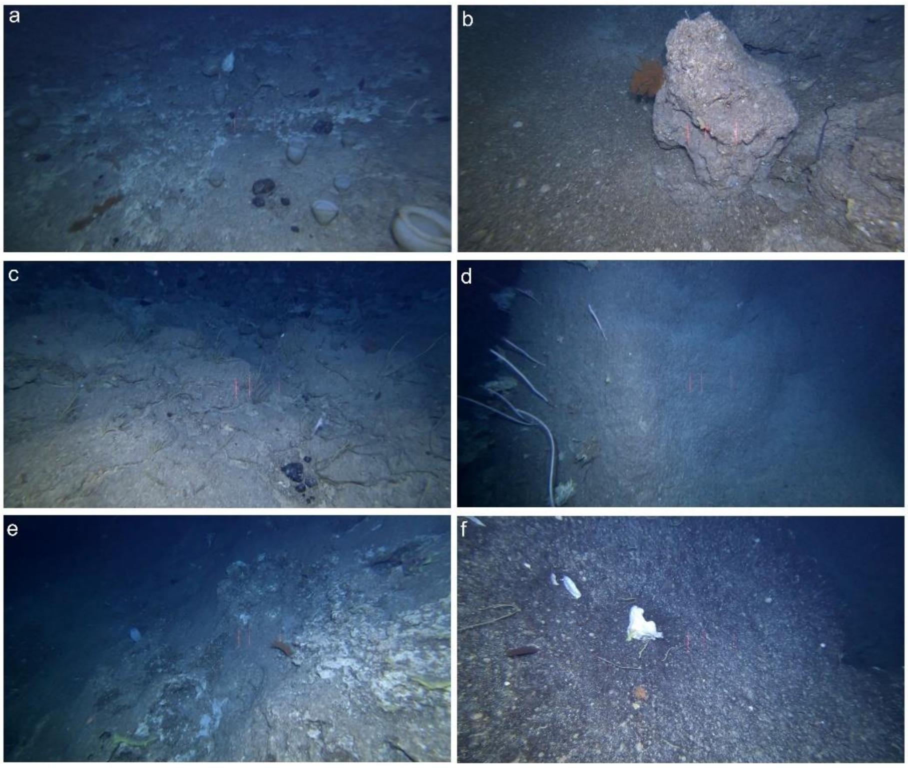



**Figure 193** Selected images representative of the main structuring species and benthic communities observed in Hard Rock Café seamount. (a) *Asconema* sp. aggregation and a small colony of black coral *Leiopathes* cf. *expansa*. (b) *Leiopathes* cf. *expansa.* (c) Aggregation of the black coral *Antipathes dichotoma.* (d) Aggregation of *Narella versluysi.* (e) Black coral *Bathypathes* sp. along with the sponges *Regadrella phoenix* and *Desmacella grimaldii*. (f) *Phakelia robusta* along with black corals *Parantipathes hirondelle* and *A. dichotoma* and the bamboo coral *Acanella arbusculla.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

Study area | Flores/Corvo

*Corvo NW*

Investigating the Corvo Northwest zone, 4 underwater video transects were performed ranging from 470 to 960 m depth (Figure 194). Examination of the video records identified 52 taxa, with 33 specified at the species level. This suggests a medium diversity of deep-sea megabenthic species in this region. Prominent taxa, based on weighted occurrences, include *Viminella flagellum* (n= 10), *Elatopathes abietina* (n= 9), and *Anthomastus*/*Pseudoanthomastus* sp. (n= 8).

The Corvo NW seafloor has the typical features of an island slope, where most of the bathymetric range explored is mostly characterized by soft-bottom substrate. Usually, only steep vertical walls and large outcrops harboured distinct benthic communities in this area.

The deepest (and flatter) regions explored contained the typical soft grounds colonized by foraminifera (*Syringammina fragillissima*) and tube-dwelling anemones. Where the terrain is steeper and rockier, it was found to be poorly colonized by some solitary coral species such as *Leptopsammia formosa* and *Flabellum* sp. and some black-corals *Parantipathes hirondelle.* Hexactinellids such as *Pheronema carpenteri* and *Hyalonema* sp. were also present. Motile fauna was observed as well, of which the silver roughy *Hoplostethus mediterraneus* and the small deep-sea shark *Deania* sp. were the most observed at these depths. At around 600m depth, type of substrate and community begin to shift to large rocky outcrops colonized by a variety of coral and sponge species. The black-coral *Elatopathes abietina* (Figure 195c, d) formed dense aggregations along most of the slope explored, with the whip coral *Viminella flagellum* (Figure 195a) and the sea fan *Acanthogoria* spp. (Figure 195e) also composing part of the faunal assemblage, with increasing densities up until 450m depth. The soft coral *Antomasthus/Pseudoantomasthus* sp. (Figure 195b) and small colonies of *Enallopsammia rostrata* (Figure 195f) were observed more sporadically. On shallower sections of the slope, dense patches of the sponge cf. *Phakellia ventilabrum* were found to dominate one of the benthic communities observed, with many other smaller sponges present as well. Some decapod species were found, namely *Paromola cuvieri, Chaceon affinis and Bathynectes maravigna* and two large sixgill sharks (*Hexanchus griseus*) were recorded as well.

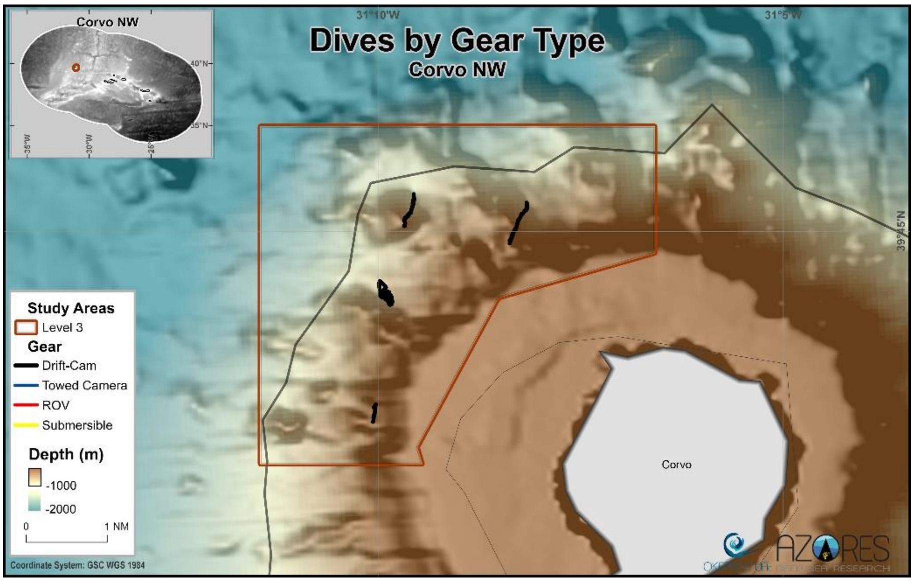


**Figure 194** Map displaying the 4 underwater dives performed in the Corvo NW area between 470 and 960 meters depth.

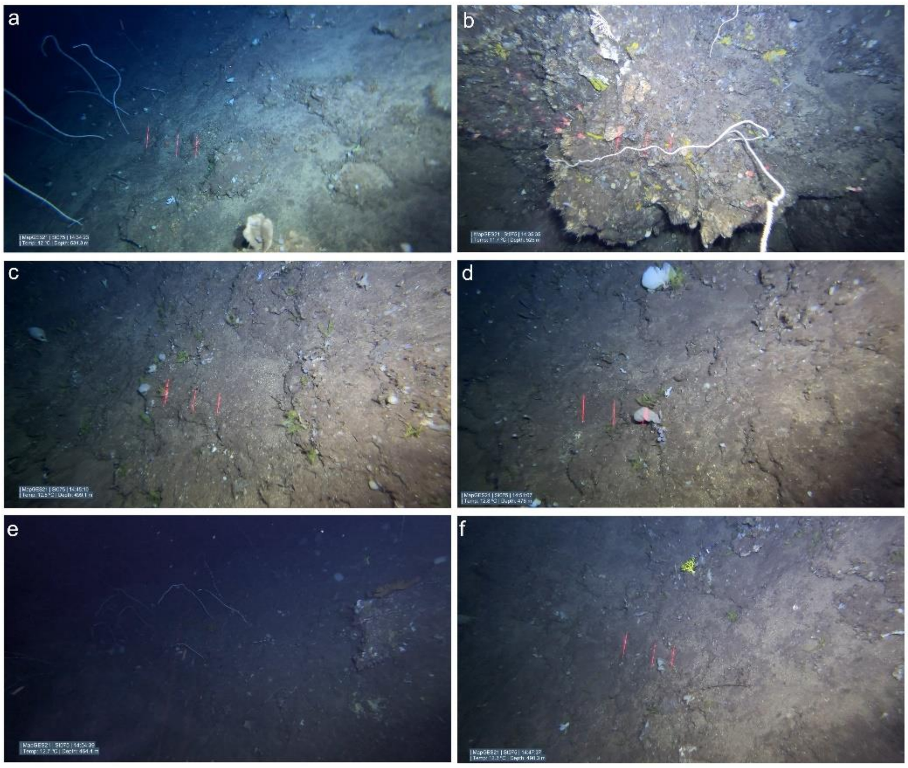



**Figure 195** Selected images representative of the main structuring species and benthic communities observed in Corvo Northwest area. (a) Large colonies of the whip coral *Viminella flagellum.* (b) Boulder densely colonized by a wide variety of sponges, the soft coral *Antomasthus/Pseudoantomasthus* sp. and *V. flagellum* (c-d) Aggregation of small colonies of the black coral *Elatopathes abietina* with several species of sponges, including *Phakellia ventilabrum.* (e) Aggregation of large colonies of *V. flagellum* with *Acanthogorgia* spp. (f) Colony of *Enallopsammia rostrata* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Corvo NE*

Our exploration of the Corvo Northeast area involved 3 underwater video transects within the depth range of 180 to 730 m (Figure 196). Analysis of the recorded footage revealed a total of 72 taxa, with 49 identified at the species level, signifying a moderate diversity of deep-sea megabenthic species. Dominant taxa based on weighted occurrences include *Viminella flagellum* (n= 34), *Elatopathes abietina* (n= 21), and *Acanthogorgia* spp. (n= 19).

The northeastern area of the slope of the little Corvo Island consisted of a very large and astonishing density and diversity of benthic megafauna. This geomorphological unit was characterized by its sandy bottoms mixed with loose pebbles at the deepest areas rapidly changing to hard grounds composed of rocky outcrops and high vertical basaltic walls when ascending the slope. The fauna encountered at the deepest part (around 620m) was mainly constituted by small and occasional aggregations of the stylasterid *Errina dabneyi* (Figure 197a) and soft corals of the genus *Anthomastus/Pseudoanthomastus* sp. always growing on hard substrates. At around 550m deep and until the shallowest observed area, the biodiversity found growing on the walls and outcrops was impressive, with large and extensive gardens of corals, constituted by communities of the gorgonians whip coral *Viminella flagellum* (Figure 197e) (both white and yellow morphotypes), *Acanthogorgia* spp. (Figure 197c), *Callogorgia verticillata* (Figure 197b) and the rare but usually known as bubble gum coral *Paragorgia johnsoni* (Figure 197c), with the presence of both white and red morphotypes, however this did not create a huge aggregation. The black corals were also represented with a large community and very often sightings of *Elatopathes abietina* (Figure 197d), and sporadic observations of *Parantipathes hirondelle*. Some more hard and soft corals were also present in large densities, such as colonies of the scleractinian *Dendrophyllia cornigera* and soft corals from the genus *Anthomastus/Pseudoanthomastus* sp. that was very common during all the depth range. It is also possible to highlight the sighting of a small aggregations of large examples of a white Plexauridae which the species is yet to be confirmed. The phylum porifera was highly represented on the bottom from which we can highlight the often presence of sponges of the genus *Petrosia* and *Leiodermatium*, and incredibly large communities of *Phakellia ventilabrum* (Figure 197c) and *Haliclona implexa*. Several very robust specimens of *Characella pachastrelloides* were also observed. To denote, the observation of a ray from the species *Tetronarce nobliliana* at around 529 m deep and it was possible to see a high number of associated fauna to the corals from which we can highlight the crustacean *Anamathia rissoana*.

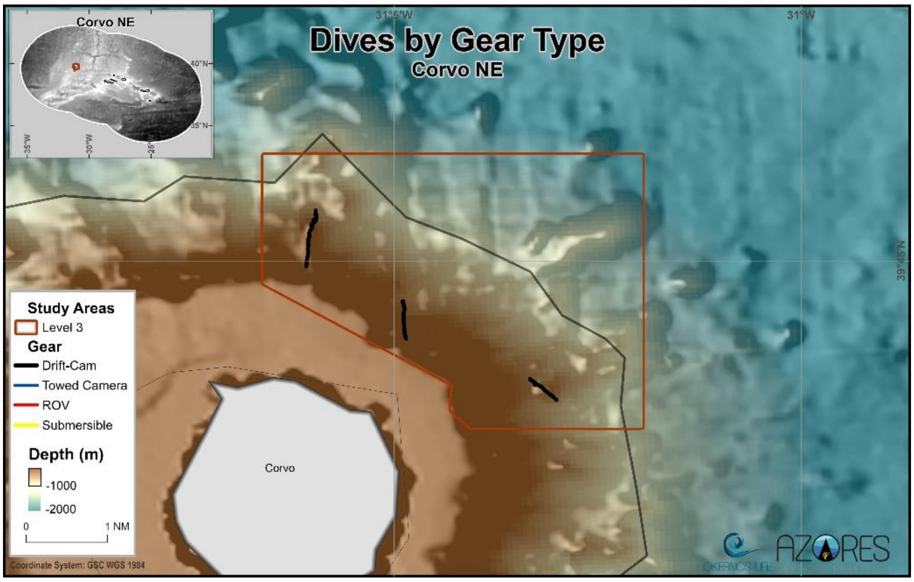



**Figure 196** Map displaying the 3 underwater dives performed in the Corvo NE area between 180 and 730 meters depth.

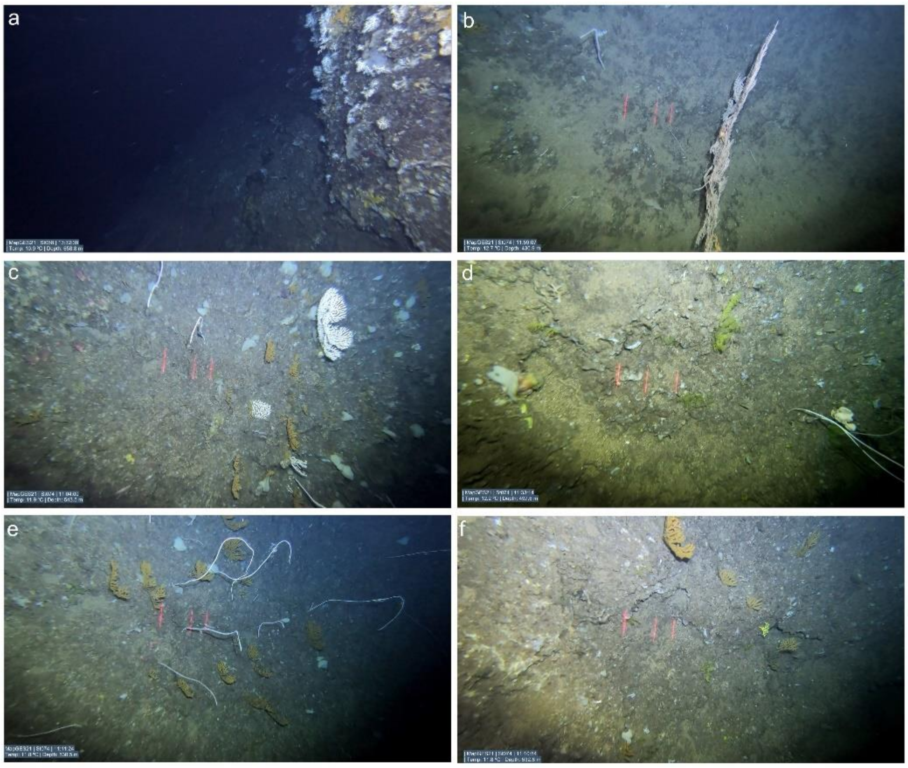



**Figure 197** Selected images representative of the main structuring species and benthic communities observed in Corvo Northeast area. (a) Vertical wall with small colonies of *Errina dabneyi* and several sponges, including encrusting species. (b) Colony of the primnoid *Callogorgia verticillata,* with spider crabs *Anamathia rissoana* asscoatided. (c) Aggregation of the gorgonians *Acanthogorgia* spp. and *Paragorgia johnsoni* together with sponges from species *Phakellia ventilabrum.* (d) Small colonies of the back coral *Elatopathes abietina.* (e) Aggregation of large colonies of *V. flagellum* with *Acanthogorgia* spp. and *P. ventilabrum.* (f) Hard substrate colonized by colonies of *Acanthogorgia* spp., *E. abientina* and a colony of *Enallopsammia rostrata.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Corvo SE*

In the Corvo Southeast area, 6 underwater video transects were conducted at depths ranging from 130 to 770 m (Figure 198). Examination of the footage identified 41 taxa, with 25 identified at the species level, suggesting a low diversity of deep-sea megabenthic species in this region. Most abundant taxa based on weighted occurrences include *Viminella flagellum* (n= 14), *Acanthogorgia* spp. (n= 10), and *Elatopathes abietina* (n= 8).

The deeper sections explored are mainly characterized by barren soft sediments, with only a few sparse black-corals *Parantipathes hirondelle* (Figure 199d) and poorly colonized small rocky outcrops, at around 700m depth. At around 450m depth, the slope increases, and a coral-dominated community is present. Even though soft sediments compose most of the substrate observed, the rocky outcrops are usually colonized by the whip coral *Viminella flagellum* (Figure 199a), the gorgonian *Acanthogorgia* spp. (Figure 199a). and the black-coral *Elatopathes abietina* (Figure 199e), present in relatively high abundances. However, most of the area explored at these depths were poorly colonized by benthic fauna.

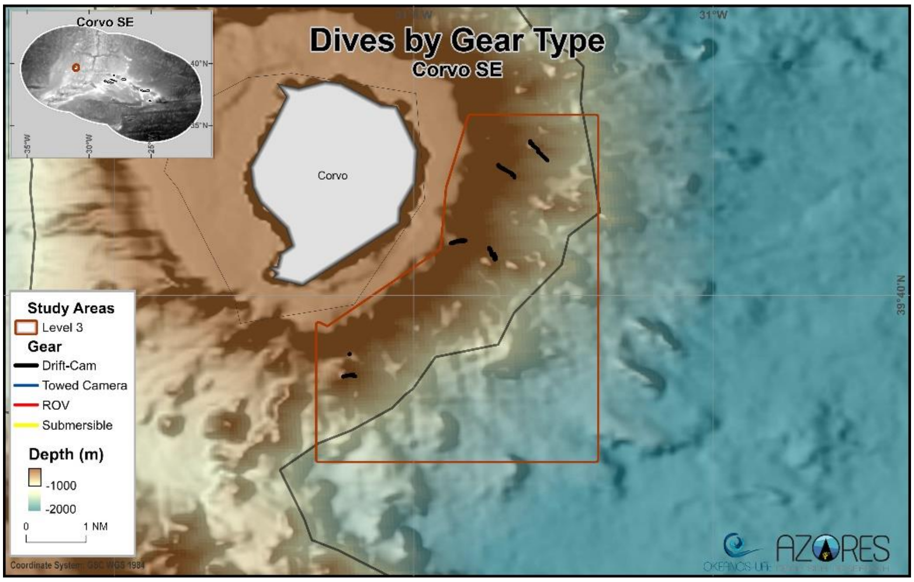



**Figure 198** Map displaying the 6 underwater dives performed in the Corvo SE area between 130 and 770 meters depth.

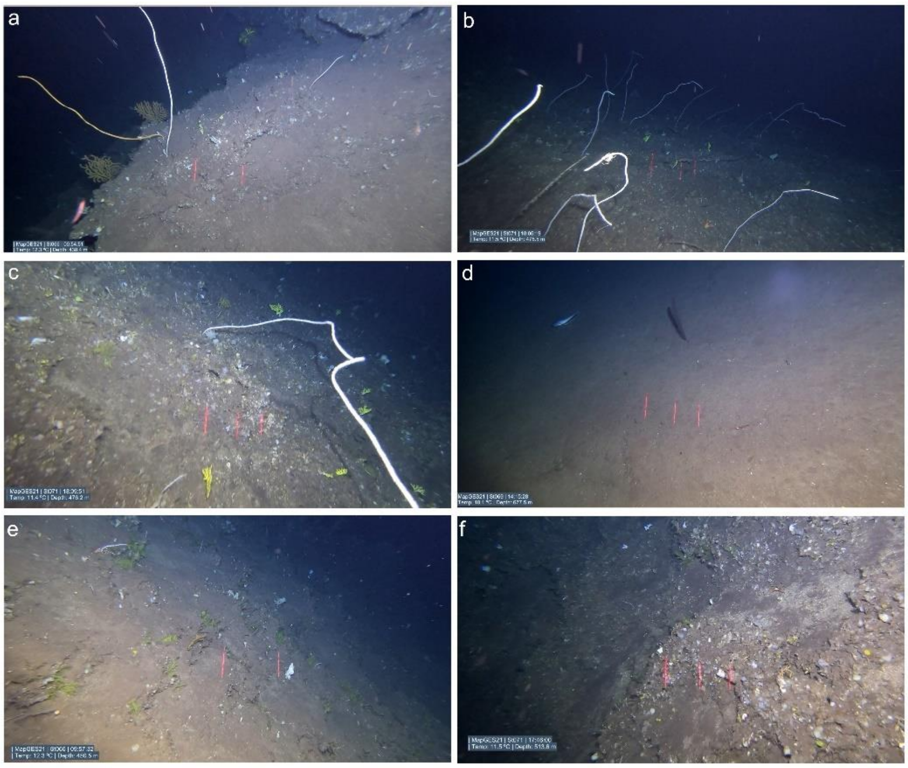



**Figure 199** Selected images representative of the main structuring species and benthic communities observed in Corvo Southeast area. (a)Two morphotypes of *Viminella flagellum* together with *Acanthogorgia* spp. on hard substrate covered with soft sediments. (b-c) Large colonies of *V. flagellum*, one with a spider crab *Anamathia rissoana* associated, and colonies of *Enallopsammia rostrata* and the sponge *Phakellia ventilabrum.* (d) The black coral *Parantipathes hirondelle.* (e) Small colonies of the black coral *Elatopathes abietina.* (f) Outcrop colonized by several sponges, including *Stylocordyla pellita* and the black coral *E. abietina.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Corvo SW*

Surveying the Corvo Southwest area involved 7 underwater video transects at depths between 280 and 850 m (Figure 200). Analysis of the videos recorded revealed a total of 84 taxa, with 55 identified at the species level, indicating a high diversity of deep-sea megabenthic species in this region. Prominent taxa based on weighted occurrences include *Anthomastus/Pseudoanthomastus* sp. (n= 23), *Viminella flagellum* (n= 20), and *Acanthogorgia* spp. (n= 17).

Little fauna was observed at the deepest areas explored in Corvo SW. Most of the substrate was composed of soft grounds very poorly colonized by benthic organisms. A few black-corals *Parantipathes hirondelle* and solitary corals *Flabellum* sp. were the only species seen at around 850m depth. However, on shallower terrains, the biodiversity and abundances of the faunal assemblages recorded was impressive. At around 750m, dense coral gardens dominated by *Narella versluysi* (Figure 201c) and *Narella bellissima* (Figure 201c) colonized vast areas of some of the slopes explored. However, at similar depths on different slopes, completely different communities were present. The seabed was found to be dense and extensively colonized by a variety of coral species, of which the gorgonians *Acanthogorgia* spp. (Figure 201e) and *Paragorgia johnsoni* (Figure 201d) composed some of the most observed. Areas close to the deep summits explored (at around 600m) were completely dominated by a small, pink-coloured soft coral, which covered vast sections of the seafloor, together with the solitary coral *Leptopsammia formosa*. Several large sponges were recorded within this community also, such as the massives *Characella pachastrelloides* and *Geodia* sp. (Figure 201f) and other smaller species (*Stylocordilla pellita*, for instance). As the terrain became steeper, the faunal assemblage was found to shift to one dominated by the seafan *Acanthogorgia* spp., with the whip coral *Viminella flagellum* (almost exclusively on its yellow morphotype) and the sleractinian *Dendrophyllia cornigera* noticeably composing the community as well, at around 400m depth, covering very jagged outcrops and overhangs. On flatter terrains, large colonies of the black-coral *Leiopathes glaberrima* (Figure 201a) began to appear, together with some sponge species such as *Haliclona implexa* and *Phakellia ventilabrum*. Around these areas, lost bottom longlines could be observed as well. However, one the highlights of this area was the extensive and dense bed of the sleractinian *Eguchipsammia cornucopia* (Figure 201b), which was found to cover vast areas of the shallowest portions explored, at around 250m, almost composing a reef-like framework.

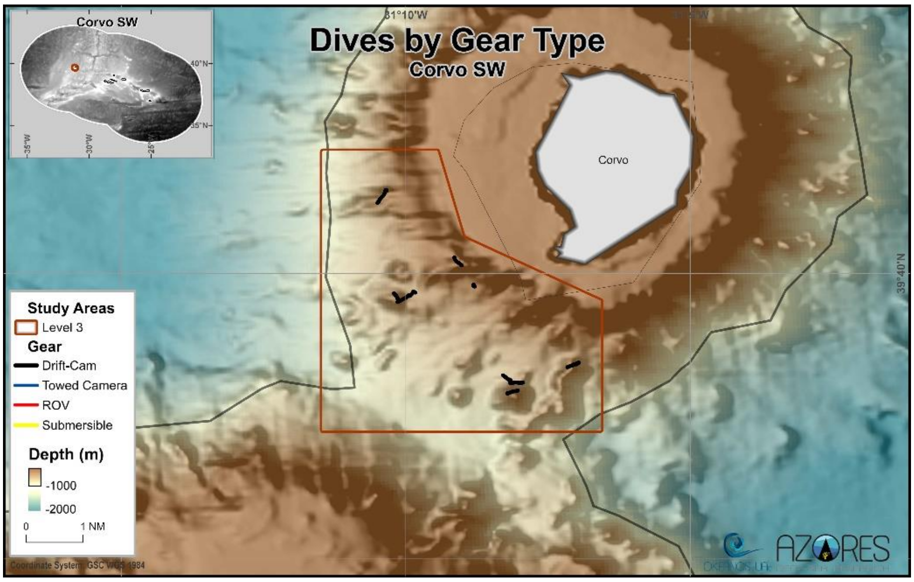



**Figure 200** Map displaying the 7 underwater dives performed in the Corvo SW area between 280 and 850 meters depth.

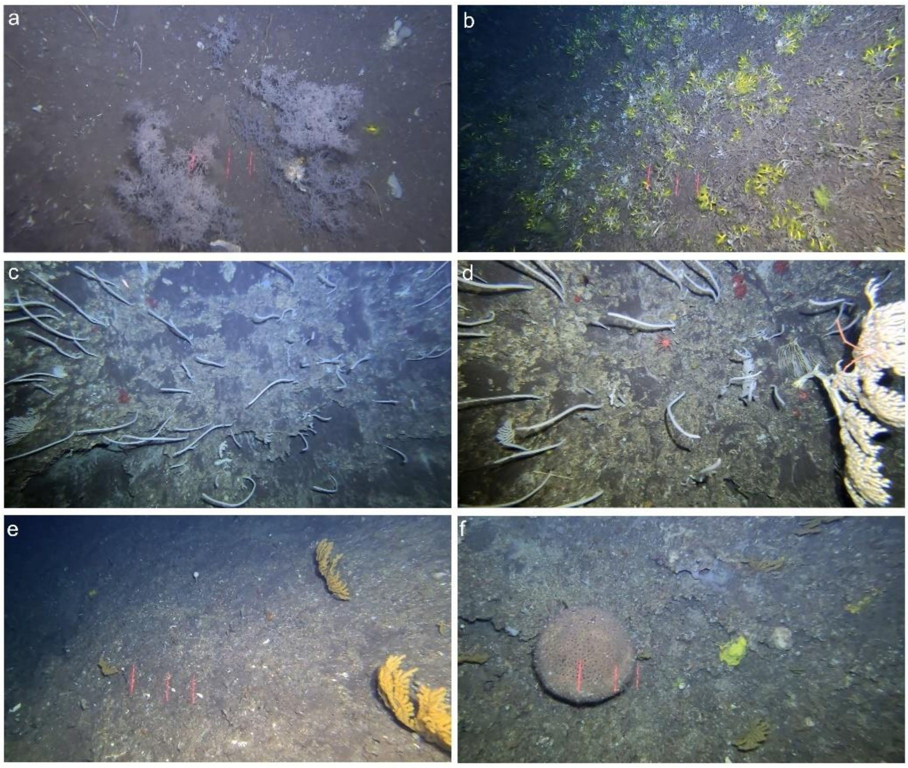



**Figure 201** Selected images representative of the main structuring species and benthic communities observed in Corvo Southwest area. (a)Black coral *Leiopathes glaberrima*. (b) Large aggregation of *Eguchipsammia cornucopia* on dead coral framework, with small colonies of the black coral *Elatopathes abietina*. (c) Vast aggregation of the primnoids *Narella versluysi* and *Narella bellissima* with sporadic occurrence of the soft coral *Anthomastus*/*Pseudoanthomastus* sp. (d) Coral gardens with primnoids from genus *Narella,* soft corals and a colony of *Paragorgia johnsoni.* (e) Small aggregation of the gorgonian *Acanthogorgia* spp. and the desmosponge *Stylocordyla pellita.* (f) Large *Geodia* sp. and *Acanthogorgia* sp. colonies. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Flores NW*

Exploring the Flores Northwest region involved 5 underwater video transects spanning depths from 430 to 1070 m (Figure 202). Examination of the footage unveiled a total of 69 taxa, with 45 identified at the species level, suggesting a moderate diversity of deep-sea megabenthic species in this area. Prominent taxa based on weighted occurrences include *Parantipathes hirondelle* (n= 19), *Haliclona filholi* (n= 17), and *Farrea occa* (n= 15).

The deepest slopes explored in this area proved to be relatively low in terms of biodiversity, with soft sediments dominating most of the substrate. However, shallower spots exhibited very interesting faunal assemblages. At depths of around 700m to 600m depth, we encountered an impressive field colonized by a dense coral garden dominated by the red and white morphotypes of the bubble gum coral *Paragorgia* cf. *johnsoni* (Figure 203b) that resembled the aggregation observed in the Western Ridge of Gigante Seamount Complex (Morato et al., 2021). This aggregation was found in reasonably good conditions, despite some colonies showing signs of impact, with some found lying over the seabed. Soft corals and small black corals (*Stichopathes gravieri)* also composed this community. At shallower depths, between 600 and 400 m depth, a community shift takes place, where the black coral *Elatopathes abietina* (Figure 203d) and the whip coral *Viminella flagellum* (Figure 203c) were the most representative species. We encountered several vertical walls, some particularly tall (150m), densely colonized by a wide variety of species, including the gorgonians *Viminella flagellum* and *Acanthogorgia* spp., the scleractinian *Dendrophyllia cornigera* as well as some sponges (*Haliclona implexa, Phakellia ventilabrum).* A large six-gill shark (*Hexanchus griseus*) and a monkfish (*Lophius piscatorius)* were observed as well, while several lost fishing lines were found lying over the seafloor at around the same depths.

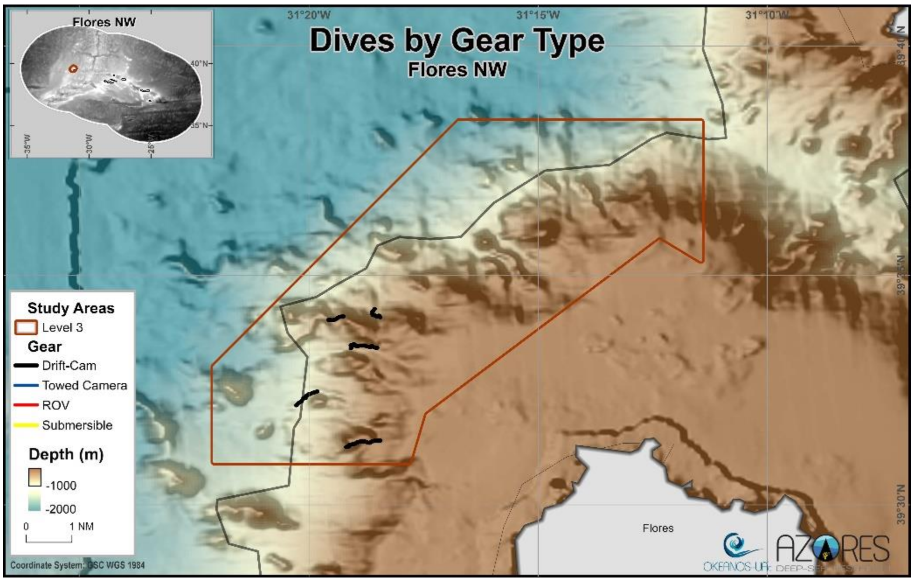



Figure 202 Map displaying the 5 underwater dives performed in the Flores NW area between 430 and 1,070 meters depth.

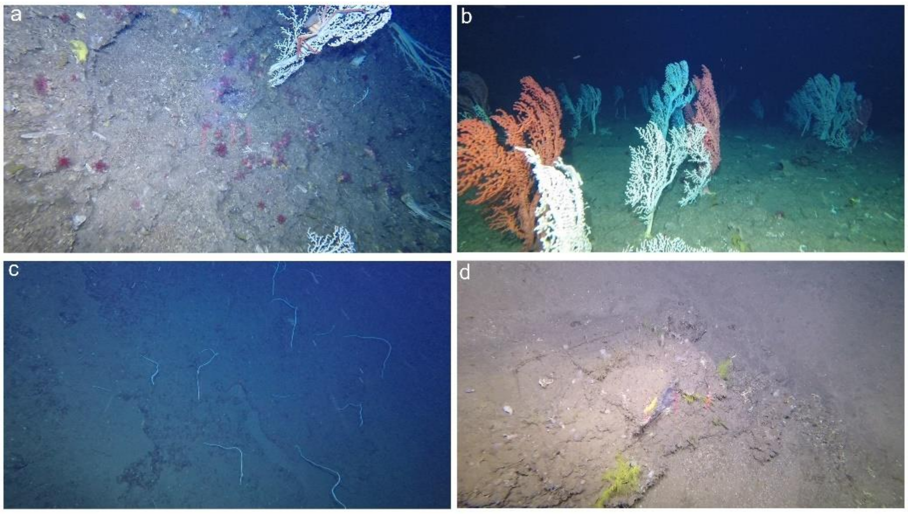



**Figure 203** Selected images representative of the main structuring species and benthic communities observed in Flores Northwest area. (a) Aggregation of the soft coral *Anthomastus/Pseudoanthomastus* sp. and a large colony of white *Paragorgia* cf. *johnsoni* with the crab *Paramola cuvieri* associated to it. (b) Aggregation of large colonies of reddish and white forms of bubble gum coral *P.* cf. *johnsoni.* (c) Small aggregation of the whip coral *Viminella flagellum*. (d) Small aggregation of the black coral *Elatopathes abietina.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Flores NE*

In the Flores Northeast area, 6 underwater video transects were performed within the depth range of 360 to 920 m (Figure 204). Analysis of the recorded footage identified 64 taxa, with 42 of them specified at the species level, pointing to a moderate diversity of deep-sea megabenthic species. Most abundant taxa based on weighted occurrences include *Farrea occa* (n= 16), *Plesionika* (n= 14), and *Bathynectes maravigna* (n= 12).

The northeastern part of the Flores Island slope was mainly characterized by its irregular geomorphology, mainly composed by little seamounts and banks. The depth range was large and the seabed at this area was principally characterized by its hard substrate, with many rocky outcrops and patches where this rocky ground was covered with coral rubble. The lower slopes had the presence of relatively high and diverse densities of benthic fauna, mainly constituted by corals, forming amazing colonies growing at this geomorphological unit. Dense patches of large corals resembling those from the genus *Paramuricea* were filmed attached to a steep wall. Several other deep corals were recorded, with dense patches of the commonly known as bubble gum coral *Paragorgia johnsoni* (presence both in white and red morphotypes) (Figure 205d), present on the top of a wall and extending for quite some time. On the deepest sectors extensive gardens of the scleractinian coral *Madrepora oculata* (Figure 205c), stylasteridae corals (Figure 205a), and together with large aggregations of soft corals of the genus *Anthomastus/Pseudoanthomastus* sp. (Figure 205c), were recorded. We also encountered some individuals of the bamboo coral *Acanella arbusculla* and black corals of the genus *Leiopathes* (Figure 205b). Sponges observed on the dives performed, included the typical bird nest sponge *Pheronema carpenteri* (Figure 205b), lamellate sponges likely of the genus *Poecillastra* and punctual aggregations of the glass sponge *Regradrella phoenix* (Figure 205b). Along the slopes, we filmed several fish and shark species, such as *Hoplostethus mediterraneus, Helicolenus dactylopterus, Deania sp., Odontaspis ferox* and many Macrouridae.

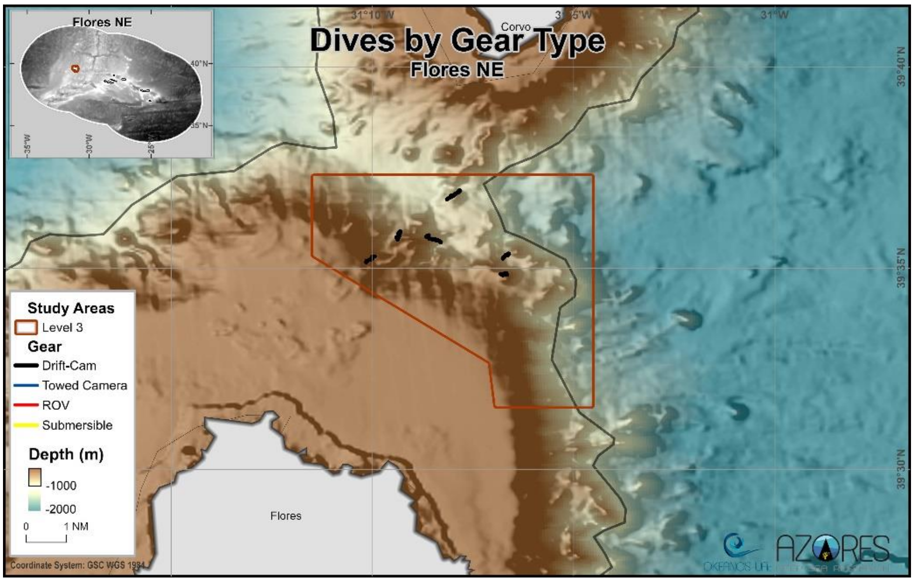



**Figure 204** Map displaying the 6 underwater dives performed in the Flores NE area between 360 and 920 meters depth.

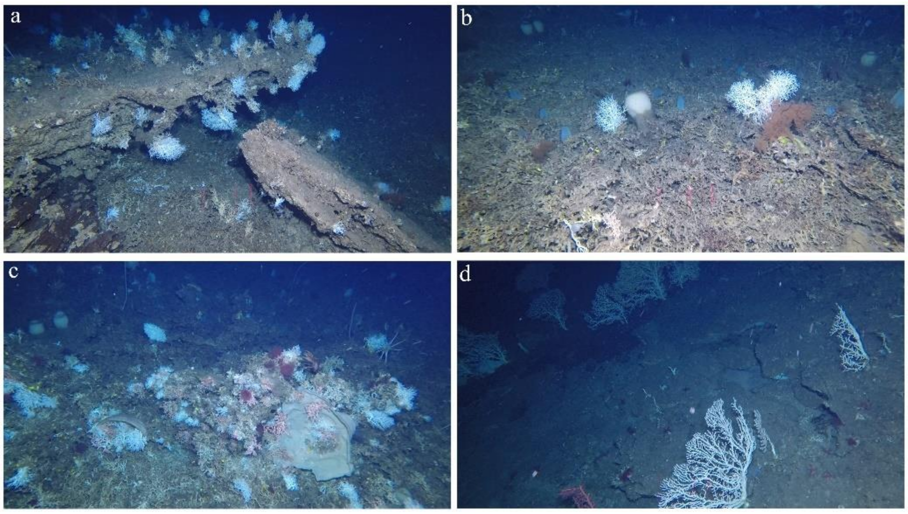



**Figure 205** Selected images representative of the main structuring species and benthic communities observed in Flores Northeast area. (a) Aggregation of stylasterids. (b) Dead coral framework colonized by stylasterids, the sponges *Pheronema carpenteri* and *Regadrella phoenix* and the back coral *Leiopathes* cf. *expansa.* (c) Dead coral framework colonized by stylasterids, *Madrepora oculata*, the soft coral *Anthomastus/Pseudoanthomastus* spp. and massive sponges. (d) Aggregation of white and pink forms of *Paragorgia cf.* johnsoni. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Flores E*

Surveying the Flores East area involved 6 underwater video transects spanning depths from 200 to 960 m (Figure 206). Examination of the footage unveiled a total of 67 taxa, with 42 identified at the species level, indicating a moderate diversity of deep-sea megabenthic species in this region. Dominant taxa based on weighted occurrences include *Viminella flagellum* (n= 17), *Petrosia* sp. (n= 16), and Ceriantharia (n= 13).

In the deeper areas explored, the substrate was mainly composed of unconsolidated soft sediment with sparse fauna present, mostly including the bamboo coral *Acanella arbuscula* (Figure 207a) and some patches of the glass sponge *Pheronema carpenteri* (Figure 207c). The common mora fish (*Mora moro)* was also seen at these depths. In the shallower dives, we crossed some diverse communities of corals and sponges with the gorgonians

*Viminella flagellum* (Figure 207b,d), *Acanthogorgia* spp., the stony coral *Dendrophyllia cornigera and* the sponges *Macandrewia azorica* and *Haliclona implexa* being the most common species observed. Many fish species were recorded, including *Pagellus bogaraveo, Beryx sp., Hoplostethus mediterraneus, Helicolenus dactylopterus* and *Dalatias licha*, at different depths.

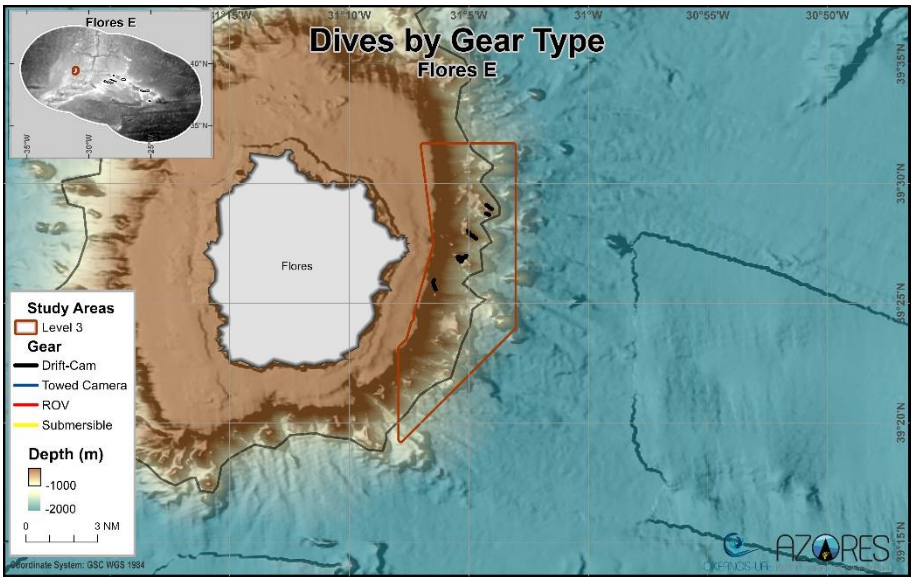



**Figure 206** Map displaying the 6 underwater dives performed in the Flores E area between 200 and 960 meters depth.

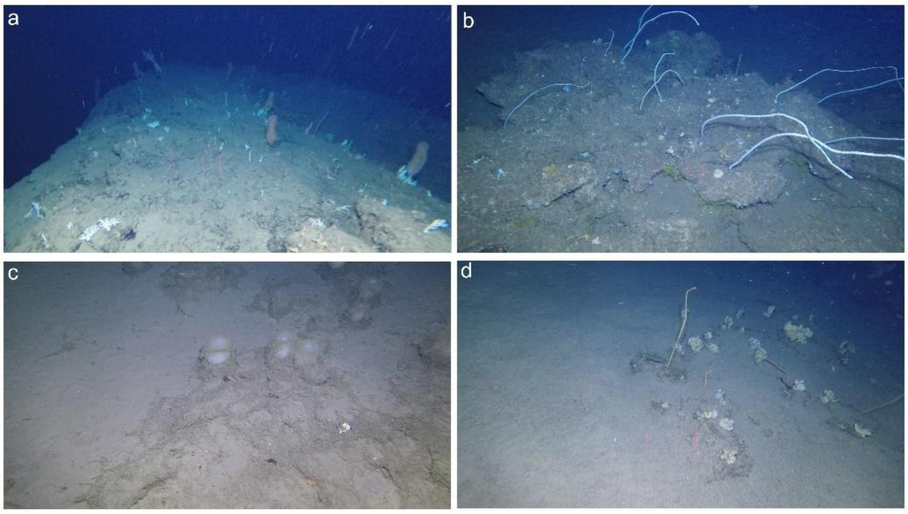



**Figure 207** Selected images representative of the main structuring species and benthic communities observed in Flores East area. (a) Scattered aggregation of the bamboo coral *Acanella arbuscula* (b) Small community of V*iminella flagellum* and the black corals *Elatopathes abietina* (c) Aggregation of the hexactinellid sponge *Pheronema carpenteri* (d) Small aggregation of the yellow morphotype of *Viminella flagellum* on soft bottom. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Flores S*

In the Flores South area, 6 underwater video transects were performed at depths ranging from 400 to 920 m (Figure 208). Analysis of the footage revealed a total of 80 taxa, with 49 identified at the species level, indicating a high diversity of deep-sea megabenthic species in this region. Notable taxa based on weighted occurrences include *Viminella flagellum* (n= 32), *Acanthogorgia* spp. (n= 22), and *Flabellum* sp. (n= 18).

The southern slopes of Flores Island, located at the western part of the Azorean archipelago were explored covering a high range of depths. On the deepest areas filmed, located at the lower slope of the Island, the seafloor was mainly composed of sedimentary environments, with sparse benthic fauna, including a few bamboo corals of the species *Acanella arbuscula*, sea urchins of the species *Cidaris cidaris* and sporadic records of the deep-sea crab *Chaceon affinis*. Motile fauna was also observed, from which we can highlight the pink frogmouth fish *Chaunax pictus*, oilfish *Ruvettus pretiosus* and several bluemouth rockfish *Helicolenus dactylopterus*. At the shallower levels of the slope, in the upper part of it, the benthic communities shifted, with the existence of much more diversity and abundance of fauna. Large aggregations of the whip coral species *Viminella flagellum* (Figure 209b) (present in both white and yellow morphotypes) were seen, often together with soft coral individuals of the genus *Anthomastus/Pseudoanthomastus* sp.. Several other gorgonians were found to be at relatively high abundances such as *Acanthogorgia* spp. (Figure 209b,c,d), and a little bit less, the *Dentomuricea* aff. *meteor* (Figure 209b-d), and *Paracalyptrophora josephinae* (Figure 209d). Small exemplars of black corals of the species *Elatopathes abietina* (Figure 209a) and *Stichopathes* gravieri were also seen growing on the hard substrate that the rocky outcrops created at these depths. Regarding sponges the species observed were not very abundant, from which we can highlight some large sponges of the genus *Leiodermatium* (blue morphotype) (Figure 209c).

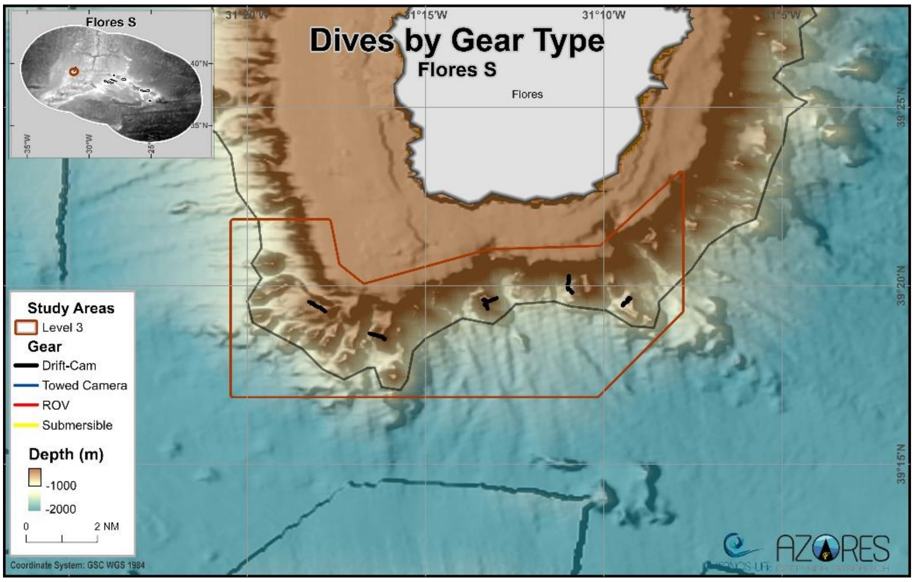



**Figure 208** Map displaying the 6 underwater dives performed in the Flores S area between 400 and 920 meters depth.

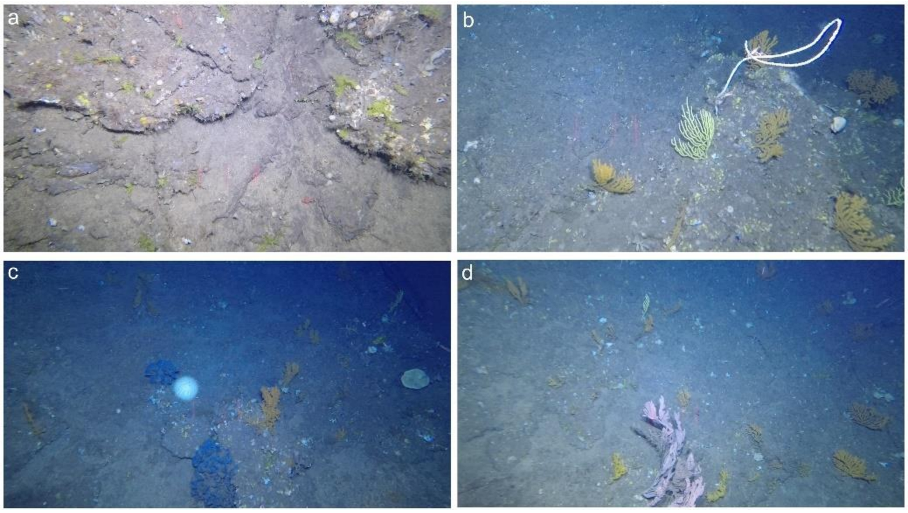


**Figure 209** Selected images representative of the main structuring species and benthic communities observed in Flores South area. (a) Small aggregation of the black coral *Elatopathes abietina* (b) Small community formed by a colony of *Viminella flagellum* associated with spider crabs *Anamathia* sp., *Dentomuricea* aff. *meteor* and *Acanthogorgia* spp. (c) Benthic community with the sponges *Leiodermatium* sp. (blue morphotype) and *Macrandrewia azorica*, *Acanthogorgia* spp. and the sea urchin *Echinus melo* (d) Small aggregation *Acanthogorgia* spp., *D.* aff. *meteor* and a colony of *Paracalyptrophora josephinae.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Flores W*

Exploring the Flores West area involved 6 underwater video transects spanning depths from 330 to 990 m (Figure 210). Examination of the footage unveiled a total of 50 taxa, with 30 identified at the species level, suggesting a moderate diversity of deep-sea megabenthic species in this region. Prominent taxa based on weighted occurrences include Ceriantharia (n= 13), *Farrea occa* (n= 12), and *Plesionika* sp. (n= 10).

The western part of the Flores Island slope was characterized by its steepness, with the geomorphology mainly characterized by the small canyons and high vertical walls. On the deepest areas of the slope (around 935 to 510m deep), the sea bottom was mainly constituted by sand/soft sediments and bare rock, and the presence of benthic megafauna was very limited and scarce with low biodiversity. On the upper sections of the slope (up to 250m deep), patches of relatively dense aggregations of the octocoral *Viminella flagellum*, present in both white and yellow morphotypes (Figure 211a,b) (although the last one in less abundance) were seen growing on the hard substrate. Several other coral species were recorded at the shallowest areas, with occurrences of the black coral *Elatopathes abietina* (Figure 211d), *Acanthogorgia* spp. and colonies of *Dendrophyllia cornigera* (Figure 211c). Sponges were not very abundant at this site, with the species *Haliclona implexa* (Figure 211c) and the fan shaped *Phakelia ventilabrum* (Figure 211c) being the most representative taxa. Motile fauna recorded included the presence of a monkfish (*Lophius piscatorius*) (Figure 211a) at the upper slope areas.

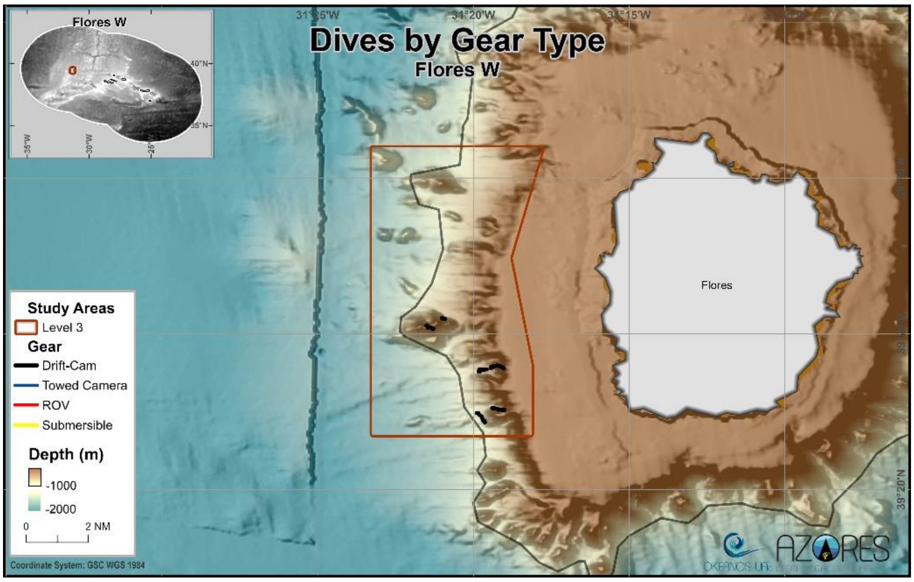



**Figure 210** Map displaying the 6 underwater dives performed in the Flores W area between 330 and 990 meters depth.

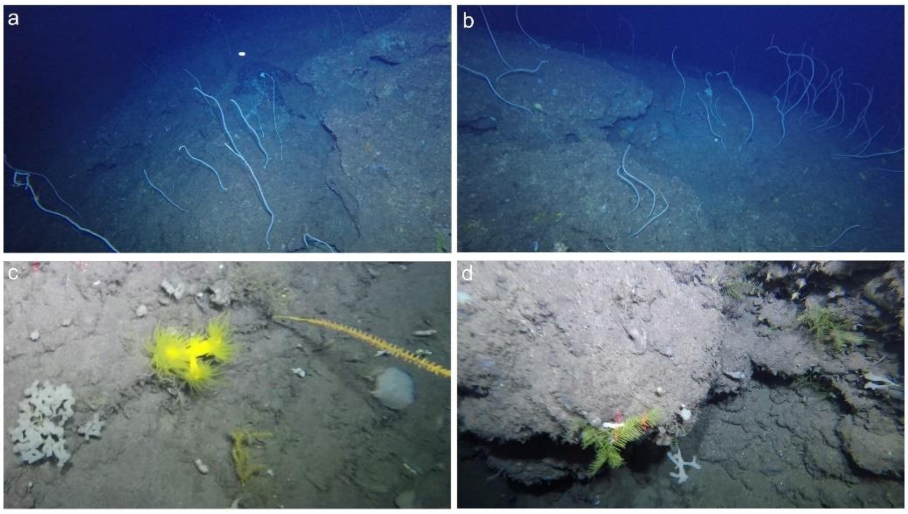



**Figure 211** Selected images representative of the main structuring species and benthic communities observed in Flores West area. (a-b) small patches of *Viminella flagellum* and a monkfish, *Lophius piscatorius* (a). (c) Sponges *Haliclona implexa* and *Phakelia* ventilabrum and the corals *Viminella flagellum* (yellow morph) and *Dendrophyllia cornigera* (d) Small aggregation of black coral *Elatopathes abietina*. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Cachalote*

Exploring the Cachalote region, there were conducted 12 underwater video transects covering depths from 450 to 1,500 m (Figure 212). Analysis of the video records unveiled a total of 94 taxa, with 60 identified at the species level, indicating a high diversity of deep-sea megabenthic species in this area. Prominent taxa based on weighted occurrences include *Viminella flagellum* (n= 68), *Anthomastus/Pseudoanthomastus* sp. (n= 64), and *Flabellum* sp. (n= 63).

The benthic communities in this area, showed a clear vertical stratification. The deepest regions explored were mainly colonized with gardens of *Narella bellissima* and *Narella versluysi* (Figure 213a,b), as well as *Acanella arbuscula*. We also observed some mobile fauna, such as a wreckfish *Polyprion americanus*, a large six-gill shark

(*Hexanchus griseus*), a couple of squids and a rarely recorded orange roughy (*Hoplostethus atlanticus*) (Figure 213d). When moving upper slope, type of substrate started to change to rocky outcrops covered with soft sediments. Large gardens of *Viminella flagellum* (Figure 213c) together with *Callogorgia verticillata* (Figure 213b) were spotted along with sponges of the genus *Characella* (Figure 213c). On these shallower sections we also noticed an aggregation of the decapod *Paromola cuvieri* around a large sponge. It was the first time this curious behaviour was recorded on video. We also drifted over some alfonsinos (*Beryx splendens*) and silver roughy (*Hoplostethus mediterraneus*).

The large abundance of lost fishing lines found on the seafloor was also noteworthy, together with other abandoned fishing gears.

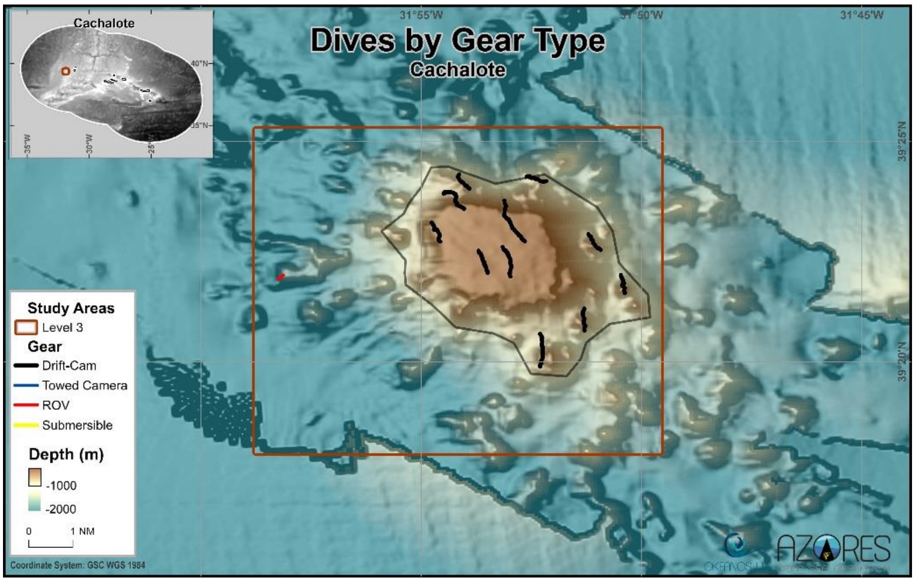



**Figure 212** Map displaying the 12 underwater dives performed in the Cachalote area between 450 and 1,500 meters depth.

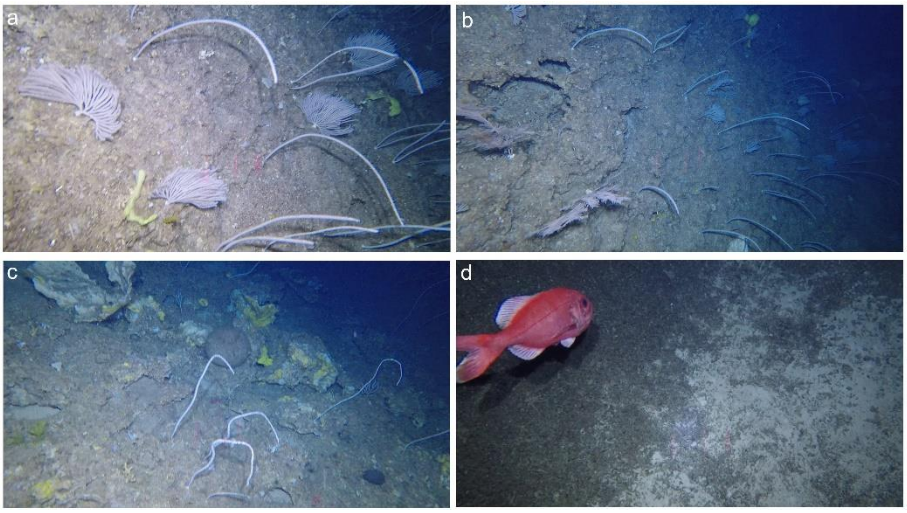



Figure 213 Selected images representative of the main structuring species and benthic communities observed in Cachalote seamount. (a-b) large gardens formed by *Narella bellisima, N. versluysi* and *Callogorgia verticillata* in deeper areas (700-900 m). Shallower benthic communities (500-600 m) were mainly formed by (c) Colonies of *Viminella flagellum* along with sponges from C*harecella pachastrelloides* complex and *Geodia* sp. (d) Fish *Hoplostethus atlanticus.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

## *10.2 Large area | Northern Mid-Atlantic Ridge*

The area Northern Mid-Atlantic Ridge is characterized by a large number of elongated ridges, with their summits generally found at depths below 1,000 m. The Kurchatov Transform Fault is the main feature on the southern sector, producing a series of shallower seamounts and ridges compared to the prevailing underwater features (Figure 214). This large area contains two study areas: South of Chaucer and Kurchatov, and a total of nine sampling areas (Figure 214). All 9 sampling areas have been explored with the towed camera system of the R/V Pelagia during the Eurofleets+ iMAR cruise (2021 and 2022), with the Azor drift-cam during the MapGES 2019 and 2023 surveys and the NOAA EX2206 and EXPLOSEA2 (2019) surveys (Figure 214).

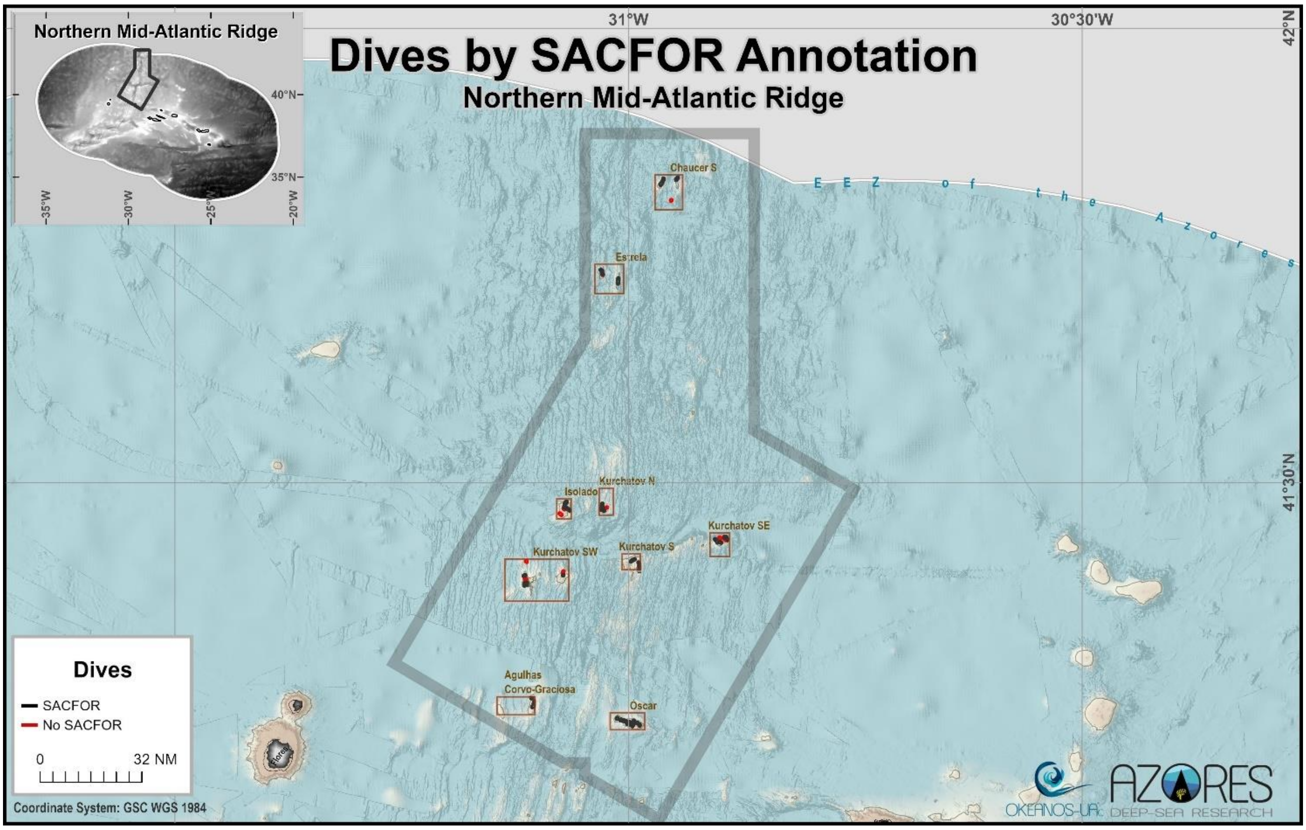


**Figure 214** Northern Mid-Atlantic Ridge sampling areas (Level 3) with or without SACFOR dive locations.

Study Area | Southern Chaucer

*Chaucer Sul*

In the Chaucer South area 3 underwater video transects were performed, within the depth range of 730 to 1250 m (Figure 215). Examination of the recorded images identified 68 taxa, with 36 specified at the species level, suggesting a medium diversity of deep-sea megabenthic species in this area. Dominant taxa based on weighted occurrences include Crinoidea (n= 79), *Acanella arbuscula* (n= 69), and *Cidaris cidaris* (n= 68).

In the deeper sectors explored, the sedimentary bottoms were characterized by accumulations of sand and gravels, in most cases mixed with coral rubble. The community found at these depths was composed by the hexactinellid *Pheronema carpenteri* (Figure 216a), the bamboo coral *Acanella arbuscula* and the echinoid *Cidaris cidaris*, which were frequently observed scattered along the seabed (Figure 216a-b). When more consolidated substrates (such as rocky outcrops and boulders) were present, framework-building scleractinian corals were frequently observed, with the cooccurrence of the species *Lophelia pertusa* and *Madrepora oculata* (Figure 216c). Locally, these calcified reef structures are known to considerably increase the diversity of associated species, a pattern observed in the presence of small crinoids, in some areas densely patching the reef-like structures. Large sponges, such as the hexactinellids *Hertwigia falcifera*, *Asconema* sp. and the white lamellate cf. *Phakellia* sp. also appeared at the 1,000-1,200 m depth zone (Figure 216d). The ridge on the southwester side presented an astonishing diversity of non-scleractianian cold-water corals, especially those in the form of tall arborescent black coral (e.g., *Leiopathes* cf. *expansa*) and bamboo corals (e.g., from the Keratoisididae family). Since these species are considered slow-growing and long-living foundation species, they also represent key three-dimensional habitats that harbour high levels of associated biodiversity. Large colonies of *Leiopathes* cf. *expansa* grow on hard substrate areas above the 1100 m layer until 800 m depth, found on many occasion times with remarkable densities in areas of steep slopes (Figure 216e). These areas of large outcropping rocks host a mixed cold-water coral community, that besides *Leiopathes* cf. *expansa*, is characterized by other antipatharians such as *Bathypathes* spp. and *Tylopathes* sp.*,* large bamboo corals from the family Keratoisididae, orange and purple plexaurids likely from the family Paramuriceidae and lace corals. Some highly specialized species associations within these coral gardens were also observed, as for instance, the decapods *Sternostylus formosus* inhabiting on the branches of the black coral *Leiopathes* cf. *expansa* (Figure 216f).

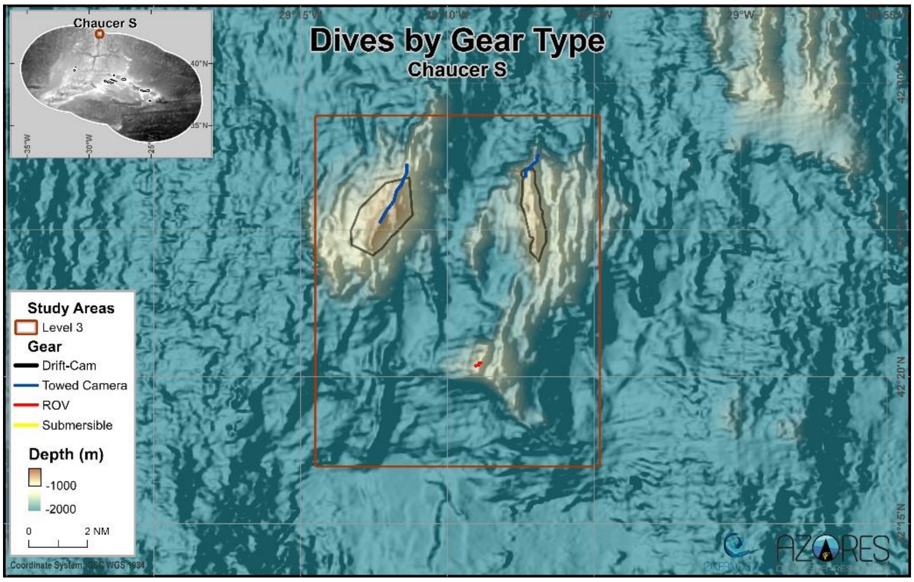



**Figure 215** Map displaying the 3 underwater dives performed in the Chaucer S area between 730 and 1,250 meters depth.

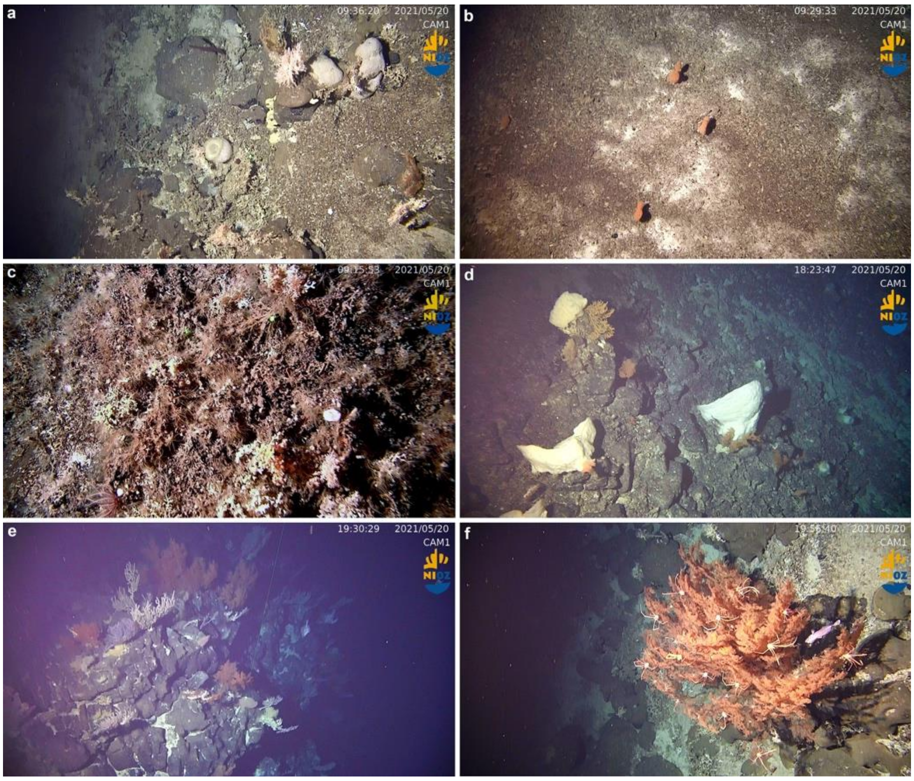


**Figure 216** Selected images representative of the main structuring species and benthic communities observed in Chaucer South area. (a-b) Two commonly observed VME indicator taxa: the hexactinellid sponge *Pheronema carpenteri* and the bamboo coral *Acanella arbuscula*. (c) Dense aggregation of small crinoids colonizing dead coral framework, possibly made by the VME indicator species *Lophelia pertusa* and *Madrepora oculata*. (d) Large white lamellate sponges on hard grounds, likely from the genus *Phakellia.* (e) Black corals of the species *Leiopathes* cf. *expansa* along with other antipatharians, gorgonians and bamboo corals, forming diverse coral gardens in the area. (f) A large *Leiopathes* cf. *expansa* hosting several decapods, likely *Sternostylus formosus*. Image credits: Eurofleets+ iMAR cruise, IMAR/Okeanos-UAz.

*Estrela*

Surveying the Estrela area involved 3 underwater video transects ranging from 600 to 1240 m depth (Figure 217). Analysis of the videos unveiled a total of 62 taxa, with 34 identified at the species level, indicating a medium diversity of deep-sea megabenthic species in this region. Notable taxa based on weighted occurrences include *Madrepora oculata* (n= 73), *Cidaris cidaris* (n= 62), and *Acanella arbuscula* (n= 61).

The composition of the benthic communities was very similar to that observed in Chaucer South. Patches of dead coral framework generated by the scleractinian corals *Lophelia pertusa*, *Madrepora oculata* and *Enallopsammia rostrata* could be observed, with some of their tips likely alive as determined by their orange coloration. On the western feature of D12 sampling area, it was common to observe colonies of the black coral *Leiopathes* cf. *expansa* (Figure 218a,b), although with smaller sizes than those observed in Chaucer S. Conversely, on the eastern feature of D12, *Leiopathes* cf. *expansa* formed a more complex community, with higher densities and larger colony sizes, with a diverse associated fauna, especially in steep slopes and large rocky outcrops. In those areas, hexactinellids such as *Pheronema carpenteri* (Figure 218c), *Hertwigia falcifera* (Figure 218d) and *Asconema* sp. were observed, as well as demosponges such as the lamellate *Phakellia* sp. and large geodiids. Other common taxa were the bamboo corals *Acanella arbuscula* and those from the

Keratoisididae family, which attained very large sizes. The gorgonians *Chrysogorgia* sp., *Iridogorgia* sp. and *Paragorgia johnsoni* were also recurrently reported (Figure 218c-d), as well as a high diversity of black corals including *Parantipathes* spp. (Figure 218e), *Bathypathes* spp., *Chrysopathes* sp. and *Tylopathes* sp., largely enhancing the diversity and complexity of the benthic community observed in this area. In shallower areas, octocorals of the family Paramuriceidae (Figure 218f) were seen forming some notable dense and tall colonies, especially in carbonate consolidated detritus, punctuated by caryophylliids (*Caryophyllia* spp. and *Desmophyllum* sp.) and dendrophylliids (*Leptopsammia formosa*). At around 800 m depth, the benthic community showed a change in its composition, with increasing densities of the primnoid corals *Narella versluysi* and *Narella bellissima*. Several Atlantic wreckfish *Polyprion americanus* and *Hoplostethus atlanticus* were observed within this rich ecosystem.

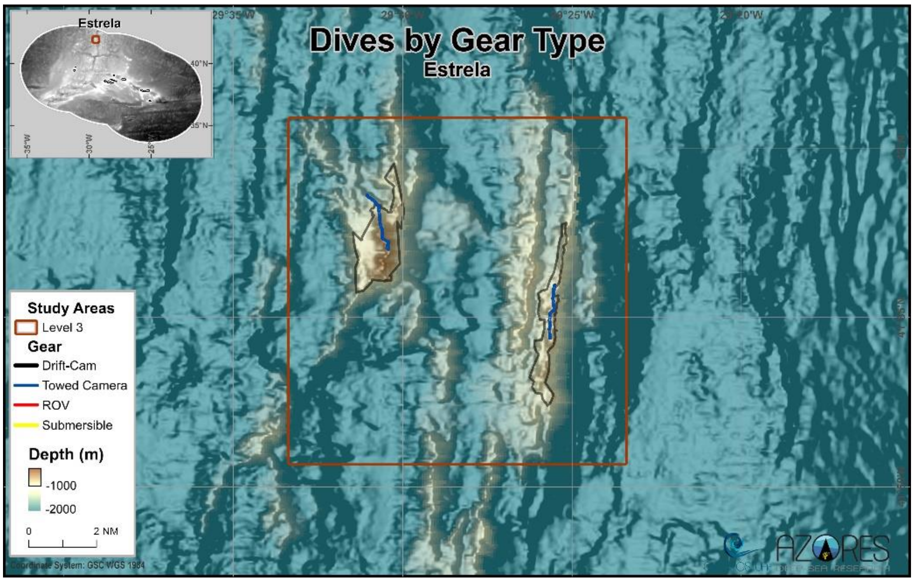



**Figure 217** Map displaying the 3 underwater dives performed in the Estrela area between 600 and 1,240 meters depth.

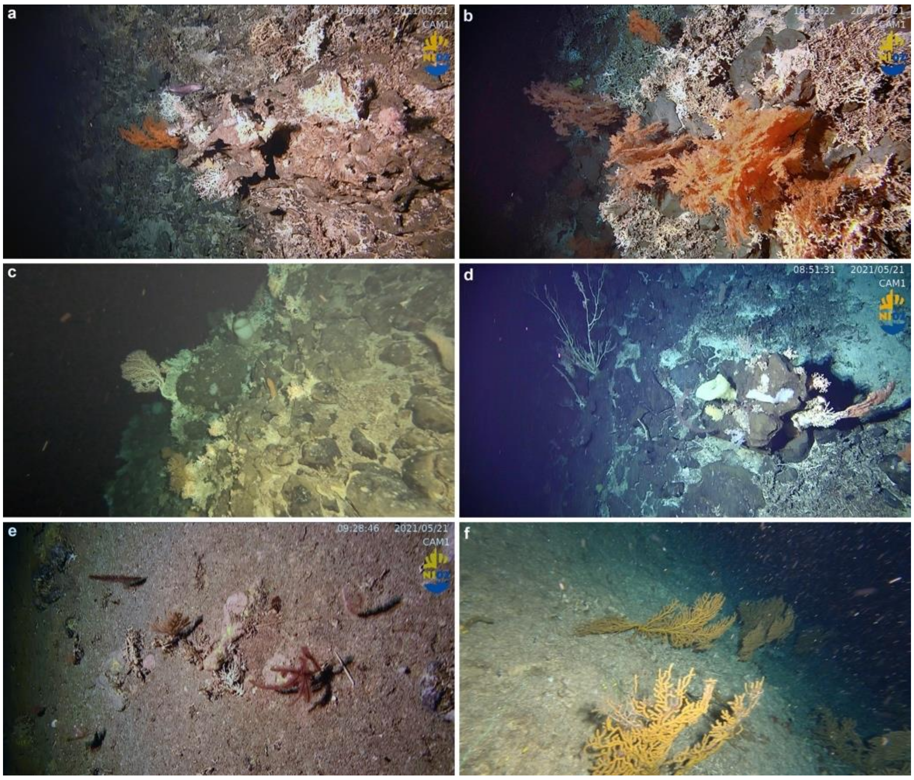


**Figure 218** Selected images representative of the main structuring species and benthic communities observed in the D12. (a) Scleractinian corals attached to rocky outcrops. (b) The VME indicator species *Leiopathes* cf. *expansa* forming high density patches along hard substrate areas. (c-d) Mixed coral gardens with *Acanella arbuscula*, bamboo corals and gorgonians (*Chrysogorgia* sp., *Paragorgia johnsoni)* alongside the hexactinellids *Pheronema carpenteri* and *Hertwigia falcifera.* (e) Black corals of the genus *Parantipathes*, also a VME indicator taxa. (f) Large colonies of a gorgonian species, from family Paramuricedae. Image credits: Eurofleets+ iMAR cruise, IMAR/Okeanos-UAz.

## Study area | Kurchatov

*Kurchatov N (former North Kurchatov America)*

In the Kurchatov North area, 2 underwater video transects were conducted within the depth range of 770 to 1040 m (Figure 219). Examination of the recorded footage identified 62 taxa, with 31 specified at the species level, suggesting a medium diversity of deep-sea megabenthic species in this area. Dominant taxa based on weighted occurrences include *Acanella arbuscula* (n= 79), *Pheronema carpenteri* (n= 64), and *Desmacella grimaldii* (n= 48).

The deepest sector explored in this geomorphological feature (~1,000 m depth) was dominated by outcropping rocks, markedly characterized by the presence of the colonial scleractinian *Madrepora oculata* together with the lace coral *Errina* cf. *atlantica*, forming some dense patches (Figure 220a). The substrate was covered by dead coral framework (coral rubble) probably resulting from the breakage of colonies of these two species. On the gentle slopes, high abundances were reported for the octocorals *Chrysogorgia* sp., the bamboo corals *Acanella arbuscula* (Figure 220b,c) and whip/branched Keratoisididae (Figure 220c), the black coral *Leiopathes* cf. *expansa* (Figure 220d) and orange and white plexaurids (Paramuriceidae). The sponge diversity is strongly represented by hexactinellids *Chonelasma* sp., *Hertwigia falcifera* (Figure 220e), *Pheronema carpenteri* (Figure

220f) and *Regadrella* sp. The most observed fishes were *Neocyttus helgae*, *Synapobranchus kaupi* and several macrourids. Although rare, the orange roughy *Hoplosthetus atlanticus* was also spotted in the area.

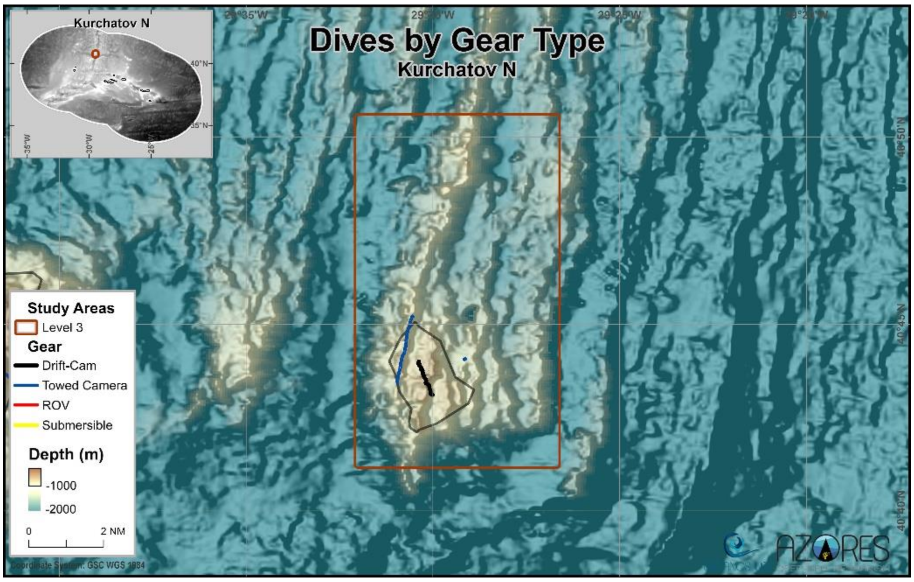



**Figure 219** Map displaying the 2 underwater dives performed in the Kurchatov N area between 770 and 1,040 meters depth.

**Figure 220** Selected images representative of the main structuring species and benthic communities observed in the North Kurchatov America area. (a) Scleractinian corals on hard substrates in association with Lace corals. (b-c) The VME indicator taxa *Acanella arbuscula* and Keratoisididae, common in the area. (d) A black coral *Leiopathes* cf. *expansa* growing over large boulders. (e) A large hexactinellid *Hertwigia falcifera* in an area of scleractinians and lace corals. (f) The VME indicator species *Pheronema carpenteri* attached to coral rubble. Image credits: Eurofleets+ iMAR cruise, IMAR/Okeanos-UAz.

*Isolado*

In the Isolado area, there were completed 6 underwater video transects covering depths from 500 to 1,180 m (Figure 221). Evaluation of the video data revealed a total of 57 taxa, with 37 identified at the species level, suggesting a medium diversity of deep-sea megabenthic species in this region. Prominent taxa based on weighted occurrences include Plesionika (n= 39), *Acanella arbuscula* (n= 38), and Caryophylliidae (n= 30).

The deepest zone explored (at around 1,100 m depth), on the southeastern flank, was characterized by flat sedimentary substrate (muddy sand) with several "lebensspuren" (Figure 222a) observed along the track, together with sparse xenophyophores (cf. *Syringammina fragilissima*) and echinoids of the species *Cidaris cidaris* (Figure 222a). A large part of the areas explored in this seamount did not show benthic communities with dense structuring species. However, some assemblages were observed developing under the outcropping rocks and large boulders. At 1,000-1,100 m depth, the coral community was dominated by bamboo corals of the species *Acanella arbuscula,* as well as others from the Keratoisididae family (Figure 222b). *Chrysogorgia* sp.*,* black corals *Antipathes dichotoma* and *Bathypathes* sp. were sparsely observed in the area. The sponge fauna was mainly composed by hexactinellids found in low densities: large *Hertwigia falcifera, Pheronema carpenteri, Asconema* sp. and *Regadrella* sp. (Figure 222c,d). In upper layers (above 900 m depth), sparse whip corals such as the primnoid *Narella versluysi* (Figure 222f)and the antipatharian *Parantipathes hirondelle* were registered intermixed with white fan-shape sponges likely from the genus *Poecillastra* attached to the hard substrates (Figure 222e). Cup corals, such as the dendrophylliid *Leptosammia formosa* and diverse caryophyllids also appeared in hard bottoms. The shallowest area explored (approx. 700 m) was characterized by the presence of deposits of coral rubble. Fishes commonly observed were macrourids (ex. *Coryphaenoides* spp.), the eels *Synapobranchus kaupii* and *Etmopterus pusillus,* especially in deeper areas. A few *Chaunax* sp.*, Neocyttus helgae*, *Trachyscorpia cristulata* and *Hoplosthetus meditarreneus* schools were also spotted along the seamount flank.

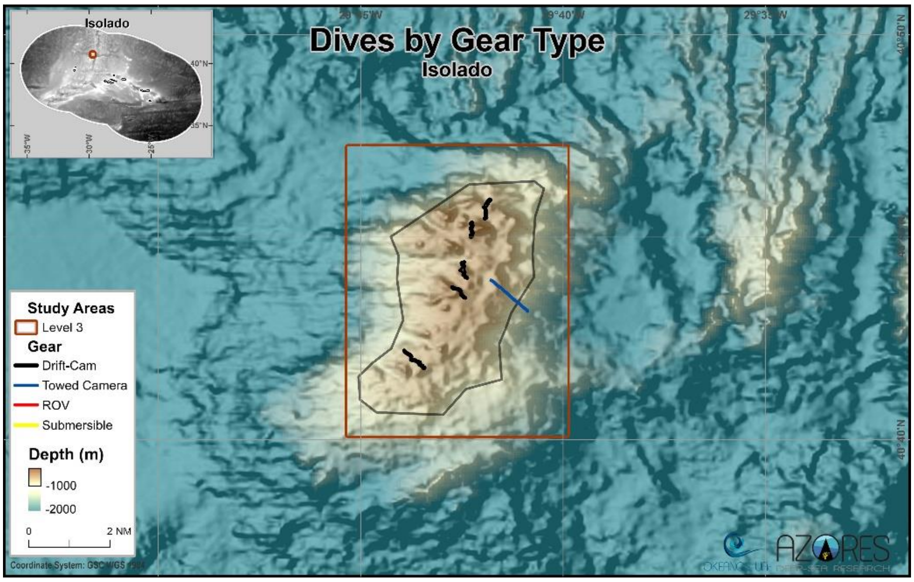



**Figure 221** Map displaying the 6 underwater dives performed in the Isolado area between 500 and 1,180 meters depth.

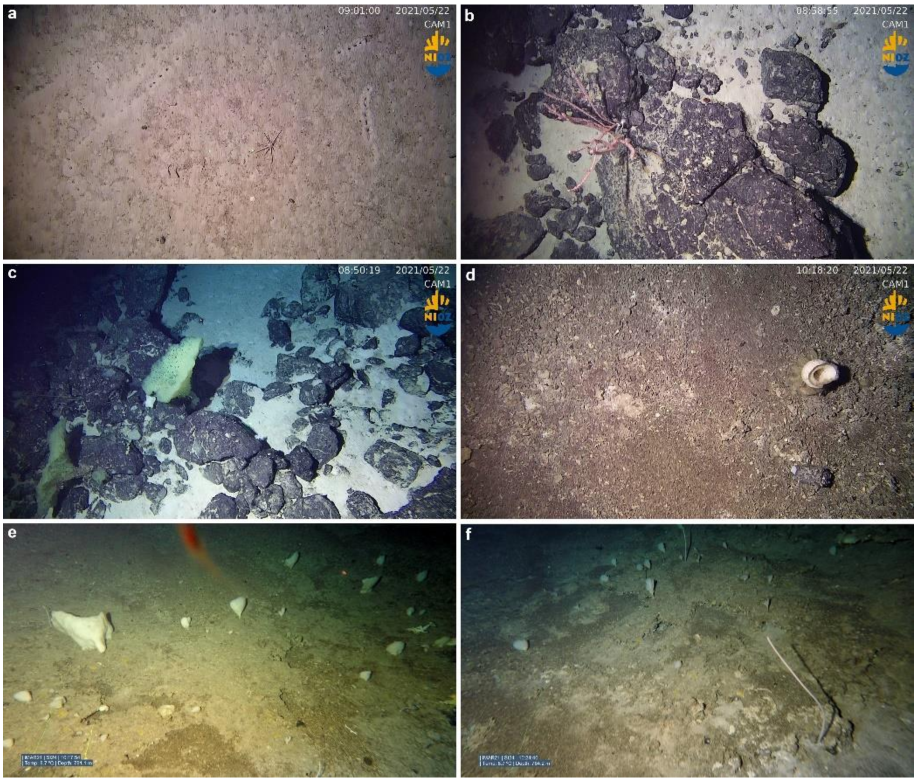


**Figure 222** Selected images representative of the main structuring species and benthic communities observed in Isolado seamount. (a) A sea urchin of the species *Cidaris cidaris* on soft sediment, surrounded by several "lebensspuren". (b) Bamboo coral over large basaltic boulders. (c-d-e) Large-sized sponges, including the hexactinellids *Hertwigia falcifera* and *Pheronema carpenteri,* and the white fan-shaped sponge of the genus *Poecillastra*. (f) Colonies of the primnoid species *Narella versluysi* scattered along the surveyed areas. Image credits: Eurofleets+ iMAR cruise, IMAR/Okeanos-UAz.

*Kurchatov SE (former Southeast Kurchatov Europe)*

In the Kurchatov Southeast area, 6 underwater video transects were performed between 580 and 1020 m depth (Figure 223). A total of 66 taxa were determined from the images, of which 46 were identified at the species level, revealing that a medium diversity of deep-sea megabenthic species is supported in this area. Based on weighted occurrences, the most frequently observed taxa include *Acanella arbuscula* (n= 33), *Parantipathes hirondelle* (n= 30), and *Anthomastus/Pseudoanthomastus* sp. (n= 25).

The slopes of the surveyed peaks were mostly of sedimentary origin, with some coral rubble and a few basaltic outcrops and vertical walls. Most of them hosted diverse benthic communities with patches of abundant coral gardens *Narella versluysi* and *Narella bellissima* (Figure 224b,c). Sometimes *N. versluysi* occurred in aggregation with *Callogorgia verticillate* (Figure 224c). Other frequent species spotted included the scleractinian *Leptopsammia formosa*, the soft coral *Anthomastus/Pseudoanthomastus* sp*.* and occasional aggregations from the bamboo coral *Acanella arbuscula* (Figure 224d) at greater depths or from the gorgonians of the genus *Acanthogorgia* spp. on shallower sections. In lower densities we observed *Hemicorallium niobe*, *Viminella flagellum* (between 825 and 489m deep), and the black corals *Leiopathes* cf. *expansa* and *Parantipathes hirondelle.* A particularly tall vertical wall was observed (of about 230m), hosting a variety of different species such as an extensive aggregation of corals of the genus *cf. Candidella* sp. (Figure 224a), *Desmophyllum dianthus*, *Dendrophyllia cornigera*, and various soft corals. Basaltic outcrops were mainly colonized by encrusting sponges, but we also noticed some occasional larger demospongia such as *Characella pachastrelloides*, *Maccandrewia azorica*, *Petrosia crassa,* and *Desmacella grimaldii*. Some sparsely ditributed glass sponges like *Pheronema carpenteri* and *Regadrella phoenix* were also observed, as well as some fan-shaped sponges likely from the species *Phakellia ventilabrum*. Sea-urchins (e.g., *Echinus melo* and *Cidaris cidaris*), decapods (e.g., *Paromola cuivieri* and *Chaceon affinis*), and various fish species such as *Lophius piscatorius, Mora moro, Helicolenus dactylopterus*, shoals of *Hoplostethus mediterraneus, Neocyttus helgae*, and others were also recorded.

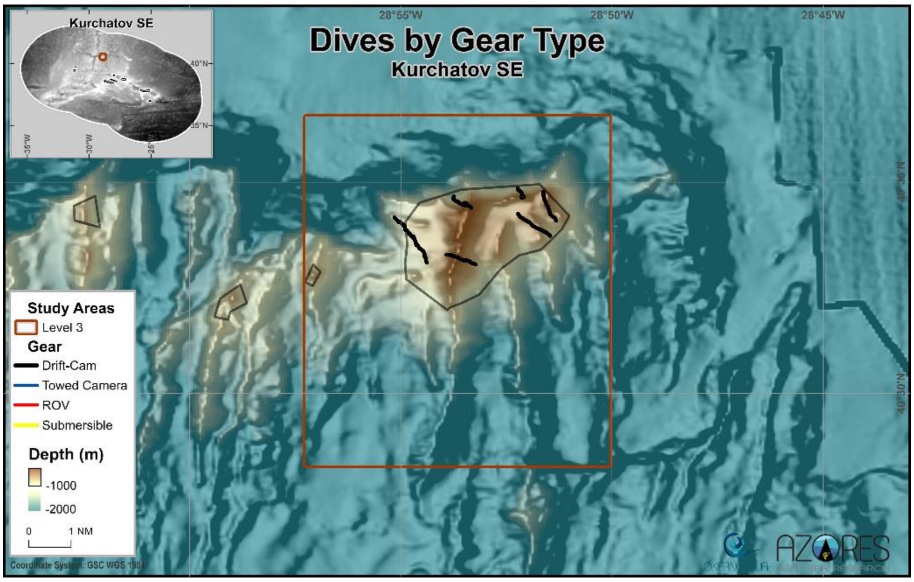



**Figure 223** Map displaying the 6 underwater dives performed in the Kurchatov SE area between 580 and 1,020 meters depth.

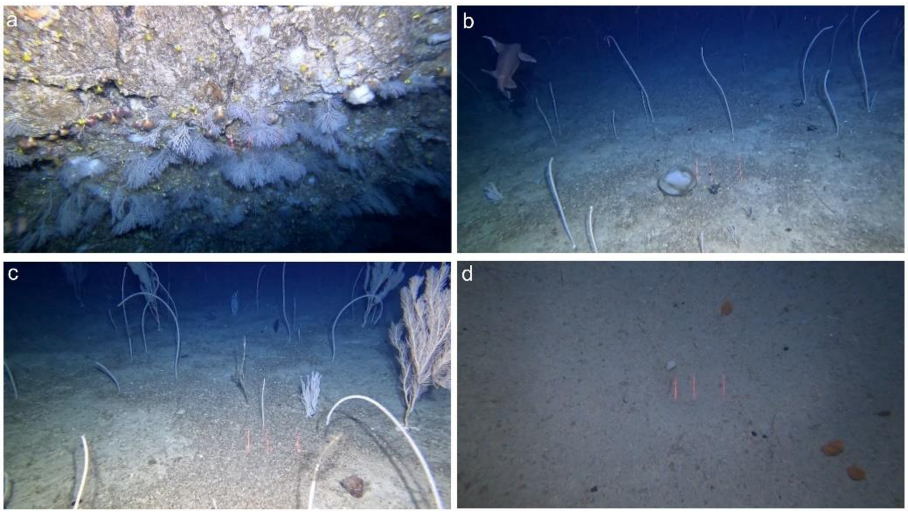



**Figure 224** Selected images representative of the main structuring species and benthic communities observed in Kurchatov Southeast area. (a) Large aggregation of cf. *Candidella* sp. on a vertical wall. (b) Aggregation of *Narella verluysi* and *N. bellissima* along with the sponge *Asconema fristedti* and a rare sighting of the sailfin roughshark, *Oxynotus paradoxus* (c) Coral aggregation of *Callogorgia verticillata, Narella verluysi* and *Narella bellissima.* (d) Small and disperse *Acanella arbuscula* on soft bottom. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Kurchatov SW (former South Kurchatov America)*

The exploration of the Kurchatov Southwest area involved 6 underwater video transects between 570 and 1240 m depth (Figure 225). A total of 76 taxa were determined from the footage, of which 44 were identified at the species level, revealing a high diversity of deep-sea megabenthic species in this area. Based on weighted occurrences, the dominant taxa include *Leiopathes* cf. *expansa* (n= 47), Plesionika (n= 42), and *Cidaris cidaris* (n= 38).

An impressively dense coral garden of large black corals of *Leiopathes* cf. *expansa* was recorded at the 1,000 m depth layer (Figure 226a,b), with other arborescent corals associated to this species, such as orange plexaurids from the family Paramuriceidae (Figure 226b), black corals *Bathypathes* spp. (Figure 226c) and cf. *Tylopathes* sp. (Figure 226d). *Acanella arbuscula* and *Chrysogorgia* sp. were also reported. In this area, the substrate was mainly characterized by rock outcrops and large boulders, with coral framework and thick deposits of coral rubble found throughout the dive. Under the coral framework, some live patches of the scleractinians *Lophelia pertusa*, *Madrepora oculata* and *Leptopsammia formosa* were observed, attached to the dead coral remains. Large hexactinellids were abundant, specially *Chonelasma* sp. (Figure 226f), *Hertwigia falcifera* and *Pheronema carpenteri.* Smaller species such as *Aphrocallistes* sp., *Farrea* sp. and euplectellids were found under the coral Framework, increasing the overall diversity of the area. The oreo fish *Neocyttus helgae* and the Atlantic wreckfish *Polyprion americanus* were also reported.

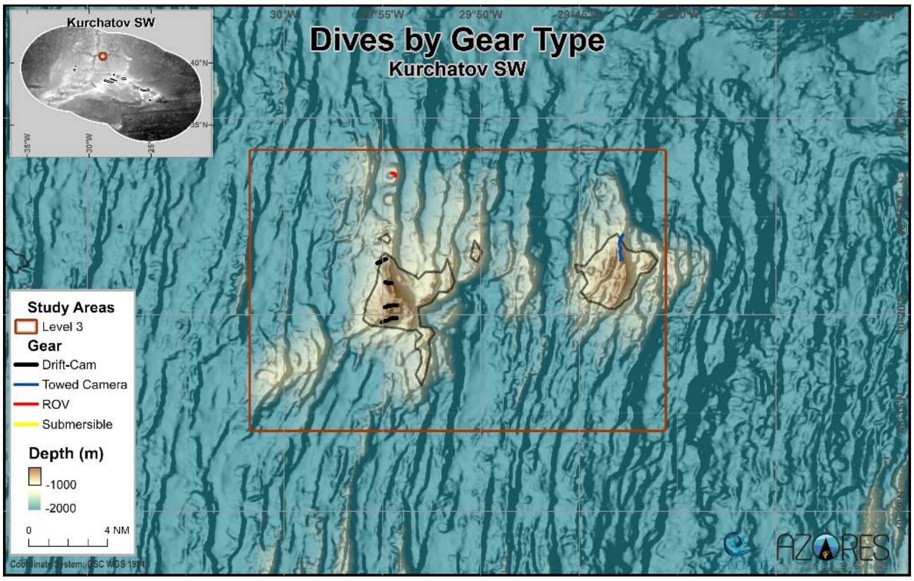



**Figure 225** Map displaying the 6 underwater dives performed in the Kurchatov SW area between 570 and 1,240 meters depth.

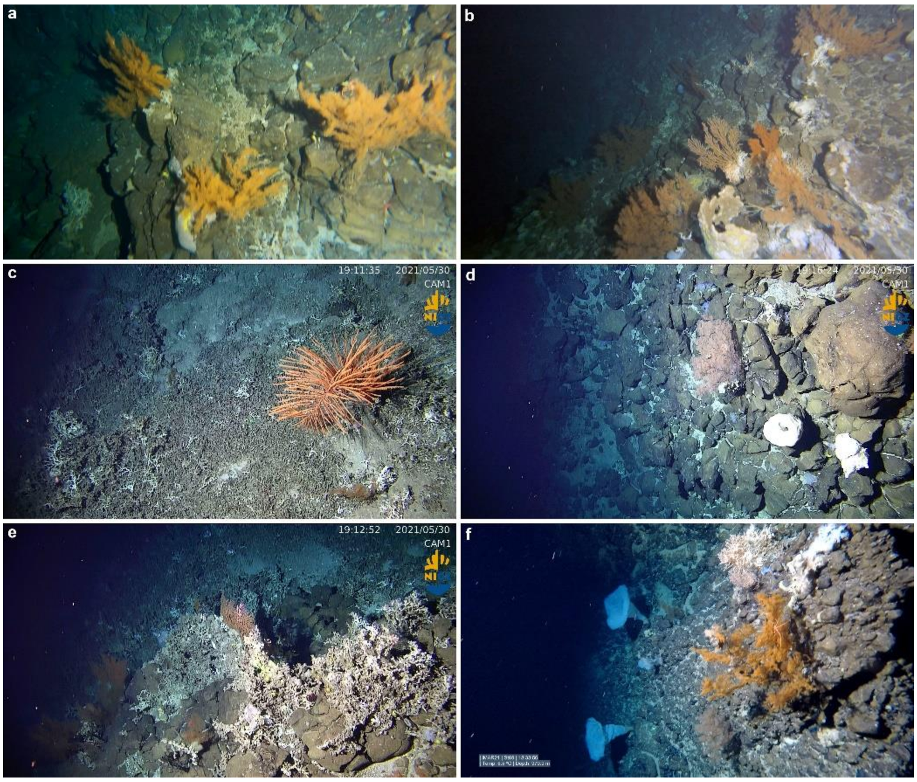


**Figure 226** Selected images representative of the main structuring species and benthic communities observed in the South Kurchatov America area. (a-b) The VME indicator species *Leiopathes* cf. *expansa* was observed reaching large sizes and in some areas with relatively high abundances. (c-d) Other genus of black corals observed: *Bathypathes* sp. and cf. *Tylopathes* sp. (e) Dead coral framework used as substrate for attachment by many species. (f) Large hexactinellids likely from the genus *Chonelasma*. Image credits: Eurofleets+ iMAR cruise, IMAR/Okeanos-UAz.

*Kurchatov S (former South Kurchatov Europe)*

In the Kurchatov South area, 3 underwater video transects were conducted between 510 and 1040 m depth (Figure 227). A total of 106 taxa were determined from the video footage, of which 64 were identified at the species level, indicating a high diversity of deep-sea megabenthic species in this area. Based on weighted occurrences, the most frequently observed taxa include *Acanella arbuscula* (n= 79), *Desmacella grimaldii* (n= 67), and *Cidaris cidaris* (n= 55).

At the deepest areas explored (approx. 1,000 m), the seafloor was covered with coral rubble colonized by *Acanella arbuscula* and *Chrysogorgia* sp. (Figure 228a). Extensive areas showed a high percentage cover of dead coral framework, with the scleractinian corals *Lophelia pertusa* and *Madrepora oculata* with some alive tips, identified by their orange colour (Figure 228b). On several occasions, the ophiuroid *Gorgonocephalus caputmedusae* (Figure 228c) was observed attached to the top of those structures. When the seabed had a complex relief, with outcropping rocks creating overhangs and small vertical walls, the diversity of coral species was highest, with the presence of black corals, especially *Leiopathes* cf. *expansa*, but also other octocoral species such as orange plexaurids from the family Paramuriceidae, the bubblegum coral *Paragorgia johnsoni* (Figure 228d), the coralliid *Hemicorallium niobe* and the bamboo corals *Keiratoisididae*. The benthic community at the 700 m depth layer was characterized by the primnoids *Narella versluysi* and *Callogorgia verticillata,* and the nest sponge *Pheronema carpenteri*, both generally found in relatively low numbers. Shallower than 600 m depth, the community started to change to that dominated by the octocorals *Viminella flagellum* and *Acanthogorgia* spp., in some areas with this last species reaching very high densities (Figure 228f). In terms of mobile fauna, some squids and octopus were filmed, as well as cardinal fishes of the genus *Epigonus* and interestingly a rarely observed deep-sea shark of the genus *Pseudotriakis*. An aggregation of the silver roughy *Hoplostethus mediterraneus* was observed, together with a large deep-sea shark of the species *Dalatias licha*.

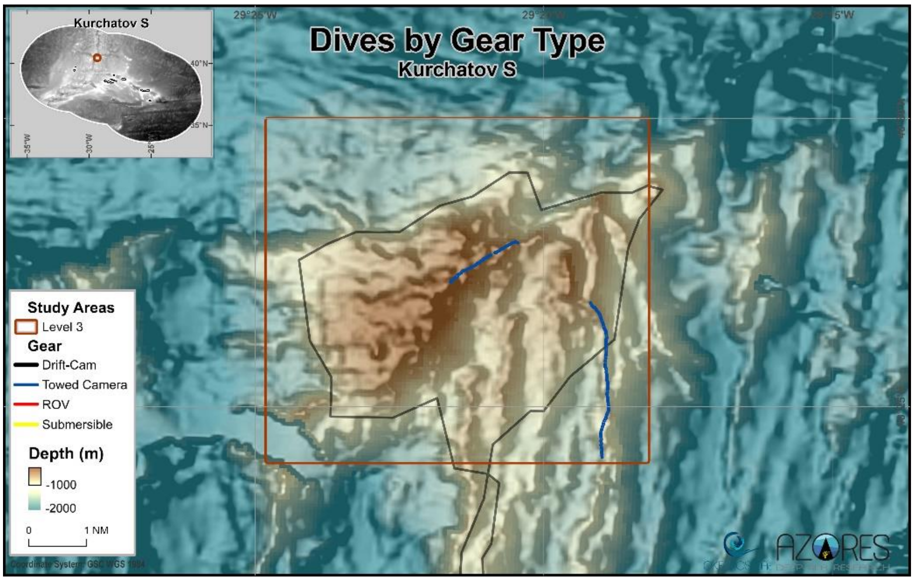



**Figure 227** Map displaying the 3 underwater dives performed in the Kurchatov S area between 510 and 1,040 meters depth.

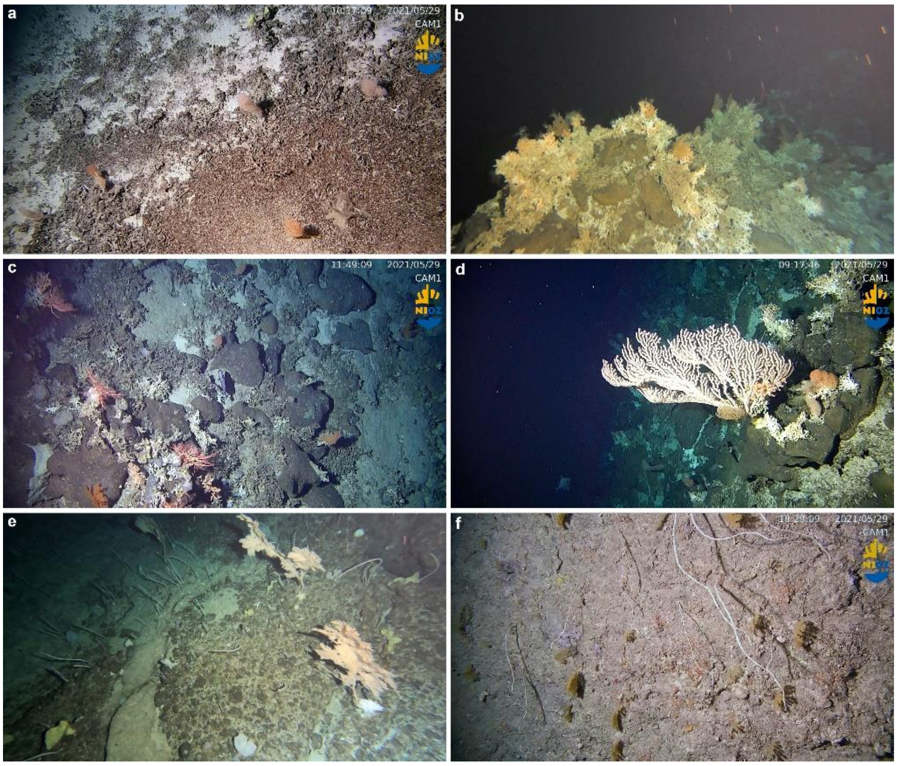



**Figure 228** Selected images representative of the main structuring species and benthic communities observed in the South Kurchatov Europe area. (a) Colonies of the bamboo coral *Acanella arbuscula* and the gorgonian *Chrysogorgia* sp. on coral rubble. (b) Dead coral framework with some alive colonies. (c) Large ophiuroids *Gorgonocephalus caputmedusae*

attached to the coral framework. (d) Very large colony of *Paragorgia johnsoni*. (e) *Narella versluysi* in high densities with *Callogorgia verticillata*. (f) The octocorals *Viminella flagellum* and *Acanthogorgia* sp. dominated shallower areas. Image credits: Eurofleets+ iMAR cruise, IMAR/Okeanos-UAz.

*Agulhas Corvo-Graciosa (a.k.a West of Oscar)*

In the Agulhas Corvo-Graciosa area, 3 underwater video transects were conducted between 680 and 1060 m depth (Figure 229). A total of 77 taxa were determined from the analysis of the recorded footage, of which 44 were identified at the species level, revealing a high diversity of deep-sea megabenthic species in this area. Based on weighted occurrences, the major observed taxa include *Cidaris cidaris* (n= 54), *Acanella arbuscula* (n= 49), and *Pheronema carpenteri* (n= 47).

The ridges at the Agulhas Corvo-Graciosa America sampling area present a complex relief, with rock-dominated habitats with a high diversity of species, especially cold-water corals. The area hosts extensive areas colonized by large black corals *Leiopathes* cf. *expansa*, in some areas with high reported abundances (Figure 230a). Highest densities were generally observed in areas of rocky outcrops and complex relieves, where also the scleractinian (Figure 230b) coral *Madrepora oculata* and species of stylasterids had a suitable substrate to attach, creating coral framework that enhances diversity. Attached to these rocky outcrops, several other species were documented, including large *Paragorgia johnsoni*, *Hemicorallium tricolor*, diverse plexaurids of the family Paramuriceidae, the black corals *Bathypathes* sp. and *Parantipathes hirondelle*, stylasterids and soft hydrozoans (Figure 230c,d). In between these high-relief areas, where softer sediments were observed, other species were dominant, sometimes even highly abundant, such as *Acanella arbuscula* and *Chrysogorgia* sp. A high diversity of hexactinellids sponge species was reported, such as the large cup-like *Chonelasma* sp., *Hertwigia falcifera*, *Regadrella* cf. *phoenix*, *Asconema* sp. and *Pheronema carpenteri* (Figure 230e,f). Regarding Demospongiae, the presence of massive Geodia sp. and the white lamellate *Phakellia* spp. were commonly observed. At shallower areas, the community represented by the primnoid *Narella versluysi* was dominant, together with the nest sponge *Pheronema carpenteri*. Several orange roughy *Hoplostethus atlanticus* were reported at the area.

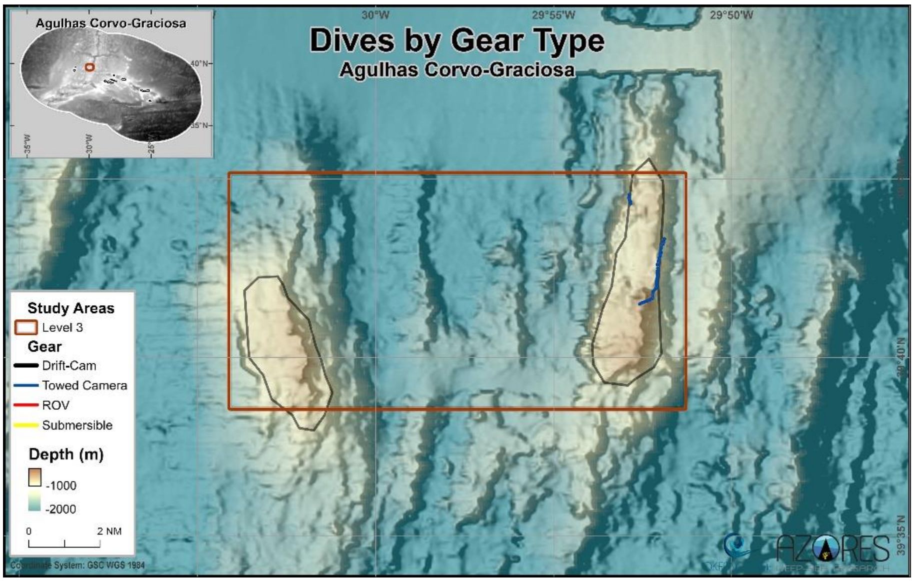



**Figure 229** Map displaying the 3 underwater dives performed in the Agulhas Corvo-Graciosa area between 680 and 1,060 meters depth.

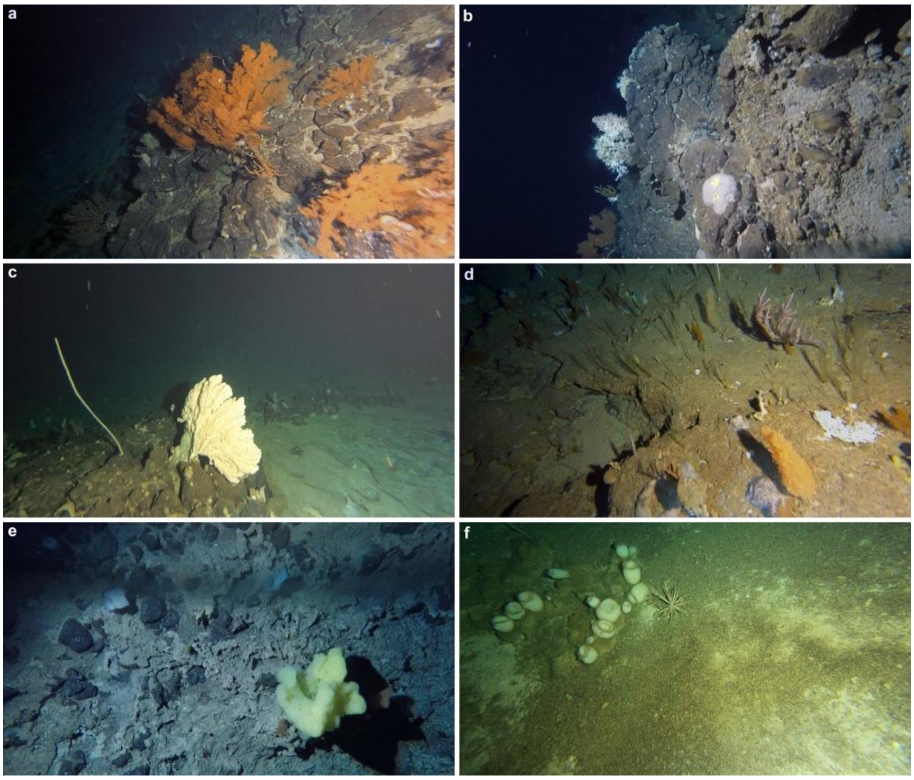



**Figure 230** Selected images representative of the main structuring species and benthic communities observed in the Agulhas Corvo-Graciosa area. (a) Large colonies of the black coral *Leiopathes* cf. *expansa*. (b) Scleractinian corals on rocky outcrops. (c) Large colony of the bubblegum coral *Paragorgia johnsoni.* (d) Diverse community composed of bamboo corals, gorgonians, stylasterids and hydrozoans. (e) The glass sponge *Hertwigia falcifera* (f) *Pheronema carpenteri* was observed forming some high-density patches. Image credits: Eurofleets+ iMAR cruise, IMAR/Okeanos-UAz.

*Óscar*

Investigating the Óscar seamount area, 15 underwater video transects were performed between 560 and 720 m depth (Figure 231). A total of 90 taxa were determined from the video footage, of which 55 were identified at the species level, revealing that a high diversity of deep-sea megabenthic species is supported in this area. The most frequently observed taxa based on weighted occurrences, include *Peltaster placenta* (n= 93), Acanthogorgia spp. (n= 90), and *Parantipathes hirondelle* (n= 78). Oscar seamount is an elongated seamount that stretches for more than 12 km following an E-W direction.

Four coral-dominated benthic communities were identified in the images, distributed along the upper part of the slope and the summit area. The most discernible community in hard substrates corresponded to that of the primnoid coral *Callogorgia verticillata* (Figure 232a), forming dense aggregations in some areas that spread along several tens of meters. Interestingly, numerous colonies were observed displaying very large sizes, above 1 m in height. Although some abandoned fishing lines were observed, not many signs of fishing impacts were detected, with the colonies retaining all or most of their branches intact or in good condition. The species was often observed in association with a few other smaller species that colonize the hard substrate available, such as small soft corals. It was very common to find the cup coral *Leptopsammia formosa* generating some very high-density patches, together with other soft-coral species, the cup coral *Desmophyllum dianthus* and various encrusting sponges (Figure 232b). The association between *Callogorgia verticillata* and the primnoid corals *Narella bellissima* and *Narella versluysi* was also commonly observed, especially at depths of 650-700 m depth. In some areas of hard substrates of the upper slope and summit, aggregations of the yellow sea fan of the genus *Acanthogorgia* reached very high densities (Figure 232c). Colonies placed themselves with their branches oriented in the same position, most likely to maximize food intake. Another commonly observed species association corresponded to the small white coral *Pleurocorallium johnsoni* and a yellow lamellate sponge, which mainly appeared on hard substrates of the slope. Some of the species identified within this community correspond to the soft coral *Anthomastus/Pseudoanthomastus* sp. and the black corals *Stichopathes gravieri* and *Parantipathes hirondelle* (Figure 232d). A yellow sea star of the Goniasteridae family (likely from the species *Peltaster placenta*) was also commonly observed along the rocky outcrops of the slope (Figure 232d), sometimes in aggregations of 3-5 specimens. On some summit areas, whip corals of the species *Viminella flagellum* were reported, forming aggregations with large porifera (e.g., *Characella pachastrelloides*). The presence of deposits of coral rubble in Oscar seamount was also commonly observed, with fragments varying in size and frequency across the different areas explored (Figure 232e). Not many megabenthic invertebrates were reported from the video footage in areas of coral rubble deposits. Soft-bottom areas found in between the coral deposits, mainly composed of sand and small gravels, were colonized by scleractinians of the genus *Flabellum*.

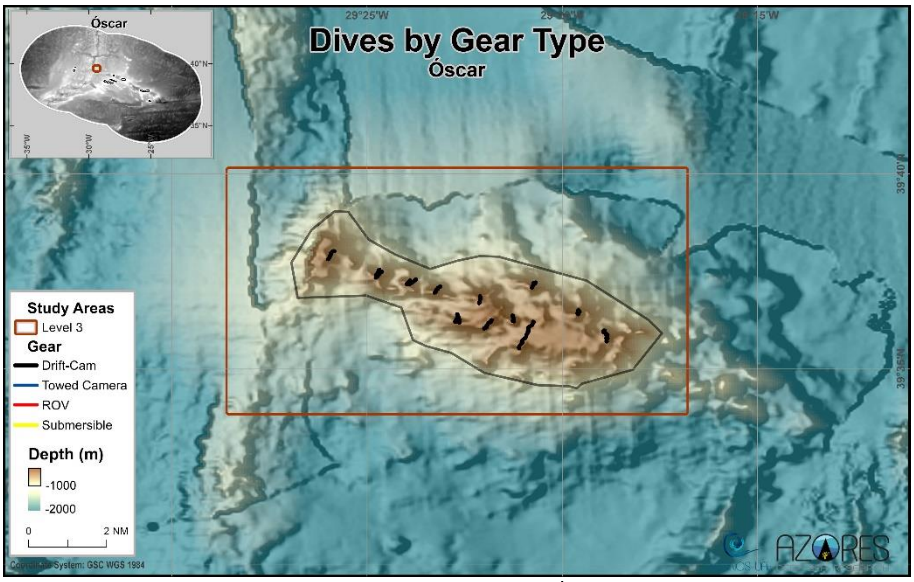



**Figure 231** Map displaying the 15 underwater dives performed in the Óscar area between 560 and 720 meters depth.

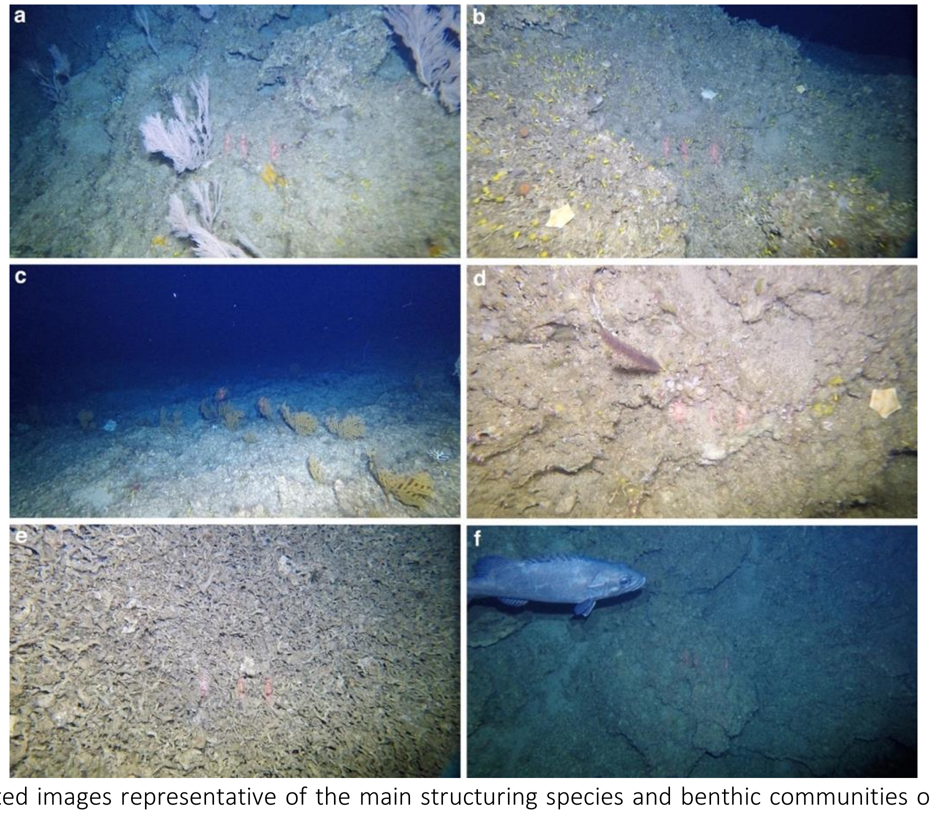



**Figure 232** Selected images representative of the main structuring species and benthic communities observed in Óscar seamount. (a) Large *Callogorgia verticillata* on hard substrates, one of the main VME indicator taxa observed in this seamount. (b) Outcropping rock colonized by the cup coral *Leptopsammia formosa*. (c) Dense patch of the sea fan *Acanthogorgia* sp. on the summit area. (d) Colony of the black coral *Parantipathes hirondelle*, a VME indicator taxa observed on the sloping hard grounds. (e). Large deposits of coral rubble. (f) A fish of the species *Polyprion americanus* gently swimming in front of the camera. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

### *10.3 Large area | Central Mid-Atlantic Ridge*

The area Central Mid-Atlantic Ridge contains 3 study areas: Gigante, Cavala and Picos SE Flores, and a total of 16 sampling areas (Figure 233). All 16 sampling areas have been explored with the towed-camera system of the R/V Pelagia during the Eurofleets+ iMAR cruise (2021 and 2022), with the Luso ROV on board of the NRP Gago Coutinho during the Blue Azores cruise (2018) and with the Azor drift-cam during the MapGES 2019 and the MapGES 2022 survey.

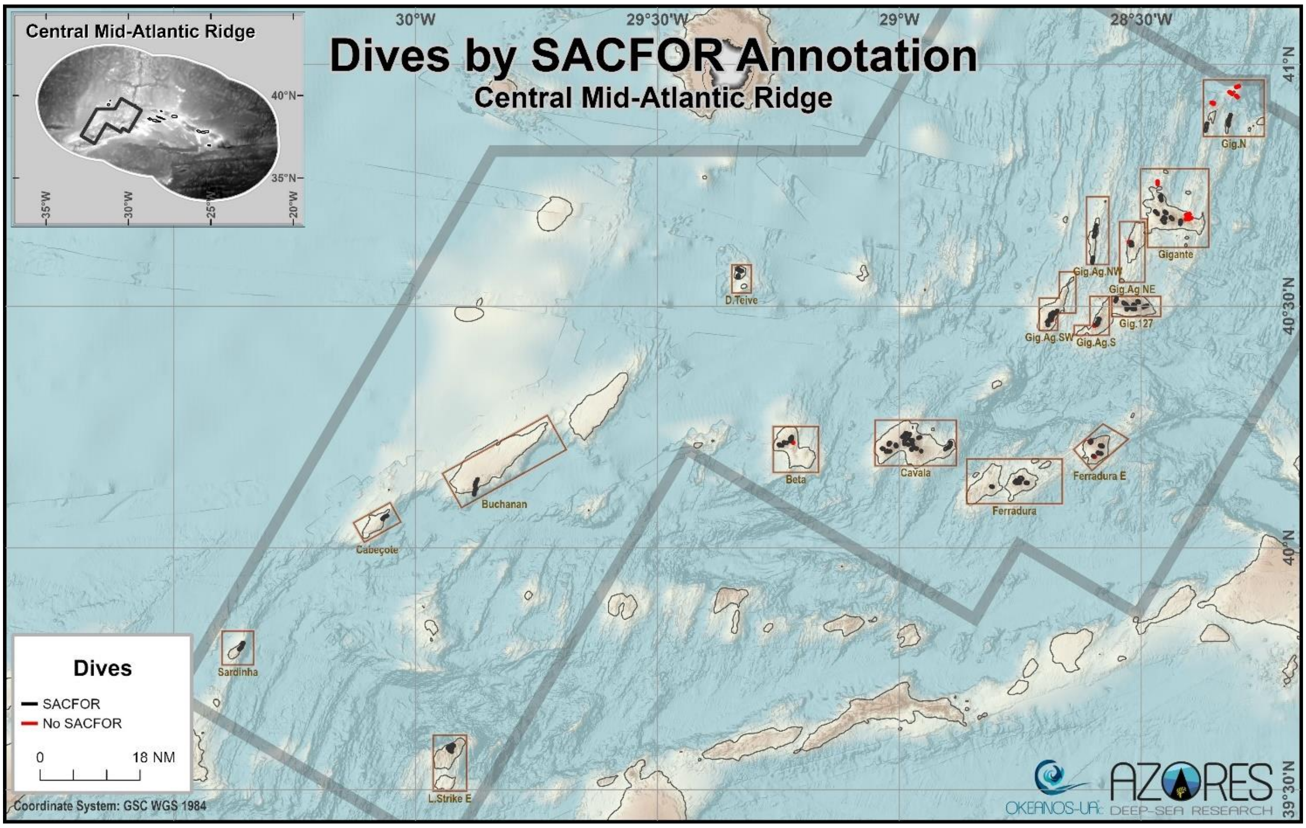


**Figure 233** Central Mid-Atlantic Ridge sampling areas (Level 3) with or without SACFOR dive locations.

#### Study area | Gigante

*Gigante N (former D6 - unnamed seamount-like structure)*

Exploring Gigante North area, 8 underwater video transects were conducted between 820 and 1430 m depth (Figure 234). A total of 88 taxa were determined from the video images, of which 49 were identified at the species level, indicating a high diversity of deep-sea megabenthic species in this area. Prominent taxa based on weighted occurrences include *Cidaris cidaris* (n= 80), *Acanella arbuscula* (n= 68), and *Pheronema carpenteri* (n= 50).

The deepest areas explored in Gigante N seamount (approx. 1,400 m) were characterized by flat or low-sloping bottoms with soft sediments, frequently colonized by sea urchins of the species *Cidaris cidaris* and ceriantharians. Areas with more consolidated sediments generated some dense aggregations of the lace coral *Pliobothrus symmetricus* (Figure 235a) and the small coralliid *Pleurocorallium johnsoni,* in association with an axineliid sponge of the genus *Phakellia* alongside other small sponges. The octocoral *Acanella arbuscula* was also commonly observed, likely representing the most common species of the megafauna in the dives analysed, together with *Chrysogorgia* sp. (Figure 235b). In areas of hard substrates with outcropping rocks, the abundance and diversity of species was high. Especially relevant was the dense aggregations of the stylasterid *Errina* cf. *atlantica*, accompanied by the octocoral *Acanella arbuscula*, the sea urchin *Cidaris cidaris* and a few glass sponges. Several other species of corals were generally observed along the dive as accompanying fauna, always in low numbers, such as the black coral *Leiopathes* cf. *expansa* and the octocorals *Paragorgia johnsoni*, Keratoisididae*, Pleurocorallium johnsoni* and several plexaurids of the Paramuriceidae family yet to be identified to species level (Figure 235c,d). Also interesting was the number of glass sponges observed throughout the slopes, including *Chonelasma* sp., *Hertwigia falcifera* (Figure 235e), *Farrea* sp., *Pheronema carpenteri* and *Asconema* sp.. Soft hydrozoans appeared in dense aggregations, a sighting not commonly observed elsewhere. Slightly above the 800 m depth, a very dense community composed of the *Narella bellissima* and *N. versluysi* (Figure 235f) together with *Phakellia* spp. colonized the hard substrate, either on the top of the crest and on the adjacent slopes. A few orange roughy *Hoplostethus atlanticus* and deep-sea sharks of the species *Dalatias licha* were observed.

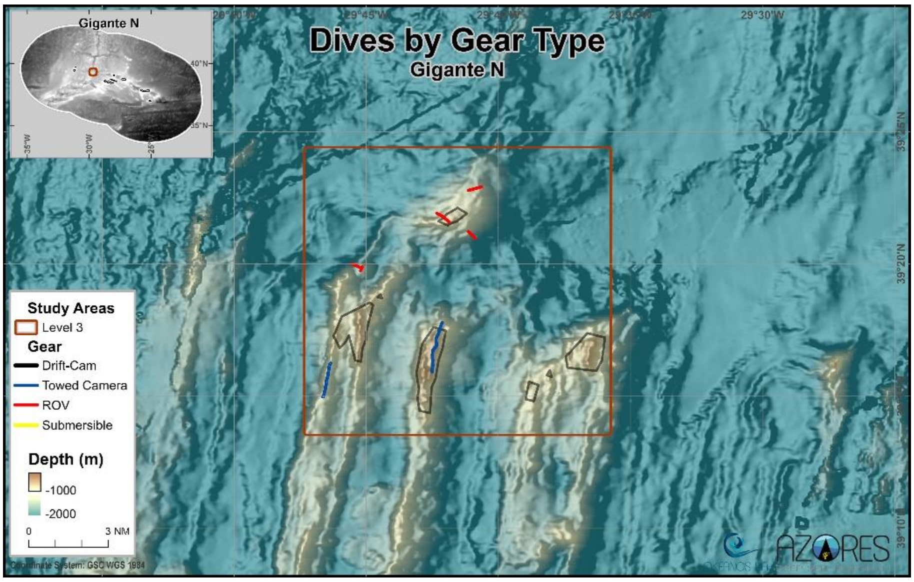



**Figure 234** Map displaying the 8 underwater dives performed in the Gigante N area between 820 and 1,430 meters depth.

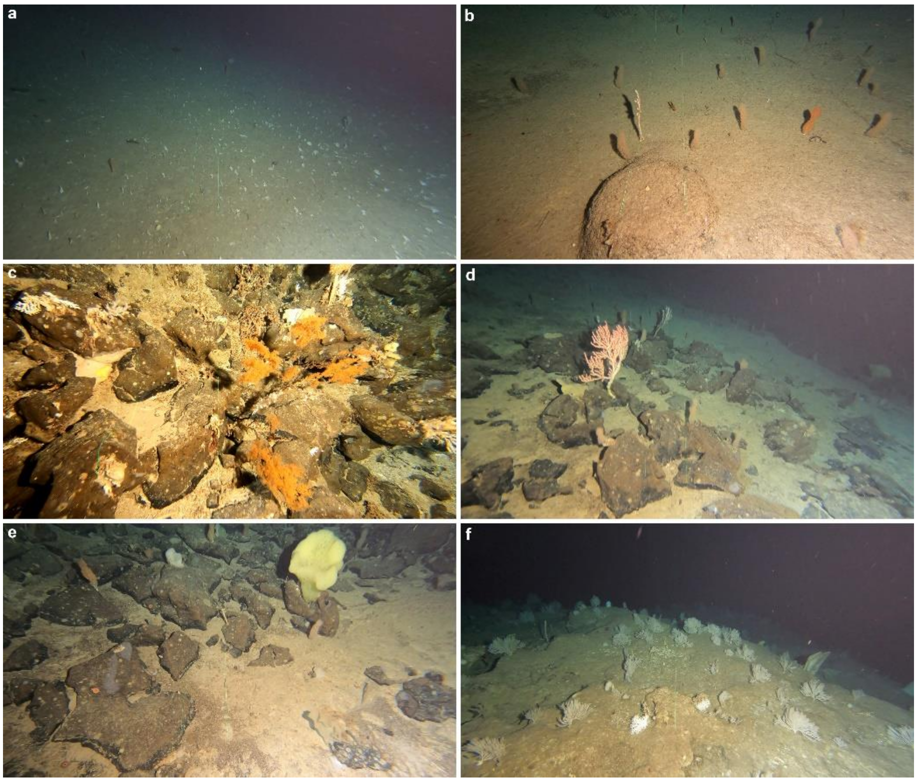



**Figure 235** Selected images representative of the main structuring species and benthic communities observed in the D6 area. (a) Aggregations of the lace coral *Pliobothrus symmetricus*. (b) The bamboo coral *Acanella arbuscula,* one of the most commonly observed VME indicator species in this area, found in association with the octocoral *Chrysogorgia* sp. (c-d) The VME indicator species *Leiopathes* cf. *expansa* and *Paragorgia johnsoni,* found with plexaurids and bamboo corals. (e) A large specimen of hexactinellid from the species *Hertwigia falcifera*. (f) A dense aggregation of *Narella bellissima* and *N. versluysi,* both included as VME indicator taxa. Image credits: Eurofleets+ iMAR cruise, IMAR/Okeanos-UAz.

*Gigante*

Surveying the Gigante area involved 13 underwater video transects between 190 and 1180 m depth (Figure 236). A total of 135 taxa were determined from the footage, of which 71 were identified at the species level, revealing in this area a very high diversity of deep-sea megabenthic species. Notable taxa based on weighted occurrences include *Viminella flagellum* (n= 139), *Acanthogorgia* spp. (n= 101), and *Echinus melo* (n= 92).

The deepest sector explored on the north-eastern flank (730-600 m) alternated detritic bottoms (with scarce presence of solitary corals) and several types of hard substrates. Lithic rocks hosted the highest diversity of organisms, although not at very high densities. *Narella* spp. (only below 650 m), *Callogorgia verticillata*, *Acanthogorgia* spp., *Pleurocorallium johnsoni* and soft corals of the genus *Anthomastus*/*Pseudoanthomastu*s sp. were found scattered around the lithic substrate, occasionally forming denser aggregations. In some areas, they were in association with glass sponges of the genus *Asconema* and *Regadrella,* as well as corals like *Pleurocorallium johnsoni*, small *Paragorgia johnsoni* and, to a lesser extent, *Acanthogorgia* spp., *Anthomastus*/*Pseudoanthomastu*s sp. and *Gersemia* sp. Crumbled lava balloons showed a lower diversity, with visible organisms limited to small Porifera and Antipatharia (*Parantipathes hirondelle* and *Stichopathes gravieri*). Between 600-550 m, *Paragorgia johnsoni* in the red and white morphs became abundant, reaching considerable sizes especially on slopping areas. The hydrothermal vent field Luso (Figure 237d) was discovered during the Blue Azores survey at around 570 m depth, where little associate megafauna was observed in its immediate proximity besides some large cirripeda.

The deepest zone on the south-eastern flank (730-620 m) mostly consisted of detritic beds colonized by *Flabellum* species, while sparse boulders presented coral assemblages of moderate diversity, similar to the deepest part of the north-eastern flank. Fields of the sponge *Pheronema carpenteri* inhabited at 650-700 m depth. Moving shallower, larger sponges such as *Leiodermatium* sp., *Characella pachastrelloides*, *Neophrissospongia nolitangere* and other arborescent species became common. Coral aggregations dominated above 390 m. At this and shallower depths, the most prominent aggregating coral species were *Callogorgia verticillata*, *Candidella imbricata*, *Dentomuricea* aff. *meteor, Acanthogorgia* spp. and *Viminella flagellum* (Figure 237a,b).

The deepest zone explored on the north-western flank (730-690 m) presented characteristic aggregations of the Primnoidae species *Narella versluysi* and *Narella bellissima*, mixed with *Pleurocorallium johnsoni*, yellow lamellate sponges of the species *Desmacella grimaldi*i, *Anthomastus*/*Pseudoanthomastu*s and, more rarely, with the sponge *Pheronema carpenteri*. Above 690 m depth, *Narella* species became rarer; benthic aggregations presented increasing abundances of small globular and incrusting sponges, as well as larger species such as *Characella pachastrelloides* and *Neophrissospongia nolitangere*. Above 550 m, the octocoral species *Viminella flagellum*, *Acanthogorgia* sp. and *Pleurocorallium johnsoni*, together with *Characella pachastrelloides*, were dominant. Above 450 m, the scleractinian *Enallopsammia rostrata* (Figure 237c) substituted *Pleurocorallium johnsoni,* while above 400 m depth, large colonies of *Dentomuricea* aff. *meteor* and the sponge *Leiodermatium* sp. became common.

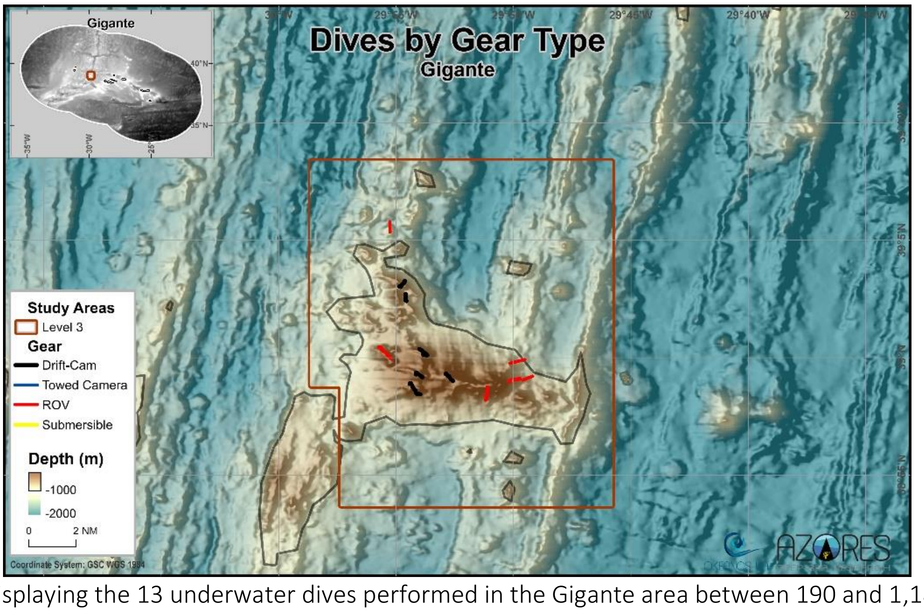



**Figure 236** Map displaying the 13 underwater dives performed in the Gigante area between 190 and 1,180 meters depth.

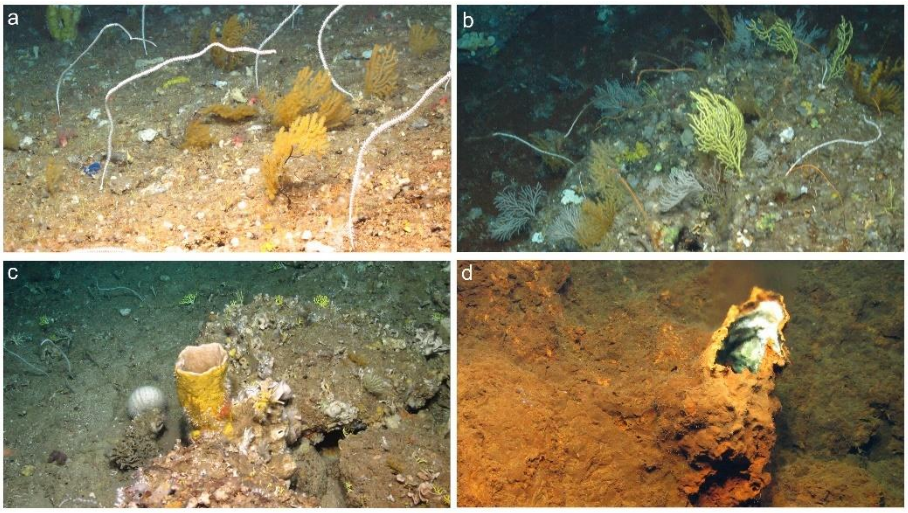



**Figure 237** Selected images representative of the main structuring species and benthic communities observed in Gigante seamount. (a) Aggregation of small *Viminella flagellum* together with *Acanthogorgia* sp. on a hard substrate covered with small and encrusting sponges. (b) Assemblage of several gorgonian corals, including two morphotypes of *Viminella flagellum, Dentomuricea* aff. *meteor* and *Acanthogorgia* sp., and small and encrusting sponges. (c) Hard substrate densely colonized by several corals species, including *Viminella flagellum* and the scleractinian *Enallopsammia rostrata* and a wide variety of sponges, including *Characella pachastrelloides* and *Petrosia* sp. (d) Hydrothermal vent. Image credits: ROV Luso/EMEPC/2018 Oceano Azul Expedition.

*Gigante Agulhas NE*

In the Gigante Agulhas Northeast area, 2 underwater video transects were performed between 590 and 800 m depth (Figure 238). A total of 41 taxa were determined from the videos recorded, of which 29 were identified at the species level, indicating that this area supports a low diversity of deep-sea megabenthic species. Dominant taxa based on weighted occurrences include *Hymedesmia (Hymedesmia) paupertas* (n= 12), *Cidaris cidaris* (n= 10), and *Echinostylinos reticulatus* (n= 9).

The Northeastern part of the Gigante Agulhas seamount complex is located on the Central Mid-Atlantic Ridge and is have a relatively deep summit at around 538m. The most often substrate was rock, with occasional walls and outcrops, as well as some soft sedimentary and coral rubble patches. On the deepest areas surveyed there was the record of the *Asteroidea Peltaster placenta* and Goniasteridae sp. on these more unconsolidated sediments, and when there were rocky outcrops, it was possible to observe several soft corals (e.g., *Anthomastus/Pseudoanthomastus* sp. and others), the gorgonian *Candidella imbricata*, and the black coral *Parantipathes hirondelle*. Attached to these hard substrates, we spotted the lamellate *Desmacella grimaldi*, *Poecillastra compressa* (Figure 239b), *Asconema* sp. (Figure 239c), *Farrea occa*, *Regadrella phoenix* and the hexactinellida *Echinostylinos reticulatus*. The presence of the sea urchins *Cidaris cidaris* and *Echinus melo* was also common (along the entire slope). A few meters up the slope, there was observed the occurrence of the hard coral *Dendrophyllia alternata*, large aggregations of *Plerurocorallium johnsoni* (Figure 239a), and the continuation of some soft corals. When climbing up to the shallowest depths, the biodiversity decreased and the bottom was mostly bare, with only some gorgonian corals *Acanthogorgia* spp., and *Pleurocorallium johnsoni* being seen.

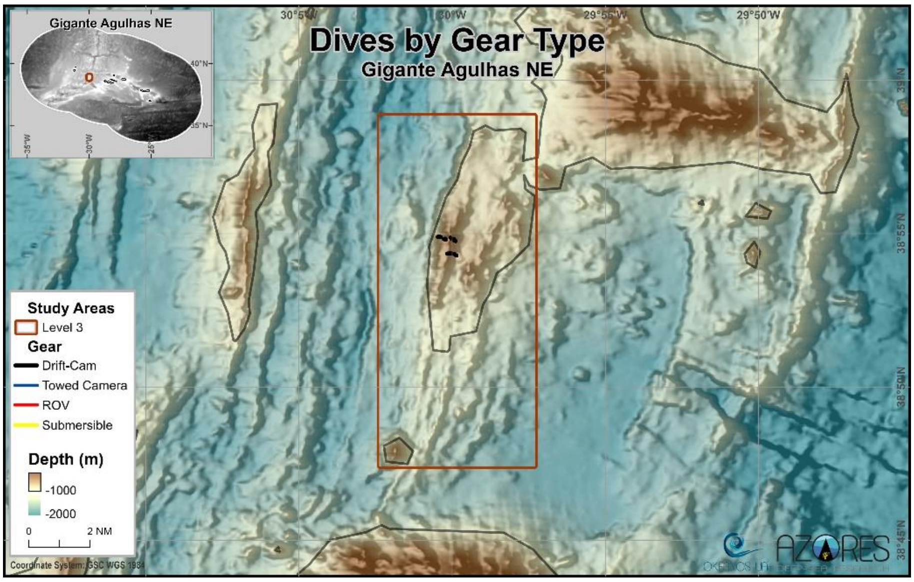



**Figure 238** Map displaying the 2 underwater dives performed in the Gigante Agulhas NE area between 590 and 800 meters depth.

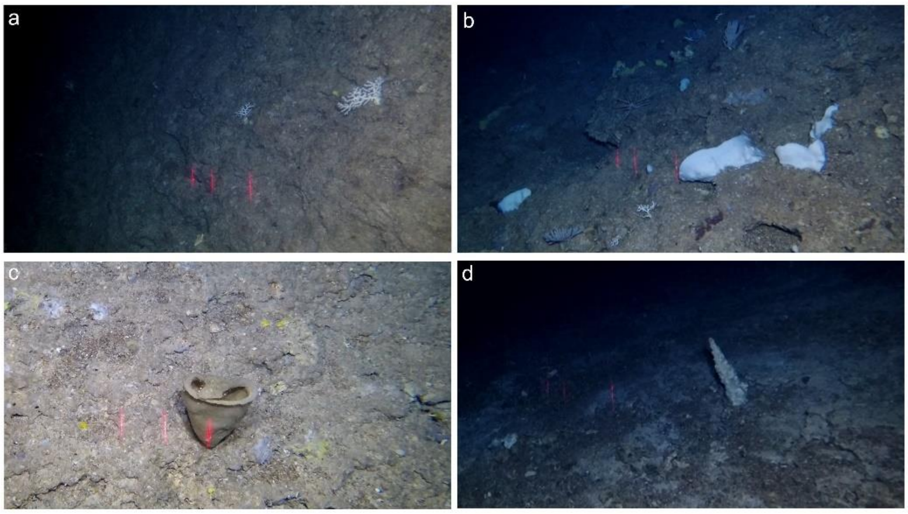



**Figure 239** Selected images representative of the main structuring species and benthic communities observed in Flores Northeast area. (a) Dispersed aggregation of *Pleurocorallium johnsoni.* (b) Basaltic bottom colonized by the lamellate sponge *Poecillastra compressa, Desmacella grimaldii* and the primnoid coral *Narella bellissima.* (c) Solitary sponge of the species *Asconema fristedti.* (d) Tubular-shape sponge. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Gigante Agulhas NW*

Exploring the Gigante Agulhas Northwest area, 2 underwater video transects were performed between 610 and 1100 m depth (Figure 240). A total of 79 taxa were determined from the video footage, of which 49 were identified at the species level, revealing a high diversity of deep-sea megabenthic species in this area. Notable taxa based on weighted occurrences include *Cidaris cidaris* (n= 69), *Acanella arbuscula* (n= 65), and *Desmacella grimaldii* (n= 61)

The most widespread coral species observed in the images was the bamboo coral *Acanella arbuscula*, which generated gardens of relatively high densities in certain areas, frequently occurring with the fan-shaped *Phakellia* spp (Figure 240a). Some hexactinellids, such as the cup shaped A*sconema* sp. (Figure 240b) were observed forming aggregations, with *Farrea occa* patching some steep walls. *Aphrocallistes* sp., *Chonelasma* sp. and *Hertwigia falcifera* had a more scattered distribution. When the rock outcropped, it was common to observe small bioconstructions made by the scleractinian corals *Lophelia pertusa* and *Madrepora oculata* (Figure 240c) and lace corals of the species *Errina* cf. *atlantica*. In those areas, several plexaurid corals from the family Paramuriceidae were observed, most of them not yet identified to species level. Large colonies of the sea fan *Paragorgia johnsoni* were present, together with other coral species such as *Hemicorallium tricolor* and orange plexaurids of the Paramuriceidae family. Associated to this community, several specimens of the ophiuroid *Gorgonocephalus caputmedusae* (Figure 240e) were found hanging on the wall, living in association with the gorgonians, which play the role of habitat forming species for these conspicuous epibionts. Very pronounced relief, sometimes in the form of vertical walls or rocky outcrops creating overhangs, was colonized by large colonies of the black coral *Leiopathes* cf. *expansa* (Figure 240f) and plexaurids of the family Paramuriceidae. The orange roughy *Hoplostethus atlanticus* was also observed in this area.

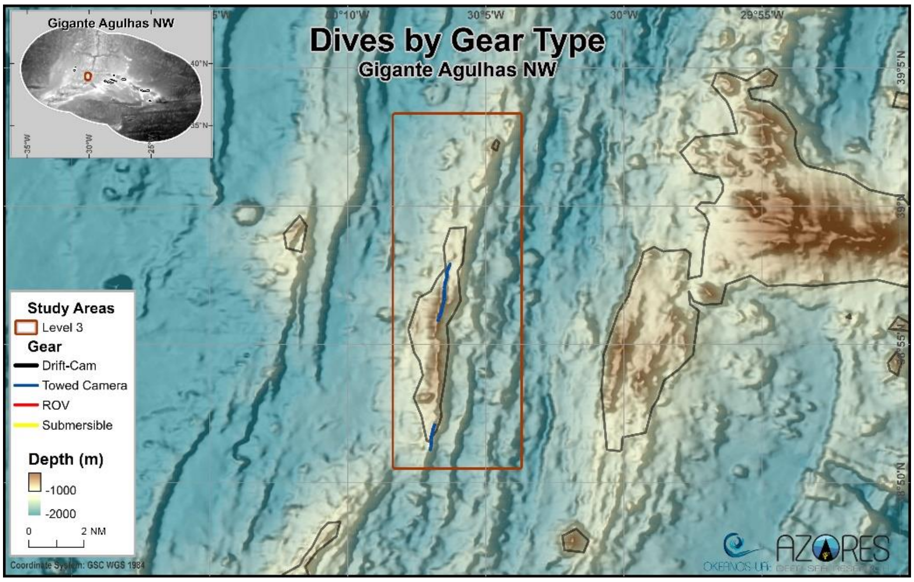



**Figure 240** Map displaying the 2 underwater dives performed in the Gigante Agulhas NW area between 610 and 1,100 meters depth.

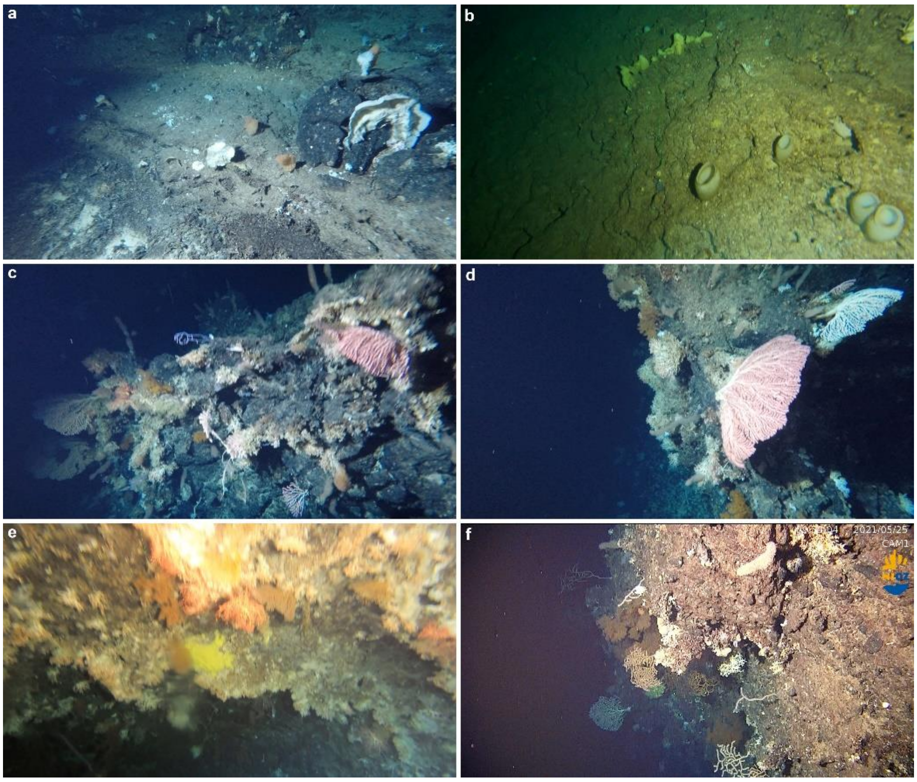



**Figure 241** Selected images representative of the main structuring species and benthic communities observed in the Gigante Agulhas NW area. (a) The bamboo coral *Acanella arbuscula* occurring alongside the fan-shaped sponge *Phakellia* spp. (b) The hexactinellid A*sconema* sp., a VME indicator species. (c) Scleractinian corals occurring with lace corals on rocky outcrops. (d) The VME indicator species *Paragorgia johnsoni* attaining large sizes. (e) Ophiuroids of the species *Gorgonocephalus caputmedusae* on steep vertical walls. (f) Black coral *Leiopathes* cf. *expansa* associated with other octocorals in areas of steep hills. Image credits: Eurofleets+ iMAR cruise, IMAR/Okeanos-UAz.

*127 Seamount*

Investigating Gigante 127 area, 10 underwater video transects were conducted between 230 and 770 m depth (Figure 242). A total of 108 taxa were determined from the footage, of which 57 were identified at the species level, revealing a high diversity of deep-sea megabenthic species in this area. Prominent taxa based on weighted occurrences include *Viminella flagellum* (n= 135), *Phlyctaenopora (Phlyctaenopora) bitorquis* (n= 63), and *Echinus melo* (n= 62).

The deepest zone explored on the southern flank (600-500 m) was characterized by sedimentary substrate colonized by several species of solitary corals of the genus *Flabellum*. The sparse rocky outcrops were of small sizes and colonized mostly by encrusting and small globular sponges (<5 cm) and, occasionally, by larger sponges. Coral colonies were scarce and mostly belonged to the families Aphanipathidae and Acanthogorgiidae. From 500 to 400 m depth, larger boulders became more frequent, associated with several species of encrusting sponges (Figure 243c) and occasional colonies of *Viminella flagellum* (Figure 243a). Soft sediments remained dominant, characterized by *Flabellum* spp. and *Macandrewia azorica*. The peak at around 360 m was characterized by more extensive rocky outcrops with a large preponderance of encrusting and globular sponges. Small Plexauridae and some large aggregations of *Viminella flagellum* (Figure 243b).

The deepest zone explored on the north-western flank (680-580 m) presented large basaltic lava balloons with the *Pleurocorallium johnsoni*, the yellow lamellate sponge *Desmacella grimaldii* and the soft corals

Anthomastus/*Pseudoanthomastus* sp.. Solitary corals and large aggregations of the fish species *Hoplostethus mediterraneus* were found at depths shallower than 610 m on soft sediments. At around 580 m, the first small colonies of the whip coral *Viminella flagellum* began to appear, forming larger and very dense patches above 550 m, and all along the summit area.

The deepest zone explored on the north-eastern flank (770-450 m) was largely sedimentary with the predominant organisms belonging to the genus *Flabellum.* The rare large boulders at these depths hosted small globular sponges and, occasionally, some coral species. Starting from 650 m, the boulders were largely covered by several species of encrusting sponges and, occasionally, by larger lithistid sponges (e.g., *Neophrissospongia nolitangere*). At around 540 m the first small colonies of *Viminella flagellum* and the soft corals *Anthomastus/ Pseudoanthomastus* sp. started to appear. From 480 m, at intermediate slopes, hard substrate became more abundant, however, possibly because of high sediment deposition, most of the colonizing organisms remained of small sizes and mainly consisted of small Porifera and little *Viminella flagellum* colonies. Moving toward shallower depths the density of sponges increases but the overall sizes remained small. The shallowest depths explored (400-300 m) were characterized by hard substrates, larger and dense patches of *Viminella flagellum*, high densities of encrusting and small globular sponges (Figure 243d), together with rarer patches of large octocorals of the species *Callogorgia verticillata* and *Candidella* cf. *imbricata*, as well as some larger flabellate and tubular sponges (e.g., *Neophrissospongia nolitangere*, *Leiodermatium* sp., *Characella pachastrelloides)*.

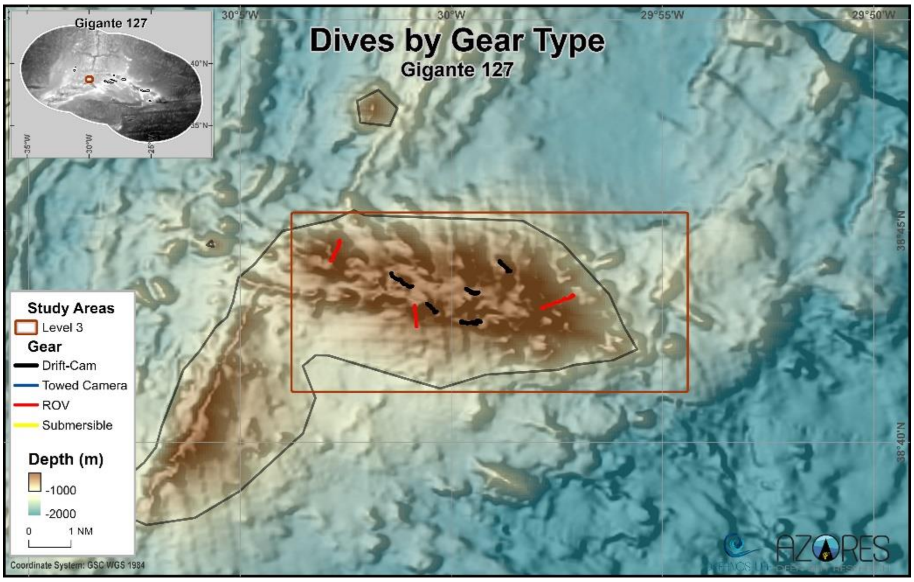



**Figure 242** Map displaying the 10 underwater dives performed in the Gigante 127 area between 230 and 770 meters depth.

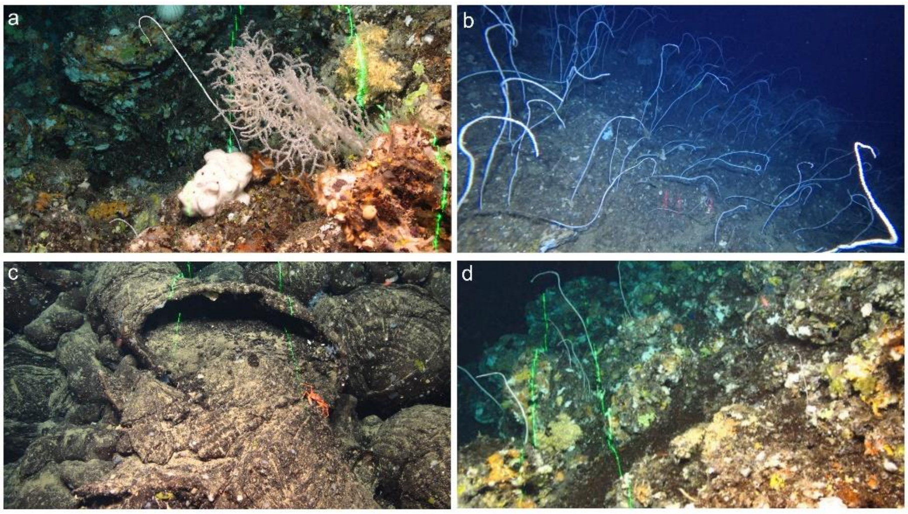



**Figure 243** Selected images representative of the main structuring species and benthic communities observed in 127 seamount, part of Gigante seamount complex. (a) Aggregation of small colonies of *Viminella flagellum*, a small colony of black coral and several sponges, including *Phlyctaenopora (Phlyctaenopora) bitorquis, Petrosia* sp. and other encrusting species. (b) Large aggregation of *Viminella flagellum*. (c) Hard substrate composed of pillow lava colonized by several encrusting and glass sponges. (d) Dense aggregation of a wide variety of small and encrusting sponges, with occasional occurrence of *Viminella flagellum* colonies. Image credits: ROV Luso/EMEPC/2018 Oceano Azul Expedition.

*Gigante Agulhas S*

In the Gigante Agulhas South area, 3 underwater video transects were performed between 490 and 680 m depth (Figure 244). Analysis of the recorded footage revealed a total of 36 taxa, and 22 of them were identified at the species level, indicating that a low diversity of deep-sea megabenthic species is supported in this area. Prominent taxa based on weighted occurrences include *Anthomastus/Pseudoanthomastus* sp. (n= 14), *Echinus melo* (n= 13), and *Viminella flagellum* (n= 12).

The southern area of the Gigante Agulhas seamount complex, generally displayed a sea bottom with hard geomorphological features, like big basaltic outcrops and walls, although not very steep. The most widespread species of benthic megafauna found at the deepest areas explored, were of the phylum porifera with the vast presence of massive *Characella pachastrelloides* (Figure 245b,c), and of the genus *Petrosia* a few *Characella connectens*, and sporadic individuals of the genus *Geodia* and the species *Haliclona magna*. Corals were also very frequently observed attached to the hard substrate, with very dense aggregations of soft corals of a species, which identification is yet to be confirmed, another soft corals of the genus *Anthomastus/Pseudoanthomastus* sp., *Paragorgia johnsoni*, the black corals *Elatopathes abietina*, *Sticopathes gravieri*, and *Parantipathes hirondelle*, and large aggregations of the whip coral *Viminella flagellum* (Figure 245a,b,c). Also, at these depths sporadic sea urchins of the species *Echinus melo* and *Cidaris cidaris* were spotted. The shallowest areas surveyed (usually with soft sediment) showed the continuation of patches with large aggregations of *Viminella flagellum*, together again with soft corals and the scleractinian *Leptopsammia formosa*, as well as some individuals of *Petrosia* sp., and Echinus melo. Motile fauna was mainly composed of the fishes *Hoplostethus mediterraneus* and from the family Macrouridae.

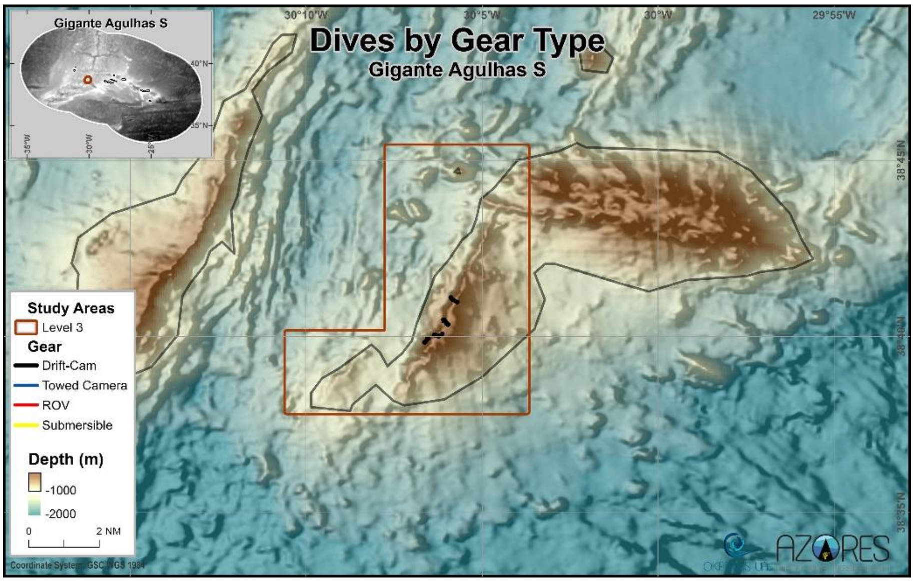



**Figure 244** Map displaying the 3 underwater dives performed in the Gigante Agulhas S area between 490 and 680 meters depth.

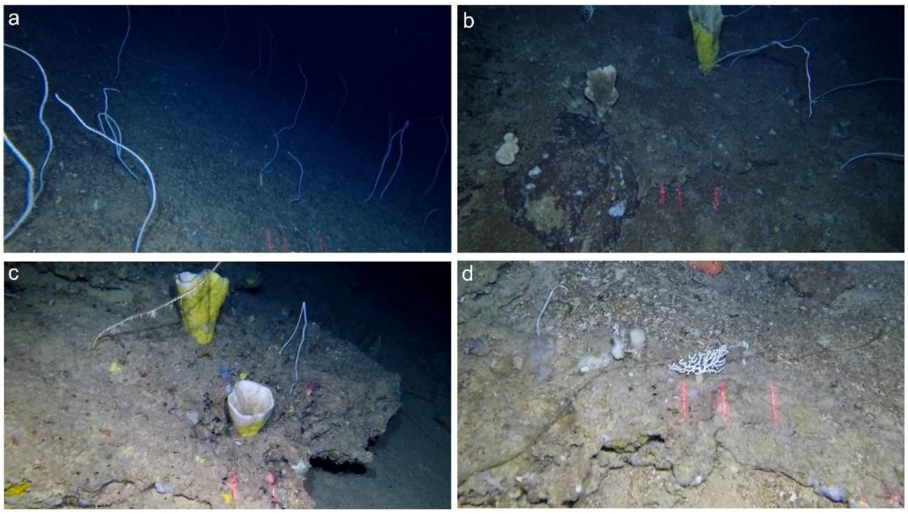



**Figure 245** Selected images representative of the main structuring species and benthic communities observed in Flores Northeast area. (a) Dispersed aggregation of *Viminella flagellum.* (b) Hard bottom colonized by several sponge species, including *Characella pachastrelloides* and colonies of *V. flagellum.* (c) Aggregation of large sponges *C. pachastrelloides* and the corals *V. flagellum* and *Anthomastus/Pseudoanthomastus* sp. (d) Small colony of the coral *Pleurocorallium johnsoni*. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Gigante Agulhas SW*

Navigating in the Gigante Agulhas Southwest area, 8 underwater video transects were performed between 440 and 670 m depth (Figure 246). A total of 77 taxa were determined from the videos recorded, of which 41 were identified at the species level, revealing a high diversity of deep-sea megabenthic species in this area. Notable taxa based on weighted occurrences include *Acanthogorgia* spp. (n= 89), *Viminella flagellum* (n= 81), and *Characella pachastrelloides* (n= 67).

The deepest sector explored of the Gigante Agulhas SW areas, at ~650 m depth, was characterized by lithic substrate colonized by a great variety of massive, encrusting, and globular sponges, together with small

Dendrophylliidae corals of the species *Leptopsammia formosa* and hydroids of the Plumulariidae family. Soft corals also appeared colonizing large areas of hard substrates, including *Anthomastus/Pseudoanthomastus* sp., with other smaller species yet to be identified to species level. The main structuring species at those depths was the *Paragorgia johnsoni* (Figure 247a,b), which was observed reaching large sizes and locally high densities. Interestingly, the octocorals were seen with their branches oriented towards deeper areas, likely in an attempt to maximize food intake from the dominant water currents. Moving towards shallower areas, the smaller octocoral *Pleurocorallium johnsoni* started to become more abundant, together with larger sponges, particularly of the species *Characella pachastrelloides* (Figure 247d), but also other lithistids suchs as *Leiodermatium* sp., *Maccandrewia* sp. and *Neophrissospongia nolitangere*. In some areas, massive demosponges became the most prominent species. Towards the shallowest sectors (~450 m), the whip coral *Viminella flagellum* became dominant, first in the form of loose aggregations but eventually reaching high densities. This species was observed in association with octocorals of the genus *Acanthogorgia* (Figure 247c), as well as *Anthomastus/Pseudoanthomastus* sp.. At those depths, the yellow gorgonian *Dentomuricea* aff. *meteor* starts to be observed, together with other octocoral species such as *Nicella granifera* and *Muriceides pacituberculata* and black corals of the Eliopathidae family.

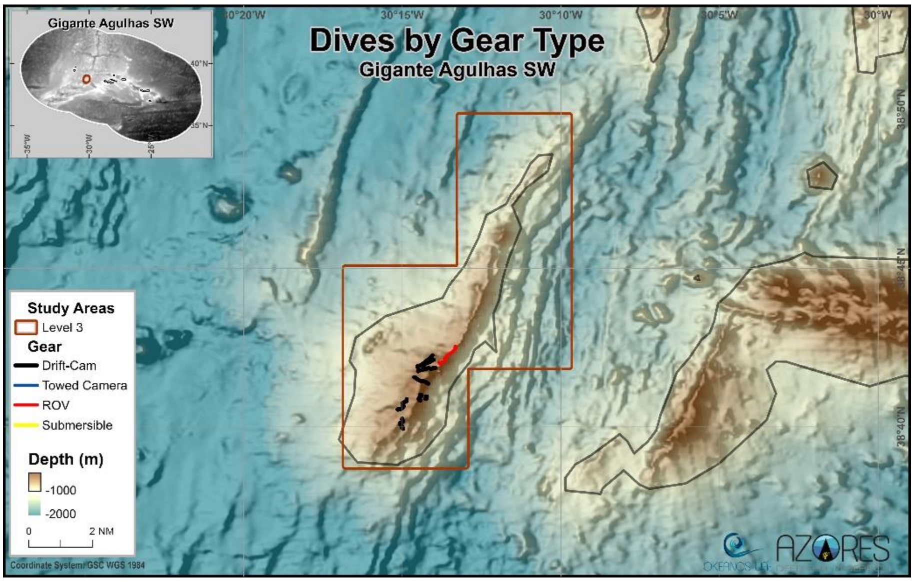



Figure 246 Map displaying the 8 underwater dives performed in the Gigante Agulhas SW area between 440 and 670 meters depth.

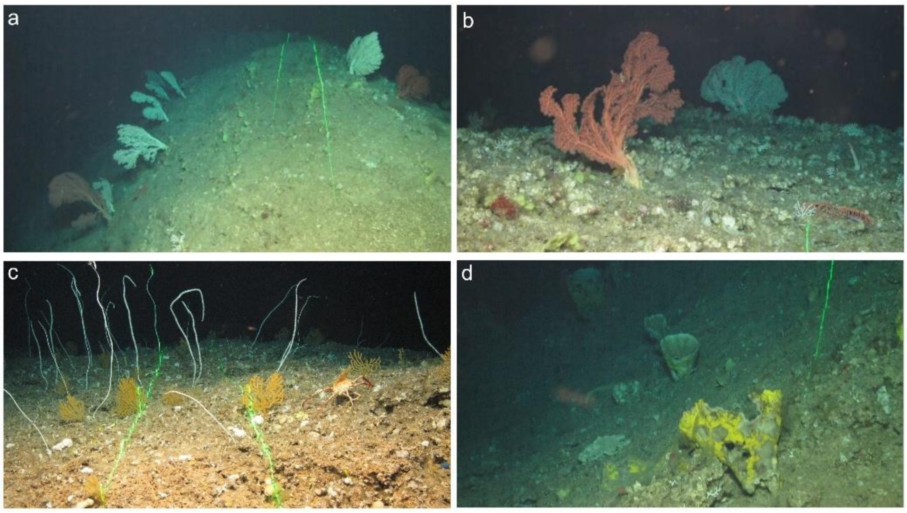



**Figure 247** Selected images representative of the main structuring species and benthic communities observed in Agulhas Southwest mound, part of the Gigante seamount complex. (a-b) Assemblage of the two morphotypes of *Paragorgia johnsoni* on hard substrate. (c) Benthic community formed by octocorals *Viminella flagellum* and *Acanthogorgia* spp. on hard substrate also colonized by small and encrusting sponges and the crab *Paramola cuvieri.* (d) Aggregation of sponges from *Characella* genus. Image credits: ROV Luso/EMEPC/2018 Oceano Azul Expedition.

**Study area | Cavala**

*Ferradura E (former A6 - unnamed structure)*

In the Ferradura East area, 7 underwater video transects were performed between 390 and 850 m depth (Figure 248). A total of 84 taxa were determined from the video footage, of which 50 were identified at the species level, indicating a high diversity of deep-sea megabenthic species in this area. Dominant taxa based on weighted occurrences include *Viminella flagellum* (n= 38), *Anthomastus/Pseudoanthomastus* sp. (n= 33), and *Petrosia (Petrosia) crassa* (n= 27).

A large part of the seamount was characterized by the presence of coral rubble deposits (Figure 249a), whose origins are still to be determined. Coral pieces scattered over the seafloor appeared in the vast majority of soft bottom areas, in some cases covering the entire surface available. At 600 m depth, aggregations of the hexactinellid *Pheronema carpenteri* were observed in between the patches of coral fragments. When the soft-bottom was available, populations of the scleractinian *Flabellum* sp. were reported, usually accompanied by the soft coral *Anthomastus/Pseudoanthomastus* sp. Deep areas of the seamount were characterized by large rocky outcrops, that in some cases generated steep slopes. Those substrates were colonized by a large number of sponges, predominantly of a small size in the form of encrusting and erect specimens. Lamellate species of larger sizes, including *Macandrewia azorica*, were also reported (Figure 249b). In such deep areas, when the rock displayed a softer relief, the benthic community was dominated by the primnoids *Narella bellissima* and *Narella versluysi*, together with the white coral *Pleurocorallium johnsoni* (Figure 249c). Shallower areas (300-500 m depth) hosted rich communities characterized by corals and sponges. Especially relevant were the dense aggregations of a pink soft coral of a small size still to be identified to species level. It was observed in very large numbers along the small crevices of the rocks, mostly on the sloping areas (Figure 249d). Large colonies of the whip coral *Viminella flagellum*, *Callogorgia verticillata*, *Paragorgia johnsoni*, and *Paracalyptrophora josephinae* were frequently observed in those areas, but also on the actual summit of the seamount. Some of the *Callogorgia verticillata* colonies identified reached some impressive sizes (Figure 249e), but not forming dense patches like those found in other seamounts/ridges of the Mid-Atlantic Ridge. Also relevant was the size of some giant sponges of the species *Characella pachastrelloides*, generally in association with the whip coral *Viminella flagellum* in the summit (Figure 249f). A few other lithistid Porifera appear alongside the large *Characella pachastrelloides*, such as *Leiodermatium* spp. and *Macandrewia azorica.*

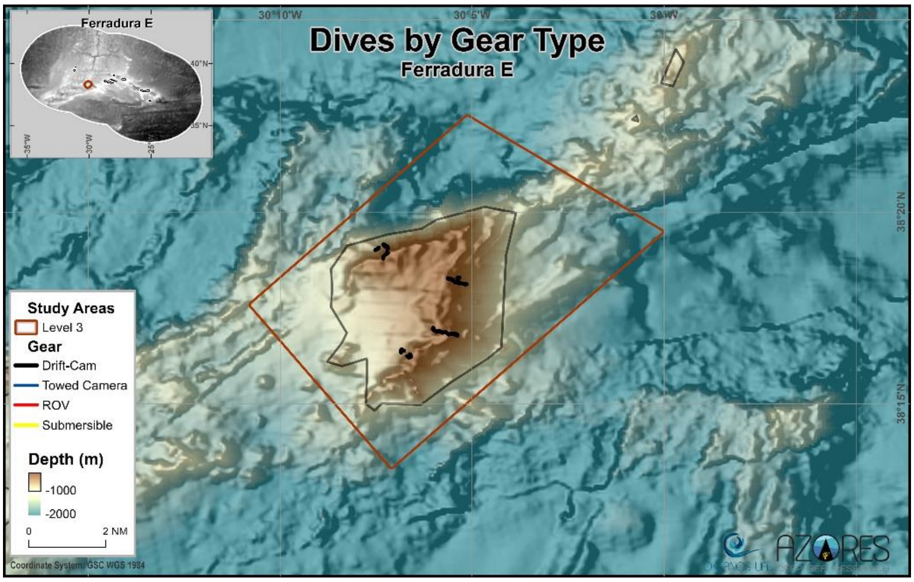



**Figure 248** Map displaying the 7 underwater dives performed in the Ferradura E area between 390 and 850 meters depth.

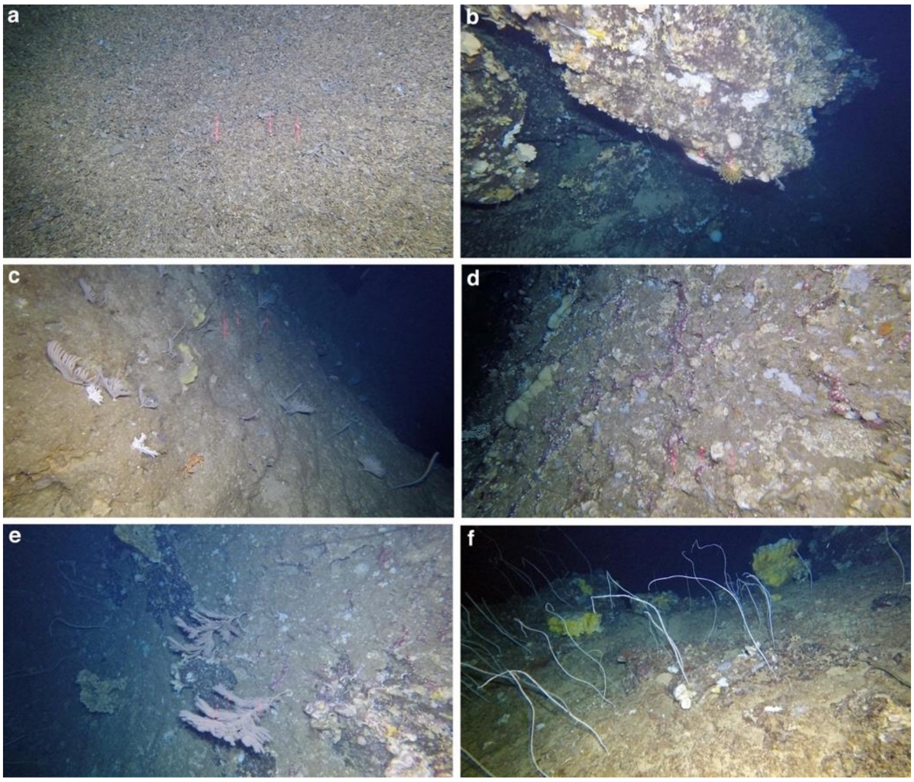



**Figure 249** Selected images representative of the main structuring species and benthic communities observed in A6 seamount. (a) Deposits of coral rubble over a soft bottom area. (b) Vertical cliffs and outcropping rocks colonized by a large variety of encrusting sponges. (c) Aggregation of the primnoid corals *Narella bellissima* and *Narella versluysi*. (d) Dense aggregations of soft corals on the upper slope. (e) Large colonies of *Callogorgia verticilata* alongside high abundances of

soft corals. (f) The whip coral *Viminella flagellum* developing in association with the giant sponge *Characella pachastrelloides*. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Ferradura seamount*

The exploration of the Ferradura seamount involved 7 underwater video transects between 480 and 820 m depth (Figure 250 Map displaying the 7 underwater dives performed in the Ferradura area between 480 and 820 meters depth.). As a result of the analysis of the videos recorded, a total of 68 taxa were determined, of which 48 were identified at the species level. This means that this area supports a medium diversity of deep-sea megabenthic species. Notable taxa based on weighted occurrences include *Anthomastus/Pseudoanthomastus* sp. (n= 61), *Narella versluysi* (n= 56), and *Acanthogorgia* spp. (n= 50).

The deepest areas of this seamount were characterized by large deposits of coral rubble, still of an unknown origin (Figure 251a). Such deposits were usually found in between patches of sand, where some specimens of the scleractinian *Flabellum* sp. could be observed. When the rock outcropped, it was common to see the sea urchin *Cidaris cidaris* and the yellow cup coral *Leptopsammia formosa* (Figure 251b), as well as the and the black coral *Parantipathes hirondelle.* At those depths, the most widespread community was that dominated by the primnoids *Narella bellissima* and *Narella versluysi*, in association with several other species. In some cases, generally when bare rock dominates, some specimens of the black coral *Leiopathes* cf. *expansa* and sea urchins of the genus *Echinus* were common (Figure 251c). Other species are also very abundant, with the anthozoan *Anthomastus/Pseudoanthomastus* sp. reaching some very high densities (Figure 251d). At shallower depths, the *Narella* community transitioned to that dominated by the gorgonian coral *Paragorgia johnsoni*, both in its red and white morphs. The accompanying fauna remained very similar to that of deeper areas, being very common the soft coral *Anthomastus/Pseudoanthomastus* sp. and lithistid sponges such as *Petrosia crassa*. The shallowest areas hosted dense patches of large primnois of the species *Callogorgia verticillata*, together with the whip coral *Viminella flagellum* and the ubiquitous *Anthomastus/Pseudoanthomastus* sp. (Figure 251f). In some areas, the large *Callogorgia verticillata* specimens disappeared, allowing for the formation of monospecific patches of *Viminella flagellum*.

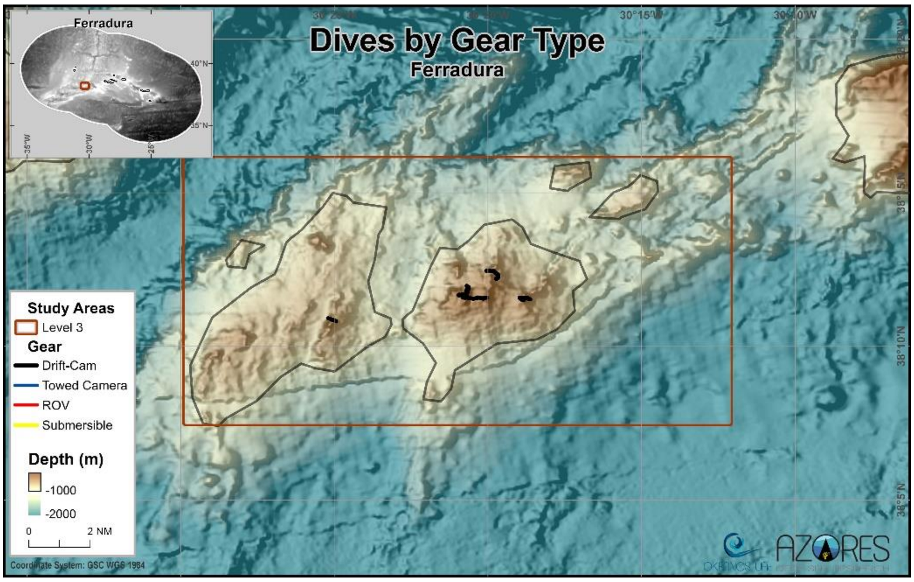



**Figure 250** Map displaying the 7 underwater dives performed in the Ferradura area between 480 and 820 meters depth.

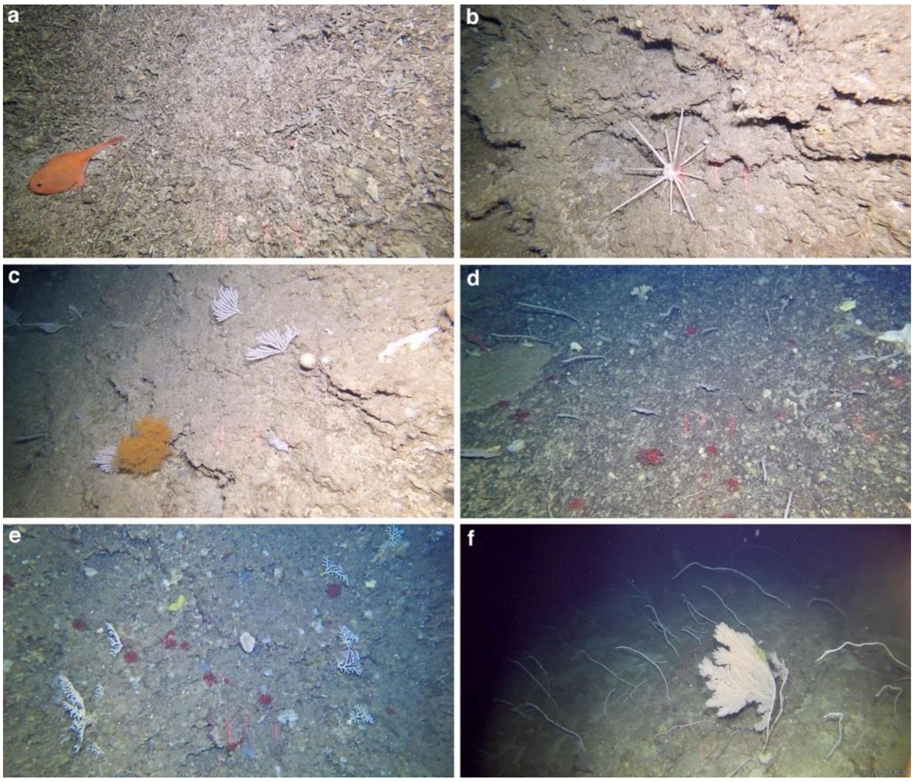



**Figure 251** Selected images representative of the main structuring species and benthic communities observed in Ferradura seamount. (a) Deposits of coral rubble over a soft bottom area with a fish of the genus *Chaunax*. (b) Bare outcropping rocks with the long-spine sea urchin *Cidaris cidaris*. (c) Aggregation of the primnoid corals *Narella bellissima* and *Narella versluysi* together with the black coral *Leiopathes* cf. *expansa*. (d) Dense aggregation of the primnoid corals *Narella bellissima* and *Narella versluysi* together with the soft coral *Anthomastus/Pseudoanthomastus* sp. on hard grounds. (e) Area of high densities of the bubblegum coral *Paragorgia johnsoni* developing in association with the soft coral *Anthomastus/Pseudoanthomastus* sp. (f) Large colonies of the octocoral *Callogorgia verticilata* within an aggregation of the whip coral *Viminella flagellum*. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Cavala seamount*

Surveying the Cavala area involved 17 underwater video transects between 370 and 930 m depth (Figure 252). A total of 132 taxa were determined from the video footage, of which 82 were identified at the species level, indicating a very high diversity of deep-sea megabenthic species in this seamount area. Prominent taxa based on weighted occurrences include *Anthomstus/Pseudoanthomastus* sp. (n= 185), *Acanthogorgia* spp. (n= 139), and *Viminella flagellum* (n= 128).

The deepest areas explored in Cavala seamount, at 900 m depth, were characterized by the presence of gravels and small volcanic rocks, with little fauna observed besides some scattered sea urchins of the species *Cidaris cidaris* (Figure 253a). Certain areas with gravels also hosted some glass sponges of the species *Pheronema carpenteri* (Figure 253b), together with the anthozoan Anthomastus/*Pseudoanthomastus* sp. and the small glass sponge *Farrea occa*, all of them always in low densities. In other areas, *Pheronema carpenteri* generated clumps of >5 individuals, appearing together with lithistids such as *Macandrewia azorica*, and other massive demosponges (*Characella pachastrelloides* and *Petrosia* spp.). The community shifts to aggregations of the primnoids *Narella bellissima* and *N. versluysi,* which locally reached some high densities together with white lamellate sponges of the genus *Phakellia.* At depths of 500 m, large boulders and outcropping rocks became more common, and were mostly colonized by the white gorgonian *Pleurocorallium johnsoni* (Figure 253c), with a diverse set of accompanying species, including the yellow lamellate sponge, the ubiquitous anthozoan Anthomastus/*Pseudoanthomastus* sp. and some black coral species such as *Elatopathes abietina* and *Stichopathes gravieri*. Some of the white coral colonies of this community may belong to *Paragorgia johnsoni,* although in some cases difficult to tell apart from video images from similar gorgonians also reported for the area. The density and size of the *Paragorgia johnsoni* colonies increases towards shallower depths (Figure 253d), while the composition and structure of the associated fauna was maintained, adding to the list the whip coral *Viminella flagellum*. Also at those depths, the presence of vertical or very steep walls constituted a change in the community composition, with a clear dominance of encrusting sponges, as well as some large individuals of the species *Macandrewia azorica* and *Petrosia crassa,* among others. The benthic community drastically changed when reaching the shallowest sectors of the seamount, with a clear dominance of the whip coral *Viminella flagellum*, becoming the most common coral species (Figure 253e). It was observed in association with the giant sponges *Characella pachastrelloides* and *Petrosia crassa* in areas colonized by a large number of encrusting sponges. It was also found in association in other areas with the gorgonian corals *Acanthogogia* sp., *Dentomuricea* aff. *meteor* and *Callogorgia verticillata*, as well as very large colonies of *Paracalyptrophora josephinae*. An exceptionally dense aggregation of the yellow sea fan *Dentomuricea* aff. *meteor* was identified in the shallowest sector of the summit, below 400 m depth (Figure 253f).

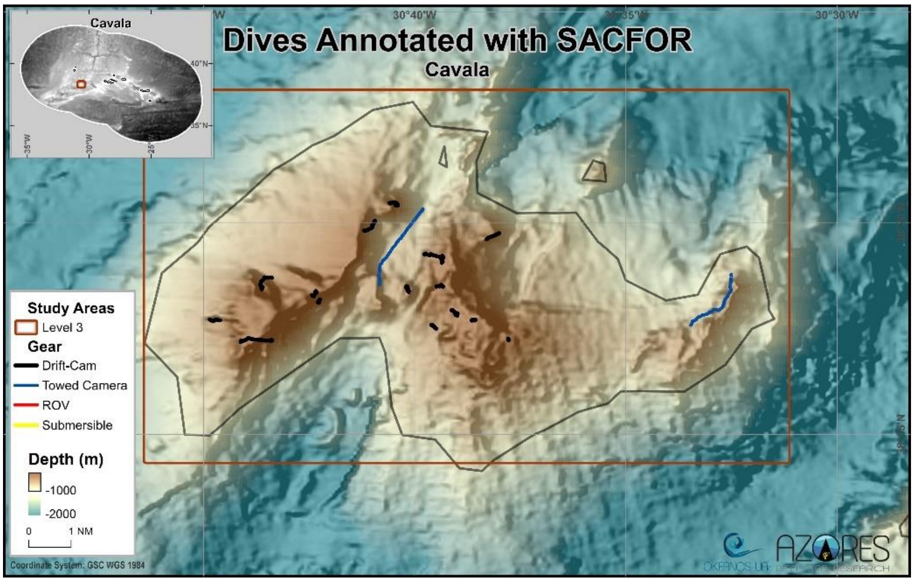



**Figure 252** Map displaying the 17 underwater dives performed in the Cavala area between 370 and 930 meters depth.

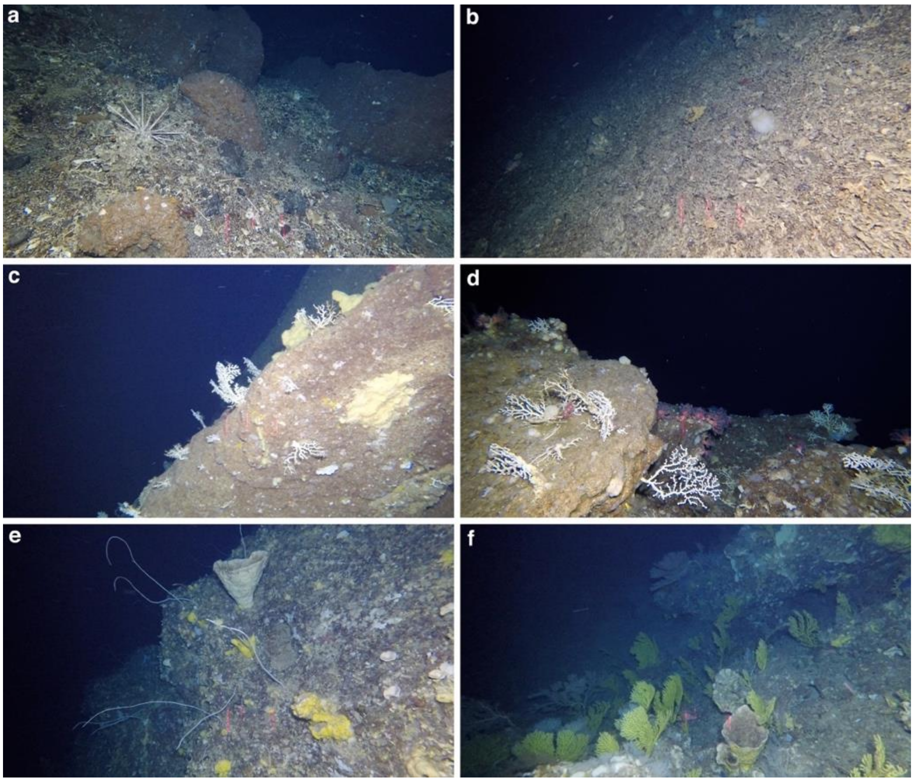



**Figure 253** Selected images representative of the main structuring species and benthic communities observed in Cavala seamount. (a) Gravels and small volcanic rocks with the sea urchin *Cidaris cidaris*. (b) Coral rubble with some specimens of the glass sponge *Pheronema carpenteri*. (c) Large boulder colonized by the white gorgonian *Pleurocorallium johnsoni* and a yellow lamellate sponge. (d) Area of high densities of the bubblegum coral *Paragorgia johnsoni* in association with soft corals, including *Anthomastus/Pseudoanthomastus* sp.. (e) Large outcropping rock with the whip coral *Viminella flagellum* and some very large sponges of the species *Characella pachastrelloides*. (f) Large densities of the yellow sea fan *Dentomuricea* aff. *meteor* in summit areas with large boulders and outcropping rocks. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Beta seamount*

In the Beta seamount area, 5 underwater video transects were conducted between 540 and 750 m depth (Figure 254). A total of 57 taxa were determined from the videos recorded, of which 38 were identified at the species level, revealing that this area supports a medium diversity of deep-sea megabenthic species. Dominant taxa based on weighted occurrences include *Paragorgia johnsoni* (n= 57), Hydrozoa (n= 56), and *Asconema fristedti* (n= 45).

From a geographical perspective, the deepest areas of Beta seamount explored until now were mainly characterized by very coarse gravels, mostly composed of coral rubble of an unknown origin. Such areas hosted very few organisms, including some crustaceans like *Chaceon affinis* (Figure 255a), and sparse corals of the species *Narella versluysi*. When the substrate became more consolidated, the density of the primnoids *Narella versluysi* and *Narella bellissima* increased, as well as that of the anthozoan *Anthomastus/Pseudoanthomastus* sp. and the glass sponge *Asconema* sp. (Figure 255b). In this *Narella* community, a few deep-sea sharks of the species *Dalatias licha* were observed gently swimming close to the seabed (Figure 255c). In shallower depths, the community changed to a more complex and diverse association, in which a large number of species could be identified: the gorgonian *Pleurocorallium johnsoni* associated with yellow lamellate sponges, as well as a wide variety of encrusting sponges and erect sponges, such as the giant sponge of the species *Characella pachastrelloides*. A very abundant small gorgonian coral of an orange coloration was observed on areas of steep slopes, likely belonging to the genus *Swiftia* (Figure 255d). Also on the slopes, but further up towards the summit, the bubblegum coral *Paragorgia johnsoni* in its red and white morphs started to appear, with colonies reaching some of the largest sizes recorded for this species in the study area of Cavala (Figure 255e). On the flat areas of the summit, a remarkable aggregation of the sponge *Asconema* sp. was also registered, with patches of some very high densities (Figure 255f).

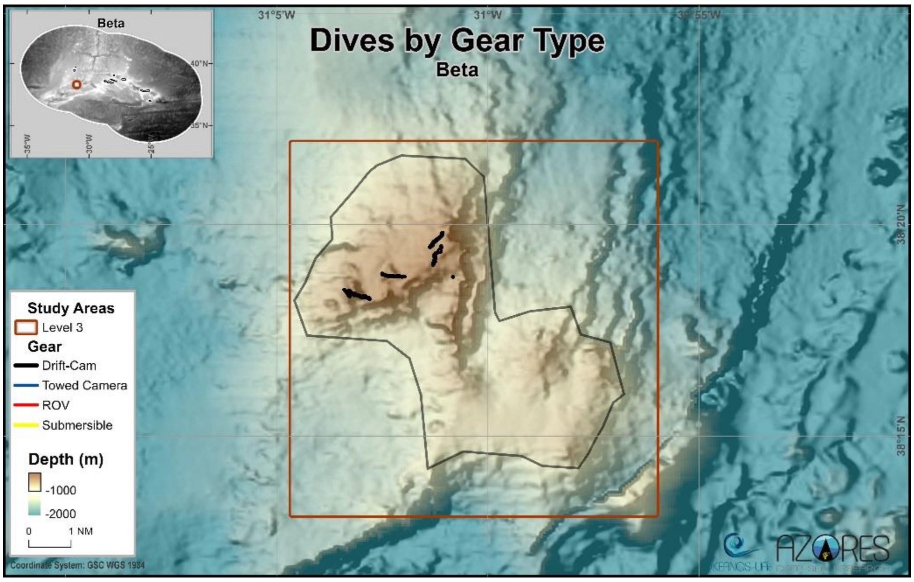


**Figure 254** Map displaying the 5 underwater dives performed in the Beta area between 540 and 750 meters depth.

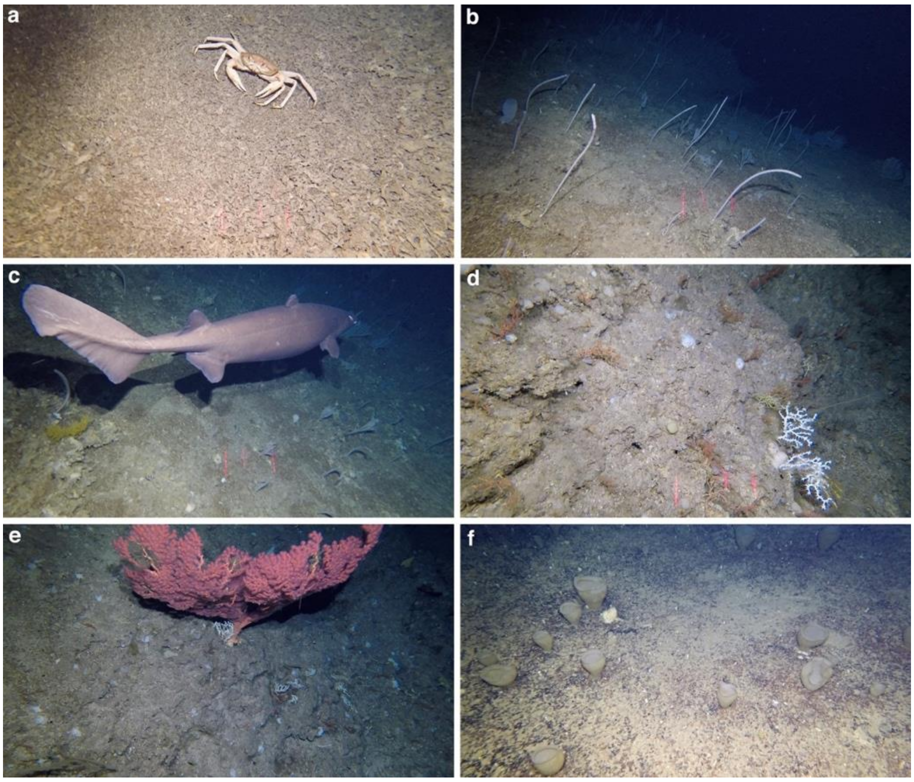



**Figure 255** Selected images representative of the main structuring species and benthic communities observed in Beta seamount. (a) Accumulations of coral rubble of an unknown origin. (b) Aggregation of the primnoid corals *Narella versluysi* and *Narella bellissima* in the deepest areas explored. (c) A large deep-sea shark of the species *Dalatias licha*. (d) High densities of an orange Plexauridae most likely of the genus *Swiftia*, alongside some specimens of the white coral *Pleurocorallium johnsoni*. (e) One example of the large sizes that the corals *Paragorgia johnsoni* reach in the slopes of Beta seamount. (f) Aggregation of the sponge *Asconema* sp. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

## Study area | Picos SE Flores

*Diogo Teive*

The exploration of Diogo Teive area involved 3 underwater video transects between 750 and 970 m depth (Figure 256). Analysis of the recorded videos revealed a total of 49 taxa, of which 33 were identified at the species level, indicating a medium diversity of deep-sea megabenthic species in this area. Dominant taxa based on weighted occurrences include *Cidaris cidaris* (n= 23), Ceriantharia (n= 22), and *Pheronema carpenteri* (n= 19). Diogo de Teive Seamount was mapped by the Portuguese Hydrographic Institute in 2019. After the discovery that this small seamount was much shallower than previous maps indicated, it was defined as a potential near-pristine area due to the lack of known fishing events.

The small seamount was covered by soft sediments on most areas with only small patches of bare rocky outcrops. In general, the biodiversity and abundance of the benthic fauna was low. The deepest areas observed held several fields of deep-sea sponges cf. *Asconema* (Figure 257b) and *Pheronema carpenteri* (Figure 257c). We also found many large and intact colonies of *Callogorgia verticillata* (Figure 257a) with no signs of impacts from fishing activities. A school of large wreckfishes of the species *Polyprion americanus* (Figure 257d) was also seen. The presence of intact colonies of large structuring corals, along with the lack of lost fishing lines and large schools of wreckfish, indicate that this seamount may classify as a near-natural or pristine area.

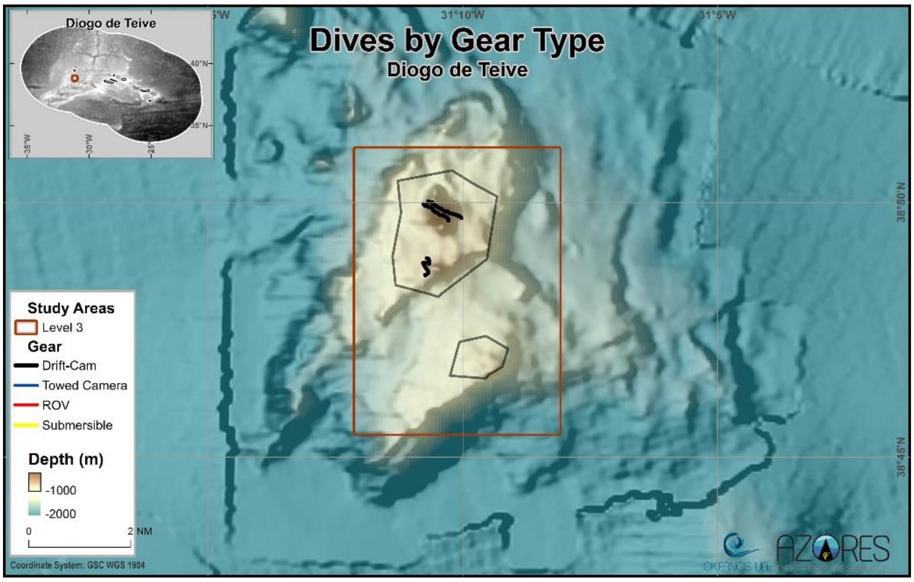



**Figure 256** Map displaying the 3 underwater dives performed in the Diogo Teive area between 750 and 970 meters depth.

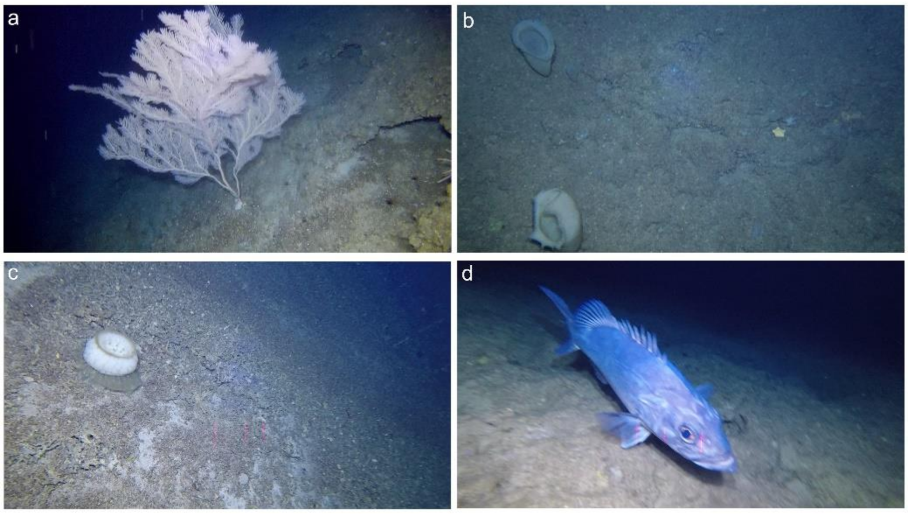



**Figure 257** Selected images representative of the main structuring species and benthic communities observed in Diogo Teive seamount. (a) A large colony of *Callogorgia verticillata*. (b-c) Deep-sea sponges *Asconema* sp. and *Pheronema carpenteri.* (d) Large wreckfish *Polyprion americanus.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Buchanan*

In the Buchanan area, 1 underwater video transect was performed between 740 and 1,210 m depth (Figure 258). A total of 78 taxa were determined from the footage of which 52 were identified at the species level, revealing that this area supports a high diversity of deep-sea megabenthic species. Notable taxa based on weighted occurrences include *Farrea occa* (n= 55), *Pheronema carpenteri* (n= 48), and *Desmacella grimaldii* (n= 40).

The Buchanan morphological unit is a ridge, with substrates characterized by the presence of large basaltic boulders and rocks. On the deepest areas surveyed the black corals and bamboo corals of the genus *Leiopathes* (Figure 259a) and the species *Acanella arbuscula*, respectively, were recorded either attached to the hard or soft substrates. It was also possible to observe some individuals of *Hemicorallium tricolor* and the rarely seen

*Iridongorgia fontinalis* (Figure 259b,f). Fan-shaped sponges, likely from the genus *Phakellia* (Figure 259b), were also observed as well as the foraminifera cf. *Syringammina fragilissima* at the sandy bottom. Just below 1000m depth, aggregations of stylasterid corals started to appear, in some areas reaching high densities and extending to depths of 800m. A few meters above, dense aggregations of the primnoids corals of the genus *Narella* (Figure 259d,e), accompanied with the gorgonians *Acanthogorgia* spp. and *Callogorgia verticillata* were reported. When climbing up to shallower depths there was a shift in the community, with the dominance of demosponges (most of a small size), for a few meters, and at around 615m depth, we could observe dense aggregations of large octocorals belonging to the family Paramuriceidae (Figure 259c). These aggregations appeared to be stretching from the upper slope to the top of the ridge, covering vast sections of the seafloor.

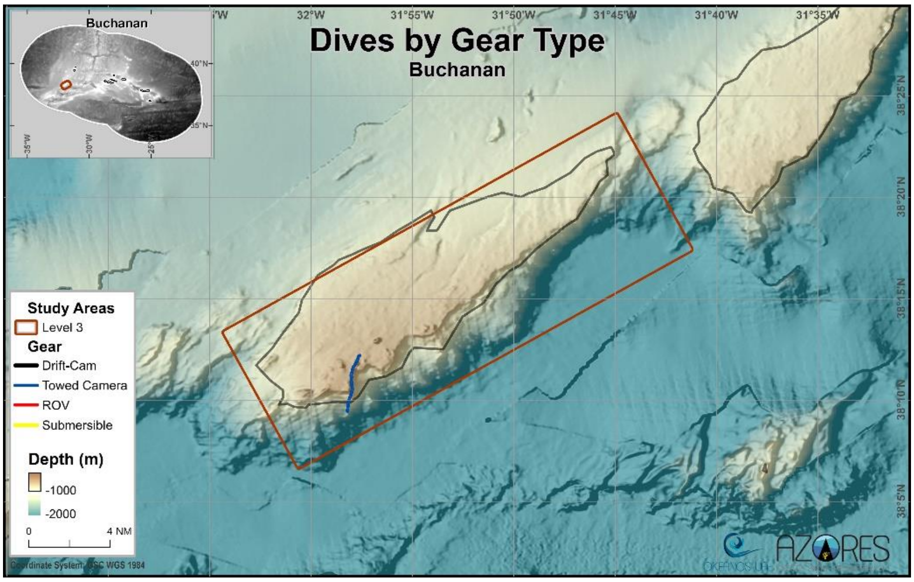



Figure 258 Map displaying the 1 underwater dive performed in the Buchanan area between 740 and 1,210 meters depth.

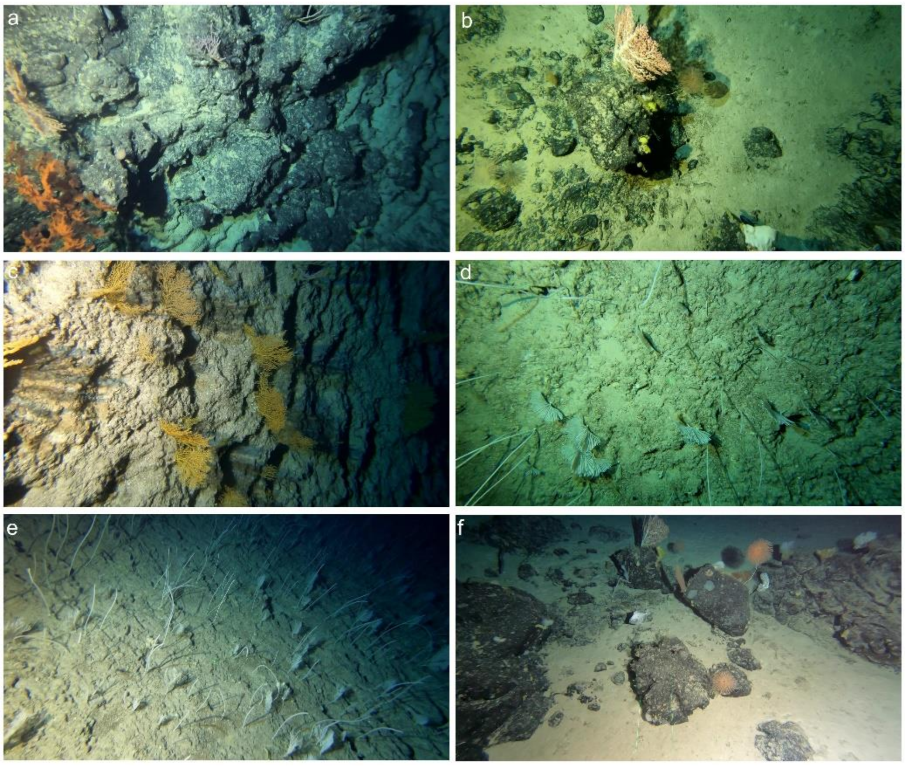



**Figure 259** Selected images representative of the main structuring species and benthic communities observed in Buchanan area. (a) *Leiopathes* cf. *expansa* on hard substrate. (b) Rock colonized by gorgonians *Hemicorallium tricolor* and *Iridongorgia fontinalis* (c) Aggregation of plexaurids, likely the genus *Placogorgia.* (d-e) Aggregation of *Narella bellissima* and *Narella versluysi.* (f) boulders colonized by *Hemicorallium tricolor* and *H. niobe, Iridongorgia fontinalis, Chrysogorgia* sp. and some encrusting sponges. Image credits: Eurofleets+ iMAR cruise, IMAR/Okeanos-UAç

*Cabeçote*

Exploring the Cabeçote area, 1 underwater video transect was performed between 700 and 1,020 m depth (Figure 260). After the analysis of the video footage a total of 50 taxa were determined, of which 35 were identified at the species level, indicating a medium diversity of deep-sea megabenthic species in this area. Prominent taxa based on weighted occurrences include *Bathynectes maravigna* (n= 26), *Chaceon affinis* (n= 20), and *Acanthogorgia* spp. (n= 19).

The deepest areas explored, at around 1000m were mostly covered by a bed of coral rubble, with a few rocks providing substrate for the bamboo coral *Acanella arbuscula* and the gorgonian *Chrysogorgia* sp., as well as several species of hexactinellids, such as *Farrea occa.* The area does not hold much more fauna until reaching depths of 800 m, where aggregations of the glass sponge *Asconema* sp. and the octocoral *Acanthogorgia* spp. are present, together with a variety of other species, such as small colonies of *Pleurocorallium johnsoni* and large lamellate sponges *Poecillastra compressa* (Figure 261a,d). At depths of 700 m, community was seen to shift to a coral garden dominated by *Narella versluysi* and *Narella bellissima*, together with *Acanthogorgia* spp. (Figure 261c,e). A dense coral garden of the small octocoral *Pleurocorallium johnsoni* (Figure 261f) was also present, in some areas reaching impressive densities. An aggregation of stylasterids (likely *Errina atlantica*) was also observed (Figure 261b).

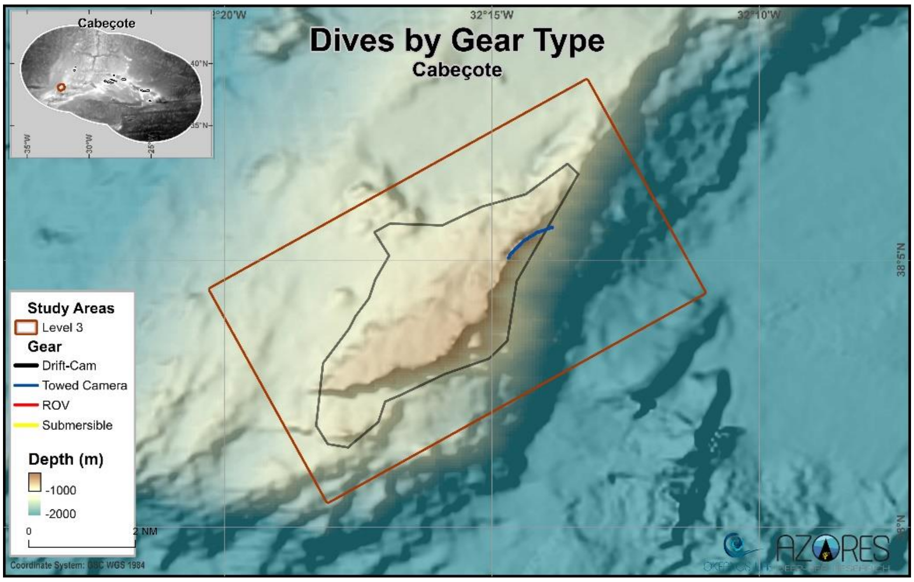



**Figure 260** Map displaying the 1 underwater dive performed in the Cabeçote area between 700 and 1,020 meters depth.

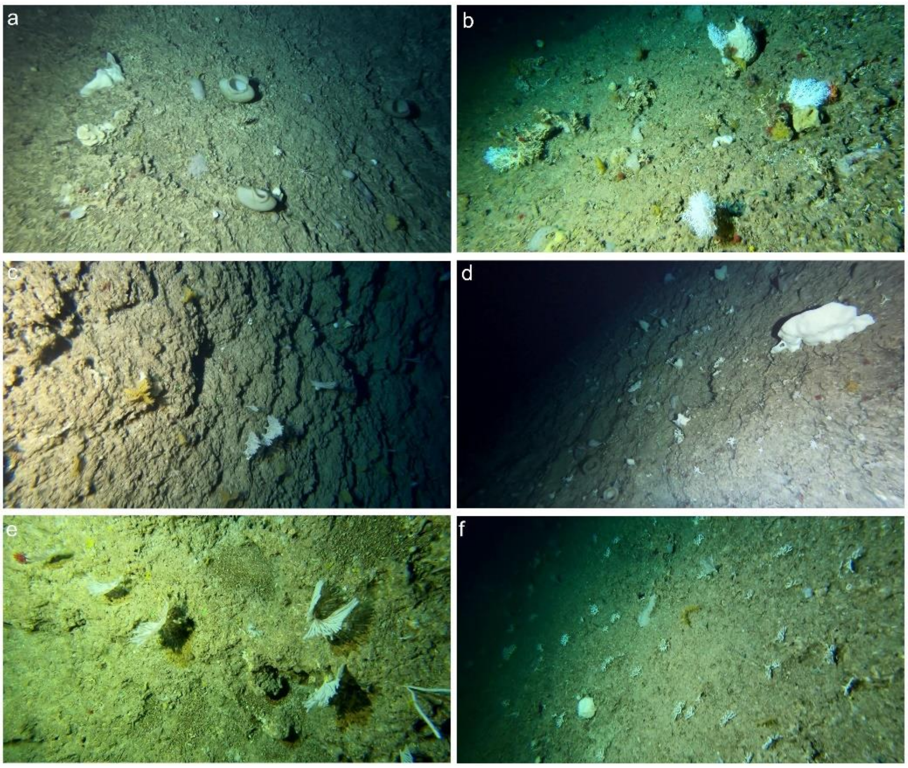



**Figure 261** Selected images representative of the main structuring species and benthic communities observed in Cabeçote area. (a) Hard substrate colonized by sponges *Asconema fristedti, Poecillastra compressa* and *Petrosia crassa* and the corals *Acanthogorgia* spp. and (b) Aggregation of the corals *Acanthogorgia* spp., the hydrozoan *Errina atlantica*, the soft-coral *Anthomastus/Pseudoanthomastus* sp. and *Leptopsammia formosa.* (c) Dispersed aggregation of *Acanthogorgia* spp. and *Narella bellissima.* (d) Aggregation of sponges *Asconema fristedti*¸ the fan-shaped sponge *Phakellia* sp. and *Poecillastra compressa* and the gorgonian *Pleurocorallium johnsoni.* (e) Hard substrate colonized by *Narella bellissima* and *N. verluysi* together with *Anthomastus/Pseudoanthomastus* sp.(f) Sparse aggregation of *Pleurocorallium johnsoni.* Image credits: Eurofleets+ iMAR cruise, IMAR/Okeanos-UAç

*Sardinha*

In the Sardinha area, 1 underwater video transect was conducted between 980 and 1020 m depth (Figure 262). A total of 46 taxa were determined from the analysis of the video footage, of which 31 were identified at the species level, indicating a low diversity of deep-sea megabenthic species in this area. Notable taxa based on weighted occurrences include *Cidaris cidaris* (n= 35), *Phlyctaenopora (Phlyctaenopora) bitorquis* (n= 26), and *Pheronema carpenteri* (n= 22).

The ridge baptized as Sardinha, was not characterized by a high or extensive abundance of deep-sea benthic megafauna. The most remote areas of this deep ridge were described by high and steep slopes generally covered in by large aggregates of coral rubble, where some glass sponges were encountered. At these deepest areas, the presence of the orange roughy (*Hoplostethus atlanticus*) was recorded. When the rock outcropped and vertical walls were seen, individuals of the bamboo coral *Acanella arbuscula* (Figure 263b) and the black coral of the genus *Leiopathes* (Figure 263a) were reported generally together. A bit upper, some areas showed to have aggregations with high densities of stylasterids (Figure 263b), indicating that the large quantities of coral rubble present could be originated by these species. At the shallowest part of the slope had the scarce presence of *Acanella arbuscula* and some glass sponges of the genus *Asconema* (Figure 263c), and large numbers of big specimens of *Characella paschastrelloides* (Figure 263d).

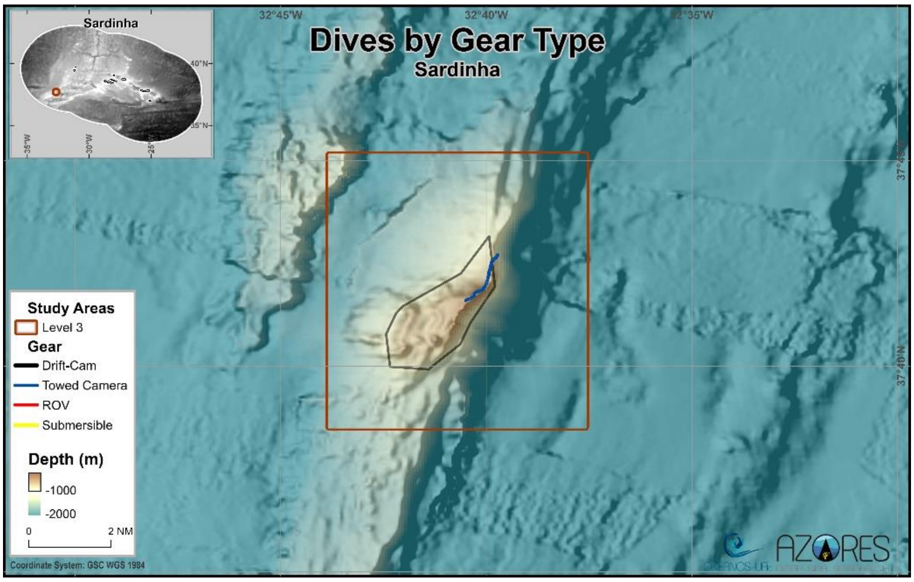



**Figure 262** Map displaying the 1 underwater dive performed in the Sardinha area between 980 and 1,020 meters depth.

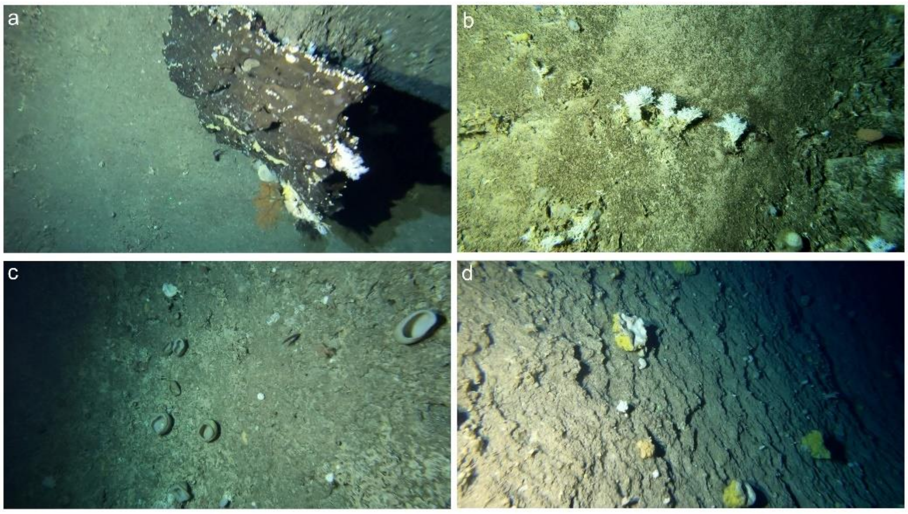



Figure 263 Selected images representative of the main structuring species and benthic communities observed in Sardinha area. (a) *Leiopathes* cf. *expansa* and *Desmacella grimaldi* on a rock. (b) Small aggregation of *Errina atlantica* with a colony of *Acanella arbuscula* (c) Aggregation of the hexactinellid sponge *Asconema fristedti.* (d) Dispersed aggregation of small *Characella pachastrelloides.* Image credits: Eurofleets+ iMAR cruise, IMAR/Okeanos-UAç

*Lucky Strike E (former A3 - unnamed structure)*

The exploration of the Lucky Strike E area involved 6 underwater video transects between 500 and 690 m depth (Figure 264). A total of 49 taxa were determined from the footage, and 31 of them were identified at the species level, indicating that this area supports a medium diversity of deep-sea megabenthic species. Dominant taxa based on weighted occurrences include *Viminella flagellum* (n= 60), *Parantipathes hirondelle* (n= 29), and Plesionika (n= 28).

The aggregations of *Viminella flagellum* were generally monospecific (Figure 265a,b), with not many other corals observed as accompanying species. Some small fauna was identified within those patches and included the black coral species *Stichopathes gravieri* and *Parantipathes hirondelle*. There was also a purple anthozoan yet to be identified to species level and a sea star of the Goniasteridae family, as well as some small and encrusting sponges and gorgonians impossible to identify from the recorded images. Sporadically, a very large specimen of the sponge species *Characella pachastrelloides* appeared within this community (Figure 265c). Some fishes were spotted swimming between the coral colonies, mostly belonging to the Gadidae family. When the rock appeared to have a darker coloration (basalts), the community shifted to one characterized by a large number of sponge species, mainly small and encrusting, but also with a few larger organisms such as *Petrosia* sp., and *Characella pachastrelloides* (Figure 265d). Also noticeable was the presence of coral rubble, either in between the rocks or on top of sandy and gravelly areas.

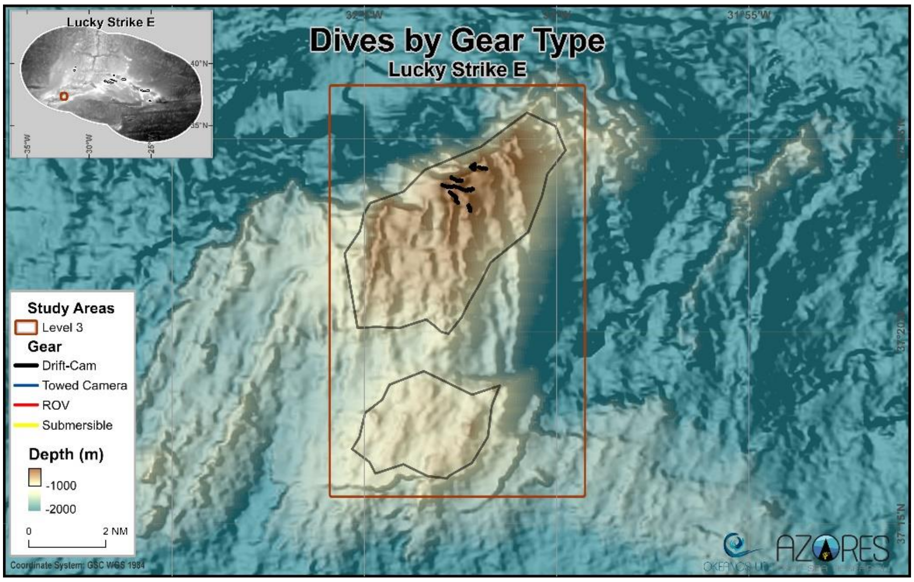



**Figure 264** Map displaying the 6 underwater dives performed in the Lucky Strike E area between 500 and 690 meters depth.

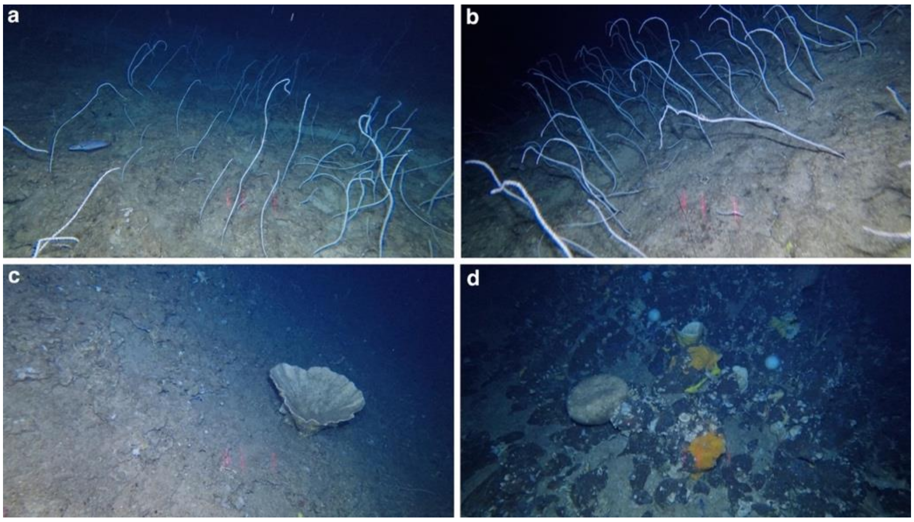



**Figure 265** Selected images representative of the main structuring species and benthic communities observed in A3 seamount. (a-b) Aggregation of the whip coral *Viminella flagellum* in relatively high densities. (c) One very large and solitary *Characella pachastrelloides* found on one of the slopes, close to the summit. (d) Sponge community found on dark rocks, with a wide variety of species. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

## *10.4 Large area | Southern Mid-Atlantic Ridge*

The large area Southern Mid-Atlantic Ridge contains three study areas: Alberto do Mónaco, Farpas and Sarda, and a total of 10 sampling areas (Figure 266). All the 10 sampling areas have been explored with the towed camera system of the R/V Pelagia during the Nico (2018) and Rainbow cruises (2019), and the Eurofleets+ iMAR cruise 2022 and with the Azor drift-cam during the MapGES 2019 and 2022 surveys.

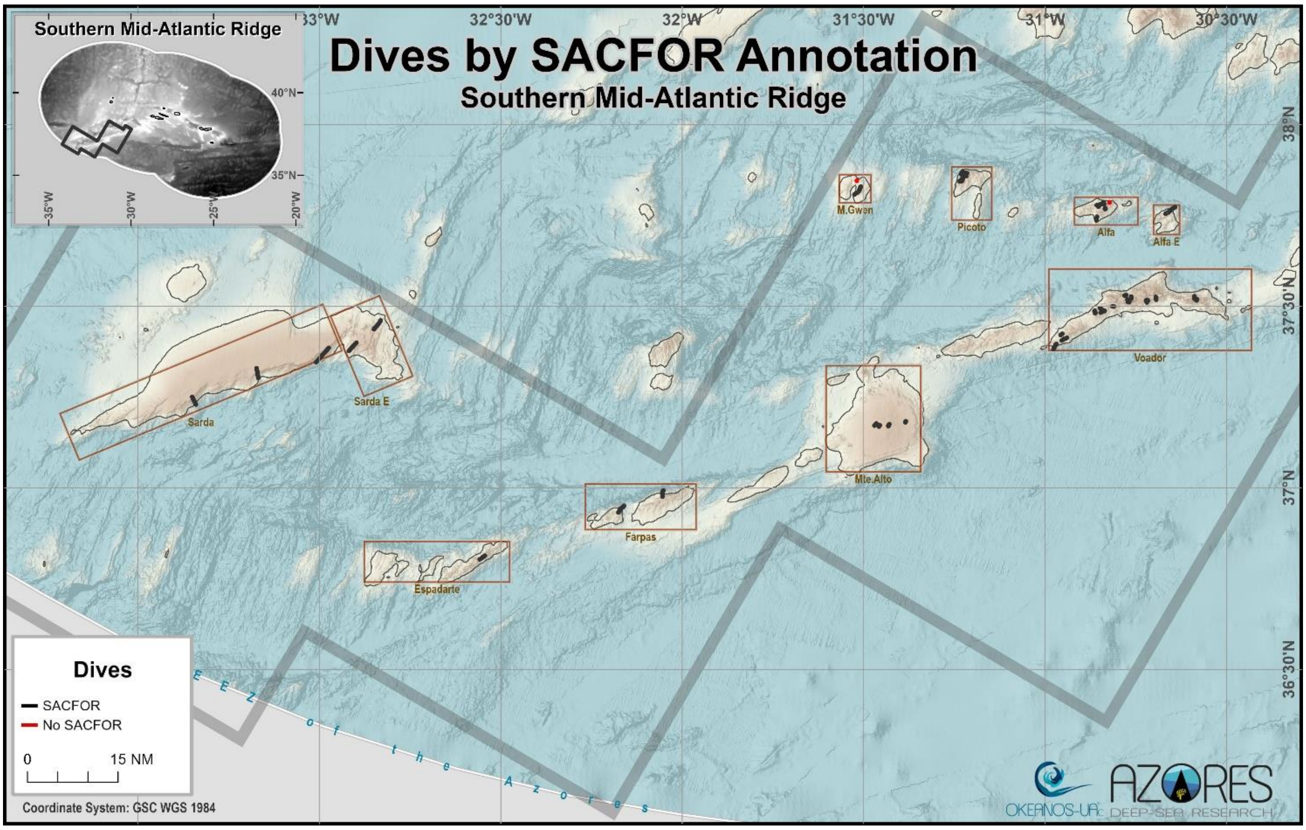


Figure 266 Southern Mid-Atlantic Ridge sampling areas (Level 3) with or without SACFOR dive locations.

Study area | Alberto do Mónaco

*Menez Gwen*

Navigating the Menez Gwen area, 2 underwater video transects were performed between 720 and 1000 m depth (Figure 267). The analysis of the video footage revealed 45 taxa, of which 26 were identified at the species level, indicating that this area supports a low diversity of deep-sea megabenthic species. Prominent taxa based on weighted occurrences include *Narella versluysi* (n= 24), *Farrea occa* (n= 23), and Decapoda (n= 21).

The area explored covered a depth gradient between 700 and 1,000 m. Most of the substrate consisted of unconsolidated sediments such as sands, gravels, coral rubble, and boulders of varying sizes. The diversity of species observed was predominantly low, although higher in shallower areas. In the deepest part explored, a few sparse black corals of the genus *Leiopathes* (Figure 268a,b), sea urchins of the species *Cidaris cidaris* and small *Lophelia pertusa* colonies were observed. Below 780 m depth, some areas hosted aggregations of the primnoid *Narella versluysi* (Figure 268d), always in low abundances, and accompanied by some other coral species such as *Hemicorallium tricolor.*

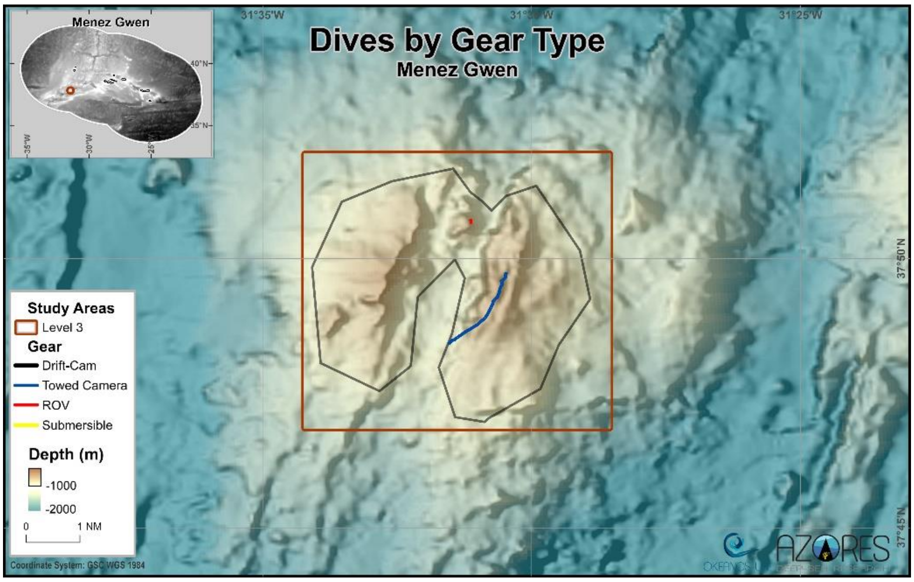



**Figure 267** Map displaying the 2 underwater dives performed in the Menez Gwen area between 720 and 1,000 meters depth.

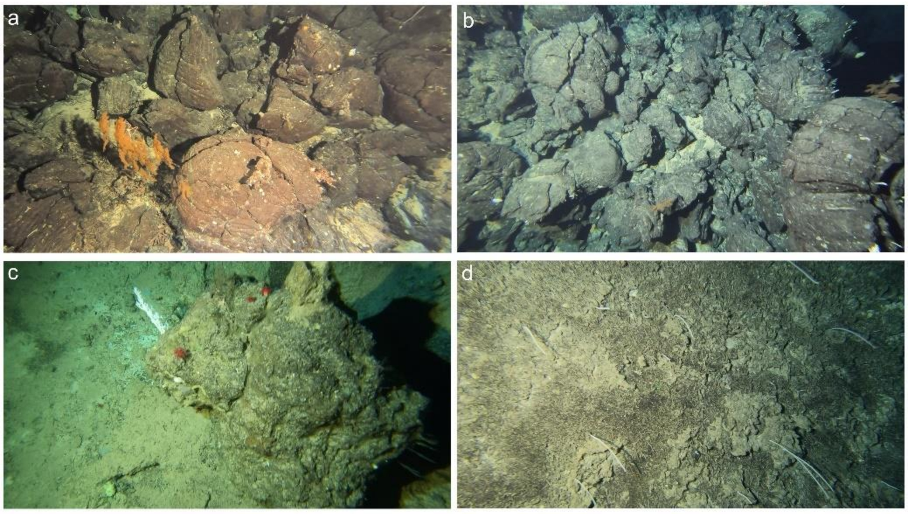



**Figure 268** Selected images representative of the main structuring species and benthic communities observed in Menez Gwen area. (a) *Leiopathes* cf. *expansa* associated with the crab *Sternostylus formosus.* (b) Small colonies of *Leiopathes* cf. *expansa.* (c) *Anthomastus/Pseudoanthomastus* sp. and one white gorgonian. (d) Aggregation of *Narella versluysi.* Image credits: Eurofleets+ iMAR cruise, IMAR/Okeanos-UAç

*Picoto*

The Picoto area was surveyed through the performance of 4 underwater video transects between 530 and 730 m depth (Figure 269). A total of 53 taxa were identified from the video annotation, with 34 at the species level, indicating a medium diversity of deep-sea megabenthic species in this area. Predominant taxa based on weighted occurrences include *Viminella flagellum* (n= 70), *Characella pachastrelloides* (n= 37), and *Echinus melo* (n= 32).

Regarding the benthic communities, the deepest part of Picoto seamount was characterized by clean slopping walls with small cnidarians, such as *Pleurocorallium johnsoni*, *Leptopsammia formosa* and *Anthomastus/Pseudoanthomastus* sp., as well as a yellow lamellate sponge (Figure 270a). Some areas of coral rubble of an unknown origin existed between the rocky outcrops, with no visible fauna associated to them. In some sections, the colour of the rock became darker (basalts), hosting a different community characterized by the presence of a wide variety of encrusting and erect sponges, such as *Petrosia crassa*, as well as several glass sponges. In shallower areas, the whip coral *Viminella flagellum* became the dominant octocoral species, forming some dense patches along the path of the video platform (Figure 270c). Interestingly, in between the *Viminella* colonies, *Callogorgia verticillata* colonies were observed, occasionally generating dense patches of very large specimens that lasted some tens of meters (Figure 270d). These aggregations hosted some of the largest *Callogorgia verticillata* colonies observed in the images so far. Within these corals, very large specimens of the fishes *Conger conger* and *Polyprion americanus* were observed, together with some deep-sea sharks.

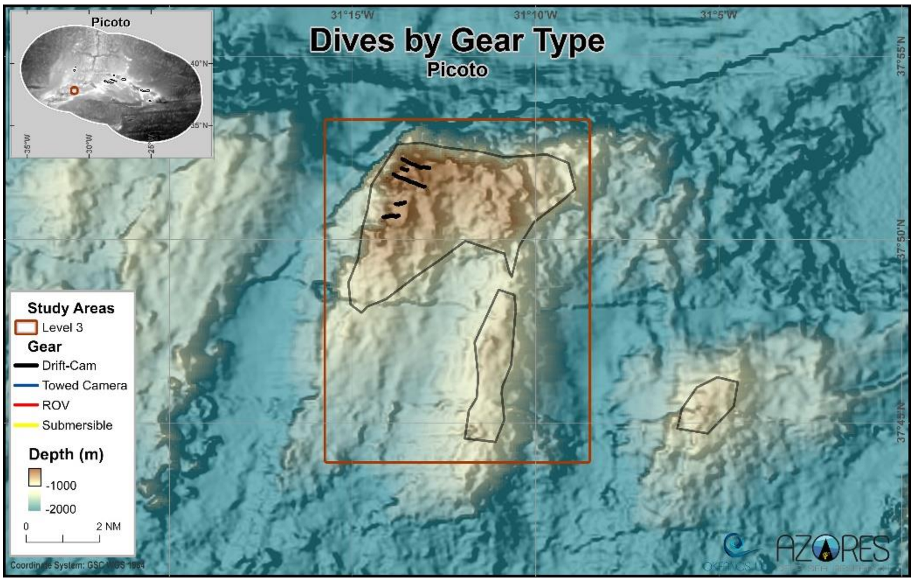



**Figure 269** Map displaying the 4 underwater dives performed in the Picoto area between 530 and 730 meters depth.

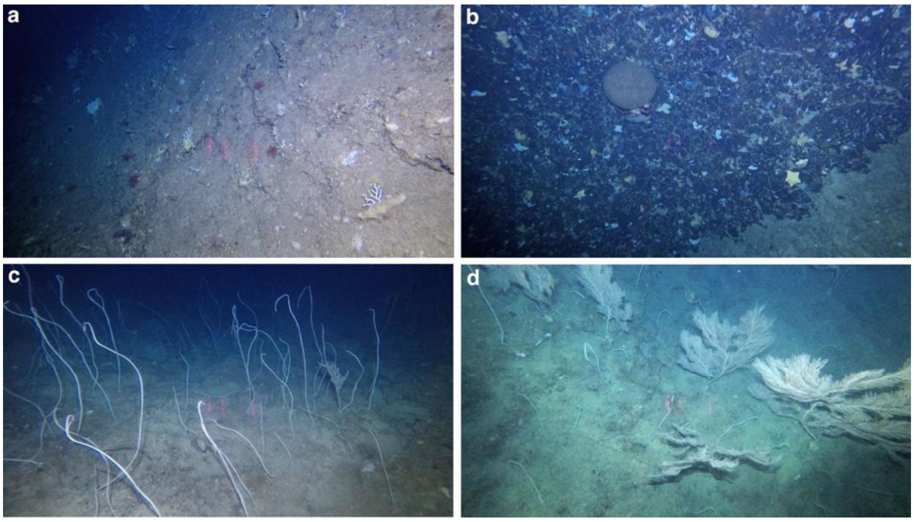



**Figure 270** Selected images representative of the main structuring species and benthic communities observed in Picoto seamount. (a) Clear outcropping rocks with *Pleurocorallium johnsoni* and *Anthomastus/Pseudoanthomastus* sp.. (b) Aspect of the rocky outcrops colonized by encrusting sponges, together with some larger species. (c) *Viminella flagellum* aggregation on the shallowest areas explored. (d) Aspect of the very large colonies of *Callogorgia verticillata* observed in several sectors of this seamount. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Alfa seamount*

In Alfa seamount, 7 underwater video transects were performed covering a depth range between 510 and 980 m (Figure 271). A total of 78 taxa were determined from the video analysis, with 54 identified at the species level, highlighting a high diversity of deep-sea megabenthic species in this area. Prominent taxa based on weighted occurrences include *Anthomastus/Pseudoanthomastus* sp. (n= 54), *Desmacella grimaldii* (n= 52), and *Viminella flagellum* (n= 41).

Regarding the benthic communities, the number identified appears to be low, with the main structuring species generally appearing in low densities. The highest diversities were found in areas where the mother rock has a darker tonality (basalts), with a dominance of encrusting species of different colours. Between the encrusting sponges, some large Porifera could be identified, including the giant sponge *Characella pachastrelloides*, as well as the ubiquitous small soft coral *Anthomastus/Pseudoanthomastus* sp. (Figure 272a). The black rock also hosted the common association between the white coral *Pleurocorallium johnsoni* and a yellow lamellate sponge (Figure 272b), although both species generally found in low abundances. When the rock displayed a clearer tonality, the dominance of species shifted to a community dominated by the whip coral *Viminella flagellum* and the small anthozoan *Anthomastus/Pseudoanthomastus*, always in relatively low densities (Figure 272c). Among all the video footage obtained, the presence of soft bottom areas of sand and gravel was low, and partially covered by deposits of coral rubble. In opposition to other seamounts of the MAR, not many large fishes were reported, besides the occasional deep-sea shark of the species *Hexanchus griseus*. Several abandoned fishing lines were registered in this seamount, some of which fully covered in small fauna indicating a long soaking time of these gears (Figure 272d).

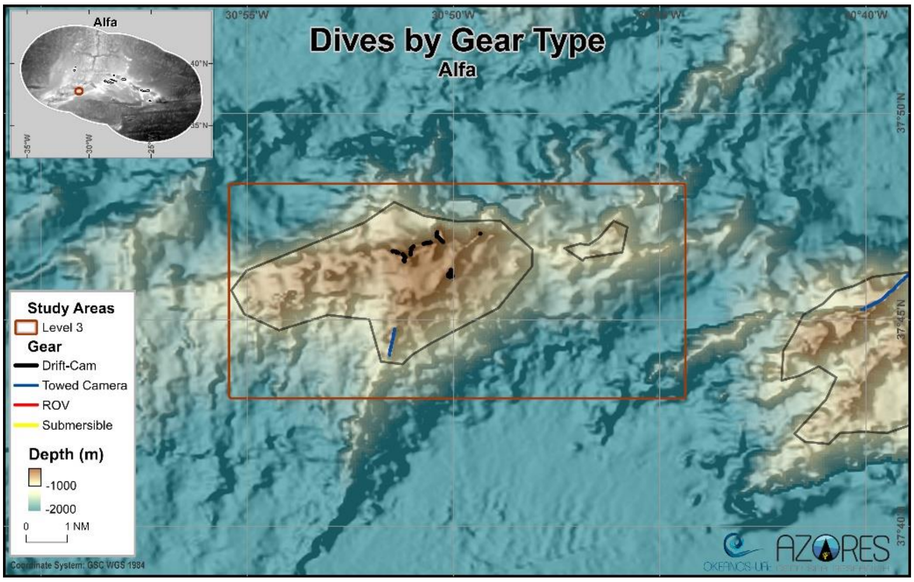



**Figure 271** Map displaying the 7 underwater dives performed in the Alfa area between 510 and 980 meters depth.

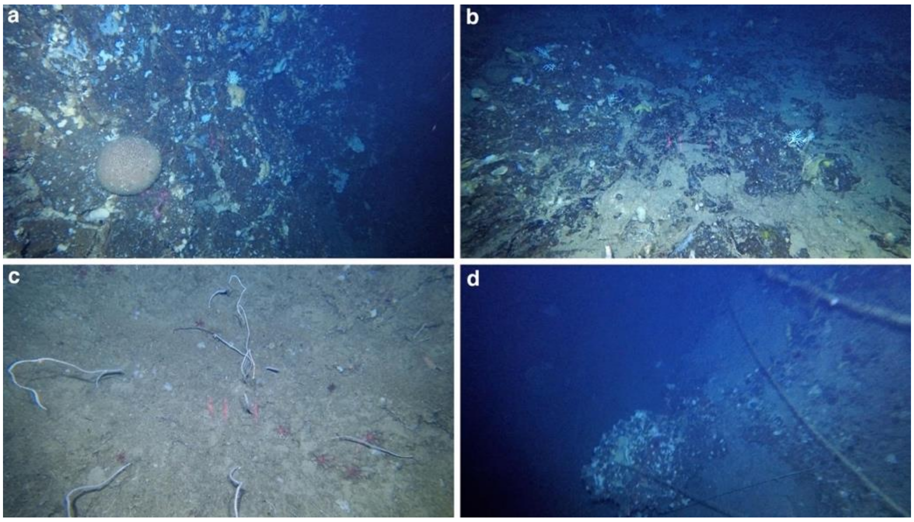



**Figure 272** Selected images representative of the main structuring species and benthic communities observed in Alfa seamount. (a) Dark rock colonized by a wide variety of sponge species. (b) Flat area of dark rock dominated by the white coral *Pleurocorallium johnsoni* and a yellow lamellate sponge. (c) The whip coral *Viminella flagellum* in association with the anthozoan *Anthomastus/Pseudoanthomastus*. (d) Some of the large fishing lines laying abandoned over the seabed. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Alfa E*

The Alfa East area was only surveyed through one underwater video transect, performed between 520 and 1100 m depth (Figure 273). A total of 57 taxa were determined from the video annotation, with 38 at the species level, indicating a medium diversity of deep-sea megabenthic species in this area. Dominant taxa based on weighted occurrences include *Farrea occa* (n= 42), *Pheronema carpenteri* (n= 38), and *Cidaris cidaris* (n= 37).

The eastern area of the Alfa seamount was explored covering a large depth range. The seabed at the slope of this seamount was mainly characterized by hard bottoms, general basaltic rock partially covered with fine sediment and at some areas with coral rubble. The seabed was generally very heterogenous, shifting very often and very irregular. The deepest areas of the ridge had some aggregations of the bird's nest sponge *Pheronema carpenteri* (Figure 274e) and several lamellate sponges such as *Poecillastra compressa* (Figure 274c,f). Occasional aggregations of the primnoid *Narella versluysi* (Figure 274a) were also recorded, together with the presence of the sea urchin *Cidaris cidaris* (Figure 274a,f). On the shallower area of the ridge a surprisingly large aggregation of the octocoral *Hemicorallium tricolor* (Figure 274b,c) was found, accompanied with bamboo corals, stylasterids and fan-shaped sponges. The sponge *Regadrella phoenix* (Figure 274d) was also present, however never in big abundances. Some notably deep-sea fishes were also found swimming around, from which we can highlight the orange roughy (*Hoplostethus atlanticus*), monkfish (*Lophius piscatorius*) and the kite fin shark (*Dalatias licha*).

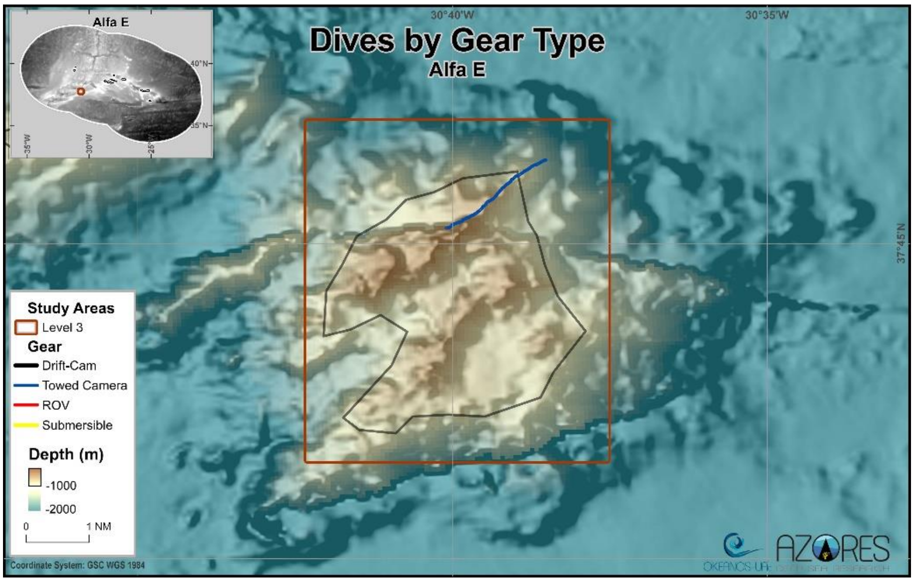



**Figure 273** Map displaying the 1 underwater dive performed in the Alfa E area between 520 and 1,100 meters depth.

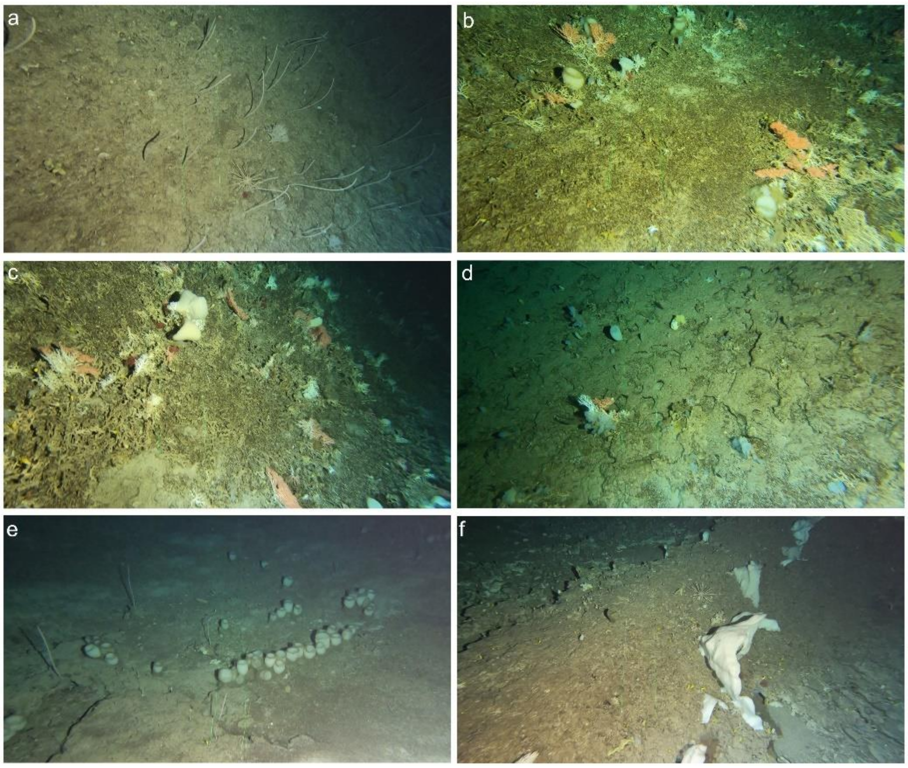



**Figure 274** Selected images representative of the main structuring species and benthic communities observed in Alfa East area. (a) Aggregation of *Narella bellissima, N. versluysi* and the sea urchin *Cidaris cidaris* (b-c) Dead coral framework colonized by *Hemicorallium tricolor* and *H. niobe*, the scleratinian *Leptopsammia formosa*, the soft-coral *Anthomastus/Pseudoanthomastus* sp. and the sponges *Pheronema carpenteri* and *Poecillastra compressa*. (d) Hard bottom covered by soft sediment colonized by *H. tricolor and H. niobe* with several sponges species. (e) Aggregation of the sponge *P. carpenteri* and some colonies of *N. versluysi*. (f) Soft sediments colonized by *P. compressa*, the corals *Anthomastus/Pseudoanthomastus* sp. and *L. formosa* and sea urchin *C. cidaris*. Image credits: Eurofleets+ iMAR cruise, IMAR/Okeanos-UAç

*Voador seamount*

In the Voador seamount, 18 underwater video transects were conducted between 280 and 1200 m depth (Figure 275). A total of 147 taxa were identified from the images recorded. From these, 87 were identified at the species level, revealing a very high diversity of deep-sea megabenthic species in this area. Noteworthy taxa based on weighted occurrences include *Characella pachastrelloides* (n= 139), *Petrosia (Petrosia) crassa* (n= 138), and *Macandrewia azorica* (n= 134).

Most of the slope and summit areas explored corresponded to rocky outcrops and large boulders, with very few mud/sand patches overall. In the rocky areas of the slopes, the megabenthic community was generally characterized by the presence of different species of sponges, especially when the rock displayed a darker coloration (basalts) (Figure 276a). Encrusting sponges were commonly observed throughout the hard substrates, accompanied by several lithistid sponges of the species *Macandrewia azorica*, *Petrosia crassa*, *Neophrisospongia nolitangere* and *Leiodermatium* spp, as well as the giant sponge *Characella pachastrelloides*. Some scattered colonies of the whip coral *Viminella flagellum* appeared within this sponge-dominated community, but never in the form of dense patches. This species composition was observed in many sectors of Voador seamount, especially in the deepest areas explored, although it also seems to extend into the summit areas. The size of some *Characella pachastrelloides* was remarkable (Figure 276b), observed serving as substrate to other life forms, such as anemones and small hydrozoans, and as refuge to small fish species, such as juveniles of *Helicolenus dactylopterus*. Interestingly, a few specimens of the lollipop sponge *Stylocordyla pellita* were also identified within this community, although always as solitary individuals and never generating dense patches, in opposition to what has been observed in other seamounts.

Very dense aggregations of *Candidella imbricata* appeared in shallower areas, mainly developing over rocky outcrops and large boulders (Figure 276c). A wide variety of small sponges and other gorgonian species were reported associated to this community, in which the yellow morph of the whip coral *Viminella flagellum* and the primnoid *Callogorgia verticillata* stand out due to the densities achieved and size of their colonies. Interestingly, some large *Callogorgia verticillata* colonies were also observed generating monospecific patches on the smooth slopes, generally with very little megafauna associated to them (Figure 276d). Another community observed in Voador seamount corresponds to that formed by the large primnoid *Paracalyptrophora josephinae,* which was observed in association with large hydroids (Figure 276e). The density of *Paracalyptrophora josephinae* in this seamount is one of the highest observed in the Mid-Atlantic Ridge in the Azores, since this primnoid is usually observed as an accompanying species in other communities, rarely seen forming dense aggregations. Over sedimentary areas, the number of invertebrates identified was low, limited to some echinoderms (e.g., sea urchins of the genus *Echinus*). In the sandy areas, some gravel deposits were reported, in some cases occupying a large part of the available seabed. Most of these deposits seem to have a lithogenic origin, although a small percentage corresponded to small pieces of coral rubble.

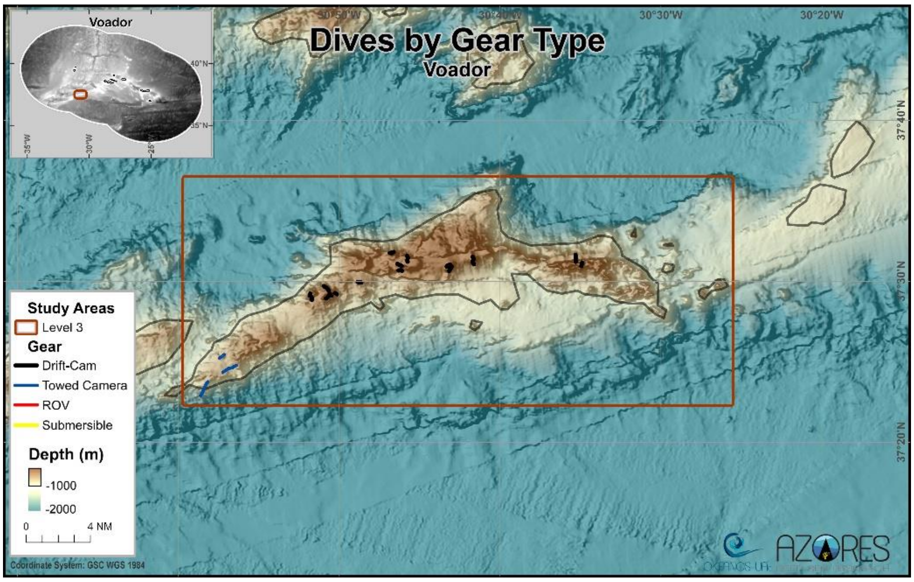



Figure 275 Map displaying the 18 underwater dives performed in the Voador area between 280 and 1,200 meters depth.

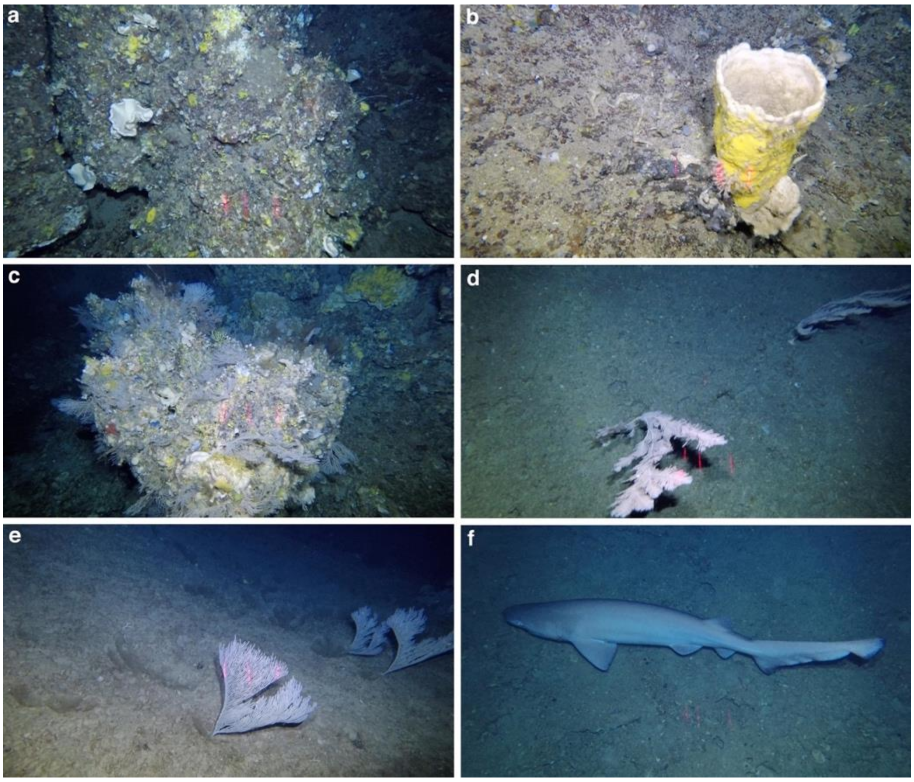



Figure 276 Selected images representative of the main structuring species and benthic communities observed in Voador seamount. (a) A wide variety of Porifera species observed on the large rocky outcrops and vertical walls. (b) A large *Characella pachastrelloides* observed on the slopes of this seamount. (c) Boulder completely covered in sea fans of the species *Candidella imbricata*. (d) Large colonies of the species *Callogorgia verticillata* on the smooth rock of the slope. (e) Association between the coral *Paracalyptrophora josephinae* and a large hydrozoan. (f) A six-gill shark *Hexanchus griseus*. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Monte Alto seamount*

In the Monte Alto seamount, 4 underwater video transects were conducted between 410 and 580 m depth (Figure 277). A total of 29 taxa were determined from the video analysis, with 18 at the species level, indicating a low diversity of deep-sea megabenthic species in this area. Predominant taxa based on weighted occurrences include *Petrosia (Petrosia) crassa* (n= 24), *Hymedesmia (Hymedesmia) paupertas* (n= 21), and *Viminella flagellum* (n= 18).

The summit of Monte Alto is characterized by soft substrates, with most of the areas explored until now corresponding to extensive sandy areas (Figure 278a). In some, well-formed ripples could be observed, likely caused by the action of bottom currents. In this homogenous habitat, the number of species reported was rather low, with two species standing out above the rest: the solitary scleractinian coral *Flabellum* sp. and a yellow/orange sea star of the Goniasteridae family. Some boulders of black rock (basalts) were sometimes observed scattered along the sand, in most cases colonized by large colonies of the whip coral *Viminella flagellum*, generally in low densities (Figure 278b). In contrast, when the substrate became coarser and the rock outcropped, a sharp increase in the number of invertebrate species could be observed. In most cases, the most abundant group was Porifera, with a clear dominance of small encrusting and digitate sponges of various colours (Figure 278c). On these hard substrates, large Porifera were reported, including *Neophrissospongia nolitangere*, *Leiodermatium* spp., *Petrosia crassa* and *Macandrewia azorica,* as well as very large *Characella pachastrelloides* (Figure 278c). Less common was the presence of structuring corals, with large *Callogorgia verticillata* colonies reported in one sector dominated by rocky outcrops, allowing these corals to reach relatively high densities (Figure 278d).

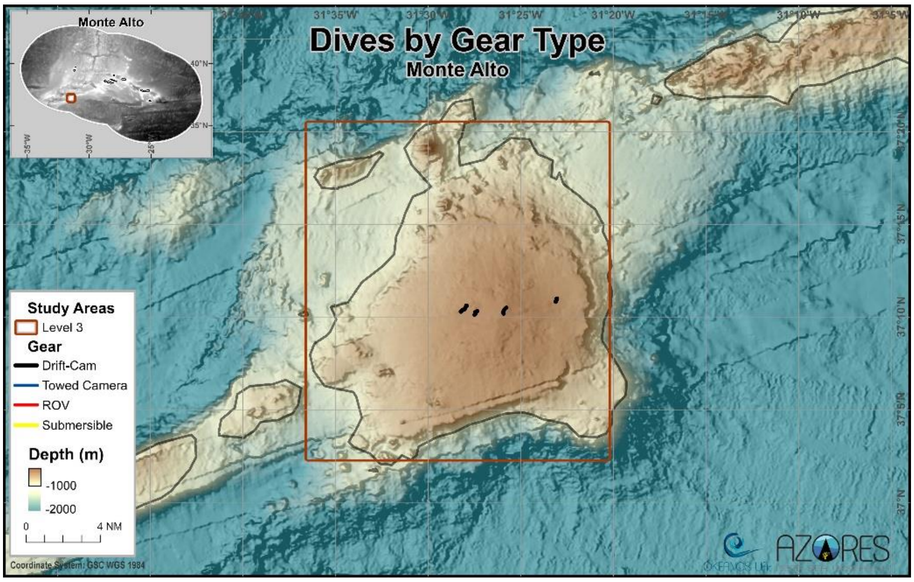



**Figure 277** Map displaying the 4 underwater dives performed in the Monte Alto area between 410 and 580 meters depth.

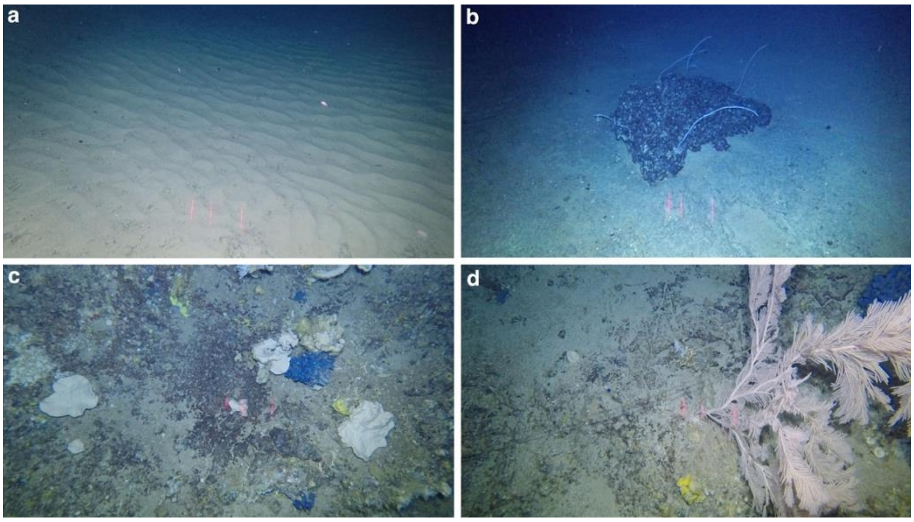



**Figure 278** Selected images representative of the main structuring species and benthic communities observed in Monte Alto seamount. (a) Ripples in sandy areas of the summit. (b) Some large whip corals of the species *Viminella flagellum* in one of the scattered boulders observed in sandy areas. (c) Aspect of the sponge aggregations found in hard grounds. (d) A well-preserved colony of the primnoid coral *Callogorgia verticillata*. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

## Study area | Farpas

*Farpas*

Overall, 2 underwater video transects were conducted in Farpas area between 650 and 1220 m depth (Figure 279). A total of 68 taxa were identified from the images. From these, 41 were identified at the species level, revealing a medium diversity of deep-sea megabenthic species in this area. Notable taxa based on weighted occurrences include *Pheronema carpenteri* (n= 72), *Farrea occa* (n= 64), and *Regadrella phoenix* (n= 56).

The seafloor explored ranged from 1170 to 650 m depth, displaying some interesting faunal assemblages throughout. The deepest sections explored showed a complex geomorphology, with large rocks colonized by plexauridae corals not yet identified and large lamellate sponges *Poecillastra compressa*. The more sedimentary areas at these depths were characterized by the bamboo coral *Acanella arbuscula* and the bird's nest sponge *Pheronema carpenteri* (Figure 280d). Several eel-like fishes swimming very close to the seabed were also recorded. On areas of steeper terrain, the octocoral *Candidella imbricata* was present, showing higher densities at around 1,000 m depth, with several dense aggregations (Figure 280c). At around 800m the community shifted to coral gardens dominated by the primnoids *Narella versluysi* and *Narella bellissima* (Figure 280a) and the sponge *Pheronema carpenteri*. The density of the primnoids of the genus *Narella* increased to reach some of the highest densities ever observed in the Azores, lasting for hundreds of meters. Some of the associated species of this dense gardens included the octocoral *Acanthogorgia* spp. The shallowest sections explored were characterized by the octocorals *Acanthogorgia* spp. and *Callogorgia verticillata* (Figure 280b).

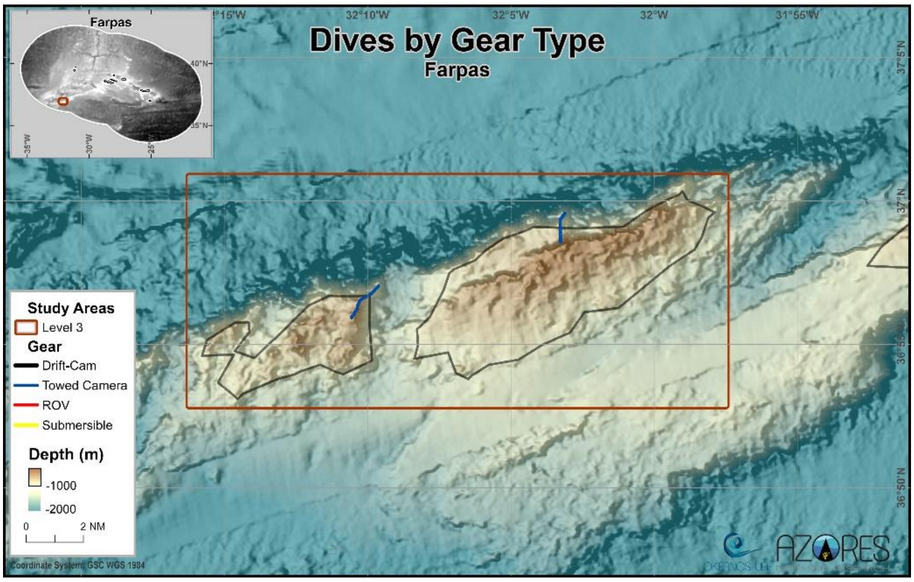



**Figure 279** Map displaying the 2 underwater dives performed in the Farpas area between 650 and 1,220 meters depth.

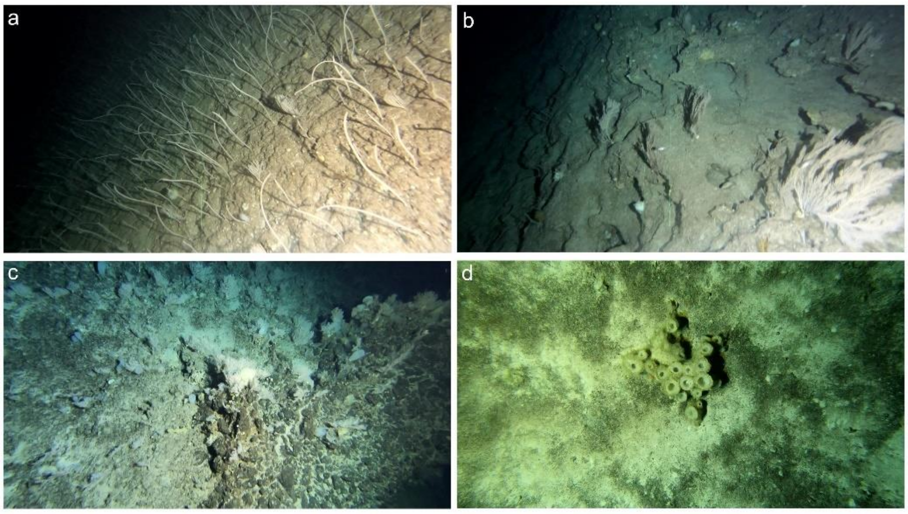



**Figure 280** Selected images representative of the main structuring species and benthic communities observed in Farpas area. (a) Large aggregation of the primnoids *Narella bellissima* and *Narella versluysi* (b) Aggregation of *Callogorgia verticillata.* (c) Aggregation of *Candidella imbricata.* (d) Small aggregation of *Pheronema carpenteri.* Image credits: Eurofleets+ iMAR cruise, IMAR/Okeanos-UAç

*Espadarte (former Cavalo ridge)*

Espadarte seamount is one of the features located furthest away from land, at a distance of more than 300 km from Faial Island. Here, only one underwater video transect was performed between 400 and 800 m depth (Figure 281). A total of 49 taxa were determined from the video recorded, with 36 identified at the species level, revealing a medium diversity of deep-sea megabenthic species for this area. Predominant taxa based on weighted occurrences include *Paragorgia johnsoni* (n= 83), Octocorallia (n= 82), and *Acanthogorgia* spp. (n= 47).

The benthic communities observed in this seamount were very rich and diverse. Most hard substrates of the deepest areas explored were dominated by the primnoids *Narella versluysi* and *Narella bellissima*, both found in rather high densities (Figure 282a,b). This community was extremely diverse, with these two corals associated to a wide range of other species, including several species of sponges (e.g., *Haliclona magna*) as well as other large corals, including *Paragorgia johnsoni*, *Pleuricorallium johnsoni* and *Callogorgia verticillata*. The anthozoan *Anthomastus/Pseudoanthomastus* sp. and the sea urchins *Cidaris cidaris* and *Echinus* sp. were also commonly observed along the slope. Areas of the upper slope close to the summit hosted some very large colonies of the gorgonian coral *Paragorgia johnsoni* (Figure 282c), which appeared with a few white lamellate sponges (Figure 282d). When the rock acquired a darker tonality (basalts), a great change in species composition was observed, transitioning to a sponge-dominated community that included *Petrosia crassa* and many encrusting and small-sized sponges of various colours (Figure 282e). In the shallowest part of the summit, the community was dominated by the yellow gorgonian *Acanthogorgia* spp. and very large colonies of the species *Callogorgia verticillata* (Figure 282f), together with many other accompanying species, including large numbers of the small *Swiftia* sp.

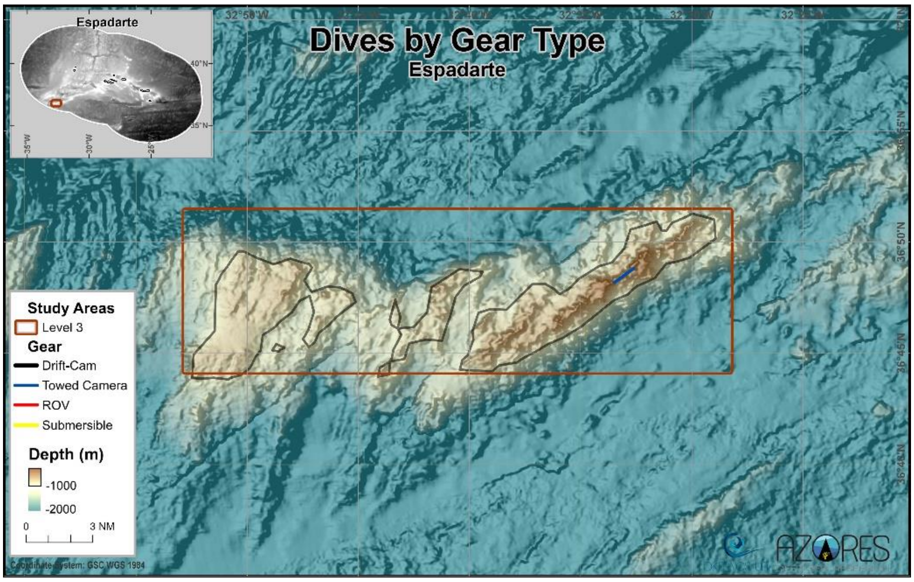



**Figure 281** Map displaying the 1 underwater dive performed in the Espadarte area between 400 and 800 meters depth.

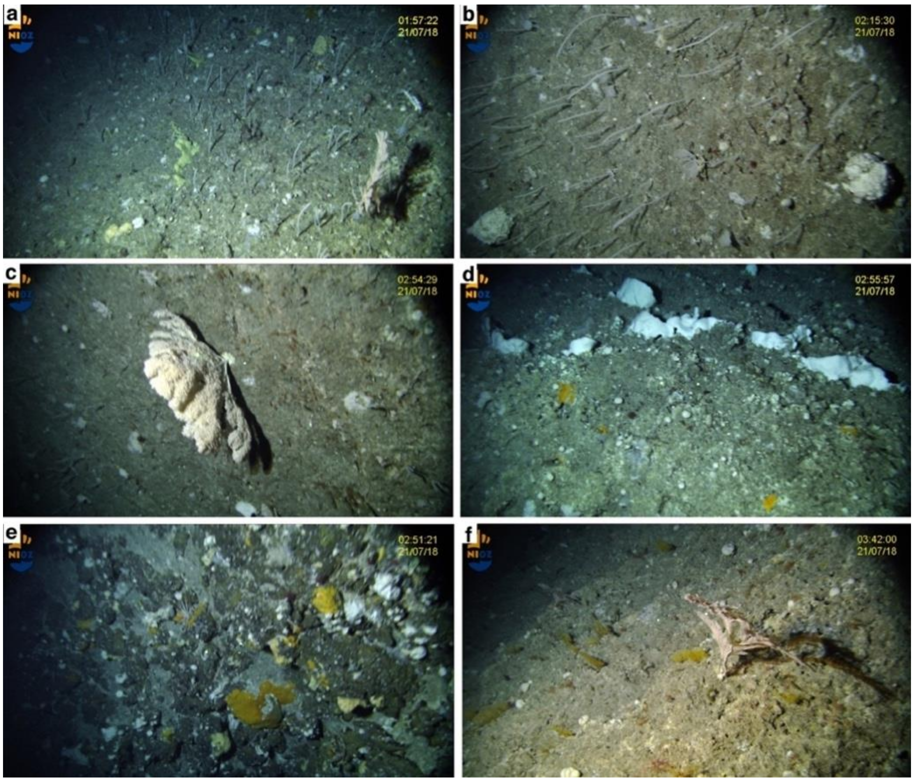


**Figure 282** Selected images representative of the main structuring species and benthic communities observed in Cavalo seamount. (a-b) Dense patches of the primnoid *Narella versluysi* on the hard substrates of the slope. (c) Large colony of the gorgonian coral *Paragorgia johnsoni*. (d) Lamellate sponges on high densities. (e) Aggregation of sponges on basaltic rocks. (f) Aspect of the summit, with dense aggregations of the yellow sea fan *Acanthogorgia* spp. with *Callogorgia verticillata*. Image credits: Hopper tow-cam, NIOZ.

Study area | Sarda

*Sarda East*

While surveying the Sarda East area, 2 underwater video transects were performed covering a depth range between 480 and 880 m (Figure 283). A total of 79 taxa were determined from the images, with 54 identified at the species level, revealing that a high diversity of deep-sea megabenthic species is supported by this area. Prominent taxa based on weighted occurrences include *Farrea occa* (n= 75), *Anthomastus/Pseudoanthomastus* sp. (n= 64), and Hydrozoa (n= 63).

The Sarda East seamount displays a very different composition regarding its benthic megafauna, with coral-dominated communities in opposition to the sponge-dominated assemblages of the western slopes. The deepest part of the mound is characterized by 4 different cold-water coral species, including *Narella bellissima* and *Narella versluysi* (Figure 284a), the large primnoid *Callogorgia verticillata* and the yellow sea fan *Acanthogorgia* spp. In shallower areas, an aggregation of large colonies of the coral *Paragorgia johnsoni* was observed, surrounded by a large number of the small scleractinian *Leptopsammia formosa*. Towards the summit, the number of sponge species increased, to finally shift to a *Viminella flagellum* (Figure 284h) community, found in association sponges such as *Leiodermatium* spp. and *Neophrissospongia nolitangere*, and also a large number of *Acanthogorgia* spp. and *Callogorgia verticillata.*

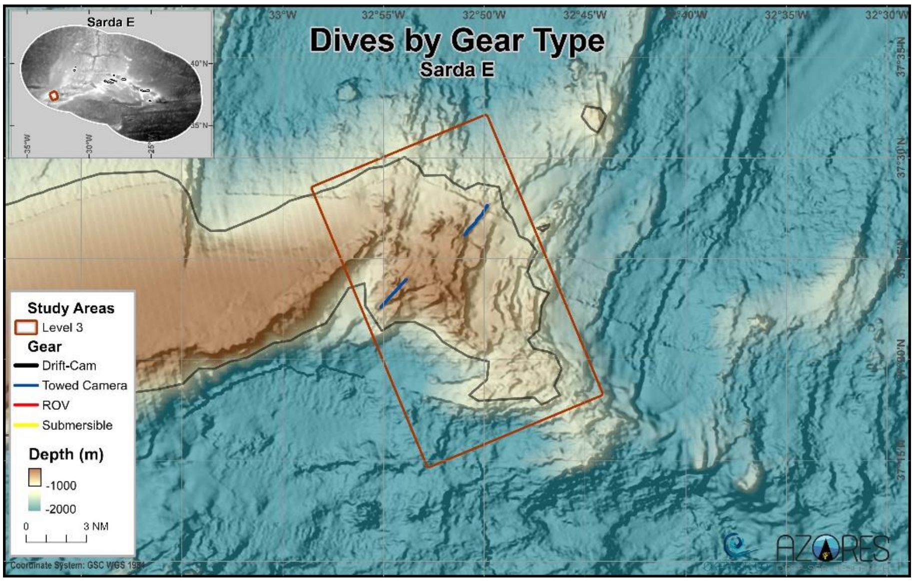



**Figure 283** Map displaying the 2 underwater dives performed in the Sarda E area between 480 and 880 meters depth.

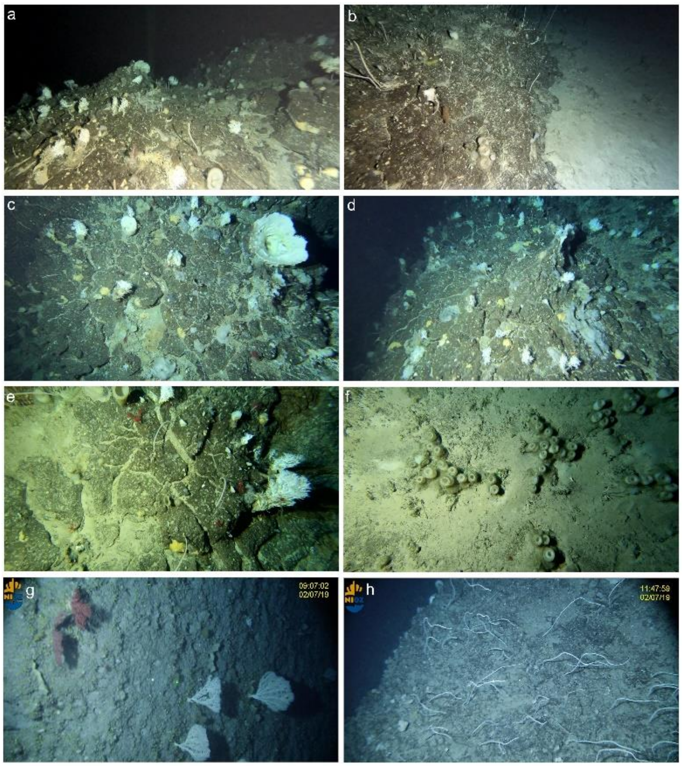


**Figure 284** Selected images representative of the main structuring species and benthic communities observed in Sarda East area. (a) Rocky outcrops colonized by small *Narella versluysi,* stylasterids and several sponges. (b) Hard substrate colonized by *N. versluysi,* small *Leiopathes* cf. *expansa* and the sponge *Pheronema carpenteri* amog other sponge species. (c) (d) (e) Rocky bottom colonized by *Errina atlantica*, *N. versluysi* and *Anthomastus/Pseudoanthomastus* sp. and the sponges *P. carpenteri* and *Asconema fristedti.* (f) *P. carpenteri* on soft sediments. (g) Colonies of the two morphotypes of *Paragorgia johnsoni.* (h) Large aggregation of the whip coral *Viminella flagellum.* Image credits: a-f Eurofleets+ iMAR cruise, IMAR/Okeanos-UAç; g,h R/V Pelagia towed camera system, NIOZ / Cruise 64PE454

*Sarda*

In the Sarda area, 3 underwater video transects were completed between 430 and 1140 m depth (Figure 285). A total of 77 taxa were determined from the images recorded, with 51 identified at the species level, revealing a high diversity of deep-sea megabenthic species for this area. Noteworthy taxa based on weighted occurrences include *Petrosia (Petrosia) crassa* (n= 106), *Viminella flagellum* (n= 95), and *Macandrewia azorica* (n= 81).

The images evaluated showed that Sarda seamount displays a very clear bathymetric zonation in terms of species composition, with two very contrasting sectors. The western ridge, which stretches for more than 70 km, presents sharper slopes and cliffs, and it was mainly characterized by a wide diversity of sponge species. Its summit however, hosted dense aggregations of the whip coral *Viminella flagellum* (Figure 286a,b). Conversely, the smaller seamount located on the eastern side was mainly dominated by several structuring octocoral species, which are clearly segregated along the bathymetric gradient. The deepest areas of the western ridge, below 1,000 m depth, are composed of a mixture of mud, sand, and gravels, and two main aggregations were observed: the glass sponge *Hyalonema* sp. and the benthic foraminifera cf. *Syringammina fragilissima*. On the deepest part of the slope, where rocks began to outcrop, aggregations the gorgonian coral *Candidella imbricata* and the large glass sponge *Pheronema carpenteri* are commonly observed (Figure 286d). Moving towards shallower areas, on the middle part of the slope, a wide variety of large sponges were observed, in which to include *Petrosia crassa, Neophrissospongia nolitangere*, *Leiodermatium* spp. and *Characella pachastreloides*. In the summit area, the whip coral *Viminella flagellum* was by far the most abundant and conspicuous species of all, reaching some very high densities in some sectors. This gorgonian coral seldom appears forming monospecific patches, and it is generally accompanied by a wide variety of species, in which to include the glass sponge *Asconema* sp., the sea fan *Acanthogorgia* spp., the yellow cup coral *Leptopsammia formosa* and large colonies of the primnoid *Callogorgia verticillata* (Figure 286c). A few lithistid sponges were generally observed accompanying the dense patches of *Viminella flagellum*, including *Petrosia* cf. *crassa*, *Macandrewia azorica*, *Neophrissospongia nolitangere* and *Characella pachastreloides*, among others.

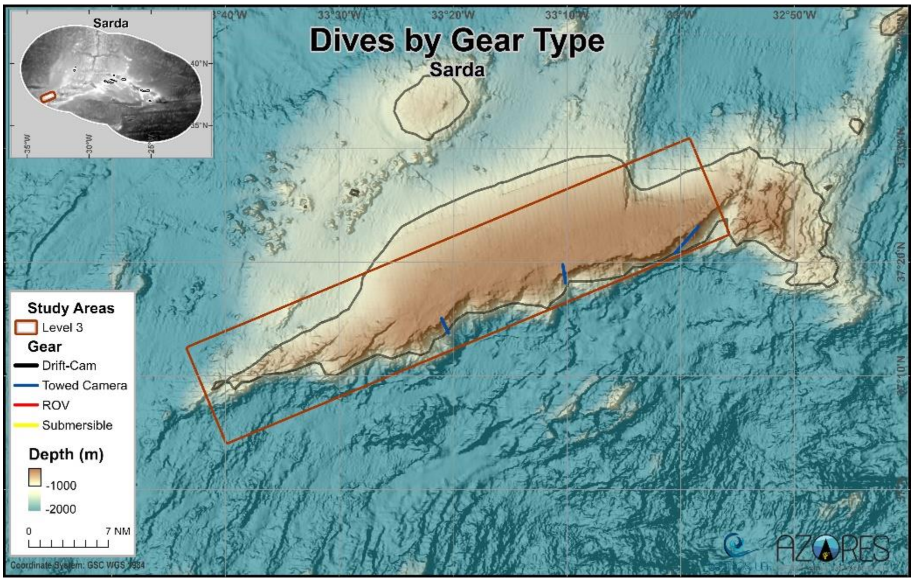



**Figure 285** Map displaying the 3 underwater dives performed in the Sarda area between 430 and 1,140 meters depth.

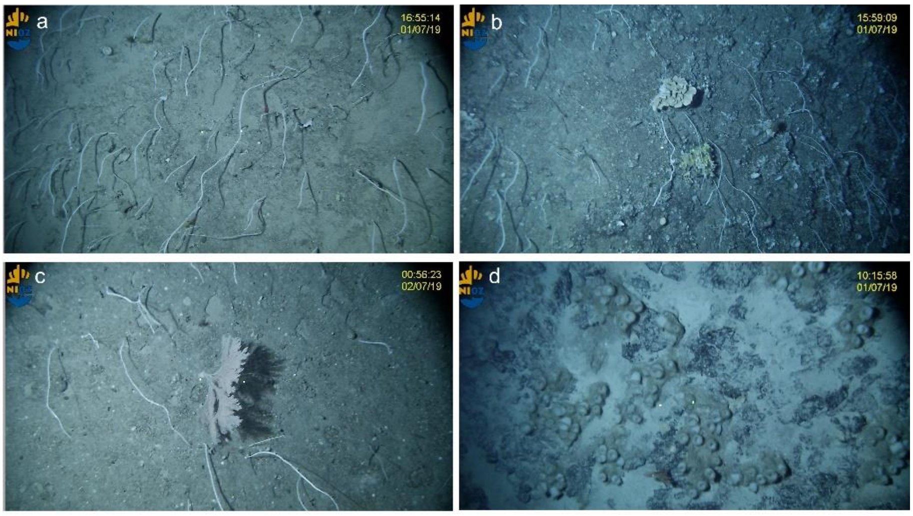



Figure 286 Selected images representative of the main structuring species and benthic communities observed in Sarda and Sarda E seamounts. (a) Colonies of the whip coral *Viminella flagellum* (b) Aggregation of *V. flagellum* and several sponges species. (c) Assemblage of *V. flagellum* and a colony of *Callogorgia verticillata.* (d) Aggregation of the hexactinellid sponge *Pheronema carpenteri.* Image credits: Hopper tow-cam, NIOZ.

## *10.5 Large area | Northern Central Group*

The large area Northern Central group of the Azores contains 4 study areas: Sedlo, Graciosa/São Jorge islands, Terceira and Dom João de Castro and several sampling areas (Figure 287). All of them have been explored with the Azor drift-cam during the MapGES 2018, 2020, 2021 and 2022 surveys, during the Blue Azores 2018 expedition with the ROV Luso, with the towed camera system of the R/V Pelagia during the Terceira (2020 and 2021) and NICO (2018 and 2021) surveys, and the NOAA (2022), DeepWalls (2020), EMEPC (2009), and the OceanX (2023) surveys.

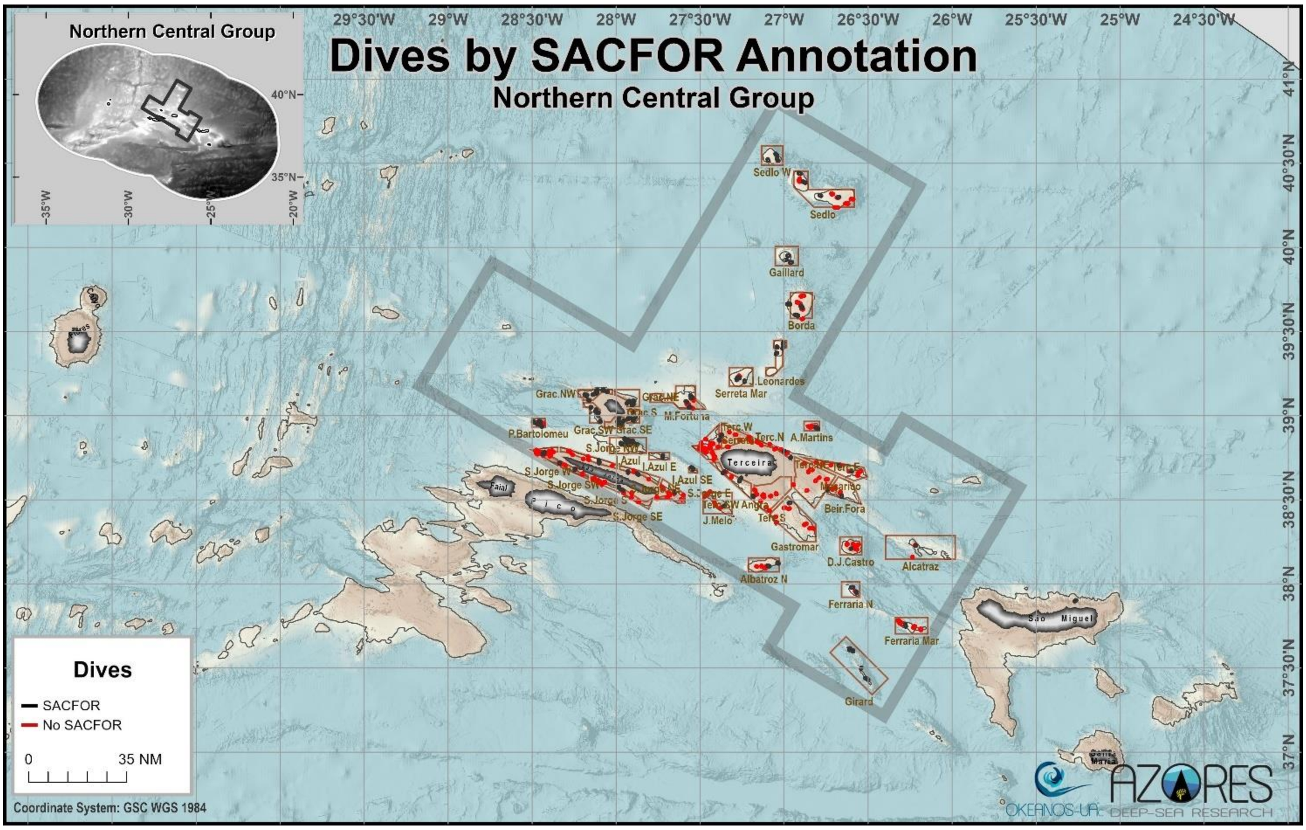


Figure 287 Northern Central Group sampling areas (Level 3) with or without SACFOR dive locations.

### Study area | Sedlo

*Sedlo W*

There were performed 3 underwater video transects around Sedlo West area, ranging from 700 to 1,000 m depth (Figure 288). A total of 68 taxa were determined from the video annotation. From these, 37 were identified at the species level, revealing that a medium diversity of deep-sea megabenthic species is supported by this area. Dominant taxa based on weighted occurrences include *Acanella arbuscula* (n= 42), Caryophylliidae (n= 24), and Crinoidea (n= 19).

The geomorphological structures of the western area of Sedlo, are described as with a flat type of morphology seamount. The depth range explored and filmed with the Azor drift-cam was narrow (slightly between 1012 and 848m) and the substrate was predominantly composed of rocky grounds (generally with no big outcrops or boulders), occasionally interrupted by soft sediment patches, in the middle or below the hard structures. The seafloor at this seamount was extensively covered with deep benthic megafauna, however at most of the cases, very scattered along the seafloor. The black coral species cf. *Leiopathes* cf. *expansa* (Figure 289a,b,c) dominated, with relatively large aggregations of sometimes voluminous colonies (the range of sizes was broad, with both very small and very large individuals). Among others, the remaining most observed coral species were the bamboo type *Acanella arbuscula* (Figure 289d), scleractinians of the family Caryophylliidae and the species *Lophelia pertusa* (normally in the company of cf. *Leiopathes* cf. *expansa*), exemplars of the family Paramuriceidae, and the hydrozoa *Pliobothrus symmetricus*. Sponges appeared in very large sizes. That was the case for the scattered glass sponge Regadrella phoenix (Figure 289e) and the fan shaped *Phakellia ventilabrum* (Figure 289f). The small sponge *Exsuperantia archipelagus* had a punctual large aggregation during one of the dives. The deep-sea crab *Chaceon affinis* and *Paromola cuvieri* were present in Sedlo W, as well as some other motile fauna, such as the fish species of Oreo fish (*Neocyttus helgae*) and *Mora moro*. To also highlight, a very large *Sternostylus formosus* associated to one of the cf. *Leiopathes expansa*.

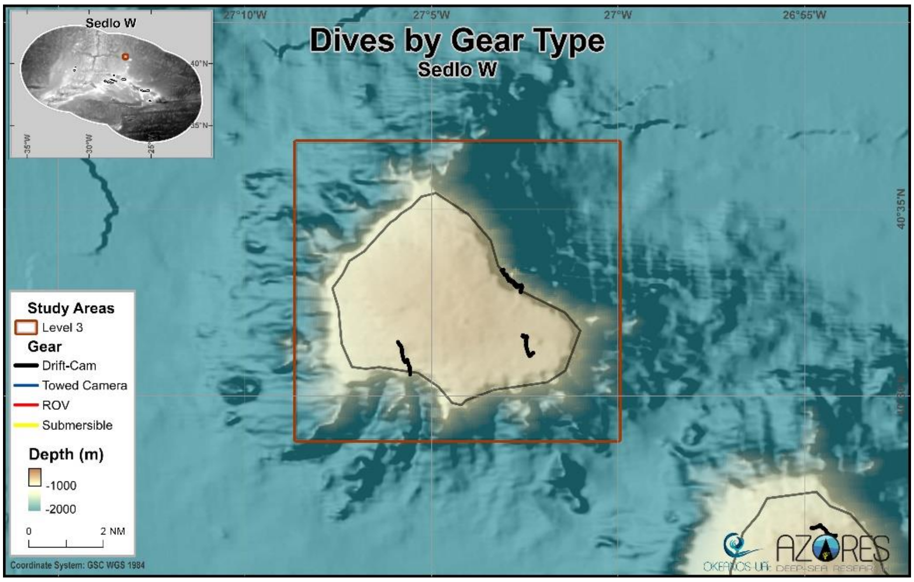


**Figure 288** Map displaying the 3 underwater dives performed in the Sedlo W area between 700 and 1,000 meters depth.


**Figure 289** Selected images representative of the main structuring species and benthic communities observed in Sedlo W area. (a-b-c) Small colonies of *Leiopathes* cf. *expansa* (d) *Acanella arbuscula* and sea urchin *Cidaris cidaris* on soft sediment (e) Large sponge *Regadrella phoenix.* (f) Sponges of the genus *Phakellia* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Sedlo*

A total of 13 underwater video transects were conducted around Sedlo area between the depths of 640 and 1080 m (Figure 290). A total of 90 taxa were determined from the images analysed, with 53 identified at the species level, revealing a high diversity of deep-sea megabenthic species for this area. Predominant taxa based on weighted occurrences include *Narella versluysi* (n= 22), Caryophylliidae (n= 21), and *Plesionika* sp. (n= 19).

Sedlo is a seamount of a flat morphology, with its central part of the seamount, between 650 and 760 m deep, being characterized by the presence of large deposits of coral rubble, where the primnoid corals *Narella versluysi* (Figure 291a) and *N. bellissima* were the most conspicuous species. Other species were also commonly observed, such as a hydrocoral likely from the genus *Errina*, large lamellate sponges of the genus *Phakellia* (Figure 291e) and the octocoral *Acanthogorgia* spp., among others. On the easternmost parts of Sedlo Seamount, in the shallowest areas of the summit (650-750 m depth), where hard substrates could be inferred from the multibeam bathymetry due to a marked change in the slope, little fauna was observed, with some colonies of the octocorals *Narella bellissima* and *Acanthogorgia* spp., hydrocorals of the genus *Errina* and some large barrel sponges likely of the genus *Characella* (Figure 291f).

On the western part of the seamount, between 950 and 780m deep, the benthic community observed was diverse but there were not many species that showed high abundances. The deepest areas hosted some sparse bamboo corals of the species *Acanella arbuscula*, accompanied by the primnoid *Narella versluysi*, the black coral *Parantipathes hirondelle,* and some sea urchins of the species *Cidaris cidaris*. When the basaltic rock outcropped, the diversity observed was higher, with colonies of the black coral *Leiopathes* cf. *expansa* (Figure

291a,b), white hydrocorals, octocorals of the species *Paragorgia johnsoni* and many digitated sponges. Interestingly, in one section between 900 and 950m deep, a large aggregation of a small white plexaurid was observed, with its species not yet determined. In areas of the eastern side of Sedlo Seamount, the benthic communities between 830 and 925m deep, have a similar aspect to that of the western part of the seamount, with many shared species. Most of the areas explored were of hard substrates, but diversity seemed to be higher when the rock was composed of basalt. In those rocks, several large species were reported, including the black corals *Leiopathes expansa*, *Parantipathes hirondelle,* and *Bathypathes* sp., hydrocorals likely from the genus *Errina*, the lamellate sponge *Phakellia ventilabrum*, the glass sponges *Pheronema carpenteri* and *Regadrella Phoenix* (Figure 291d)*,* among others.

On the slopes of the easternmost area of Sedlo Seamount, at depths ranging from 950 to 1030 m. the fauna observed was very similar to that reported at those depths. Soft-bottom areas were generally poor regarding large sessile species, but more diverse in the case of mobile fauna, such as crustaceans (e.g., *Aristaeopsis edwardsiana*), eel-like and macrourid fishes and one chimaera of the genus *Hydrolagus* were filmed. Interestingly, an aggregation of brachiopods was observed on sandy substrates, although it covered a very small area of the seabed. When the rock outcropped, the diversity of benthic species was much higher, although never observed in large abundances. Typical fauna observed were the black corals *Leiopathes expansa* and *Parantipathes hirondelle*, the bamboo coral *Acanella arbuscula*, the scleractinian *Madrepora oculata*, the hydrocoral *Cryptellia* sp. and lamellate sponges of the genus *Phakellia*.

With regards to mobile fauna, interestingly, in the central part a large number of crabs of the species *Chaceon affinis* were observed, as well as several large angler fishes and some deep-sea sharks. On the easternmost parts of the seamount, some crabs were observed of the species *Paromola cuvieri* (Figure 291f) and *Chaceon affinis*, a few species of large fishes such as monkfishes (*Lophius piscatorius*), wreckfishes (*Polyprion americanus*) and the Spanish ling *Molva macrophthalma*, as well as several species of deep-sea sharks, some of which were observed quite regularly throughout the dives.

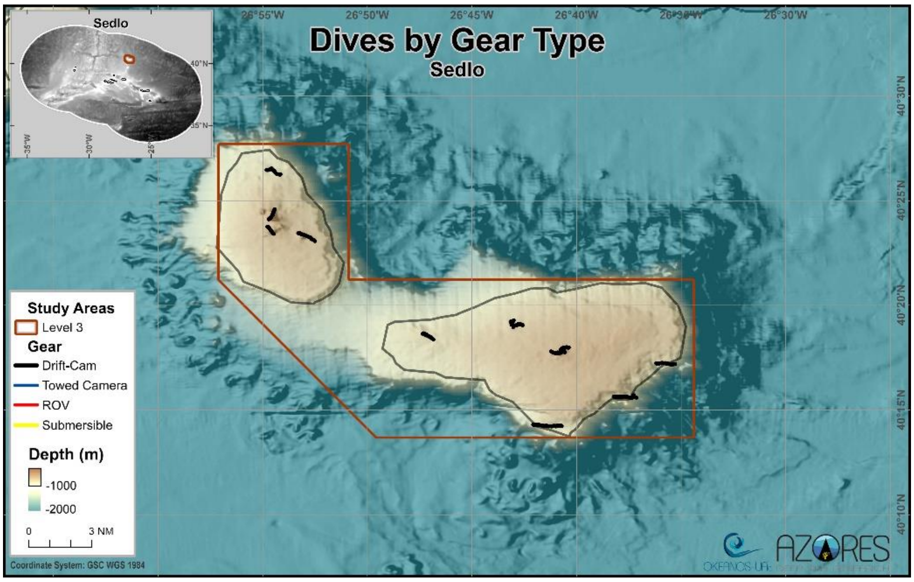



**Figure 290** Map displaying the 13 underwater dives performed in the Sedlo area between 640 and 1,080 meters depth.

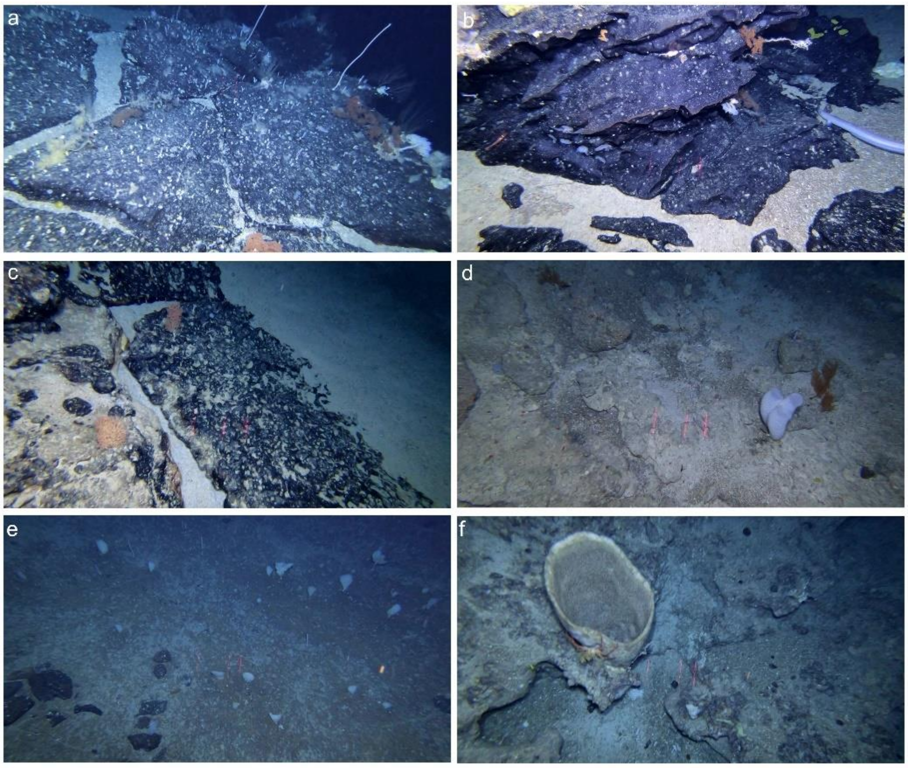


**Figure 291** Selected images representative of the main structuring species and benthic communities observed in Sedlo seamount. (a) Rocky bottom colonized by small *Leiopathes* cf. *expansa, Narella versluysi,* hydrozoans from family Haleciidae and encrusting sponges. (b) Small *L.* cf. *expansa* and the sponge of the genus *Aphrocallistes* along with other encrusting sponges. (c) Basaltic bottom with colonies of *Acanella arbuscula.* (d) Small colony of *L.* cf. *expansa* and the sponge *Regadrella phoenix.* (e) Aggregation of sponges of the genus *Phakellia.* (f) Large *Characella pachastrelloides* associated with the crab *Paramola cuvieri.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Gaillard*

The Gaillard area was explored through the performance of 3 underwater video transects between the depths of 700 and 1,020 m (Figure 292). A total of 37 taxa were determined from the images recorded, with 22 identified at the species level, revealing that a low diversity of deep-sea megabenthic species is supported by this area. Notable taxa based on weighted occurrences include *Desmacella grimaldii* (n= 15), *Plesionika* (n= 12), and *Errina atlantica* (n= 11).

Gaillard is a small seamount located just a few miles north of Borda Seamount. The areas explored covered the summit and slopes around the seamount, at different depths. The soft-bottom areas of the summit were characterized by deposits of coral rubble, with little associated fauna besides some mobile species, such as the crab *Chaceon affinis*, eel-like fishes, and some deep-sea sharks. When the rock outcropped, the diversity of benthic fauna increased, characterized by the primnoid *Narella bellissima*, stylasterids of the genus *Errina* and some grey sponges for which identification to species level has not yet been possible (Figure 293a). The areas explored on the slope hosted the typical fauna found in similar depths in seamounts further north, with the black corals *Leiopathes* cf. *expansa* and *Parantipathes hirondelle*, the bamboo coral *Acanella arbuscula* (Figure 293c), stylasterids of the genus *Errina* (Figure 293b,c), the sea urchin *Cidaris cidaris* (Figure 293a,d), and lamellate sponges of the genus *Phakellia* (Figure 293c) among others. Some fishes of the species *Hoplostethus atlanticus* (Figure 293f) were spotted in the deepest sectors.

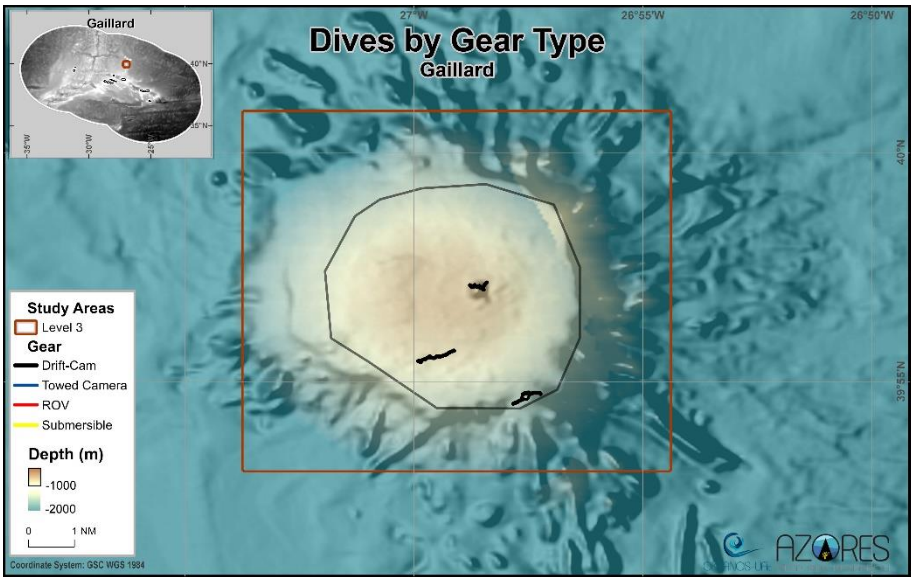



**Figure 292** Map displaying the 3 underwater dives performed in the Gaillard area between 700 and 1,020 meters depth.

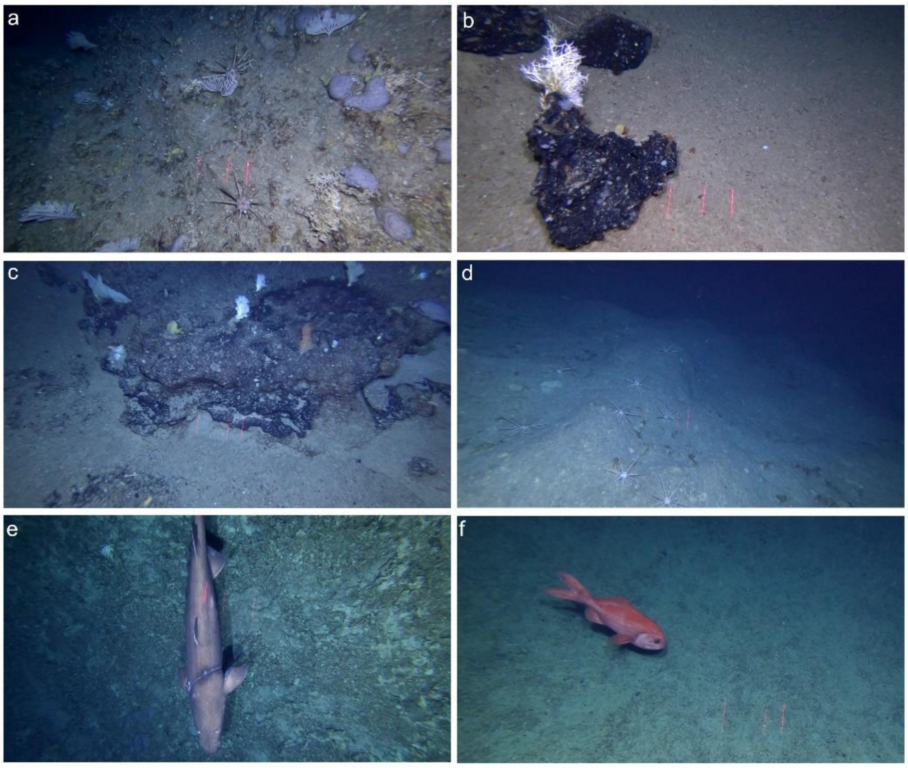


**Figure 293** Selected images representative of the main structuring species and benthic communities observed in the summit of a small seamount Gaillard. (a) Aggregation of *Narella bellissima* with sea urchin *Cidaris cidaris* and grey sponges not identified. (b) Small rock colonized by *Errina atlantica* and encrusting sponges. (c) Rocky outcrop colonized by the bamboo coral *Acanella arbuscula*, *E. atlantica*, and the sponges *Poecillastra compressa* and other from the genus *Phekellia*. (d) Large area of soft sediments covered with *C. cidaris*. (e) Deep-sea shark *Dalatias licha* injured by a fishing line. (f) *Hoplostethus atlanticus.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Borda*

While exploring the Borda seamount, 8 underwater video transects were performed between the depth of 480 and 1,160 mb(Figure 294). A total of 56 taxa were determined from the images analysed, with 31 identified at the species level, revealing a medium diversity of deep-sea megabenthic species for this area. Predominant taxa based on weighted occurrences include *Peltaster placenta* (n= 23), *Leptopsammia formosa* (n= 22), and *Acanthogorgia* spp. (n= 13).

Borda Seamount is a large geomorphological structure characterized by its flat and relatively deep summit. We expected most of the potential areas to be surveyed on the summit to be characterized by sedimentary substrates, and for that reason, locations with more complex reliefs were targeted. We explored areas of both hard and soft bottoms across a wide depth range. The soft-bottom areas on the deepest sections were characterized by the presence of the bamboo coral *Acanella arbuscula* (Figure 295a,b,f), together with the cup coral *Leptopsammia formosa*, the hydrocoral *Cryptellia* sp. (Figure 295b), and the sea urchin C*idaris cidaris* (Figure 295e). Where the rock outcropped, some sparse black corals could be observed, mainly from the genus *Leiopathes* (Figure 295c) and *Phanopathes*. In shallower areas, the seabed was home to very little benthic fauna, including some octocorals of the genus *Acanthogorgia*, some crabs of the genus *Paromola*, sea stars, and small sponges.

On the northern sector of the summit of Borda Seamount, areas between 600 and 970 m deep were surveyed, in which the soft-bottom areas were characterized by deposits of coral rubble with little fauna, besides some aggregations of the sea urchin *Cidaris cidaris*. When the rock outcropped, the fauna observed was different but never showing large abundances, and included the bamboo coral *Acanella arbuscula,* the primnoid *Candidella imbricata*, small colonies of the black coral *Leiopathes expansa,* the scleractinian *Madrepora oculata* and *Eguchipsammia cornucopia* (Figure 295d) among others.

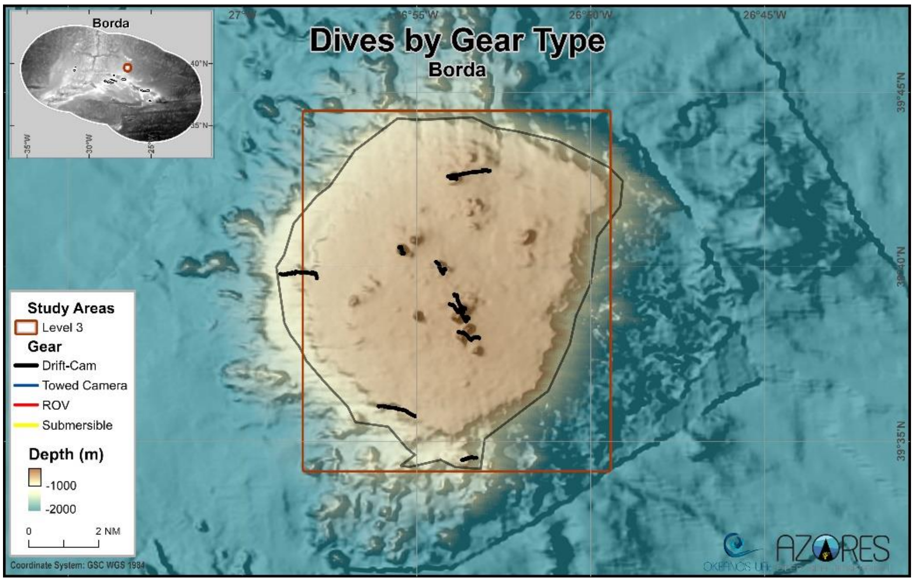


**Figure 294.** Map displaying the 8 underwater dives performed in the Borda area between 480 and 1,160 meters depth.

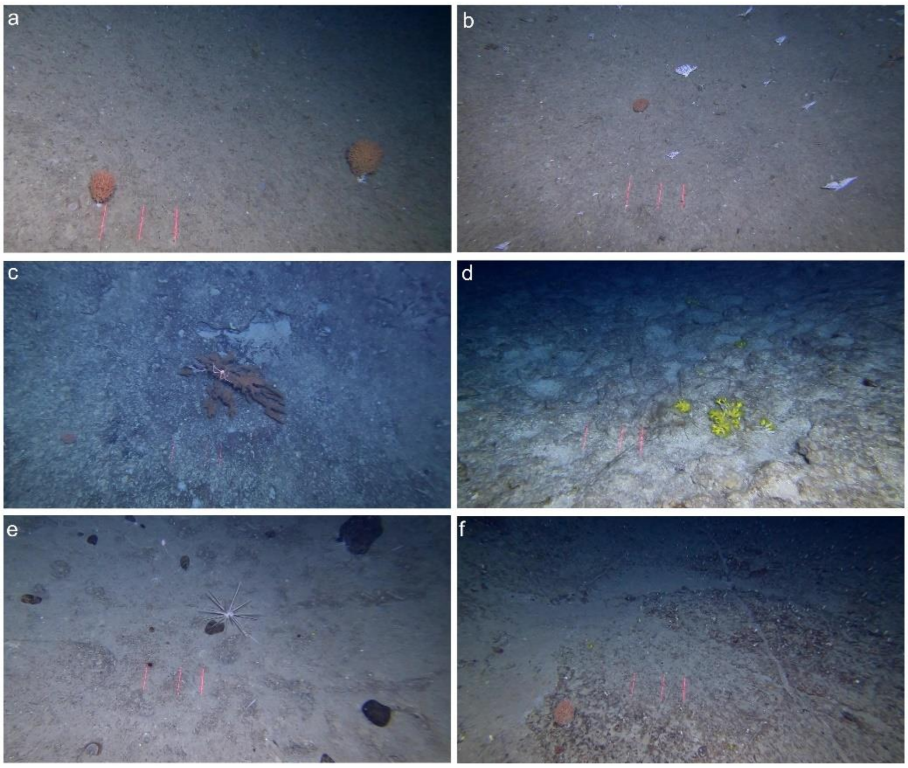



**Figure 295** Selected images representative of the main structuring species and benthic communities observed in Borda seamount. (a) *Acanella arbuscula* on soft sediments. (b) Soft sediments with the bamboo coral *A. arbuscula* and a hydrocoral. (c) Small sized *Leiopathes* cf. *expansa* with a *Sternostylus formosus* associated. (d) Small aggregation of *Eguchipsammia cornucopia.* (e) Sea urchin *Cidaris cidaris* and the scleractinian *Flabellum* sp.(f) Rocky bottom with *Acanella arbuscula* and some sponges digitate. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*João Leonardes*

In the area of João Leonardes seamount, 4 underwater video transects were performed between 740 and 1060 m depth (Figure 296). A total of 40 taxa were reported from the video annotation, with 25 identified at the species level, indicating a low diversity of deep-sea megabenthic species. Noteworthy taxa based on weighted occurrences include *Desmacella grimaldii* (n= 26), *Acanella arbuscula* (n= 20), and Crinoidea (n= 17).

The geomorphological unit called João Leonardes consists in horizontally large and deep seamount, situated on the Northern area of the central group of the Azorean archipelago. The features evaluated and explored at João Leonardes unit were always situated at relatively deep areas, and generally characterized by soft sediments, sporadically with the presence of dead coral framework, and sometimes with loose small rocks. This type of seabed was eventually replaced by rocky outcrops, but with considerable patches of sand regularly present. The benthic megafauna recorded at this geomorphological unit was generally poor, with scattered occurrences of the bamboo coral *Acanella arbuscula* (Figure 297c), the gorgonians *Candidella imbricata* and *Chrysogorgia* sp., and the glass and fan shaped sponges *Regadrella phoenix* (Figure 297b,c) and *Phakelia ventilabrum*, respectively. On the upper slope, and even on the summit, is frequent to observe the echinoderms of the genus Goniasteridae and the species *Peltaster placenta* always laying on sand, the deep-sea crab *Chaceon affinis* and a punctual aggregation of small individuals of the primnoid coral *Narella versluysi*. Widespread presence of the yellow lamellate sponge *Desmacella grimaldii* (Figure 297a). Various species of motile fauna were detected such as fishes belonging to the macrouridae family, some long-lived orange roughies *Hoplostethus atlanticus* (Figure 297d) and the sight of a deep-sea shark *Dalatias licha*.

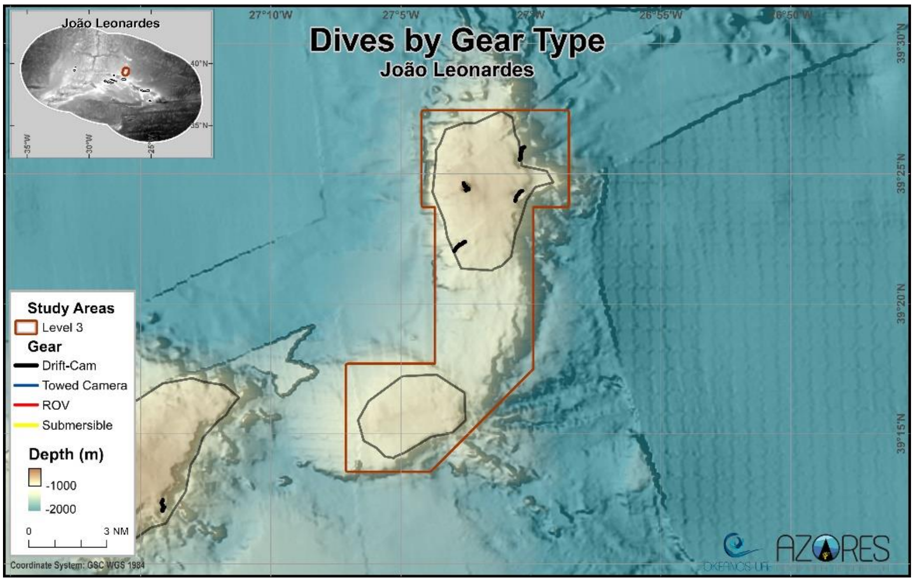



**Figure 296.** Map displaying the 4 underwater dives performed in the João Leonardes area between 740 and 1,060 meters depth.

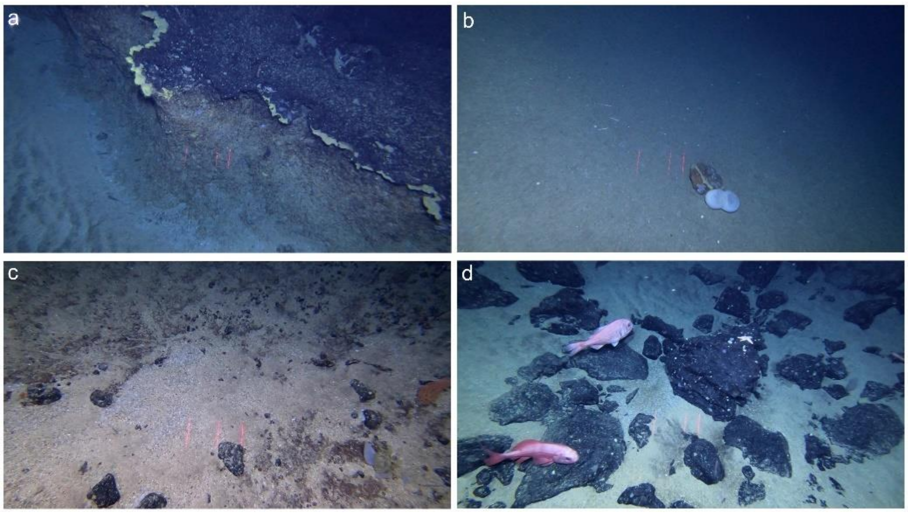



**Figure 297** Selected images representative of the main structuring species and benthic communities observed in João Leonardes seamount. (a) *Desmacella grimaldi* on rocky outcrop. (b) *Regadrella phoenix* on soft sediments together with a rock covered with encrusting sponges and *D. grimaldii.* (c) Bamboo coral *Acanella arbuscula* and *R. phoenix* on soft sediments. (d) The commercial species *Hoplostethus atlanticus.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Serreta Mar*

Serreta Mar area was surveyed via 5 underwater video transects, performed between 600 and 1000 m depth (Figure 298). A total of 59 taxa were determined from the video analysis, with 36 identified at the species level, revealing that a medium diversity of deep-sea megabenthic species is supported by this area. Prominent taxa based on weighted occurrences include *Narella versluysi* (n= 33), *Acanthogorgia* spp. (n= 32), and *Narella bellissima* (n= 27).

The deepest areas explored were almost entirely covered by coral rubble deposits, particularly on flatter terrain, with little benthic fauna present. When the slope increased, it was common to witness extensive aggregations of the primnoid corals *Narella versluysi* and *N. bellissima* (Figure 299a). Medium-sized colonies of *Callogorgia verticillata* (Figure 299d) were present as well, with small *Acanthogorgia* spp. colonies appearing more sporadically within this community, as well as some sponges from the species *Asconema frsitedti* (Figure 299b). Several decapods were observed at these depths, such as *Aristaeopsis edwardsiana*, *Chaceon affinis*, *Paromola cuvieri*, together with many fish species, including *Lophius piscatorius*, *Mora moro*, *Beryx* sp., *Dalatias licha*, *Molva macrophthalma* and *Dalatias licha*. It was of particular interest the sudden and contrasting community shift witnessed at around 620m depth while exploring a particular slope. The sparse and small colonies of *Acanthogorgia* spp. which colonized the seafloor until said depth, abruptly gave way to an uncommon and impressively dense coral garden dominated by large colonies of a species likely belonging to the family Paramuriceidae (Figure 299c). Its full extension was not covered, but it seemed to be colonizing a very large area of the deep summit explored. A small, pink-coloured soft coral was also seen within this garden, as well as several other associated species, such as the decapods *Chaceon affinis, Paromola cuvieri* and some galatheoids, and different species of starfish. The shallowest areas of Serreta Mar proved to be quite barren, with soft sediments composing most of the seafloor observed, with only a solitary toothed rock crab *Cancer bellianus* being seen.

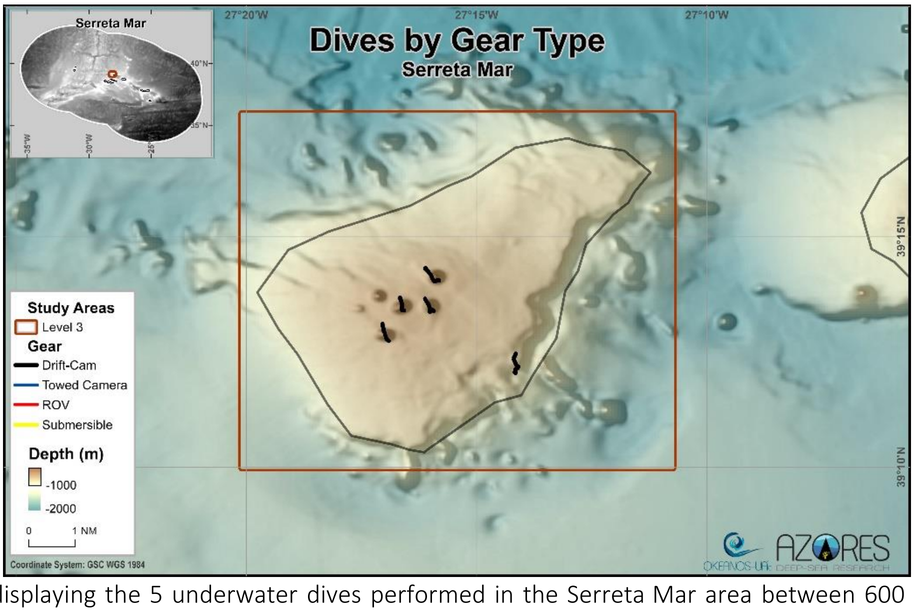



**Figure 298** Map displaying the 5 underwater dives performed in the Serreta Mar area between 600 and 1,000 meters depth.

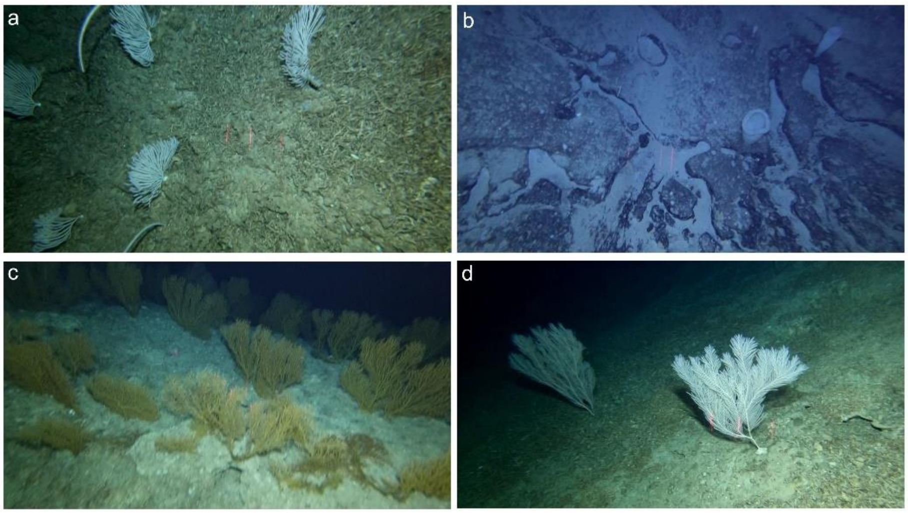



**Figure 299** Selected images representative of the main structuring species and benthic communities observed in Serreta Mar seamount. (a) Aggregation of the primnoids *Narella versluysi* and *Narella bellissima*. (b) Two sponges of the species *Asconema fristedti* on basaltic bottom. (c) Large aggregation of plexaurids, likely of family Paramuriceidae. (d) Medium-sized colonies of *Callogorgia verticillata.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

## Study area | Graciosa/São Jorge

*Mar da Fortuna*

A total of 8 underwater video transects were performed in Mar da Fortuna area, between 300 and 910 m depth (Figure 300). Overall, 77 taxa were determined from the video analysis, with 50 identified at the species level, revealing a high diversity of deep-sea megabenthic species for this area. Notable taxa based on weighted occurrences include *Anthomastus/Pseudoanthomastus* sp. (n= 46), *Pheronema carpenteri* (n= 31), and *Farrea occa* (n= 30).

The Mar da Fortuna geomorphological unit is an area on the Northern central group of the Azorean archipelago and is constituted by a group of seamounts. The deepest areas of this unit (around 970 to 720m) were characterized by its generally hard substrate, with the frequent presence of more robust boulders, where most of the fauna was attached. These deeper benthic communities were dominated by the whip coral *Narella versluysi*, accompanied by the corals *Narella bellissima* and cf. *Candidella imbricata*. Sporadically, some stylasterids, the bamboo coral *Acanella arbuscula* and the scleractinian *Leptopsammia formosa* were observed. The deepest areas were also characterized by frequent and small aggregations of the bird's nest *Pheronema carpenteri*, together with other sponges such as *Phakellia ventilabrum* and large *Poecillastra compressa* (Figure 301a,b,c). On shallower areas of the slope, the communities were substantially different, and the bottom stayed the same. At this level, sponges were frequent, from which we can focus large aggregations of the desmospongiae *Exsuperantia archipelagus*, and the often presence of *Macandrewia azorica*, *Pheronema carpenteri*, *Petrosia crassa*, *Siphonodictyon viridescens* and large *Characella pachastrelloides*. Several species colonies of corals have started appearing on rocky outcrops such as soft corals of the genus *Anthomastus/Pseudoanthomastus* sp., the whip coral *Viminella flagellum* and the gorgonians *Callogorgia verticillata* and *Acanthogorgia* spp. (the first one showing individuals apparently in a poor state), and the black coral *Parantipathes hirondelle* (Figure 301d). The summit areas (around 300m deep), or the shallowest areas, hosted amazingly high densities of corals. At this level, vast gardens of the gorgonians *Viminella flagellum* (both white and yellow morphotypes), *Acanthogorgia* spp., and *Dentomuricea* aff. *meteor* were recorded. These aggregations were both found growing at the soft and hard substrate that composed the bottom at the summit. The phylum porifera was mainly represented by the appearances of individuals of the species *Haliclona magna*, *Neophrisospongia nolintagere* and of the genus *Petrosia* and *Leiodermatium*. Motile fauna was widely present, and was mainly represented with the species *Trachyscorpia cristulata*, Polyprion americanus, *Conger conger* and several *Paromola cuvieri*.

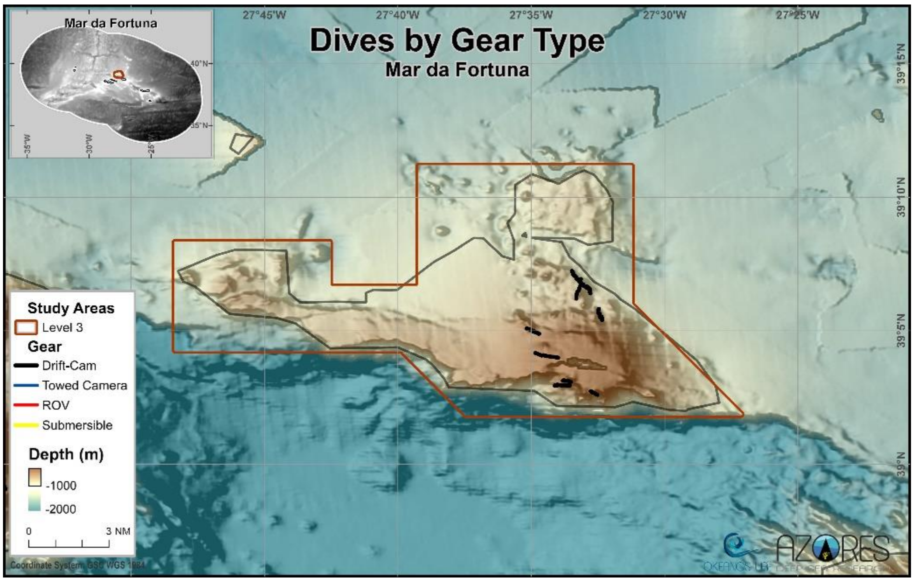



**Figure 300.** Map displaying the 8 underwater dives performed in the Mar da Fortuna area between 300 and 910 meters depth.

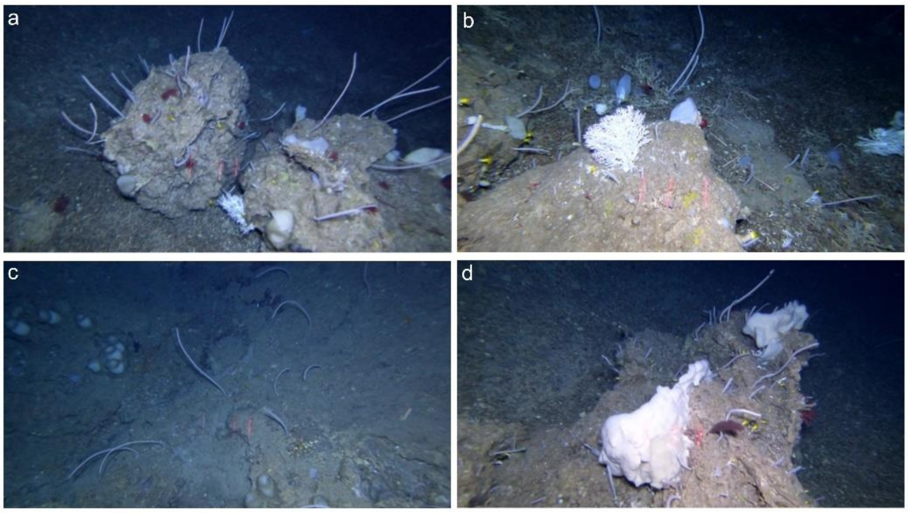



**Figure 301** Selected images representative of the main structuring species and benthic communities observed in Mar da Fortuna seamount. (a-b) Boulder colonized by the corals *Narella versluysi, Anthomastus/Pseudoanthomastus* sp., *Leptopsammia formosa* and *Errina atlantica* and the sponges *Poecillastra compressa* and *Pheronema carpenteri* (a) and Rega*drella phoenix.* (c) Aggregation of *N. versluysi* and *P. carpenteri* on soft sediments. (d) Boulder colonized by *N. versluysi*, *Parantipathes hirondelle, L. formosa* and the sponge *P. compressa.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Graciosa NW*

In Graciosa Northwest area, 8 underwater video transects were performed between 370 and 700 m depth (Figure 302). Video analysis resulted in a total of 73 taxa. From these, 41 were identified at the species level, revealing a medium diversity of deep-sea megabenthic species for this area. Dominant taxa based on weighted occurrences include *Petrosia (Petrosia) crassa* (n= 64), *Characella pachastrelloides* (n= 51), and *Xestospongia variabilis* (n= 48).

The Northwest part of the Graciosa Island slope was in general characterized by a high benthic biodiversity and abundance, both of sponges and corals. On the lower slope regions (around 700m) the soft bottom that constitute the seabed are commonly colonized by the sea-urchin *Echinus melo* during a vast length of the segment and has always a regular presence until the summit area of the slope. There is a big change in the benthic community's presence, and only with slight change in depth, that constitutes the upper slope (~600 to 400m). This change is also accompanied by different substrate, with the basaltic outcrops now prevailing at the seafloor. This new type of grounds makes the perfect base for massive white sponges mainly of the genus *Petrosia* and *Characella* (Figure 303d) and aggregations of the lollipop sponge *Stylocordyla pellita*. It was also possible to start observing several coral species, normally found at these depths, like for example *Dentomuricea* aff. *meteor*, *Viminella flagellum* and *Callogorgia verticillata* (Figure 303a,b,c). These aggregations become even more prominent at the summit of the slope (around 300m), but this time mostly covered by sand, where there are extensive gorgonian gardens mainly constituted by big specimens of *Viminella flagellum*, *Calllogorgia verticillta*, a considerable abundance of *Acanthogorgia* spp. and huge aggregations of the black coral *Elatopathes abietina*.

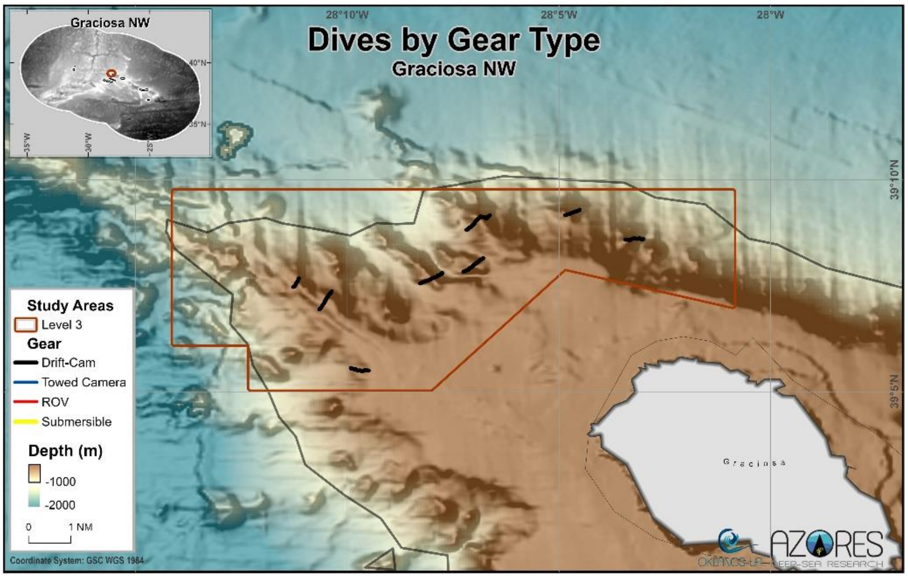


**Figure 302.** Map displaying the 8 underwater dives performed in the Graciosa NW area between 370 and 700 meters depth.

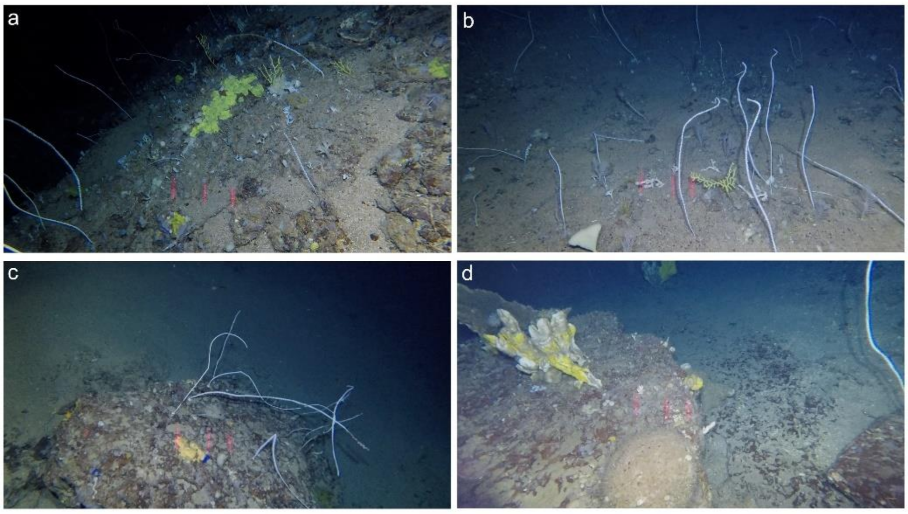



Figure 303 Selected images representative of the main structuring species and benthic communities observed in Graciosa Northwest area. (a) Hard substrate colonized by *Viminella flagellum* and *Dentomuricea* aff. *meteor,* together with encrusting sponges. (b) Area with several species of corals *Viminella flagellum, Callogorgia verticillata,* one *D.* aff. *meteor* and a wide variety of sponges. (c) Boulder with *Viminella flagellum* and encrusting sponges (d)Massive sponges of the genus *Characella* and *Geodia* on hard substrate also colonized by encrusting sponges. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Graciosa NE*

While surveying the Graciosa Northeast area, 6 underwater video transects were performed covering a depth range from 330 to 770 m (Figure 304). The video analysis resulted in a total of 66 taxa. From these, 43 were identified at the species level, revealing that a medium diversity of deep-sea megabenthic species is supported by this area. Predominant taxa based on weighted occurrences include *Xestospongia variabilis* (n= 18), *Characella pachastrelloides* (n= 16), and *Petrosia* sp. (n= 15).

This area of the Island slope of Graciosa was characterized by its hard bottoms, composed by basaltic outcrops sporadically interrupted with soft sediment patches that sometimes cover a substantial part of the rocky grounds. On the deepest parts, at around 770 m deep, the lower slope of the Island is home of a diversity of sponges of which we can highlight the high number of impressively big specimens of the jar sponge *Characella pachastrelloides* complex and the vast count of *Macandrewia azorica* and *Farrea occa* individuals, associated to this hard substrate. At this deeper environment, the, occasional sandy bottom (more common at around 650m deep) made possible for a community of the Xenophyophores *Syringammina fragilissima* to take place, for several meters. A little further up the slope (~550 to 330m, upper slope) it was possible to observe a shift in the communities present with a more relevant presence of corals, with uncommonly large aggregations (gardens) of abnormally massive examples of the gorgonians *Callogorgia verticillata* (Figure 305b) and *Viminella flagellum* (Figure 305a,b). The abundance of the black coral *Elatopathes abietina* (Figure 305a) and colonies of *Dendrophyllia cornigera* (Figure 305c) progressively increased as the depth decreased, being very common to find on the upper slope, always associated to the basaltic outcrops that continued to constitute most of the substrate type during the dive. These abundances and diversity of benthic fauna encountered on the upper slope, was even more impressive due to the immense number of lost fishing lines laying on the ground or suspended between outcrops.

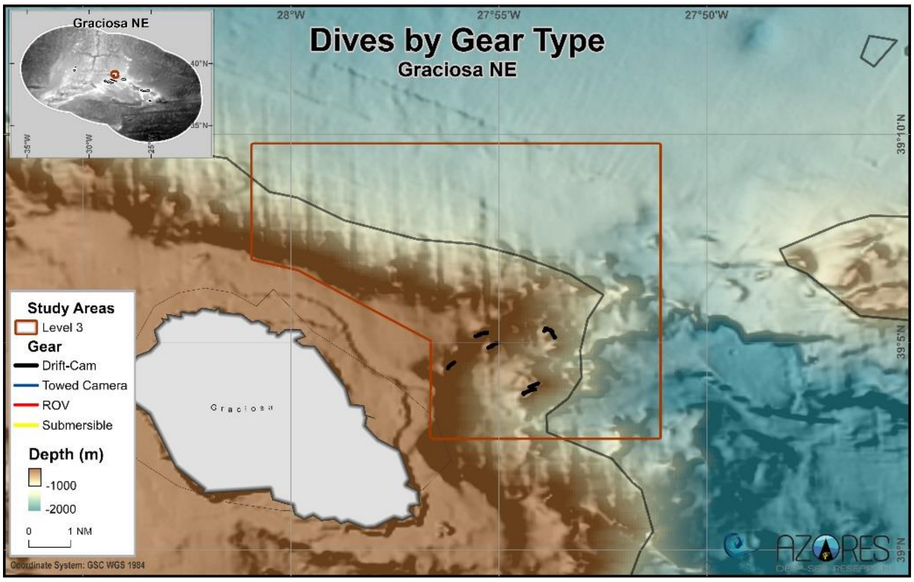



**Figure 304** Map displaying the 6 underwater dives performed in the Graciosa NE area between 330 and 770 meters depth.

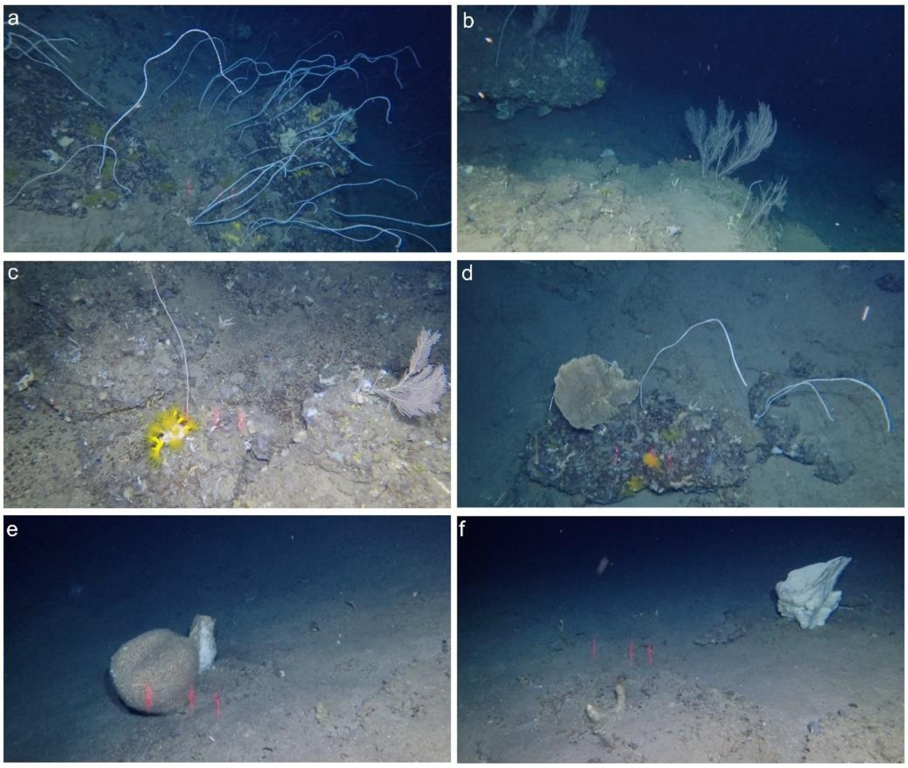



**Figure 305** Selected images representative of the main structuring species and benthic communities observed in Graciosa Northeast area. (a) Large aggregation of *Viminella flagellum* and the *Elatopathes abietina* on hard substrate together with a wide variety of sponges. (b) Boulder with several corals species: *Callogorgia verticillata, V. flagellum* and sponges species like *Neophrissospongia nolitangere.* (c) Colony of *Dendrophyllia cornigera* together with a small colonies of *V. flagellum* and *C. verticillata.* (d) Massive sponge with large colonies of *V. flagellum* on a boulder also covered with encrusting sponges. (e) Large *Geodia* sp. on soft sediments. (f) Massive white sponge of soft sediments. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Graciosa SE*

Graciosa Southeast area was explored through 5 underwater video transects performed between 250 and 670 m depth (Figure 306). A total of 68 taxa were determined from the video analysis, with 37 identified at the species level, suggesting a medium diversity of deep-sea megabenthic species for this area. Predominant taxa based on weighted occurrences include *Viminella flagellum* (n= 42), *Acanthogorgia* spp. (n= 32), and *Haliclona (Soestella) implexa* (n= 30).

The range and rapid change of benthic fauna (Figure 307) at the Southeastern slope of Graciosa Island was incredible. Characterized for the rocky bottom, in most of the dives barely covered with fine sediment, and patches of coral rubble, the deepest depths of the slope were dominated by the presence of large litisthid sponges, specimens of *Farrea occa*, and massive *Characella pachastrelloides*. Also, on the lower slope coral assemblages were composed by the a few gorgonians such as *Acanthogorgia* spp., and black corals like *Stichopathes gravieri*. Soft corals of the genus *Anthomastus/Pseudoanthomastus* sp. start appearing at around 620m deep, always associated to basaltic boulders. Upper slope of the Island hosted an enormous benthic biodiversity, with species reaching densities not usually seen and with many associated species. Some examples of this amazing biodiversity were the gardens of the whip coral *Viminella flagellum*, the gorgonians *Callogorgia verticillata* and *Dentomuricea* aff. *meteor* and closer to the summit the black coral *Elatopathes abietina*. All these species were commonly accompanied by hydrocorals. Sponges also had an enormous diversity and incredible densities from which we can highlight the very well-preserved individuals of *Phakellia ventilabrum*, the many *Haliclona implexa* and *Macandrewia azorica* and varied litisthids such as exemplars of the genus *Leiodermatium* and *Petrosia crassa*. The summit (around 250m deep) of the slope had a high contrast with the upper part of it, being characterized by a sedimentary environment very scarce of benthic megafauna.

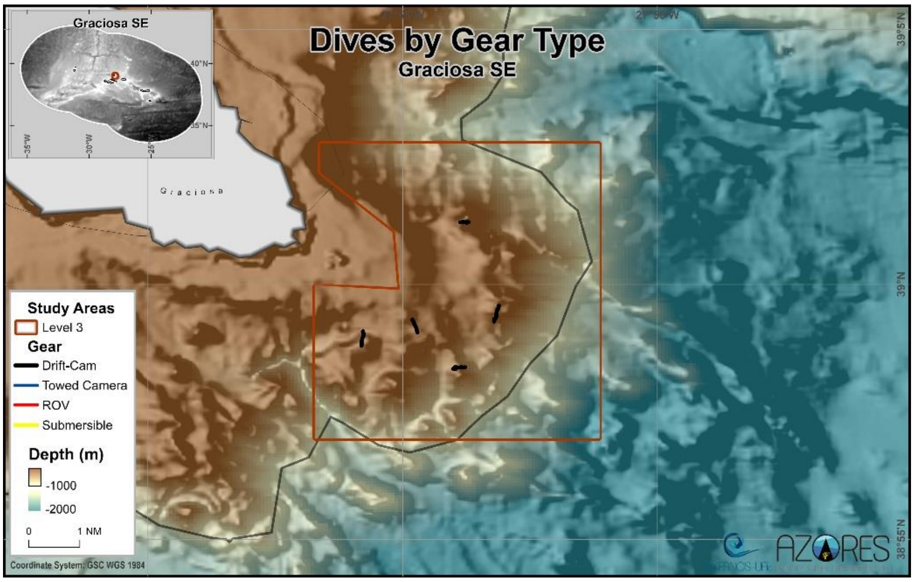



**Figure 306** Map displaying the 5 underwater dives performed in the Graciosa SE area between 250 and 670 meters depth.

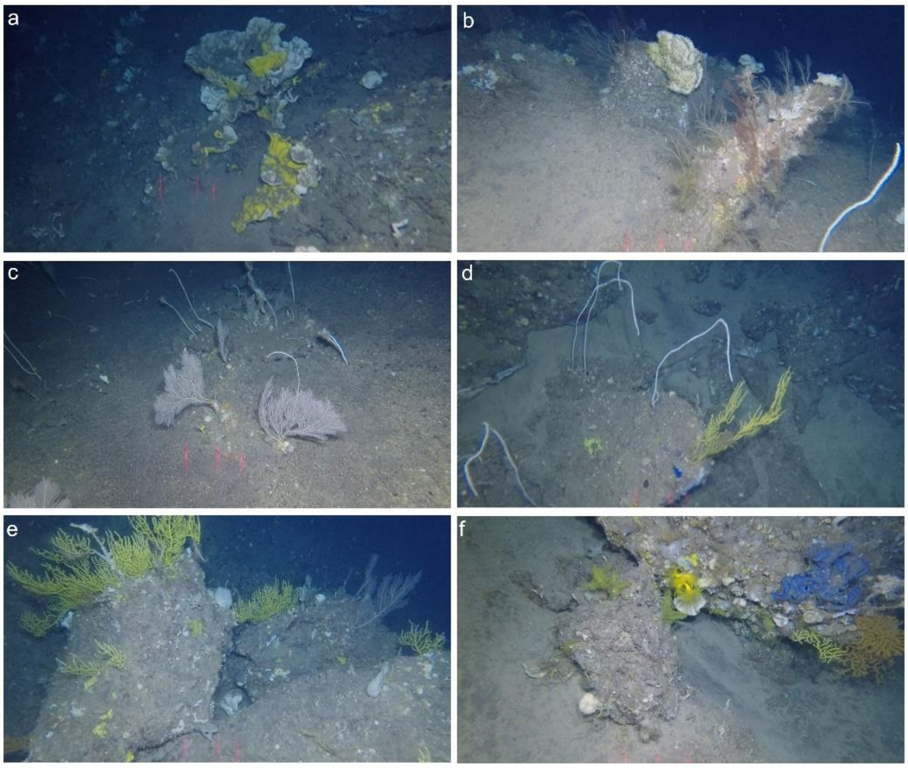


**Figure 307** Selected images representative of the main structuring species and benthic communities observed in Graciosa Southeast area. (a) Large area covered with several species of sponges, like *Characella pachastrelloides.* (b) Boulders with several species of hydrozoans and massive sponges. (c) Aggregation of *Callogorgia verticillata* and *Viminella flagellum*(d) The coral species *V. flagellum* and *Dentomuricea* aff. *meteor* on hard substrate. (e) Boulder with large colonies of *D* aff. *meteor* and *C. verticillata* and some sponges, like *Phakellia* sp. and encrusting sponges. (f) Rock colonized with the black coral *Elatopathes abientina* and other species like *Acanthogorgia* sp., *D.* aff. *meteor* and *Dendrophyllia cornigera* and the sponges *Leiodermatium* sp. (blue morphotype), *Neophrissospongia nolitangere* and others. *Image* credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Graciosa S*

In the Graciosa S area, 7 underwater video transects were performed between 300 and 710 m depth (Figure 308). A total of 59 taxa were determined from the images, with 38 identified at the species level, revealing that a medium diversity of deep-sea megabenthic species is supported by this area. Noteworthy taxa based on weighted occurrences include *Characella pachastrelloides* (n= 30), *Hymedesmia (Hymedesmia) paupertas* (n= 27), and *Elatopathes abietina* (n= 23).

The deepest areas (around 710 m) of the south slope of Graciosa Island the soft sediment that dominates the seabed was found to have some Xenophyophores *Syringammina fragilissima*, but never in high densities and not for extensive portions of the seabed. Hard corals of the genus Flabellum were sporadically found as well, and always associated to the sandy ground. A few basaltic boulders occasionally appear, as well as some rocky outcrops, and these are usually covered in fine sediment. These hard substrates appear with several encrusting sponges attached, among other porifera taxa, such as the massive *Characella pachastrelloides* (Figure 309) and an unusually high presence of sponges from the genus *Geodia*. At around the same depths, there was a sporadic presence of *Pleurocorallium johnsoni* growing on the boulders and the black coral *Parantipathes hirondelle*. On the shallower part of the slope, the substrate was very similar, with rocky outcrops mixed with sandy patches.

At these depths (~500 to 350m), the benthic fauna observed was particularly abundant and diverse. Scattered gardens of some common gorgonians such as *Viminella flagellum*, *Callogorgia verticillata*, *Dentomuricea* aff. *meteor* (Figure 309) and *Paramuricea* genus individuals, were usually observed at these depth ranges, and always associated to the hard substrate. As observed in other areas of this Island slope, the black coral *Elatopathes abietina* (Figure 309) was very abundant. In terms of the sponge assemblage, a variety of species were found in the patches of sand between outcrops, including *Macandrewia azorica*, *Haliclona implexa* and species from the genus *Leiodermatium* and *Petrosia*. Mainly the species *Haliclona implexa* were more observed near the summit, progressively disappearing towards the top where the substrate was completely composed by fine sediment and fauna was very limited.

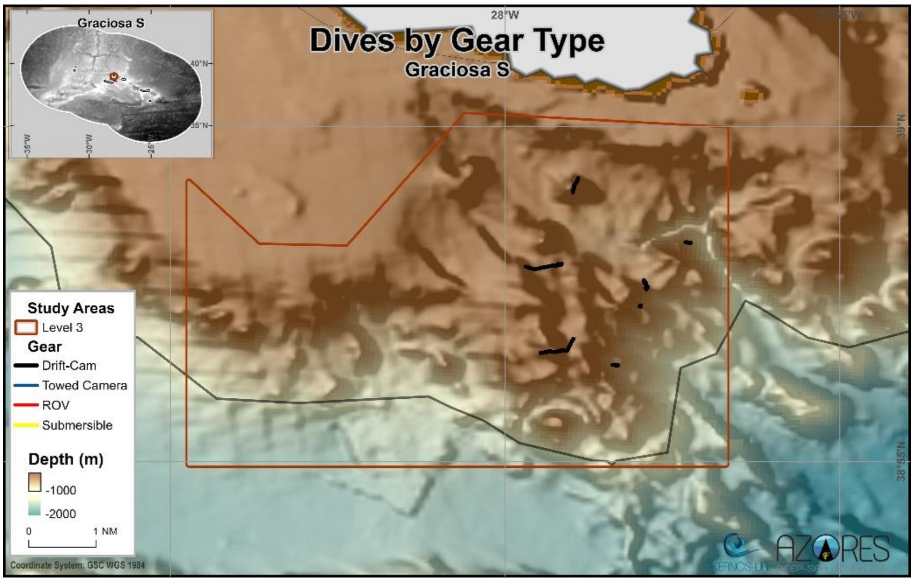



**Figure 308** Map displaying the 7 underwater dives performed in the Graciosa S area between 300 and 710 meters depth.

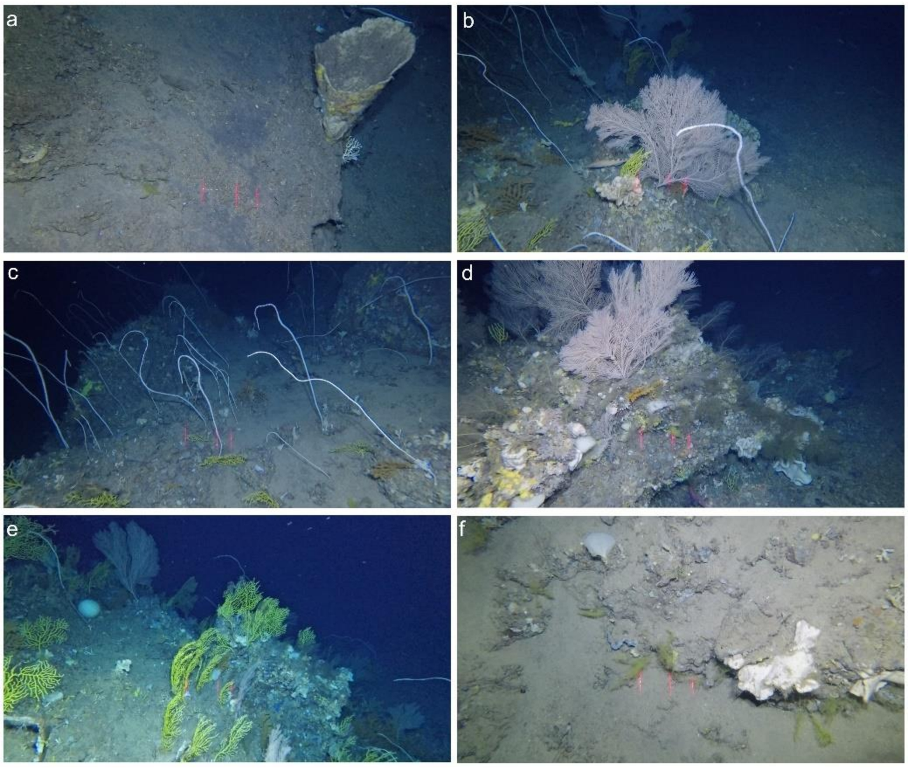



**Figure 309** Selected images representative of the main structuring species and benthic communities observed in Graciosa South area. (a) Massive *Characella pachastrelloides* on hard substrate covered by soft sediments. (b) Aggregation of *Viminella flagellum, Callogorgia verticillata, Acanthogorgia* sp. and *Dentomuricea* aff. *meteor* together with sponges *Leiodermatium* sp. (white morphotype) and others. (c) Large aggregation of *V. flagellum, Acanthogorgia* sp. and *D.* aff. *meteor* and other small sponges. (d) Very colonized boulder with large colonies of *C. verticillata,* small colonies of *D.* aff. *meteor, Acanthogorgia* sp. and several species of hydrozoans together with a wide variety of sponges. (e) Several colonies of *D.* aff. *meteor* and a few colonies of *C. verticillata* and *Acanthogorgia* sp. (f) Soft sediments with black coral *Elatopathes abietina* and several sponges. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Graciosa SW*

The Graciosa Southwest area included 6 underwater video transects, performed between 300 and 710 m depth (Figure 310). A total of 57 taxa were determined from the video annotation, with 37 identified at the species level, revealing that a medium diversity of deep-sea megabenthic species is supported by this area. Prominent taxa based on weighted occurrences include *Elatopathes abietina* (n= 39), *Haliclona filholi* (n= 31), and *Viminella flagellum* (n= 30).

The lower depths of the southwestern slope of Graciosa Island showed an accentuated shortage of benthic sessile fauna. The substrate at these depths (~700 to 600m) was mainly composed of sedimentary substrate where the most common sightings of fauna were the Foraminifera *Syringammina fragilissima* and a few animals of the genus *Flabellum* in the extensive sand banks. On the upper slope (around 600 to 300m) and on the top of the lower slope, the hard substrate started appearing and with it the fauna associated. The biodiversity (Figure 311) at these depths was similar to the other areas of Graciosa slope, with the phylum porifera being mainly represented by encrusting sponges, and aggregations of *Farrea occa* and *Macandrewia azorica*. At the shallowest part of the upper slope, it was possible to observe *Haliclona implexa* in high numbers. Phyllum Cnidaria was dominated by the presence of communities of the gorgonian *Viminella flagellum* and the black coral *Elatopathes abietina*, as in other sloping areas of the Island. Interestingly, at around 600m, it was possible to get a sight of a monkfish (*Lophius piscatorius)* using its white lure.

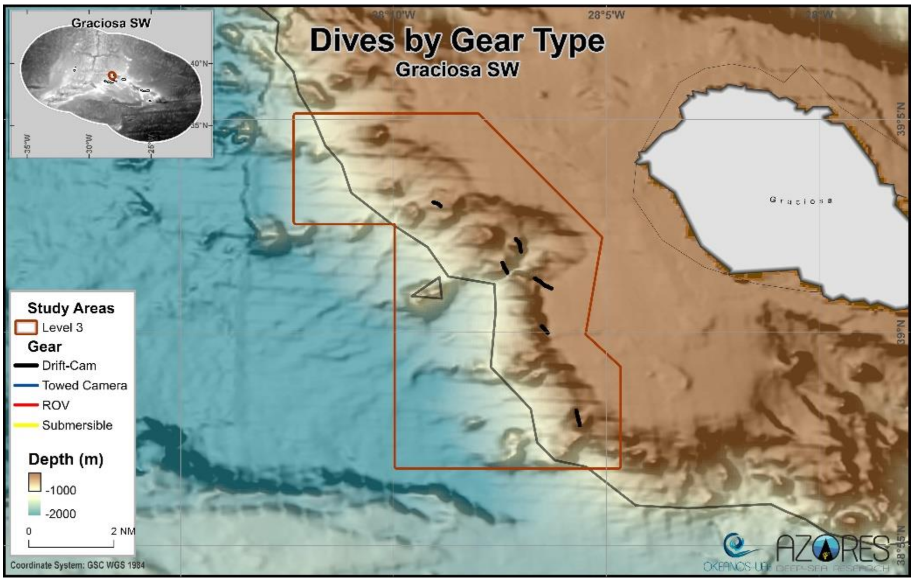



**Figure 310** Map displaying the 6 underwater dives performed in the Graciosa SW area between 300 and 710 meters depth.

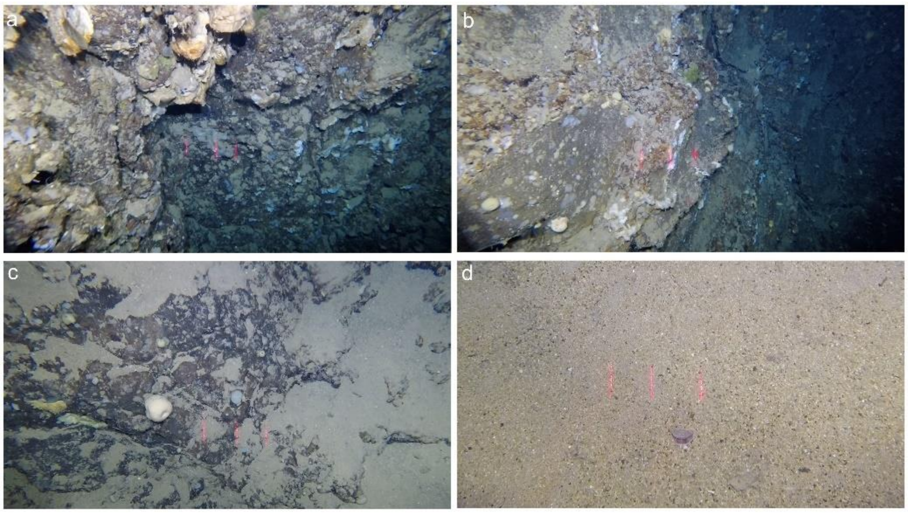



**Figure 311** Selected images representative of the main structuring species and benthic communities observed in Graciosa Southwest area. (a) Vertical wall densely colonized by encrusting sponges and the bivalve *Neopycnodonte cochlear.* (b) Vertical wall colonized by a wide variety of encrusting and smaller sponges. (c) Basaltic bottom covered with soft sediments and colonized by encrusting sponges, *Haliclona filholi.* (d) Scleractinian *Flabellum* sp. on soft sediments Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Perestrelo Bartolomeu*

Overall, 7 underwater video transects were performed in Perestrelo Bartolomeu area, between 510 and 900 m depth (Figure 312). The video analysis resulted in a total of 60 taxa determined from the images. From these, 37 were identified at the species level, suggesting a medium diversity of deep-sea megabenthic species. Dominant taxa based on weighted occurrences include *Leptopsammia formosa* (n= 37), *Plesionika* sp. (n= 26), and *Pliobothrus symmetricus* (n= 25).

The Perestrelo Bartolomeu is a seamount located near the Azores archipelago central group, with a relatively shallow summit. With the dives performed at this unit, it was possible to cover the slope and summit of the seamount, and so the descriptions of the benthic megafauna present are mostly from those depths. The deepest features of the Perestrelo Bartolomeu seamount presented a seafloor generally covered with sand and sometimes with patches of coral rubble and progressively changing for a harder substrate with the presence of some basaltic outcrops and vertical walls. On these deepest sectors the sedimentary bottom hosted sporadic colonies of the bamboo coral *Acanella arbuscula*. When there was more rock outcropping, mainly at the upper slopes of the seamount, the primnoid corals *Narella versluysi* and *N.bellissima* (Figure 313) showed a large community, together with other more sporadic species such as *Leptopsammia formosa*, *Hemicorallium* n*iobe* and *Pliobothrus symmetricus.* Some of the most frequently spotted sponge species included *Pheronema carpenteri* (generally in small, scattered aggregations), *Desmacella grimaldii*, and some individuals of *Characella pachastrelloides*. We also observed some common fishes and crab species from these depths including *Mora moro, Neocyttus helgae*, some eel-like fish and *Chaceon affinis*, as well as some deep-sea sharks likely of the genus *Deania*. We also spotted some sea-stars (*Peltaster placenta*) and sea-urchins (*Cidaris cidaris*) (Figure 313), the last appearing in small aggregations between 1054m and 720m.


**Figure 312** Map displaying the 7 underwater dives performed in the Perestrelo Bartolomeu area between 510 and 900 meters depth.

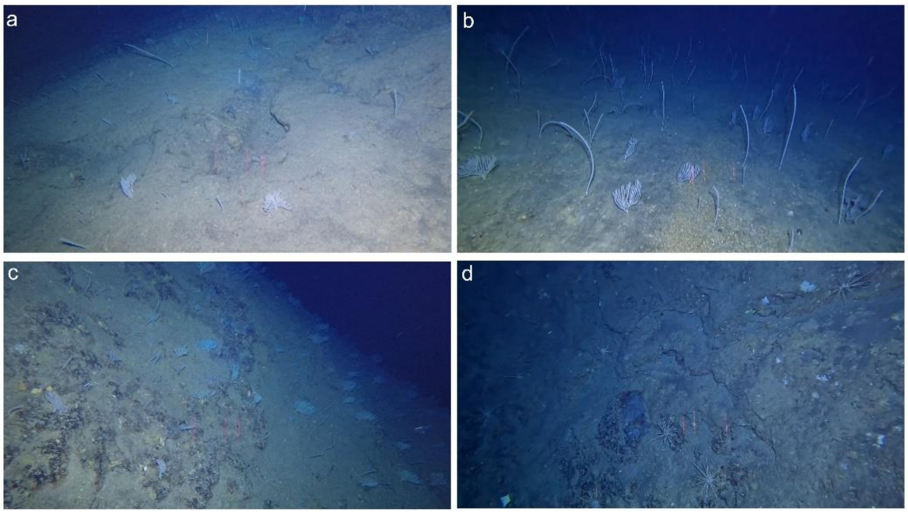


**Figure 313** Selected images representative of the main structuring species and benthic communities observed in Perestrelo Bartolomeu area. (a-b-c) Large areas covered with the primnoids *Narella bellissima* and *Narella versluysi.* (d) Sea urchins *Cidaris cidaris.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Ilha Azul*

In the Ilha Azul area, 11 underwater video transects were performed between 430 and 850 m depth (Figure 314). A total of 80 taxa were determined from the images, with 51 identified at the species level, revealing that a high diversity of deep-sea megabenthic species is supported by this area. Notable taxa based on weighted occurrences include *Anthomsus/Pseudoanthomastus* sp. (n= 62), *Acanthogorgia* spp. (n= 54), and *Haliclona filholi* (n= 46).

This geomorphological unit was characterized by a seafloor dominated by rocky framework at most of the deepest areas, with the presence of basaltic outcrops and walls when reaching shallower depths at the upper slope region. Normally the deep soft sediments were substrate for a low number of benthic species. The rocky outcrops and the high vertical walls had attached a big biodiversity of corals from which is mandatory to highlight the huge garden of the gorgonians *Narella versluysi* and *N.bellissima* (Figure 315) at around 760m deep, a community that extents for various meters on the hard seafloor and that is accompanied by large aggregations of the bird's nest sponge *Pheronema carpenteri* and soft corals of the genus *Anthomastus/Pseudoanthomastus*, and some other porifera such as *Regadrella phoenix* and *Asconema fristedti*. A few specimens of *Callogorgia verticillata* and *Acanthogorgia* spp. were spotted at these deep areas of the slope. With the decrease in depth (~600 to 400m) it was possible to observe a shift in the communities of benthic fauna more present such as the presence of extensive colonies the whip coral *Viminella flagellum* (Figure 315) and the observation of robust sponges of the genus *Characella*. Aggregations of small sized black corals like *Elatopathes abietina* or the bubble gum coral *Paragorgia johnsoni* (Figure 315) were spotted at around 500m deep, always attached to hard substrates. To note that a big and not so common shoal of the silver scabbard fish (*Lepidopus caudatus*) was possible to observe at around 520m deep.

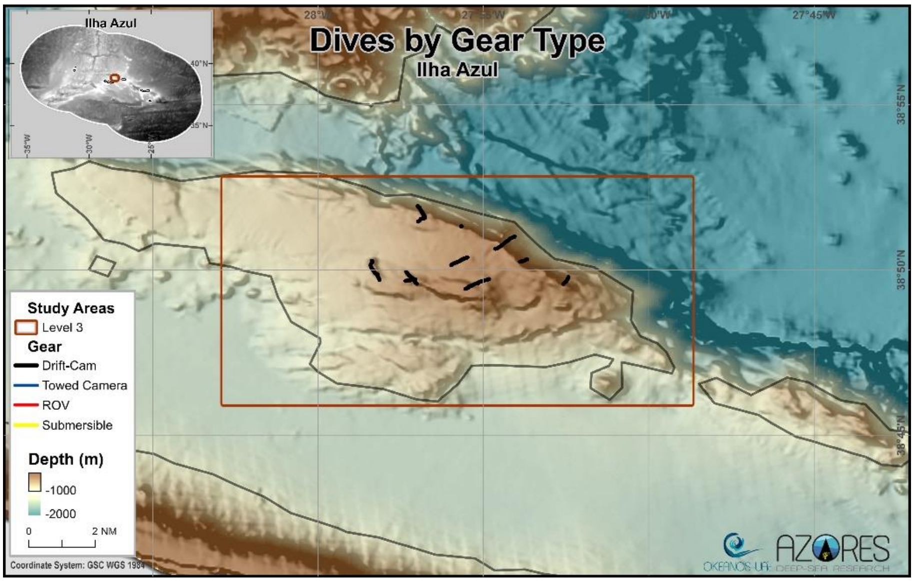



**Figure 314.** Map displaying the 11 underwater dives performed in the Ilha Azul area between 430 and 850 meters depth.

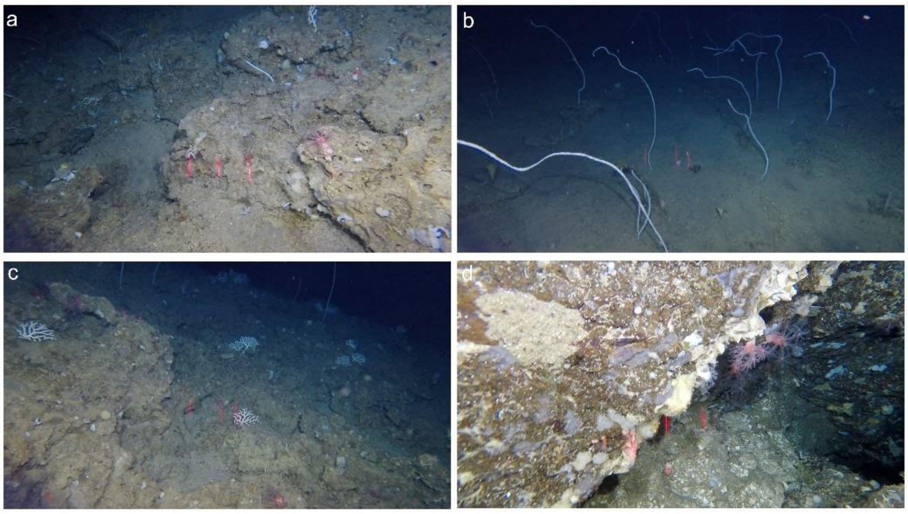



**Figure 315** Selected images representative of the main structuring species and benthic communities observed in Ilha Azul seamount. (a) Hard substrate with *Narella versluysi, Anthomastus/Pseudoanthomastus* sp. and *Paragorgia johnsoni* and small sponges. (b) Large colonies of *Viminella flagellum* on soft sediments. (c) Small colonies of *P. johnsoni* and *Anthomastus/Pseudoanthomastus* sp. (d) Rocky area covered with encrusting sponges and the soft-coral *Anthomastus/Pseudoanthomastus* sp. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Ilha Azul E*

There were performed 3 underwater video transects in the Ilha Azul East area, covering a depth range between 720 and 920 m (Figure 316 ). The video annotation resulted in a total of 31 taxa. From these, 21 were identified at the species level, suggesting a low diversity of deep-sea megabenthic species for this area. Predominant taxa based on weighted occurrences include *Farrea occa* (n= 8), *Haliclona filholi* (n= 6), and *Leptopsammia formosa* (n= 4).

The eastern area of the Ilha Azul slope was relatively deep, with the summit at depths around 700m. The zones surveyed in this geomorphological unit ranged from depths of about 900 to 700m, covering the upper slope and the summit of this area. The upper slope area of this unit was characterized by its sedimentary environment often interrupted by rocky outcrops and large deposits of loose rocks and coral rubble. This deep environment was scarce in benthic fauna, with only a few sightings of encrusting sponges and the sea urchin *Cidaris cidaris* when the rock outcropped and a solitary individual of the bamboo coral *Acanella arbuscula*. At the shallower depths of the summit (~700m) a widespread community of the primnoids *Narella versluysi* and *N. bellissima* (Figure 317) dominated the hard seabed, often accompanied by other sponge species such as *Ragadrella phoenix* (Figure 317) and patches of large aggregations of the commonly found *Pheronema carpenteri* (Figure 317). The hard substrate was highly colonized by several individuals of the small sponge *Haliclona filholi* (Figure 317).

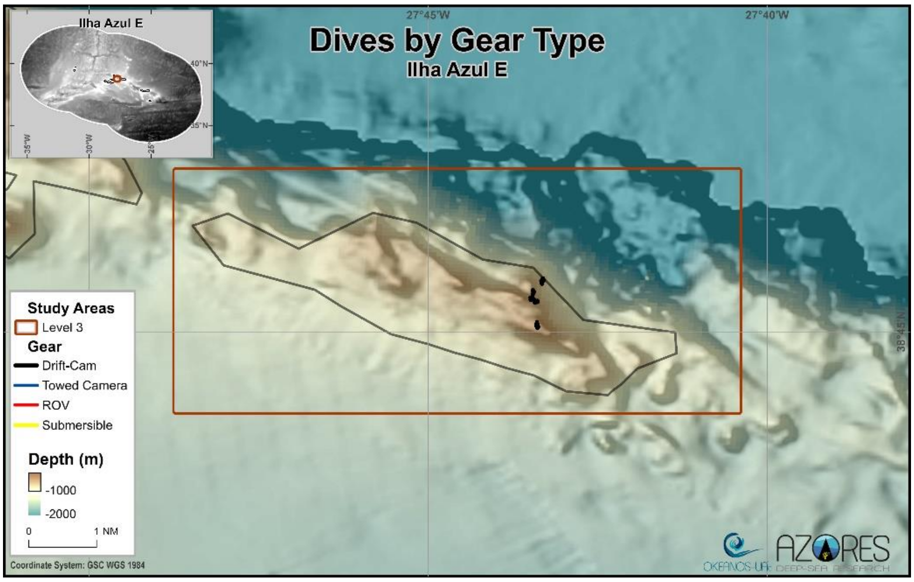



**Figure 316** Map displaying the 3 underwater dives performed in the Ilha Azul E area between 720 and 920 meters depth.

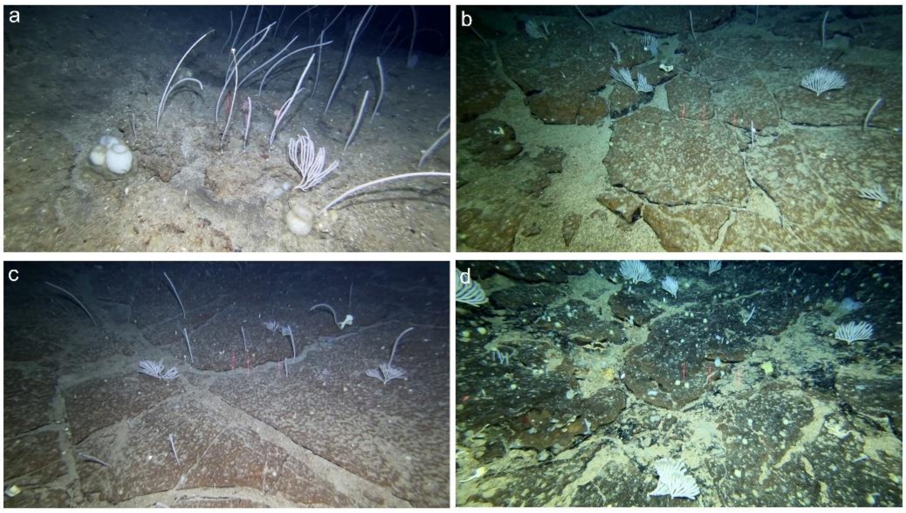



**Figure 317** Selected images representative of the main structuring species and benthic communities observed in Ilha Azul seamount. (a) Assemblage of *Narella versluysi* and *Narella bellissima* with sponges *Pheronema carpenteri.* (b) Dispersed aggregation of *N. versluysi* and *N. bellissima* with the glass sponge *Regadrella phoenix* and *Macandrewia azorica* on hard substrate. (c) Small colonies of *N. versluysi* and *N. bellissima* with small sponges. (d) Small colonies of *N. versluysi* and *N, bellissima* with small sponges, including the desmosponge *Haliclona filholi.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Ilha Azul SE*

While exploring Ilha Azul Southeast area, only one underwater video transect was conducted between 850 and 970 m depth (Figure 318). The results obtained from video analysis revealed a total of 30 taxa. From these, 19 were identified at the species level, showing a low diversity of deep-sea megabenthic species for this area. Predominant taxa based on weighted occurrences include *Farrea occa* (n= 26), *Leptopsammia formosa* (n= 24), and *Chrysogorgia* spp. (n= 17).

The southeastern slopes of the deep seamount of Ilha Azul, were dominated by soft sediments, normally representing a thin layer covering a harder substrate normally composed of sparse boulders that were progressively more common, creating robust rocky outcrops when climbing up the slope. The fauna encountered on this deep geomorphological unit, was very constant and with the same biodiversity maintaining along the upper slope. Several coral and sponge species common of deep environments were observed, from which we can highlight the large aggregations and sizes of lamellate sponges such as *Poecillastra compressa* and *Phakellia robusta*, the glass sponge *Farrea occa*, huge individuals of the genus *Asconema*, and the usual bird's nest sponge *Pheronema carpenteri*, although several seemed to be partially covered with sand. Colonies of black corals were an often sight and with an incredible diversity, since it was possible to spot species like *Leiopathes* cf. *expansa* (Figure 319) attached to the vertical basaltic walls, *Parantipathes hirondelle* and *Bathypathes pseudoalternata*. Bamboo corals and gorgonians were also recorded with the observation of *Acanella arbuscula* and colonies of the genus *Chrysogorgia*, the species *Candidella imbricata* and *Metallorgia melanotrichos*. Several aggregations of stylasterids (Figure 319) were also seen on the rocks. To also denote that on the sandy patches between rocks or when the soft sediment strongly covered the outcrops several echinoderms were found such as *Cidaris cidaris*, and *Zoaster fulgens*.

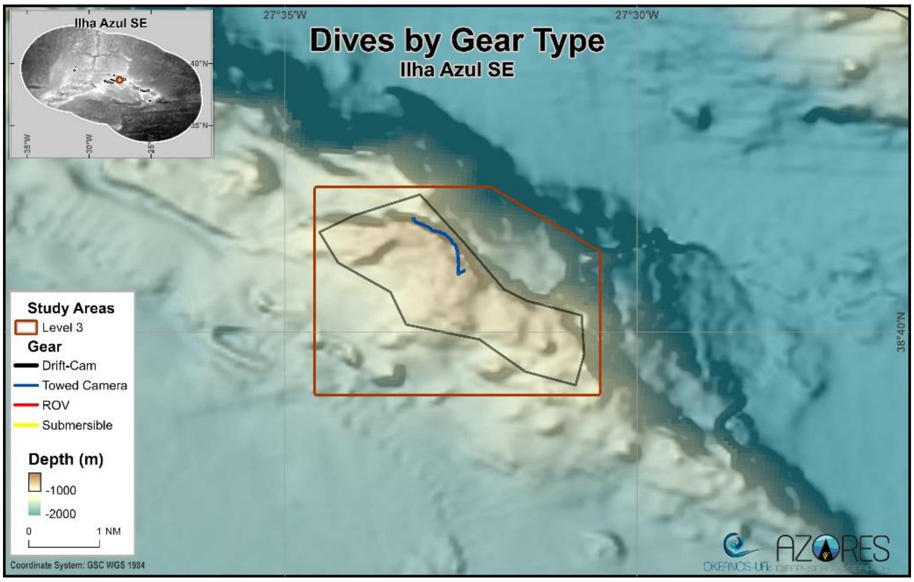



**Figure 318** Map displaying the 1 underwater dive performed in the Ilha Azul SE area between 850 and 970 meters depth.

**Figure 319** Selected images representative of the main structuring species and benthic communities observed in Ilha Azul Southeast area. (a-b-c) Large rocky outcrops with several colonies of the black coral *Leiopathes* cf. *expansa,* stylasterids and other octocorals, together with a large variety of sponges. Image credits: R/V Pelagia towed camera system, NIOZ / Cruise 64PE456

*São Jorge NW*

Altogether, there were performed 8 underwater video transects in São Jorge Northwest area, raging from depths between 480 and 980 m (Figure 320). The results revealed a low diversity of deep-sea megabenthic species, with 36 taxa were determined from the images. Among these, 20 were identified at the species level. Predominant taxa based on weighted occurrences include *Plesionika* (n= 17), Echinothuriidae (n= 11), and Ceriantharia (n= 10).

The dives were conducted mostly on steeps slopes covered by soft sediment with some bare rock in small portions of the dives. In general, we observed low biodiversity and low abundance of benthic species, especially on the deepest sections of the area. Soft sediments were occasionally colonized by solitary corals *Flabellum* sp., Xenophyophores, and tube-dwelling anemones. Occasional slopes covered in dead coral framework were also observed, although quite barren in terms of associated fauna. As slope increased, sediment became mostly characterized by basaltic outcrops and coral rubble, occasionally colonized by some bird's nest sponges *Pheronema carpenteri* (Figure 321) and more sporadically by the gorgonians *Callogorgia verticillata* and *Acanthogorgia* spp. in shallower areas. Some sponge species were also present at similar depths, including several massives *Characella pachastrelloides* and tubular-shaped sponges, and lamellate sponges such as *Desmacella grimaldii* and *Poecillastra compressa* (Figure 321). Some bluemouth rockfishes (*Helicolenus dactylopterus*) were frequently spotted. An aggregation of (at least) 4 kitefin sharks (*Dalatias licha*) and one bluntose sixgill shark (*Hexanchus griseus*) are among some of the motile fauna observed. Lost bottom longlines were observed at shallower spots.

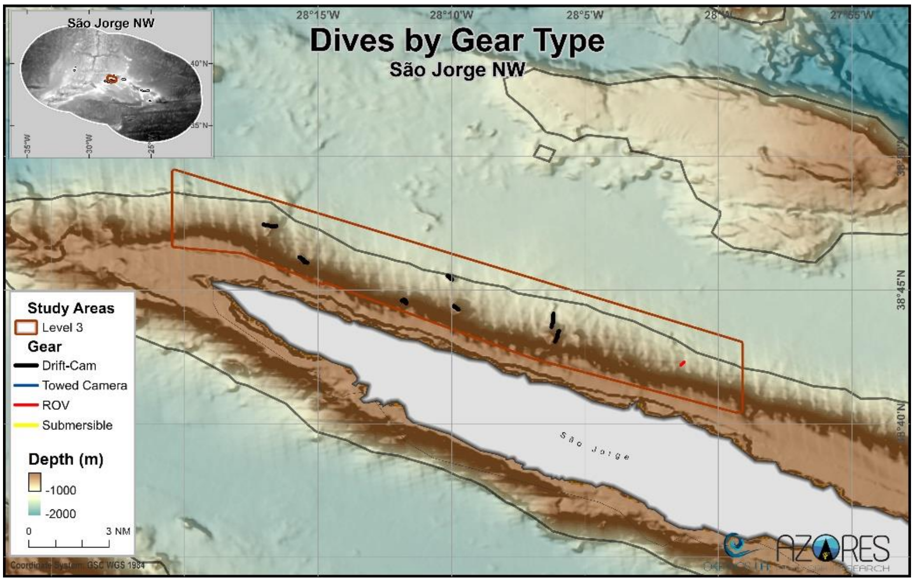



**Figure 320** Map displaying the 8 underwater dives performed in the São Jorge NW area between 480 and 980 meters depth.

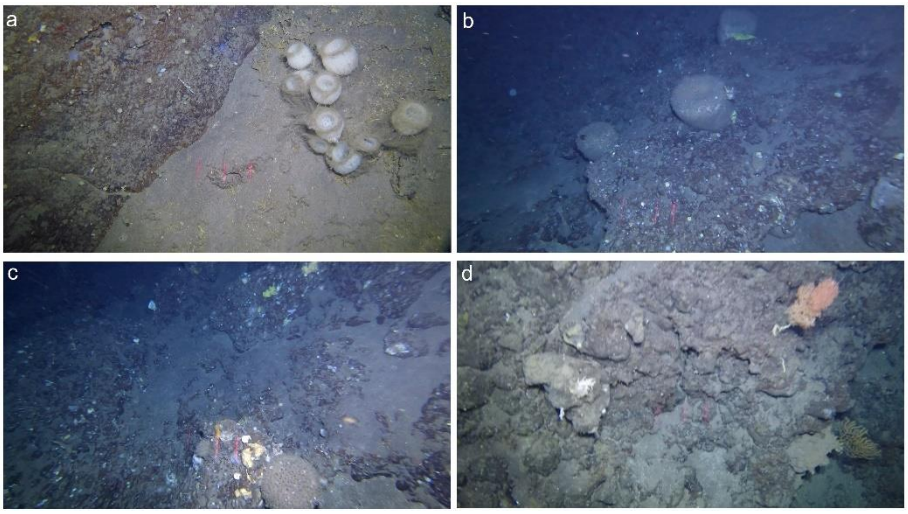


**Figure 321** Selected images representative of the main structuring species and benthic communities observed in São Jorge Northwest area. (a) Aggregation of the glass sponge *Pheronema carpenteri* (b-c) Rocky outcrops colonized by large sponges *Geodia* sp. and encrusting sponges (d) *Acanella arbuscula* and *Paramuricea* sp. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*São Jorge NE*

In the São Jorge Northeast area, 5 underwater video transects were performed between 240 and 940 m depth (Figure 322). The video annotation resulted in 40 taxa, suggesting a low diversity of deep-sea megabenthic species. From these, 21 were identified at the species level. Prominent taxa based on weighted occurrences include *Plesionika* (n= 17), Ceriantharia (n= 11), and Bryozoa (n= 9).

The seabed in this area was very sedimentary along the depth range explored, but particularly in the deepest areas explored. Different species were observed, including sea urchins and starfishes as well as occasional patches of the bird's nest sponge *Pheronema carpenteri* (Figure 323). Deep-sea sharks *Deania* sp., and the decapod *Aristeopsis edwardsiana* were also reported at these greater depths. When vertical walls and rocky outcrops started to appear, sponges began to dominate the community, including large demosponges such as *Characella pachastrelloides*, *Macandrewia azorica*, *Neophrisospongia nolitangere* (Figure 323), and *Leiodermatium* sp. However, flatter areas were usually covered by fine sediments, rendering the substrate unsuitable for many benthic species. Several species of fish were reported, including *Helicolenus dactylopetrus*, *Chaunax* sp., as well as some grenadiers, eel-like and flat fishes.

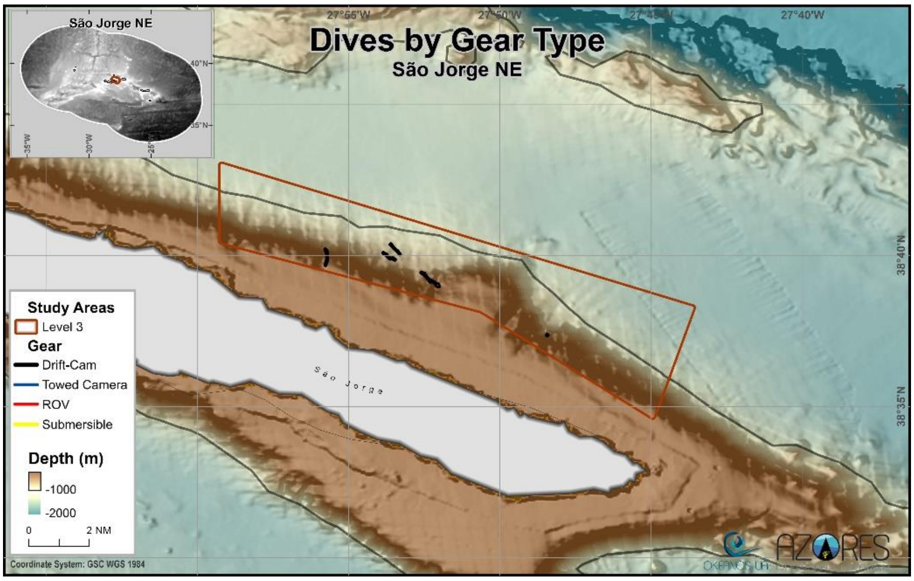



**Figure 322** Map displaying the 5 underwater dives performed in the São Jorge NE area between 240 and 940 meters depth.

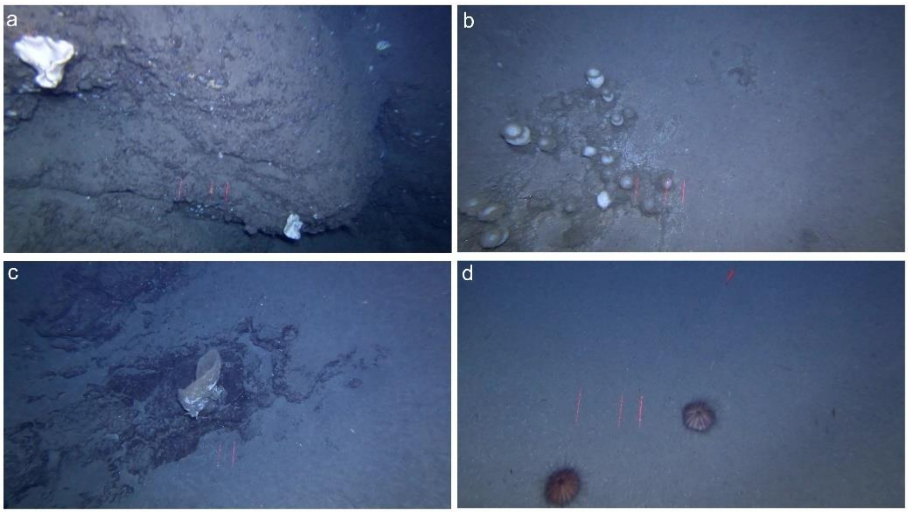



**Figure 323** Selected images representative of the main structuring species and benthic communities observed in São Jorge Northeast area. (a) Demospongia *Neophrisospongia nolitangere* (b) Aggregation of the glass sponge *Pheronema carpenteri* (c) Large *Characella pachastrelloides* (d) Sea urchins from the family Echinothuriidae. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*São Jorge E Topo*

While surveying São Jorge East Topo area, 8 underwater video transects were performed between 200 and 1070 m depth (Figure 324). A total of 44 taxa were determined from the videos recorded, with 27 identified at the species level, revealing that a low diversity of deep-sea megabenthic species is supported by this area. Noteworthy taxa based on weighted occurrences include *Narella versluysi* (n= 17), Ceriantharia (n= 14), and Hydrozoa (n= 9).

The eastern area of the São Jorge Island (or known as Topo) is characterized by an extensive shelf that ends with a chain of geomorphological features that resemble small seamounts. The depth coverage of this unit was very wide reaching deep and shallow sectors of the slope. The deepest areas explored, were characterized by basaltic outcrops covered by soft sediments and some sandy bottom areas, typical substrate of deep areas. The rocky areas hosted diverse benthic communities with patches of abundant coral gardens of *Candidella imbricata* with the cup coral *Leptopsammia formosa*, *Narella versluysi* with some scattered *Narella bellissima* (Figure 325), occasional stylasterids, *Anthomastus/Pseudoanthomastus* spp., and *Bathypathes* sp. (Figure 325), among many other species. The unconsolidated substrates showed the typical fauna present at such depths, which included the corals such as *Acanella arbuscula* and *Chrysogorgya sp.* (Figure 325), In these areas, we also observed some scattered glass sponges such as *Farrea occa*, *Regadrella phoenix*, large *Asconema* sp. (Figure 325), the bird's nest *Pheronema carpenteri*, and the big sponge *Leiodermatium* (white morphotype). On upper areas of the slope, only a few small and sparse corals of the species *Acanthogorgia* spp. (Figure 325), *Hemicorallium niobe*, *Viminella flagellum,* and the black coral *Elatopathes abietina.* Concerning sponge communities observed, we identified several individuals from the complex *Characella pachastrelloides*, *Geodia* spp. and *Haliclona magna.* At the summit areas of this unit, although characterized by sandy nature, the communities were impressive, and were mostly formed by small aggregations of the hydrozoan *Lytocarpia myriophyllum*, some small and dispersed aggregations of the coral species *Viminella flagellum* (yellow and white morphotypes) (Figure 325), occasional colonies of the gorgonians *Paracalyptrophora josephinae* and *Dentomuricea* cf. *meteor.* Extensive and large aggregations of *Acanthogorgia* spp. were also observed. Sponges of the species*, Macandrewia azorica and Haliclona implexa* were also spotted at these shallower spots. Concerning motile fauna we were able to identify several species such as the bluemouth rockfish (*Helicolenus dactylopterus*)*, Molva macrophthalma, Hoplostethus mediterraneus*, an angler fish (*Lophius piscatorius*) and some interesting rays such as *Raja clavata* and *Tetronarce nobiliana*, as well as one kitefin shark (*Dalatias licha*).

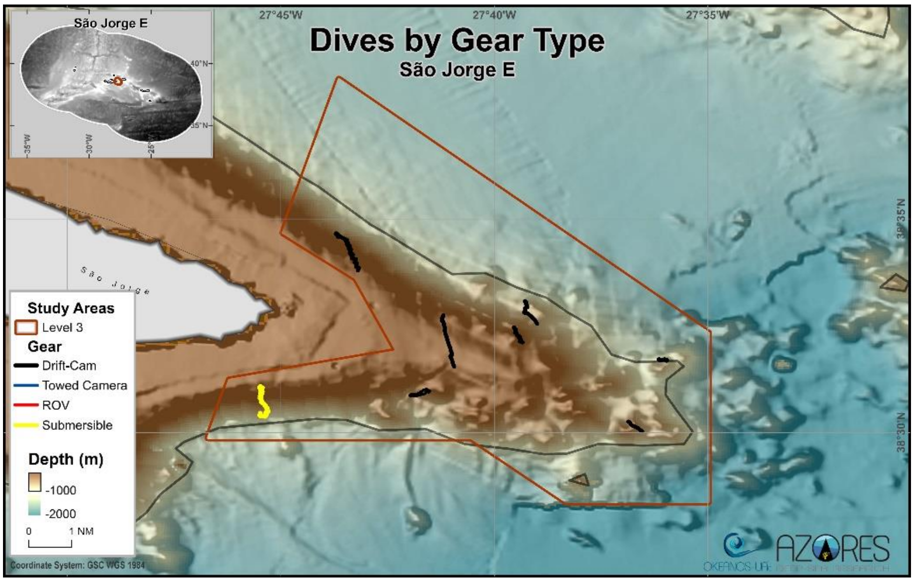



**Figure 324** Map displaying the 8 underwater dives performed in the São Jorge E Topo area between 200 and 1,070 meters depth.

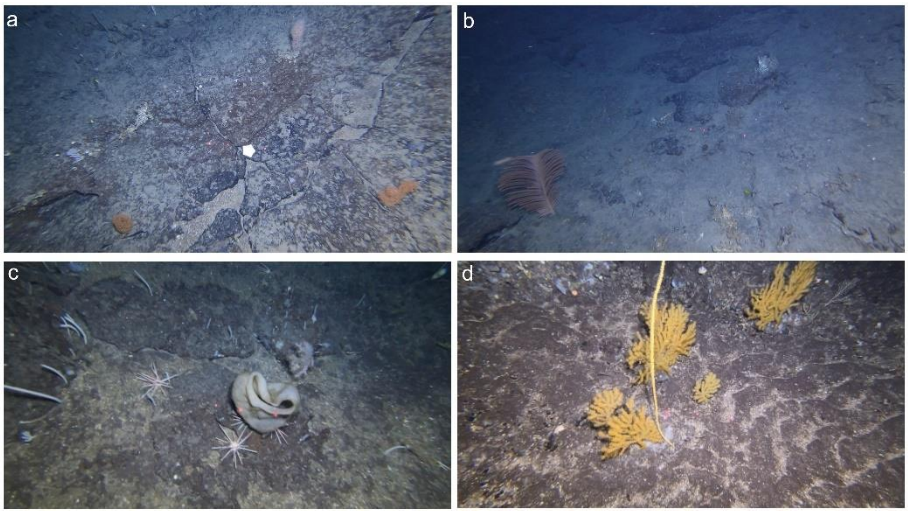



**Figure 325** Selected images representative of the main structuring species and benthic communities observed in São Jorge East Topo area. (a) *Acanella arbuscula, Chrysogorgia* sp. and *the* sea star from the family Goniasteridae (b) Black coral *Bathypathes* sp. (c) Small aggregation of *Narella versluysi* along with the sea urchin *Cidaris cidaris* and the sponge *Asconema fristedti* (d) *Acanthogorgia* spp. and the yellow morph of *Viminella flagellum*. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*São Jorge SE*

Exploring the São Jorge Southeast area, 6 underwater video transects were conducted between 180 and 890 m depth (Figure 326). The analysis unveiled a low diversity of deep-sea megabenthic species, with a total of 27 taxa determined from video annotation. Of these, 18 were identified at the species level. The most frequently observed taxa based on weighted occurrences were *Haliclona filholi* (n= 12), *Haliclona (Soestella) implexa* (n= 10), and *Echinus melo* (n= 9).

Most of the seabed explored in this São Jorge SE area showed strong sediment deposition, with occasional rocky outcrops harbouring some fauna. The shallowest area explored, in the island shelf, was usually colonized by several coral species such as by the *Viminella flagellum* (both its white and yellow morphotypes), *Acanthogorgia* spp. (Figure 327), and the scleractinian *Dendrophyllia cornigera.* Large black coral colonies likely from the species *Leiopathes glaberrima* were also seen at these depths. Various sponge species (e.g. *Haliclona implexa* and cf. *Poecillastra compressa)* (Figure 327) and occasional sea-urchins were also spotted. Small aggregations of the demosponge *Macandrewia azorica* (Figure 327) were seen colonizing flat basalt bottoms at greater depths, at around 700m. The deepest areas surveyed showed, again, high degrees of sedimentation, with vast soft grounds frequently colonized by aggregations of the glass sponges *Hyalonema (Cyliconema) thomsonis* (Figure 327)*,* and the bird's nest *Pheronema carpenteri.* Small deep-sea sharks (*Dalatias licha* and *Deania* sp.), and some fishes (*Capros aper, Mora moro, Phycis pyhcis*) were also observed at various depths.

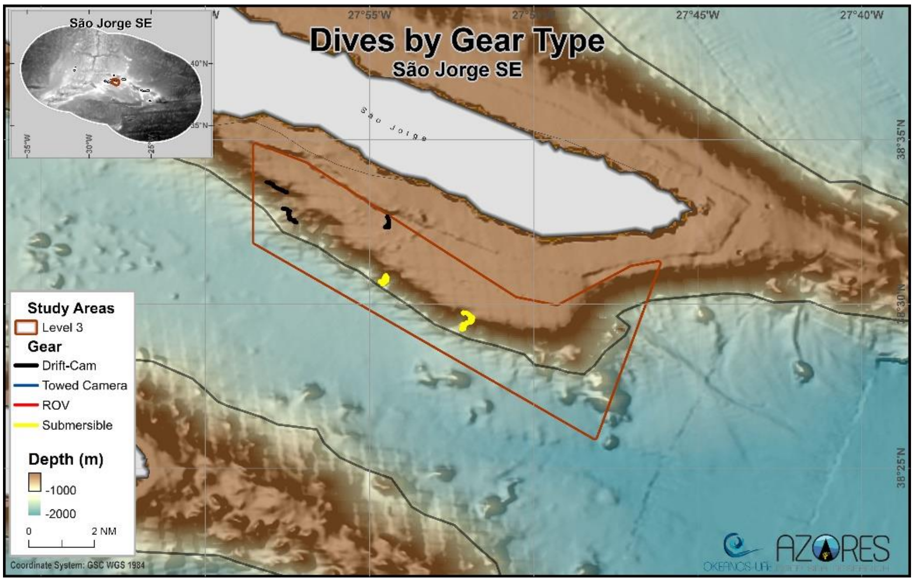



**Figure 326** Map displaying the 6 underwater dives performed in the São Jorge SE area between 180 and 890 meters depth.

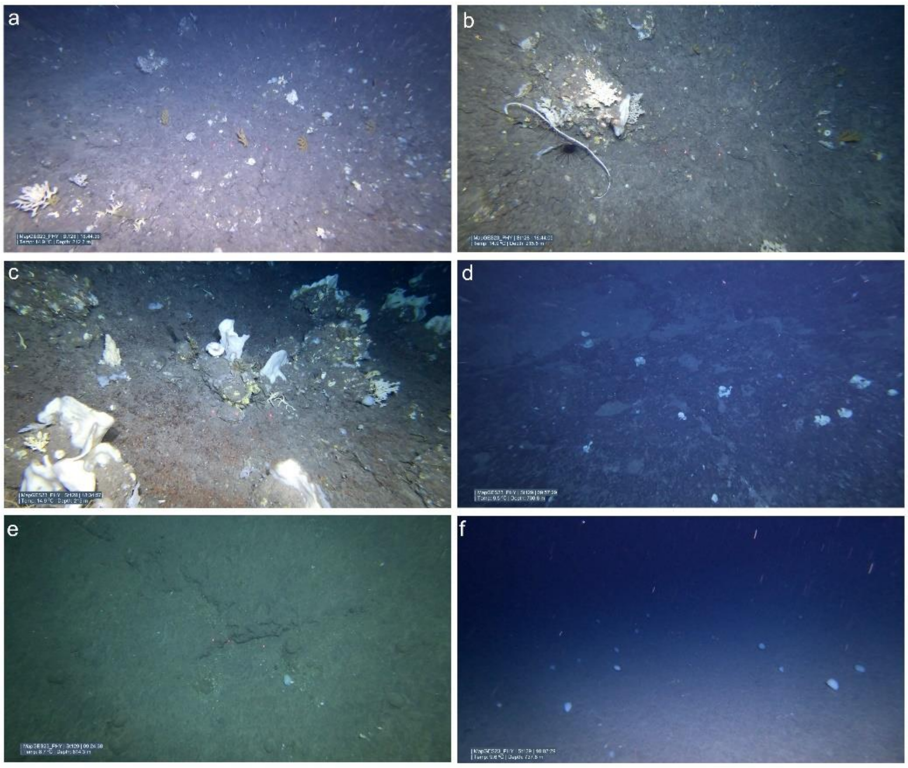



Figure 327 Selected images representative of the main structuring species and benthic communities observed in São Jorge Southeast area. (a) Small colonies of *Acanthogorgia* spp. on hard bottom with a wide variety of sponges, including *Haliclona implexa.* (b) Colony of gorgonians *Viminella flagellum* and *Acanthogorgia* spp. on hard substrate next to a rock densely colonized by sponges, *Haliclona implexa* and *Poecillastra compressa,* and scleractinians. (c) Large area dominated by lamellate sponge *Poecillastra compressa.* (d) Dispersed aggregation of the desmosponge *Macandrewia azorica* (e) Foraminifera *Syringammina fragilissima.* (f) Extensive aggregation of the sponge *Hyalonema thomsonis* with occasional occurrence of *S. fragilissima.* Image credits: ROV Luso / EMEPC / 2018 Oceano Azul Expedition, organized by Oceano Azul Foundation & partners.

*São Jorge S Urzelina*

Overall, 10 underwater video transects were performed in the São Jorge South Urzelina area between 240 and 1190 m depth (Figure 328). A total of 25 taxa were determined from the images, with 12 identified at the species level, showing that a low diversity of deep-sea megabenthic species is supported by this area. Dominant taxa based on weighted occurrences include *Viminella flagellum* (n= 7), *Ircinia polejaeffi* (n= 6), and *Petrosia* sp. (n= 5).

The slopes visited in São Jorge South Urzelina, between 650 m and 290 m, were essentially dominated by soft sediment. The bathyal soft-bottom habitat was characterized by different sponge species. The scarce rocky outcrops covered by sediments presented a diverse sponge assemblage (Figure 329), with *Petrosia* sp., *Leiodermatium* sp., *Neophrissospongia nolitangere* and *Macandrewia azorica* being sighted. The densest sponge concentrations were observed at about 350 m depth. Corals were distributed sporadically along the whole depth range explored, mainly *Nicella granifera*, *Muriceides* sp., *Swiftia* sp. and Caryophylliidae. The shallowest areas unveiled extensive areas of uncolonized sandy substrate, with occasional rocky outcrops hosting some corals such as the yellow morphotype of *Viminella flagellum* and *Acanthogorgia* spp. (Figure 329) A wide variety of small sponges was also observed at these depths with *Haliclona implexa* and other unidentified species composing most of the assemblage observed. The only hydrocoral observed was cf. *Errina dabneyi*. In the deeper areas (700 m) and at around 400m depth, assemblages of *Neopycnodonte zibrowii* and *Cyathidium foresti* were observed. Lots of myctophids followed the ROV during the descend. Once again, not many fish species were observed during the dive. Among those, *Hoplostethus mediterraneus*, Macrouridae, *Helicolenus dactylopterus*, cf. *Arnoglossus rueppelli* and maybe cf. *Chlorophthalmus agassizi*.

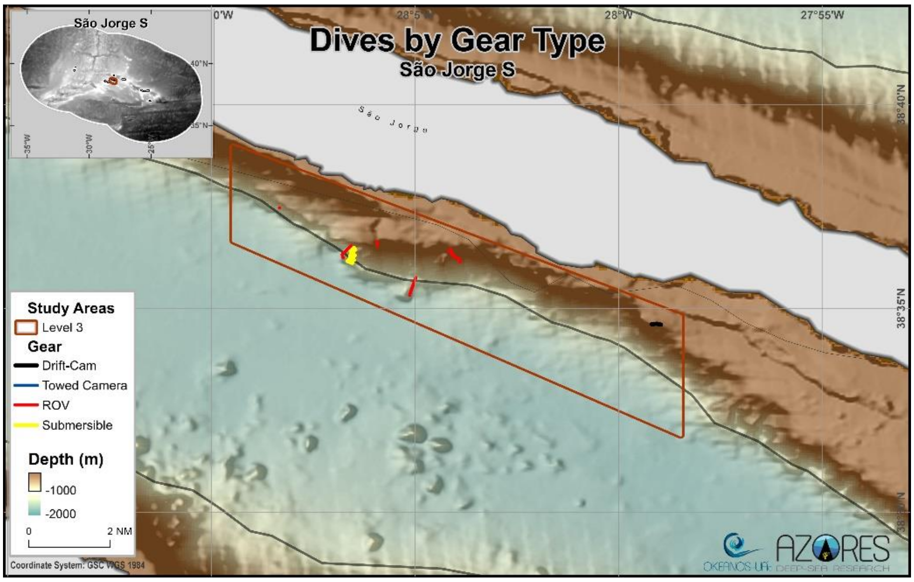



**Figure 328** Map displaying the 10 underwater dives performed in the São Jorge S Urzelina area between 240 and 1,190 meters depth.

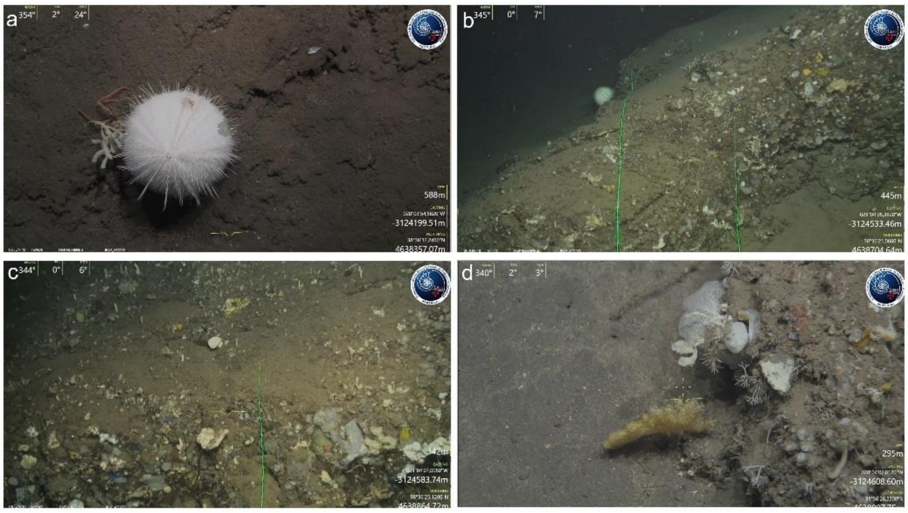


Figure 329 Selected images representative of the main structuring species and benthic communities observed in São Jorge South Urzelina area. (a) Sea urchin *Echinus melo* on soft sediments. (b-c) Outcrop densely colonized by a wide variety of small and encrusting sponges. (d) Assemblages composed by the gorgonian *Acanthogorgia* spp. together with several species of small sponges and bryozoans. Image credits: ROV Luso / EMEPC / 2018 Oceano Azul Expedition, organized by Oceano Azul Foundation & partners.

*São Jorge SW Velas*

The exploration of the São Jorge Southwest Velas area resulted in 5 underwater video transects completed between 190 and 870 m depth (Figure 330). The results revealed a low diversity of deep-sea megabenthic species, with a total of 40 taxa determined. From these, 27 were identified at the species level. Predominant taxa based on weighted occurrences include *Phlyctaenopora (Phlyctaenopora) bitorquis* (n= 8), *Echinus melo* (n= 7), and *Cyathidium foresti* (n= 6).

A deep ridge west of the municipality of Velas was surveyed, where rocky outcrops covered by soft sediments were found. Most of the steep slopes surveyed were covered by soft sediments, likely fallen from the small island shelf and possibly of terrestrial influence. The benthic communities observed in the deepest areas explored were dominated by small deep-sea sponges, with aggregations of *Hyalonema (Cyliconema) thomsonis,* and the bird's nest *Pheronema carpenteri* (Figure 331). Fields of Xenophyophores were also present, as well as tube-dwelling anemones. On shallower areas, we found some colonies of the endemic cf. *Errina dabneyi* (Figure 331) on rocky outcrops, while soft sediments harbored a diverse assemblage of sponges such as the repent *Pseudotrachya hystrix* and the fan shaped *Phakellia ventilabrum* (Figure 331)*,* together with other non-identified species. The whip coral *Viminella flagellum* was also occasionally spotted. Several kitefin sharks (*Dalatias licha*) (Figure 331) were recorded at 500m and the common mora *Mora moro,* at greater depths.

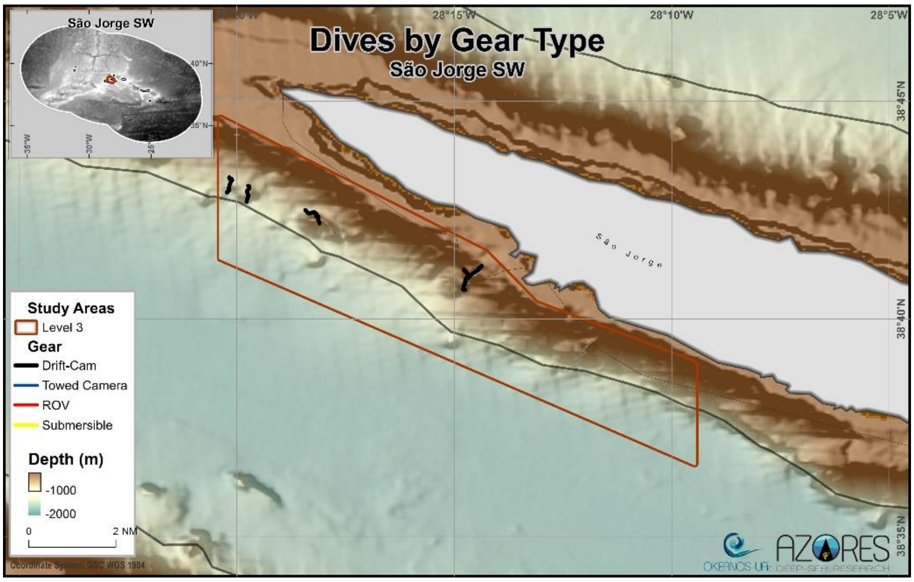



**Figure 330** Map displaying the 5 underwater dives performed in the São Jorge SW Velas area between 190 and 870 meters depth.

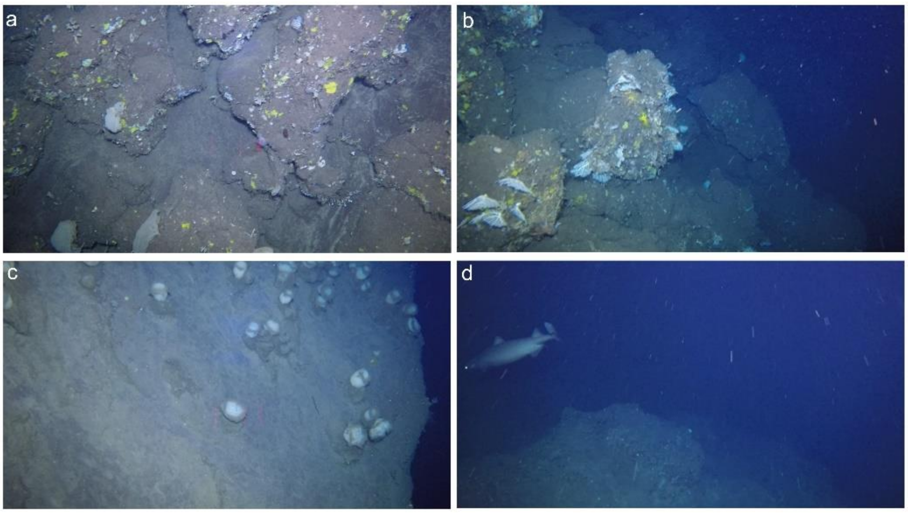



**Figure 331** Selected images representative of the main structuring species and benthic communities observed in São Jorge Southwest Velas area. (a) Area colonized by soma encrusting sponges along with *Phakelia ventilllabrum* and other small sponges (b) Rocky boulders colonized by some colonies of the endemic cf. *Errina dabneyi* (c) Aggregation of *Pheronema carpenteri* (d) Kite fin shark, *Dalatias licha*. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*São Jorge W Rosais*

A total of 15 underwater video transects were conducted in the São Jorge W Rosais area, covering a depth range from 180 to 930 m (Figure 332). The video analysis resulted in 52 taxa determined. From these, 28 identified at the species level, revealing that a medium diversity of deep-sea megabenthic species is supported by this area. Notable taxa based on weighted occurrences include *Leiodermatium* sp. (n= 23), *Echinus melo* (n= 21), and *Characella pachastrelloides* (n= 16).

The deepest areas surveyed showed high degrees of sedimentation, at around 850m depth. Nevertheless, interesting faunal assemblages were spotted, with fields of Xenophyophores on flatter terrain and aggregations of the glass sponges *Pheronema carpenteri* and *Hyalonema* sp. appearing in higher densities when the slope started to increase. At round 700m depth, coral rubble deposits started to dominate the sediment, with only some colonies of *Callogorgia verticillata* and the solitary coral *Flabellum* sp. colonizing the seafloor., as well as a few large sponges *Characella pachastrelloides.* The decapods *Chaceon affinis, Paromola cuvieri* and the sea urchin *Cidaris cidaris* (as an aggregation of small individuals) were also recorded at these depths, as well as the fishes *Beryx sp.* and *Molva macrophthalma.* A couple of bottom longlines were also drifted over. The bivalve *Neopycnodonte zibrowii* was also seen occasionally attached to rocky overhangs. At around 450m depth, the benthic community started to shift, where large colonies of *Paracalyptrophora josephinae* (Figure 333) in between vast aggregations of *Acanthogorgia* spp. (Figure 333) dominated most of the faunal assemblage at these depths. The black coral *Leiopathes glaberrima* also appeared, but several colonies were found dead or greatly impacted. A large shoal of *Hoplostethus mediterraneus* was also observed. At the shallowest depths explored, a large field of the scleractinian coral *Eguchipsammia cornucopia* (Figure 333) was seen covering a vast area. The framework this aggregation created was quite dense, forming a reef-like structure, almost exclusively dominated by this species.

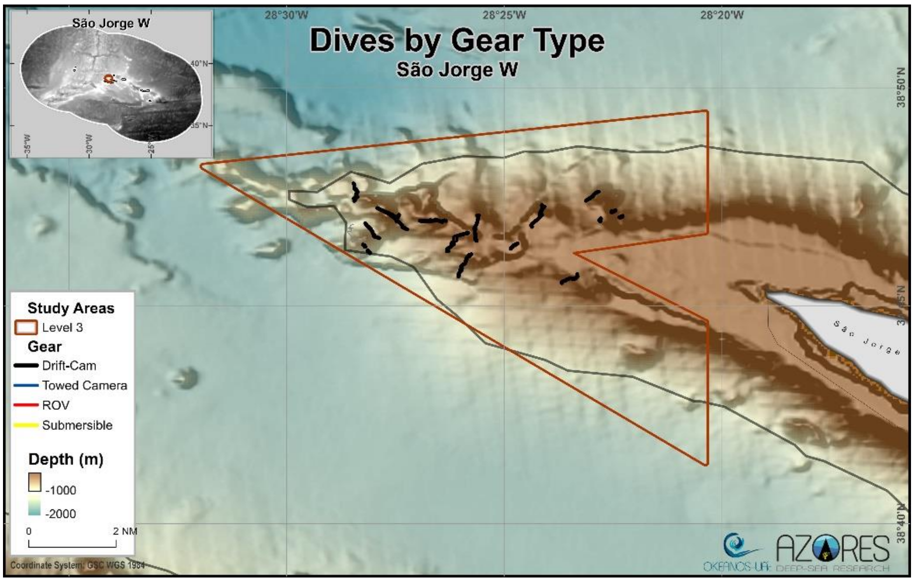



**Figure 332** Map displaying the 15 underwater dives performed in the São Jorge W Rosais area between 180 and 930 meters depth.

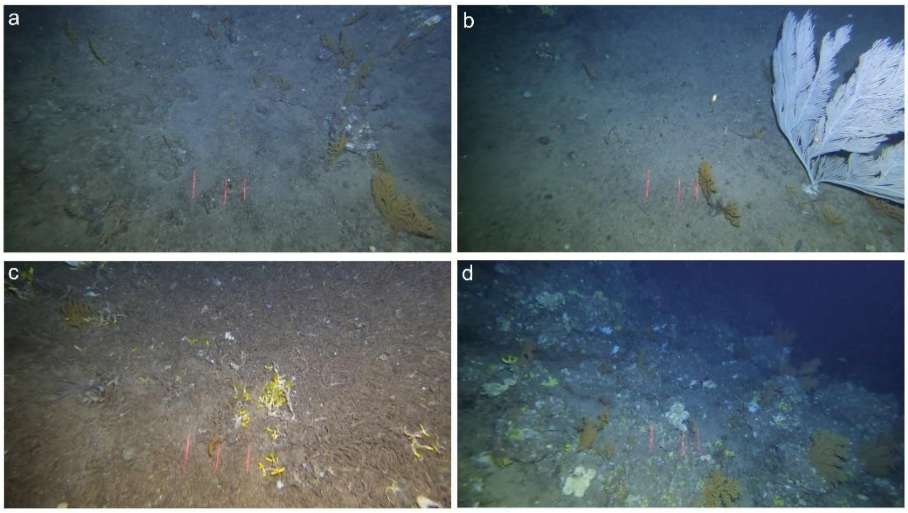



**Figure 333** Selected images representative of the main structuring species and benthic communities observed in São Jorge West Rosais area. (a) Aggregation of the gorgonian *Acanthogorgia* spp. (b) Assemblage of *Acanthogorgia* spp. together with the primnoid *Paracalyptrophora josephinae,* with a spider crab *Anamathia rissoana* associated to. (c) Colonies of *Eguchipsammia cornucopia* on a dead coral framework. (d) Outcrop densely colonized by a wide variety of sponges and *Acanthogorgia* spp. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*João de Melo (a.k.a São Jorge de Fora)*

Surveying João de Melo area resulted in 4 underwater video transects, conducted between 330 and 1,310 m depth (Figure 334). A total of 22 taxa were identified from the images recorded, with 11 determined at the species level, indicating a low diversity of deep-sea megabenthic species for this area. Predominant taxa based on weighted occurrences include *Characella pachastrelloides* (n= 10), *Viminella flagellum* (n= 9), and *Petrosia* sp. (n= 8).

João de Melo seamount is an elongated feature south of Terceira Island that stretches for 21 km. A very clear zonation pattern regarding the structure of the benthic communities was observed, with very well-defined species associations along the depth gradient. Overall, this sampling area shows a high degree of sediment deposition and low number of organisms within the communities identified. The deepest areas explored, at the base of the seamount, were characterized by flat soft bottoms with muds and fine sands, where the most important megafauna species was the foraminifera cf. *Syringammina fragilissima*. Not many species have been identified within this community besides some sea urchins of the species *Cidaris cidaris* and sparse *Acanella arbuscula*. corals, together with some large crustaceans of the species *Aristaeopsis edwardsiana* (Figure 335a). Aggregations of the primnoids *Narella bellissima* and *Narella verluysi* were observed on the flanks of the seamount, accompanied by the sea urchins *Cidaris cidaris* and *Echinus* sp., the yellow cup coral *Leptopsammia formosa* and the large sponge *Pheronema carpenteri* (Figure 335b). At around 600 m depth, an aggregation of large gorgonians of the species *Callogorgia verticillata* was registered, with relatively high densities in some local patches, which lasted several tens of meters (Figure 335c). On the summit, at around 500 m depth, the hard substrates were mostly colonized by gorgonians of the species *Viminella flagellum* (Figure 335d), accompanied by other corals such as *Parantipathes hirondelle*, *Anthomastus/Pseudoanthomastus* and *Acanthogorgia* spp., the white sea urchin *Echinus* sp. and many encrusting sponges.

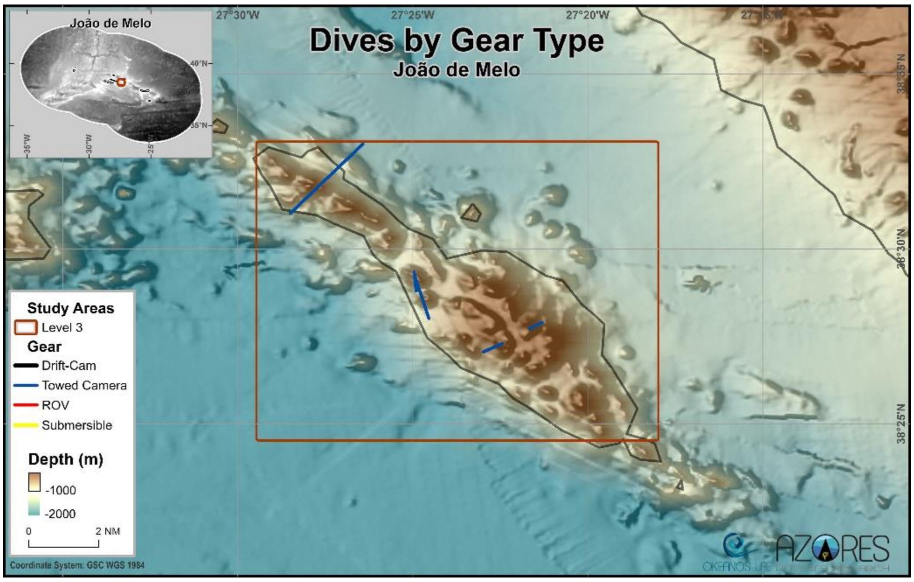



Figure 334 Map displaying the 4 underwater dives performed in the João de Melo area between 330 and 1,310 meters depth.

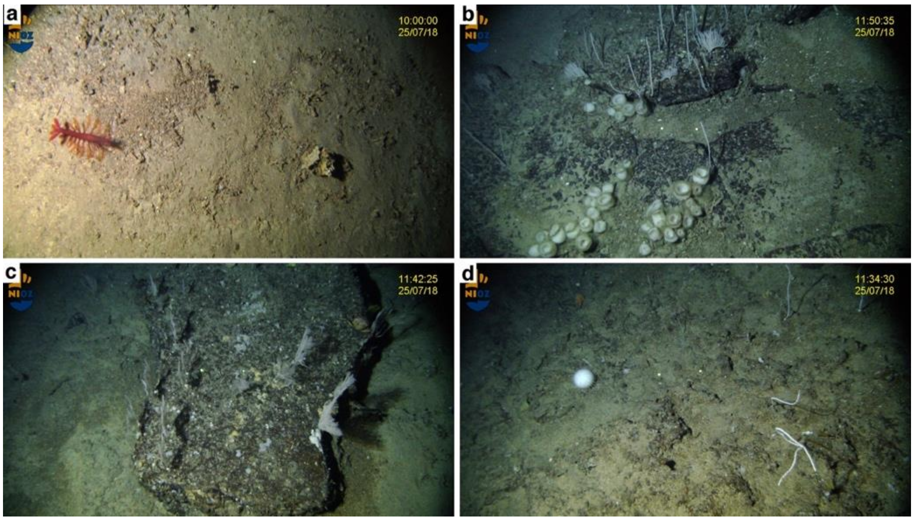



Figure 335 Selected images representative of the main structuring species and benthic communities observed in the São Jorge de Fora seamount. (a) One specimen of the shrimp *Aristaeopsis edwardsiana* on the soft bottoms below 1,000 m depth. (b) Association between the corals *Narella versluyisi* and *Narella bellisima*. and the glass sponge *Pheronema carpenteri*. (c) One of the few aggregations of the primnoid *Callogorgia verticillata*. (d) Sparse colonies of the whip coral *Viminella flagellum* on the summit. Image credits: Hopper tow-cam, NIOZ.

**Study area | Terceira**

*Terceira NE*

Overall, 8 underwater video transects were conducted in the Terceira Northeast area between 270 and 1010 m depth (Figure 336). A total of 56 taxa were identified from the images analysed, with 32 determined at the species level, revealing that this area supports a medium diversity of deep-sea megabenthic species. Notable taxa based on weighted occurrences include *Phlyctaenopora (Phlyctaenopora) bitorquis* (n= 14), *Anthomastus/Pseudoanthomastus* sp. (n= 11), and *Characella pachastrelloides* (n= 10).

The deepest spots surveyed in Terceira Northeast area were characterized by sand-like bottoms, partially from biogenic origin, and quite barren in terms of benthic fauna. Apart from several eel-like fishes roaming close to the seabed, and a sea-urchin *Cidaris cidaris,* no more fauna was observed at 1,000m depth. When visiting steeper and shallower terrains, a mixture of soft sediments with biogenic rubble covered most of the substrate observed. Within these biogenic deposits, several dead bivalves likely from the species *Neopycnodonte zibrowii* also composed this type of substrate, which had quite possibly come from the large rocky overhangs observed several meters above, which they once colonized. Some demosponges *Desmacella grimaldii, Macandrewia azorica* and *Geodia* sp. (Figure 337) sparsely colonized basaltic outcrops at around the same depths, as well as the whip coral *Viminella flagellum* and *Pleurocorallium johnsoni* (Figure 337) in shallower sections (550m depth). Aggregations of the same whip coral were recorded at around 480m depth, in relatively flat and rocky areas, together with several hydrozoans. The shallowest sections were mostly characterized by sandy substrate poorly colonized by benthic fauna. Some bluemouth rockfish (*Helicolenus dactylopterus*), shoals of boar fish (*Capros aper*) and krill swarms were recorded at these depths.

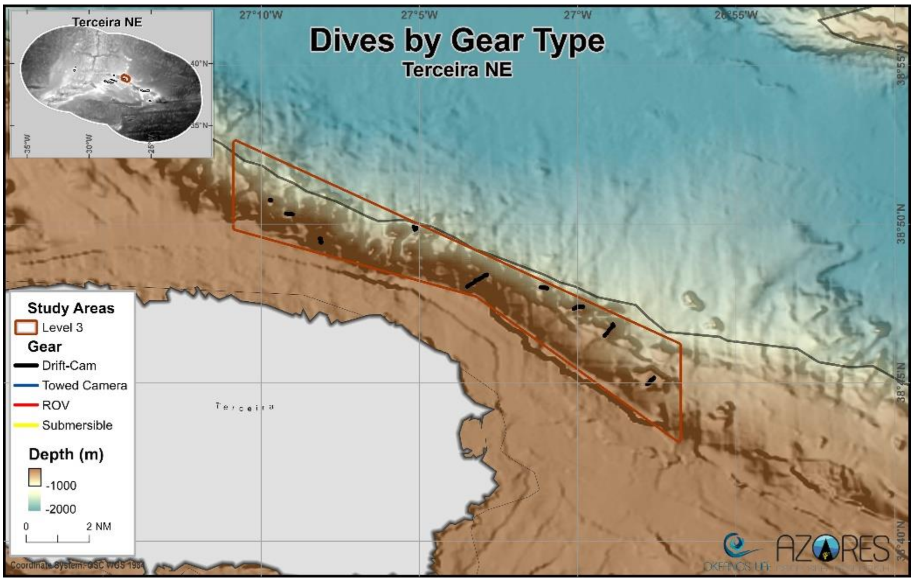



**Figure 336.** Map displaying the 8 underwater dives performed in the Terceira NE area between 270 and 1,010 meters depth.

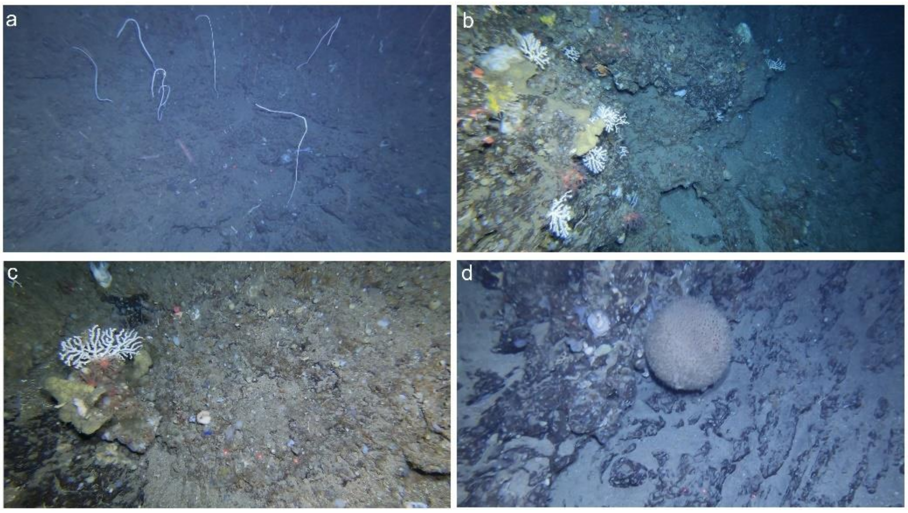



**Figure 337** Selected images representative of the main structuring species and benthic communities observed in Terceira Northeast area. (a) Small aggregation of the whip coral *Viminella flagellum.* (b-c) Aggregation of *Pleurocorallium johnsoni* along with *Anthomastus/Pseudoanthomastus* sp. and some encrusting sponges and *Desmacella grimadi.* (d) Sponge *Geodia* sp. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Terceira N*

In the Terceira North area, 11 underwater video transects were completed between 190 and 800 m depth (Figure 338). The results showed a low diversity of deep-sea megabenthic species for the area with a total of 46 taxa identified. From these, 27 determined at the species level. Prominent taxa based on weighted occurrences include *Acanthogorgia* spp. (n= 14), *Anthomastus/Pseudoanthomastus* sp. (n= 13), and *Paragorgia johnsoni* (n= 12).

In terms of benthic fauna observed, Terceira N was a very interesting area, with a number of different communities present. The deepest areas explored were characterized by frequent and small aggregations of the glass sponge *Pheronema carpenteri* and occasional demosponges of the species *Macandrewia azorica.*

In shallower areas (~500 – 250 m) the benthic communities observed were quite unique, with impressive assemblages of several species of corals, sponges and mobile fauna dominating vast areas. Irregular, jagged basaltic outcrops usually harboured aggregations of *Viminella flagellum* (in particular, its yellow morphotype) (Figure 339), many different sponge species (e.g., *Neophrissospongia nolitangere*, *Petrosia crassa)* (Figure 339) and fish (*Hoplostethus mediterraneus, Conger conger, Pontinus kuhlii, Phycis phycis*, and a shark *Dalatia licha*), usually in amongst lost fishing lines. It was also observed an extensive but partially dead reef of the scleractinian *Eguchipsammia cornigera*, and impressive and vast coral gardens composed by many different species such as *Viminella flagellum, Acanthogorgia* spp., *Dentomuricea* aff. *meteor*, *Errina dabneyi* and large colonies of *Callogorgia verticillata* (Figure 339). A particular highlight of this area was the coral garden dominated by *Dentomuricea* aff. *meteor.* What was truly striking about this coral garden was the density and size achieved by the colonies of this species, quite possibly the largest specimens we have recorded so far in the Azores region. Moreover, the large extent of this coral garden was truly remarkable, being present for at least ~650 m long. Most of the colonies seemed to be in a good condition but some were rather impacted. Sponge species also composed these communities, such as the white lamellate *Poecillastra compressa* (Figure 339). Interestingly, large krill swarms were also present, actually being preyed on by schools of *Trachurus picturatus*. A large ray *Dipturus intermedius* was observed also. The deepest areas explored had some octocorals from the species *Narella versluysi* and *Acanthogorgia* spp., as well as the cup coral *Leptopsammia formosa*. Regarding sponge assemblage, it was mainly composed of smaller glass sponges such as *Farrea occa* and *Aphrocallistes beatrix* complex. Regarding mobile fauna, we spotted several bluemouth rockfish (*Helicolenus dactylopterus*), one monkfish (*Lophius piscatorius*) and one bluntnose sixgill shark (*Hexanchus griseus*).

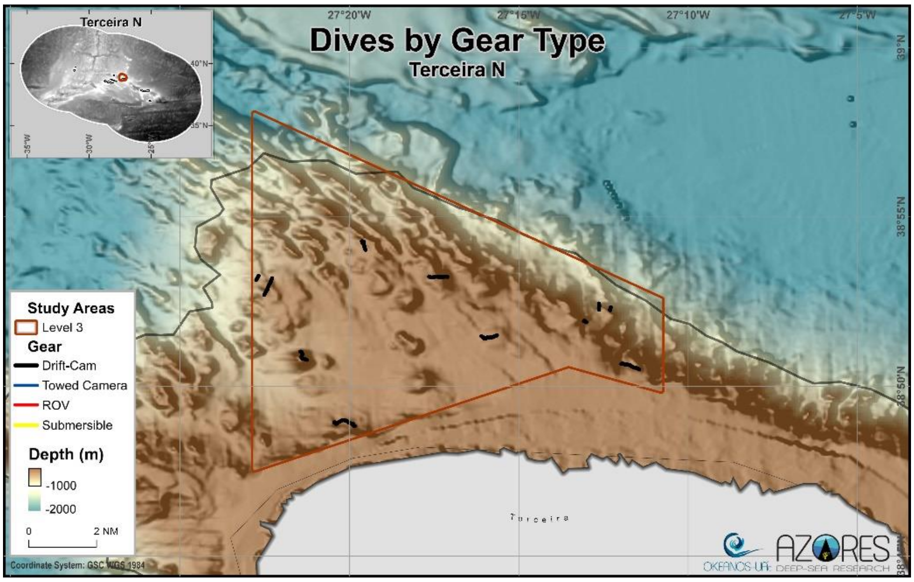


**Figure 338.** Map displaying the 11 underwater dives performed in the Terceira N area between 190 and 800 meters depth.


Figure 339 Selected images representative of the main structuring species and benthic communities observed in Terceira North area. (a) Hard substrate colonized by the corals *Dentomuricea* aff. *meteor,* the yellow morphotype of *Viminella flagellum*, hydrozoans, and several sponges, including *Leiodermatium* sp. (blue morphotype), *Neophrissospongia nolitangere* and other smaller sponges. (b) Large colonies of the gorgonian *D.* aff. *meteor.* (c) Boulder colonized by *V. flagellum.* (d) Large colonies of *Callogorgia verticillata* and *V. flagellum*. (e) Aggregation of the gorgonians *C. verticillata* and *Acanthogorgia* spp. together with large hydrozoans and encrusting sponges. (f) Sponges, including *Farrea occa, Regadrella phoenix* and *Pheronema carpenteri* together with the corals *Pleurocorallium johnsoni* and *Acanthogorgia* sp. on basaltic bottom. (g) Basaltic bottom with patches of soft sediments colonized by the bird's nest sponge *P. carpenteri.* (h) Small boulders occupied by small encrusting sponges and the lamellate sponge *Poecillastra compressa.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Terceira E*

Terceira East is a particularly impressive area in terms of benthic fauna recorded. In these area, 11 underwater video transects were performed between 310 and 950 m depth (Figure 340). The results obtained from video analysis revealed a total of 40 taxa. From these, 23 were determined at the species level, revealing that this area supports a low diversity of deep-sea megabenthic species. Dominant taxa based on weighted occurrences include Plesionika (n= 13), *Leptopsammia formosa* (n= 11), and *Pliobothrus symmetricus* (n= 9).

In the shallowest areas explored, we observed several lush colonies of *Leiopathes glaberrima* (most of which entangled by lost bottom longlines), concomitantly covering the seafloor with *Callogorgia verticillata*, *Dentomuricea* aff. *meteor,* cf. *Candidella imbricata* and some colonies of *Enallopsammia rostrata,* sometimes forming small aggregations. The seafloor was also abundantly covered by what we believe to be small primnoid corals, yet to be identified. We also spotted large coral gardens of *Viminella flagellum, Acanthogorgia* spp., *Callogorgia verticillata*, *Dentomuricea* aff. *meteor*, *Paracalyptrophora josephinae* and the black coral *Leiopathes glaberrima* (Figure 341). Sparse colonies of *Parantipathes hirondelle*, and the endemic cf. *Errina dabneyi* also composed this diverse community. Between 320 and 490m deep, some *Viminella flagellum* aggregations were found associated with *Elatopathes abietina* and *Enallopsammia_rostrata*. At around 650 m deep, we drifted over an especially interesting area showing an extensive aggregation of the white morphotype of *Paragorgia johnsoni* with at least one red morphotype of *Paragorgia johnsoni* (Figure 341). At around 800m deep, small aggregations of cf. *Candidella imbricata* were seen covering the seafloor.

The sponge assemblage was also quite diverse and interesting. Large specimens of the *Characella pachastrelloides* (Figure 341) complex seen colonizing basaltic substrate, among other species such as *Geodia* sp., *Leiodermatium* both its white and blue morphotypes, *Neophrissospongia nolitangere*, *Phakellia ventilabrum, Poecillastra compressa, Macandrewia azorica, Petrosia crassa*, *Desmacella Grimaldi, Haliclona magna*, *and Haliclona implexa,* and including an aggregation of *Stylocordilla pellita* and small aggregations of *Xestospongia variabilis.*

In terms of motile fauna, we observed some fishes from the species *Helicolenus dactylopterus*, *Lophius piscatorius* and *Lepidorhombus whiffiagonis*; one ray *Dipturus intermedius*, and two bluntnose sixgill shark *Hexanchus griseus*. We also spotted two different species of crabs: *Cancer bellianus* and *Paramola cuvieri*. A lot of lost bottom longlines were seen, many entangled in some corals.

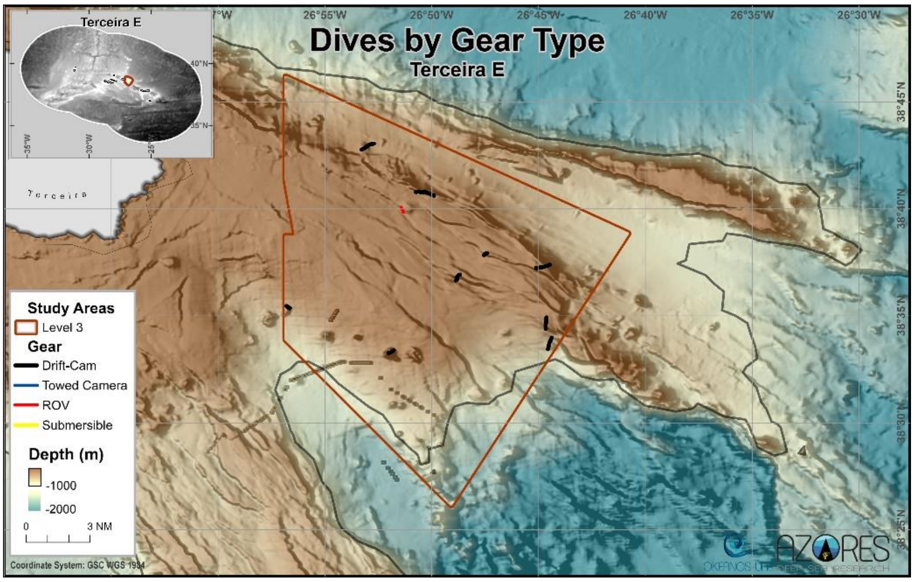



**Figure 340** Map displaying the 11 underwater dives performed in the Terceira E area between 310 and 950 meters depth.

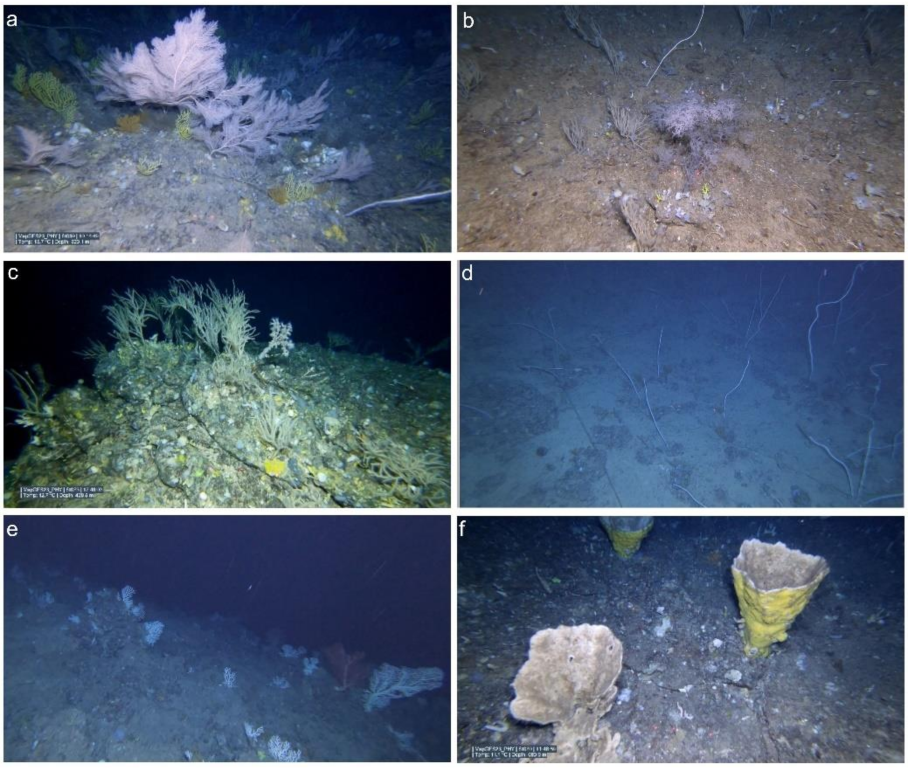



**Figure 341** Selected images representative of the main structuring species and benthic communities observed in Terceira East area. (a) Large aggregation of *Callogorgia verticillata, Viminella flagellum, Dentomuricea* aff. *meteor* and *Acanthogorgia* spp. (b) Small colony of the black coral *Leiopathes glaberrima* and several colonies of an unidentified primnoid coral. (c) Aggregation of unidentified primnoids on a hard substrate densely colonized by small and encrusting sponges. (d) Aggregation of *Viminella flagellum* of soft sediments with occasional occurrence of *Acanthogorgia* spp. in an area with evidence of fishing activities. (e) Sparsed aggregation of two morphotypes of the *Paragorgia johnsoni.* (f)Large specimens of the sponge species *Characella pachastrelloides.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Terceira S*

While exploring Terceira South area, 11 underwater video transects were conducted between 250 and 910 m depth (Figure 342). A total of 51 taxa were identified from the video annotation, with 29 determined at the species level, suggesting that this area supports a medium diversity of deep-sea megabenthic species. Predominant taxa based on weighted occurrences include *Leptopsammia formosa* (n= 16), Caryophylliidae (n= 13), and *Acanthogorgia* spp. (n= 11).

The Terceira South area was mostly characterized by sandy substrates with some sedimentary or basaltic outcrops and boulders, and occasional small vertical walls and coral rubble. In general, this area was not exceptionally rich in terms of benthic fauna. Thriving benthic communities were found in the shallowest parts (440 and 260 m), with impressively abundant coral gardens of *Dentomuricea* aff. *meteor, Callogorgia verticillata, Viminella flagellum, Paracalyptrophora josephinae* and particularly lush colonies of *Acanthogorgia* spp. (Figure 343). We also spotted many lost fishing lines and bottom longlines, entangling some corals. On the top of one of the hills, we drifted over a vast reef of the scleractinian *Eguchipsammia cornigera.* As we drifted along a vertical wall, we marvelled at how it was densely colonized by large corals of the species cf. *Candidella imbricata* (Figure 343), *Acanthogorgia* spp. and *Dentomuricea* aff. *meteor.* Most of the colonies observed seemed to be healthy. Large, funnel-shaped sponges of the *Characella pachastrelloides* complex and many smaller sponges also colonized most of the shallower seafloor explored. In deeper areas, between 440 and 550 m deep, we also observed some aggregations of *Viminella flagellum,* some colonies of *Callogorgia verticillata, Elatopathes abietina* and *Pleurocorallium johnsoni.* The bottom was characterized by basaltic outcrops with sand and some coral rubble, which were for the most part covered in encrusting sponges. Some hydrozoans and large sponges from the complex *Characella pachastrelloides* were also observed*.* Between 500 m to 850 m depth, occasional specimens of *Petrosia crassa*, *Farrea occa*, *Macandrewia azorica*, *Regadrella phoenix*, *Neophrisopongia nolitangere*, *Stylocordila pellita* and *Phakellia ventilabrum* and some small aggregations of *Phakelia robusta* colonizing coral rubble were also observed. The glass sponge *Pheronema carpenteri* (Figure 343)*,* the primnoid corals *Narella versluysi, Narella bellissima* and possibly a couple of colonies of *Paragorgia johnsoni* occasionally inhabited mixed substrate between 660 and 860 m deep. On the deepest areas, between 814 and 920m deep, we spotted some black corals from the species *Parantipathes hirondelle,* the bamboo coral *Acanella arbuscula,* and some stylasterids as well as some small aggregations of *Narella versluysi* and *N. bellissima*, mostly at the basaltic outcrops. *Leiopathes expansa* was also spotted with *Sternostylus formosus* associated.

In terms of mobile fauna, many fish species were seen exploring the dense coral gardens, such as *Hoplostethus mediterraneus* and *Pontinus kuhlii.* We also encountered alfonsinos (*Beryx decadactylus*), skittish angler fish (*Lophius piscatorius*), *Chaunax pictus*, *Helicolenus dactylopterus* and one *Dipturus intermedius* spotted at around 600 m deep.

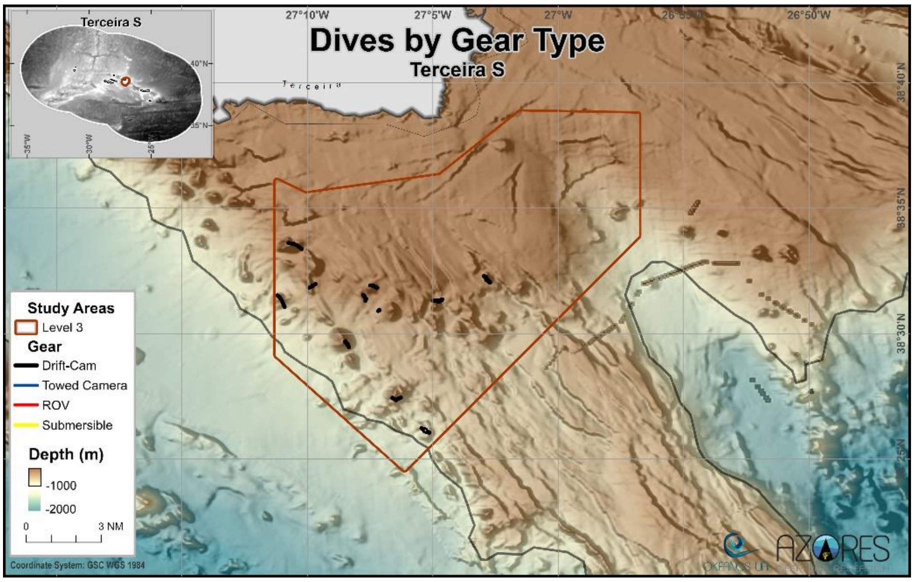



Figure 342 Map displaying the 11 underwater dives performed in the Terceira S area between 250 and 910 meters depth.

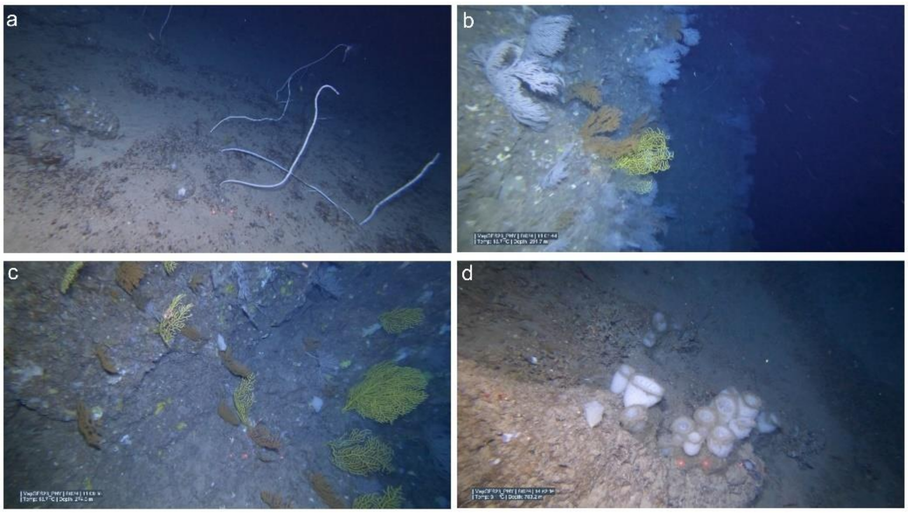



Figure 343 Selected images representative of the main structuring species and benthic communities observed in Terceira South area. (a) Dispersed colonies of *Viminella flagellum.* (b) Vertical wall colonized by several species of gorgonians, including *Dentomuricea* aff. *meteor, Acanthogorgia* spp., *Candidella imbricata.* (c) Colonies of the gorgonians *Acanthogorgia* spp. and *D.* aff. *meteor* on hard substrate. (d) Small aggregation of the sponge *Pheronema carpenteri* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Terceira SW Angra*

In the Terceira Southwest Angra area, 5 underwater video transects were performed between 150 and 960 m depth (Figure 344). The results revealed a medium diversity of deep-sea megabenthic species with 66 taxa identified from video annotation. From these, 40 were determined at the species level. Noteworthy taxa based on weighted occurrences include *Viminella flagellum* (n= 26), Hydrozoa (n= 25), and Echinothuriidae (n= 24).

Soft sediments characterized the deepest sections explored, mostly colonized by what seemed to be the foraminifera cf. *Syringammina fragilissima* (Figure 345). Not many species of invertebrates could be observed in these depths, besides some sponges and corals attached to the sparse boulders that appeared in between the soft sediment, including the yellow cup coral cf. *Leptopsammia formosa*, which reached relatively high densities. The rocks were always covered by a layer of mud/sand, which possibly limited the capacity of other fauna to colonize. A few fish species could be identified in the soft bottom bottoms, being the bluemouth rockfish (*Helicolenus dactylopterus*) the most abundant of all, with the frogmouth fish *Chaunax* sp. also observed resting over the seabed. Areas of large rocky outcrops that generated very steep slopes were common, however, the number of megafauna species remained low. Large deposits of dead coral rubble could be observed, likely belonging to the cold-water coral *Lophelia pertusa*. Some sparse organisms could be identified in between the coral rubble, in which the yellow gorgonian *Acanthogorgia* spp. (Figure 345) and the sponge *Pheronema carpenteri* were the most abundant species. At around 675 m depth, the substrate becomes coarser with many more rocky outcrops being observed, with the number of invertebrate megafauna species starting to increase together with the available hard surface. High numbers of *Acanthogorgia* spp., cf. *Lytocarpia myriophyllum* or different laminate sponges were recorded. The presence of some large gorgonians of the species *Paragorgia johnsoni* (Figure 345) was noticeable, some of them showing signs of being affected by the fishing activity. In this regard, some fishing lines were observed lying over the seabed, especially in shallower depths. Some areas were also characterized by the presence of the white gorgonian *Pleurocorallium johnsoni* (Figure 345), together with the white sea-urchin *Echinus melo.* In the shallowest parts explored, large colonies of the whip coral *Viminella flagellum* (Figure 345) were present, becoming the most abundant coral species as depth decreased.

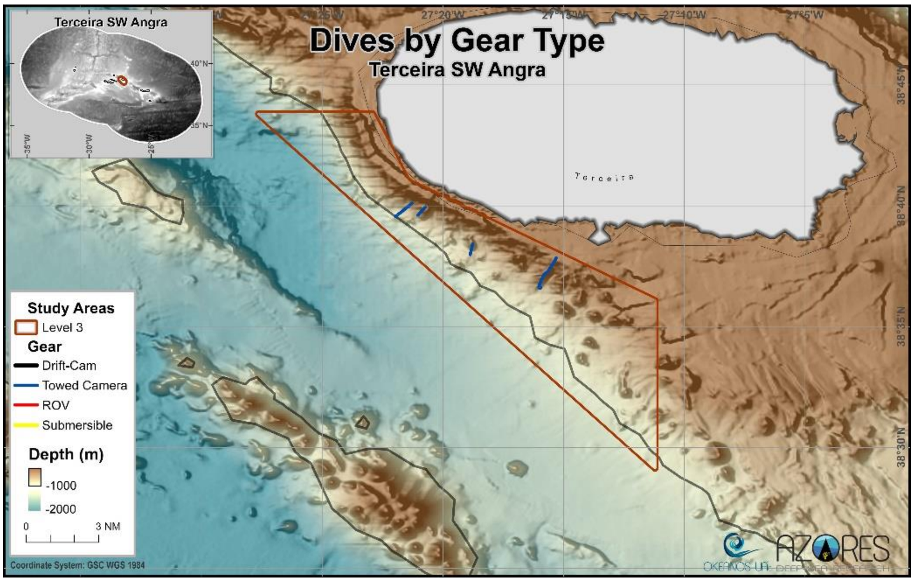



**Figure 344** Map displaying the 5 underwater dives performed in the Terceira SW Angra area between 150 and 960 meters depth.

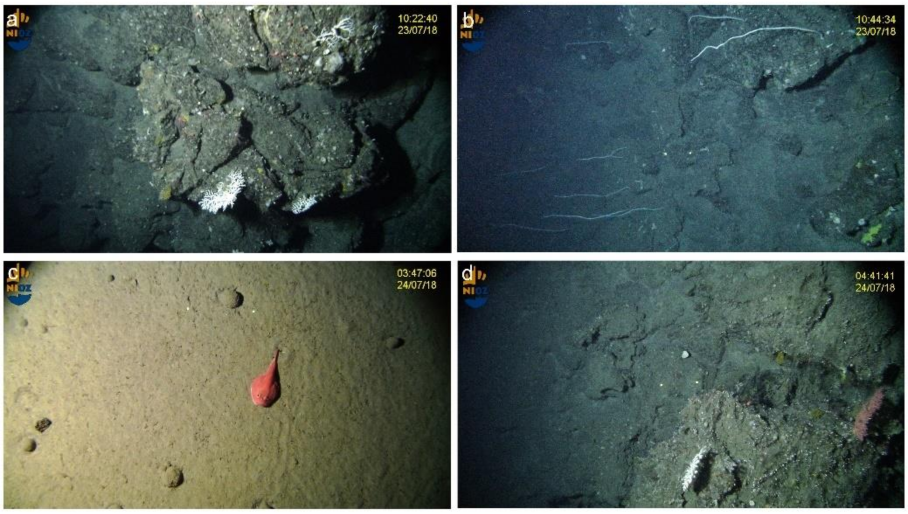



**Figure 345** Selected images representative of the main structuring species and benthic communities observed in Terceira Southwest Angra area. (a) Colonies of the *Pleurocorallium johnsoni, Acanthogorgia* spp. and the soft-coral *Anthomastus/Pseudoanthomastus* sp. on hard substrate. (b) Sparse aggregation of *Viminella flagellum.* (c) Foraminifera *Syringaminna fragilssima.* (d) Rocky area with two colonies of the bubble gum *Paragorgia johnsoni,* small soft-coral aggregation and *Acanthogorgia* spp., and the sponge *Macandrewia azorica.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Terceira W Serreta*

A total of 17 underwater video transects were completed in Terceira West Serreta area, covering a depth range from 160 to 1170 m (Figure 346). The video analysis resulted in 72 taxa were identified from the images, with 39 determined at the species level, revealing that this area supports a medium diversity of deep-sea megabenthic species. Dominant taxa based on weighted occurrences include Bryozoa (n= 11), *Farrea occa* (n= 10), and Plexauridae (n= 9).

The dives performed in this geomorphological unit allowed us to have an insight of the benthic fauna present at each part of its slope and for a wide range of depth. The deepest areas explored were constituted by the soft seabed, with occasional patches of coral rubble deposits, characteristic of sedimentary environments. The benthic fauna at these more expressive depths, was limited and with poor biodiversity, with occurrences almost only at some basaltic boulders. These were mainly composed by the assemblages of the gorgonians *Acanthogorgia* spp., and *Pleurocorallium johnsoni* (that reach great densities at more shallow depths) (Figure 347), together with several glass sponges (*Pheronema carpenteri, Farrea occa, Regadrella phoenix).* When climbing up the slope the aggregations of *Acanthogorgia* spp., and *Pleurocorallium johnsoni* were more expressive, and accompanied with soft coral species, mainly of the genus *Anthomastus/Pseudoanthomastus* (Figure 347), the octocoral *Dentomuricea* aff. *meteor*, and colonies of the scleractinian *Dendrophyllia cornigera* (Figure 347). The more common sponges were the fan shaped *Phakellia ventilabrum* (which appeared in large aggregations), *Macandrewia azorica* and *Haliclona implexa* (Figure 347). Shoals of the fish *Caprus aper*, *Trachurus picturatus* and a large ray *Dipturus intermedius* were also observed swimming around. On the part that is thought to be the summit (less than 200m) the seabed is mainly composed of fine sediment and very scarce in fauna, with only the record of a few examples of the hydrozoan *Lytocarpia myriophyllum*.

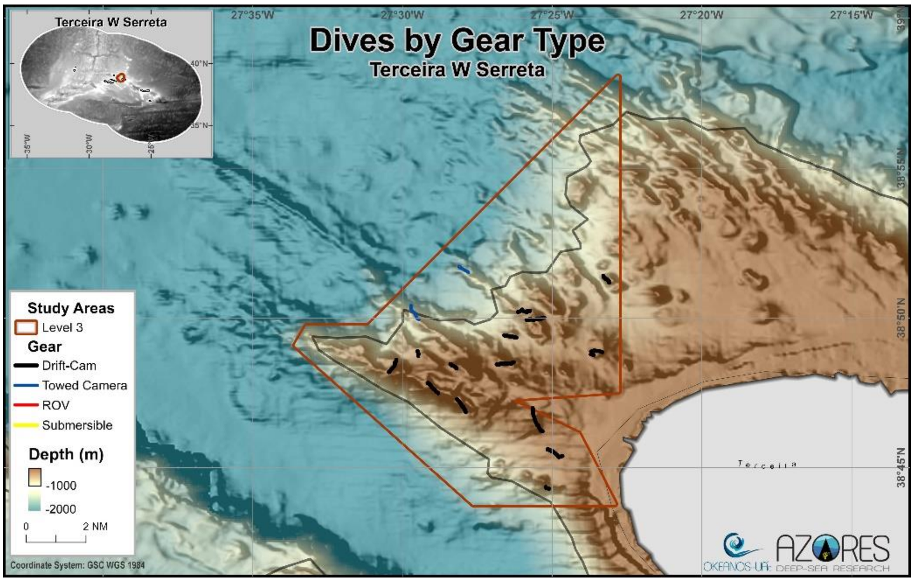


**Figure 346** Map displaying the 17 underwater dives performed in the Terceira W Serreta area between 160 and 1,170 meters depth.

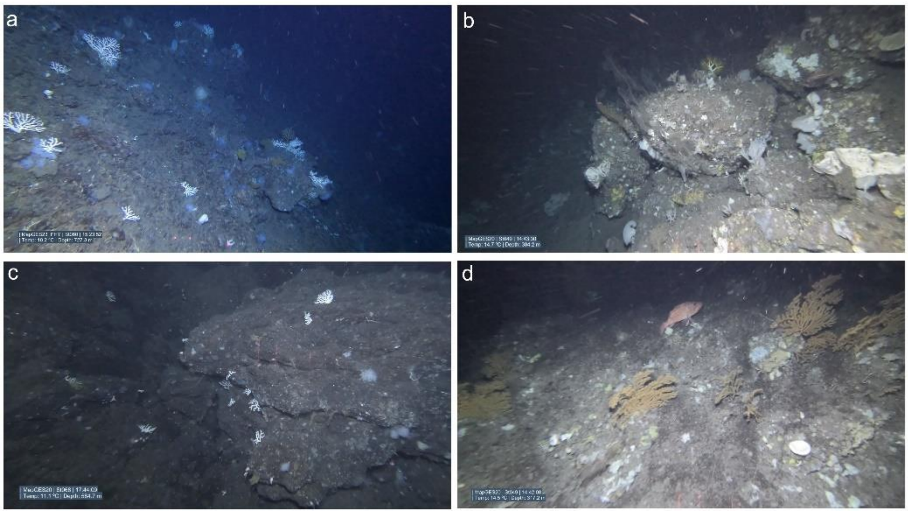



Figure 347 Selected images representative of the main structuring species and benthic communities observed in Terceira West Serreta area. (a) Aggregation of the gorgonians *Pleurocorallium johnsoni* and *Acanthogorgia* spp. together with several species of glass and other small sponges. (b) Boulder densely colonized by several species of sponges, including *Phakellia ventillabrum* and *Haliclona implexa,* and the scleractinian *Dendrophylia cornigera* and hydrozoans. (c) Aggregation of *P. johnsoni* with sporadic occurrence soft coral *Anthomastus/Pseudoanthomastus* sp. and glass sponges on a hard substrate. (d) Colonies of *Acanthogorgia* sp. on hard bottom with several sponges including *Macandrewia azorica.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Álvaro Martins*

There were performed 4 underwater video transects in the Álvaro Martins area, ranging between 680 and 940 m depth (Figure 348). A total of 45 taxa were identified from the images. From these, 29 were determined at the species level, revealing that this area supports a low diversity of deep-sea megabenthic species. Prominent taxa based on weighted occurrences include *Narella bellissima* (n= 31), *Narella versluysi* (n= 21), and *Plesionika* sp. (n= 18).

The geomorphological unit called Álvaro Martins is a small seamount close to the Terceira NE area. This seamount has a flat plateau at around 650m depth with gentle to steep slopes on the northern and southern sides of the structure. Most of the slopes of this seamount were covered by soft sediments, sometimes interrupted by sparse basaltic boulders and some patches of coral rubble. These soft sediments were, at some areas, only covering the hard substrate below. At the deepest areas explored, the bamboo coral *Acanella arbuscula* was very common, during all the transects made, together with some other coral species such as the aggregations of the black coral *Leiopathes expansa* (with several associated *Sternostylus formosus*) (Figure 349) on the occasional boulders, the scattered scleractinians *Leptopsammia formosa*, the hydrocoral *Pliobothrus symmetricus*, and the sighting of a coral from the genus *Gersemia*. The main highlight regarding corals went to the vast aggregations of the stylasterid *Errina atlantica* (Figure 349) and the several *Caryophyllidae* sp. At these depths it was also possible to observe several individuals (both in sand and rocky substrates) of Crinoids, the foraminifera *Syringammina fragilissima*, on unconsolidated sediments, and the sea urchin *Cidaris cidaris*. Apart from the small encrusting sponges, very few and usually solitary *Pheronema carpenteri* (Figure 349) and the glass sponge *Regadrella phoenix* (Figure 349) were spotted. At shallower areas of the slopes, spectacular gardens of *Narella versluysi* and *N. bellissima* (Figure 349) covered some areas of the sea bottom. Some scattered *Acanthogorgia* spp. were also observed. The hard substrate was often covered with *Haliclona filholi* and relatively large patches of *Phakellia ventilabrum* and *Macandrewia azorica*. The fish species *Phycidae* spp., *Mora moro Molva macrophtalma*, *Neocyttus helgae*, the Chimaera *Hydrolagus pallidus* and several Anguilliformes were recorded.

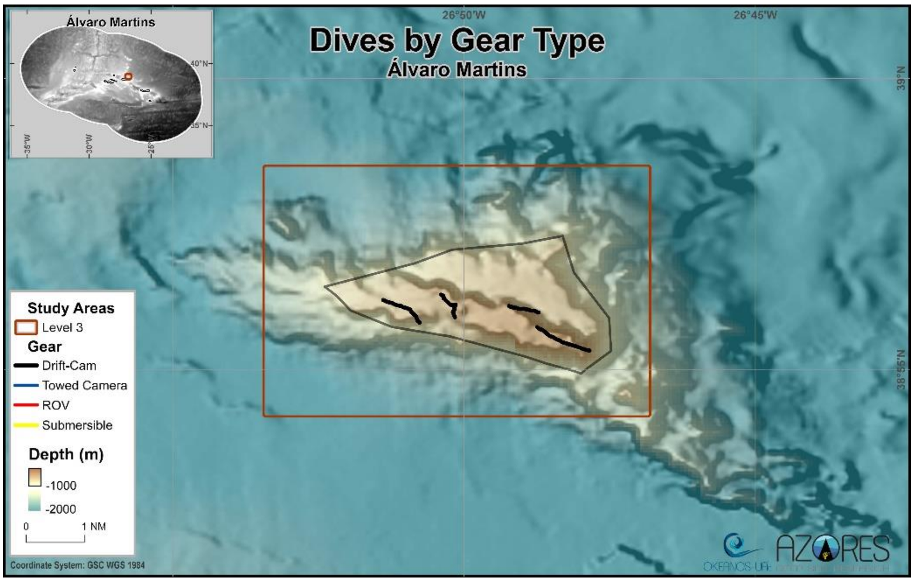


Figure 348 Map displaying the 4 underwater dives performed in the Álvaro Martins area between 680 and 940 meters depth.

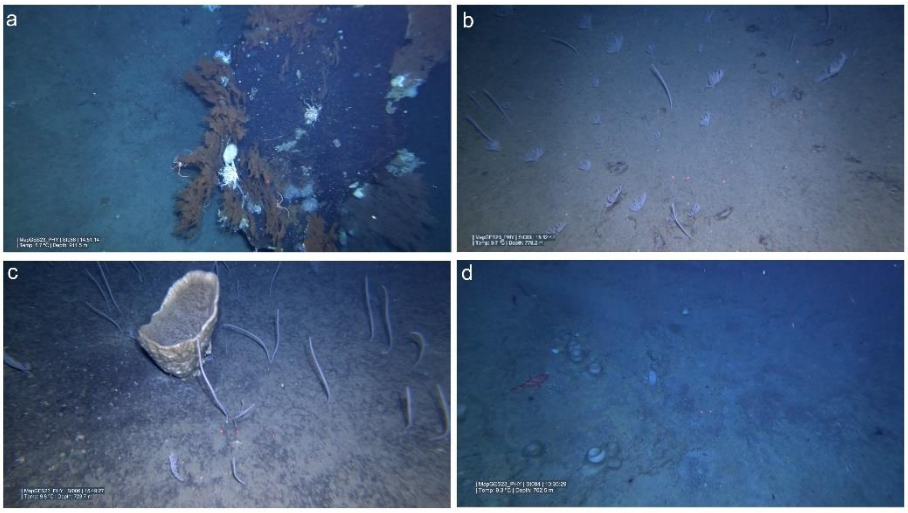



Figure 349 Selected images representative of the main structuring species and benthic communities observed in Álvaro Martins seamount. (a) Black coral *Leiopathes* cf. *expansa* with the crab *Sternostylus formosus* associated, and some stylasterids (b) Aggregation of *Narella verluysi* and *N. bellissima* on soft sediments. (c) Assemblage of *N. versluysi* and *N. bellissima* with a large specimen of the sponge *Characella pachastrella.* (d) Aggregation of the “bird nest” sponge *Pheronema carpenteri* and *Regadrella phoenix.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Beirada de Fora*

In the Beirada de Fora area, 5 underwater video transects were conducted between 420 and 800 m depth (Figure 350). The results showed that this area supports a low diversity of deep-sea megabenthic species. A total of 38 taxa were identified from the images, with 26 determined at the species level. Noteworthy taxa based on weighted occurrences include *Pliobothrus symmetricus* (n= 16), *Acanthogorgia* spp. (n= 14), and *Farrea occa* (n= 13).

The geomorphological unit Beirada de fora is an area located close to Terceira Island, on the Northern central group of the Azorean archipelago. The surveys taken at this unit allowed us to explore the upper areas associated with the slopes and geomorphological features of the area. The geomorphology of the bottom was diverse, varying from soft to hard sediments, with sporadic patches of coral rubble. Regarding the observed benthic megafauna, the deepest areas explored had the often presence of consolidated sediment allowed the presence of a few primnoid coral *Narella versluysi* together with *N. bellissima*, as well as some patches of the bird's nest sponge *Pheronema carpenteri* (Figure 351) and already some large *Characella pachastrelloides* (Figure 351). On shallower areas, the community slightly changed, being mainly composed by the hydrozoans cf. *Lytocarpia myriophyllum* (Figure 351) at the patches of soft sediment and when there were basaltic outcrops, there were vast aggregations of the whip coral *Viminella flagellum* (Figure 351), casual colonies of *Paracalyptrophora josephinae* (sometimes assuming very large sizes), and a few black corals of the species *Parantipathes hirondelle* (Figure 351) and *Elatopathes abietina*, and the gorgonian *Acanthogorgia* spp. The sponges didn't vary much from the usually found around Terceira area, in which, in addition to the small encrusting ones, the following were spotted: *Characella pachastrelloides*, *Phakellia ventilabrum*, *Farrea occa*, *Macandrewia azorica*, patches of *Stylocordila pellita*, *Petrosia* sp., *Geodia* sp., and *Leiodermatium* sp (Figure 351). There were also some frequent motile megafauna, with the occurrence of the fishes *Chaunax* sp., *Hoplostenus mediterraneus* and the commercially important *Helicolenus dactylopterus*.

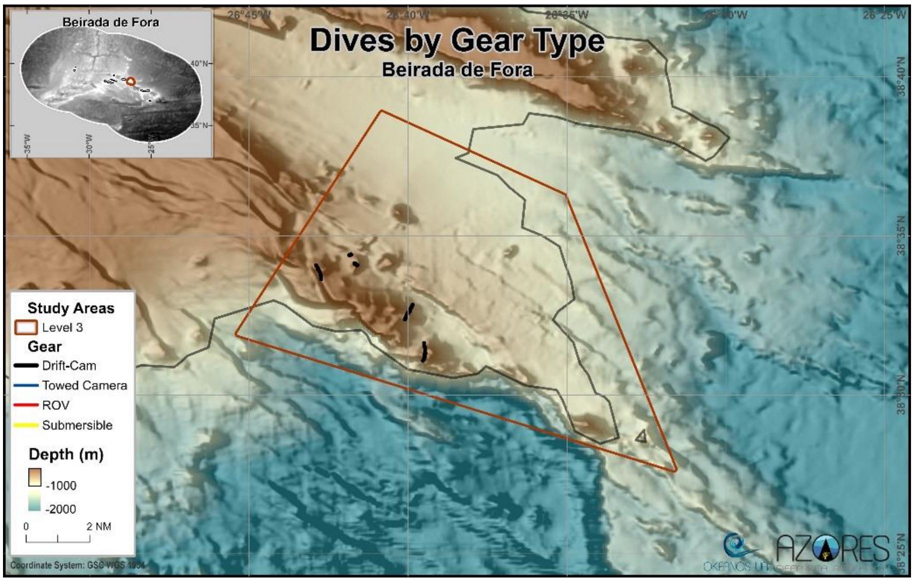



**Figure 350** Map displaying the 5 underwater dives performed in the Beirada de Fora area between 420 and 800 meters depth.


Figure 351 Selected images representative of the main structuring species and benthic communities observed in Beirada de Fora area. (a) Small aggregation of cf. *Lytocarpia myriophyllum.* (b) A colony of the black coral *Parantipathes hirondelle.* (c) The sponge *Characella pachastrelloides.* (d) The sponge *Geodia* sp. together with *Macandrewia azorica* and other encrusting sponges. (e) Small aggregation of the soft coral *Anthomastus/Pseudoanthomastus* sp. (f) Aggregation of large *Callogorgia verticilllata* and *Viminella flagellum.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Gastromar*

While exploring the Gastromar area, 9 underwater video transects were performed between 550 and 990 m depth (Figure 352). A total of 30 taxa were identified from the images, with 18 determined at the species level, suggesting that this area supports a low diversity of deep-sea megabenthic species. Predominant taxa based on weighted occurrences include *Anthomastus/Pseudoanthomastus* sp. (n= 16), *Plesionika* sp. (n= 13), and *Pheronema carpenteri* (n= 12).

Gastromar area, located 20 nm south-eastern of Terceira Island, was mostly characterized by sandy bottoms with some sporadic basaltic boulders and outcrops and coral rubble. We encountered diverse faunal assemblages, from communities dominated by *Narella versluysi* and *Narella bellissima* (Figure 353), occasionally forming small aggregations, to ones composed of more sparse colonies such as *Acanella* sp., cf. *Crypthelia* sp., *Leiopathes* cf. *expansa* and *Chrysogorgia sp.* As the definitive highlight in this area, we drifted over an extensive and abundant aggregation of coral colonies belonging to the Paramuriceidae family, small soft corals of the genus *Pseudoanthomathus* and dense *Pleurocorallium johnsoni* (Figure 353) patches*,* possibly associated with several small and medium sized colonies of white *Paragorgia johnsoni* (Figure 353) and its red morphotype as well. We also recorded some occasional *Acanthogorgia* spp. (Figure 353), quite common at around 800m deep, and the black coral *Parantipathes hirondelle*. Regarding the sponge assemblage, we identified several different species colonizing the seafloor. From larger and more occasional species such as *Haliclona magna,* to *Pheronema carpenteri* and *Macandrewia azorica* dominated areas. Hexatinellids such as *Poecillastra compressa* and *Regadrella phoenix* were also observed. Between 600 and 800 m deep, large *Pheronema carpenteri* aggregations were observed (Figure 353). Along with the bird's nest sponge, we observed other hexactinellids such as *Farrea occa* and cf. *P. robusta* and larger sponges such as *Characella connectens* and *Characella pachastrelloides.* The fan shaped *Phakelia ventillabrum* was also present, showing higher densities between 740 and 830m. In terms of mobile fauna, we identified a small shoal of *Hoplosthenus mediterraneus* and other more solitary fishes such as *Conger conger, Mora morro* and *Beryx splendens.* We also highlighted the appearance of the deep-sea shark *Dalatias licha*.

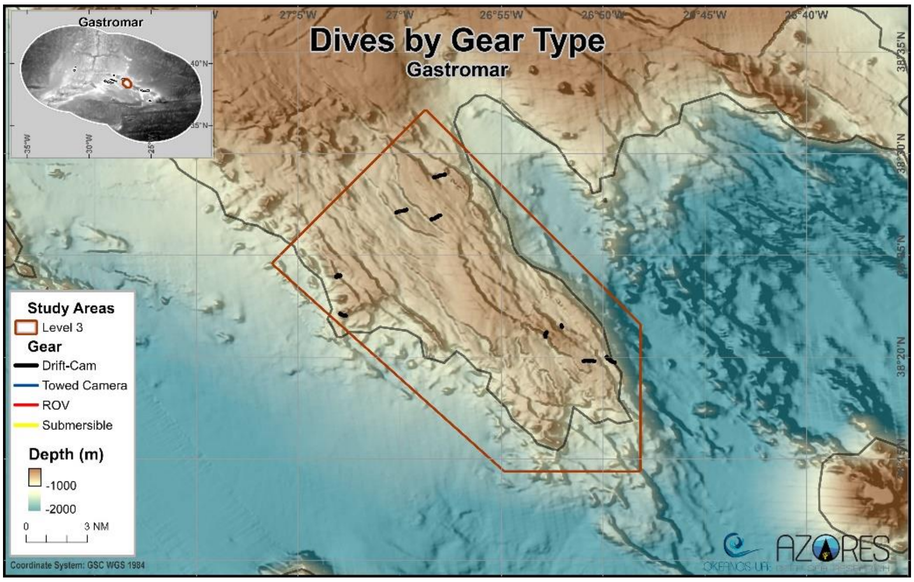



**Figure 352** Map displaying the 9 underwater dives performed in the Gastromar area between 550 and 990 meters depth.

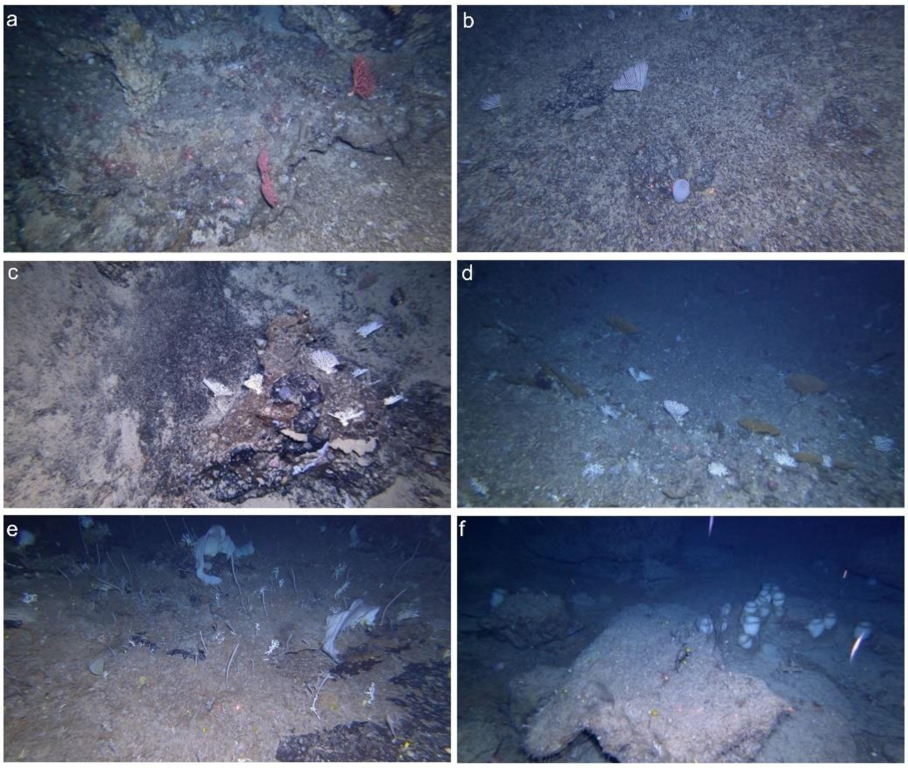



**Figure 353** Selected images representative of the main structuring species and benthic communities observed in Gastromar area. (a) Small colonies of the red form of *Paragorgia johnsoni*. (b) Small aggregation of *Narella bellissima* and *Regadrella phoenix*. (c) Small rock colonized by *Pleurocorallium johnsoni*. (d) Aggregation of *Pleurocorallium johnsoni* and *Acanthogorgia* spp. (e) Benthic community dominated by *Narella verluysi* with some colonies of *Narella belissima*, the hexatinelid sponge *Poecillastra compressa.* (f) Aggregation of the bird's nest sponge *Pheronema carpenteri*. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Maçarico*

Surveying the Maçarico area, 10 underwater video transects were accomplished between 400 and 950 m depth (Figure 354). The findings suggested a low diversity of deep-sea megabenthic species, with 41 taxa determined from the video data. Among these, 27 were identified at the species level. The most frequently observed taxa based on weighted occurrences were *Anthomastus/Pseudoanthomastus* sp. (n= 17 weighted occurrences), *Asconema fristedti* (n= 15), and *Viminella flagellum* (n= 12).

In the shallowest parts, between 480 and 540 m deep, aggregations of large colonies of *Viminella flagellum* (Figure 355) were observed, together with aggregations of the glass sponge *Asconema fristedti* (Figure 355), an uncommon community composition. Within these aggregations, some coral species were also found, such as small *Pleurocorallium johnsoni*, *Callogorgia verticillata* (Figure 355), and *Paracalyptrophora josephinae.* Other sponge species were present as well, such as large *Characella pachastrelloides* sponges and *Haliclona magna*, the lamellate *Poecillastra compressa* and *Desmacella grimaldi,* and big specimens of the genus *Geodia* (Figure 355). Between 500 and 993m, the explored seafloor was covered by a large extent of rocky bottoms. Several soft coral species were found densely colonizing vast extensions of the steep slope, with large colonies of *Callogorgia verticillata* and some hydrozoans also observed. Furthermore, *Acanthogorgia* spp. and *Pleurocorallium johnsoni* (Figure 355) were also found composing this community.

Several bluemouth rockfish *Helicolenus dactylopterus* and conger eel *Conger conger* were also seen, one of which was curiously spotted using a large sponge *Haliclona magna* as refuge. We also drifted over a few *Dalatias licha,* a ~2.3m long false catshark (*Pseudotriakis microdon)* and other fishes such as *Trachyscorpia cristulata* and *Hoplostenus mediterraneus*.

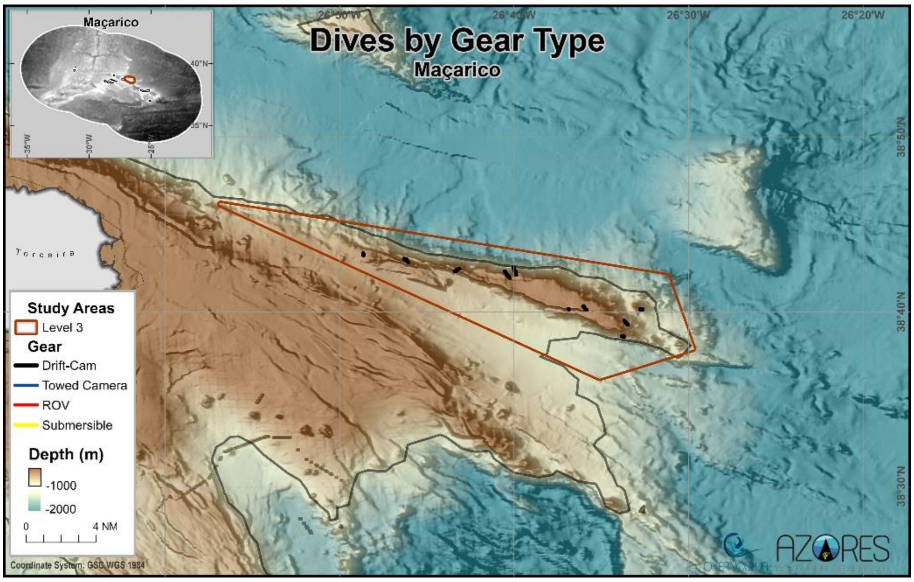



**Figure 354** Map displaying the 10 underwater dives performed in the Maçarico area between 400 and 950 meters depth.


Figure 355 Selected images representative of the main structuring species and benthic communities observed in Maçarico area. (a) Large colonies of *Viminella flagellum* and a sponge *Geodia* sp.. (b) A colony of the primnoid *Callogorgia verticillata* and a black coral *Parantipathes hirondelle.* (c) Benthic community formed by small colonies of *Pleurocolrallium johnsoni* with the soft-coral *Anthomastus/Pseudoanthomastus* sp. and the sponges *Desmacella grimaldi* and *Characella pachastrelloides.* (d) Aggregation of *Pleurocorallium johnsoni* with the lamellate sponge *Poecillastra compressa* and *Haliclona magna* (e) Aggregation of *Characella pachastrelloides* and *Asconema fristedti.* (f) Sponge *Haliclona magna* used as refuge for a conger eel (*Conger conger*). Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Albatroz do Norte*

The Albatroz do Norte area was explored through the performance of 6 underwater video transects, covering depths between 550 and 980 m (Figure 356). The results indicated this area supports a medium diversity of deep-sea megabenthic species. A total of 51 taxa were identified from the images, with 32 determined at the species level. Dominant taxa based on weighted occurrences include *Leptopsammia formosa* (n= 18), *Narella bellissima* (n= 15), and Hydrozoa (n= 14).

The areas explored in the Albatroz do Norte seamount, covered a depth range that permitted to survey the deepest and shallower areas of the slopes. In the deepest sectors explored, the sedimentary seafloor was relatively barren, with very few species observed, from which we can highlight sparse patches of *Pheronema carpenteri* along with a few other glass sponges. Slightly further up the slope, the diversity and abundance of fauna considerably increased, with the presence of tall and flat basalt outcrops. Large colonies, mainly of the Antipatharian *Leiopathes* cf. *expansa* were observed attached to crevices, with a lot of associated fauna. Other black corals were seen, including the *Parantipathes hirondelle* and *Stichopathes gravieri*. On the flatter hard bottom, extensive aggregations of the primnoid corals *Narella versluysi* and *N. bellissima* (Figure 357) were recorded, often with soft corals likely of the genus *Anthomastus/Pseudoanthomastus* (Figure 357), mainly growing at coral rubble deposits. A few small and dispersed individuals of the gorgonians *Acanthogorgia* spp., *Callogorgia verticillata* and some patches of very small red and white bubble gum corals *Paragorgia johnsoni*, were seen along with very scattered scleractinians of the species *Leptopsammia Formosa* (Figure 357). Some large sponges such as *Characella pachastrelloides*, *Petrosia* sp., *Desmacella grimaldii*, and cf. *Poecillastra compressa* were also recorded during the surveys along this unit. A variety of fish were identified, from which the most common were *Cyttopsis rosea*, *Chaunax sp*., *Neocyttus helgae, Trachyscorpia* sp.*, Hoplostethus mediterraneus*, and some fish from the families Macrouridae and Phycidae. It was also possible to identify one *Dipturus intermedius* (Figure 357), *Chimaera opalescens*, and some deep-sea sharks from the species *Deania calcea* and *Dalatias licha*.

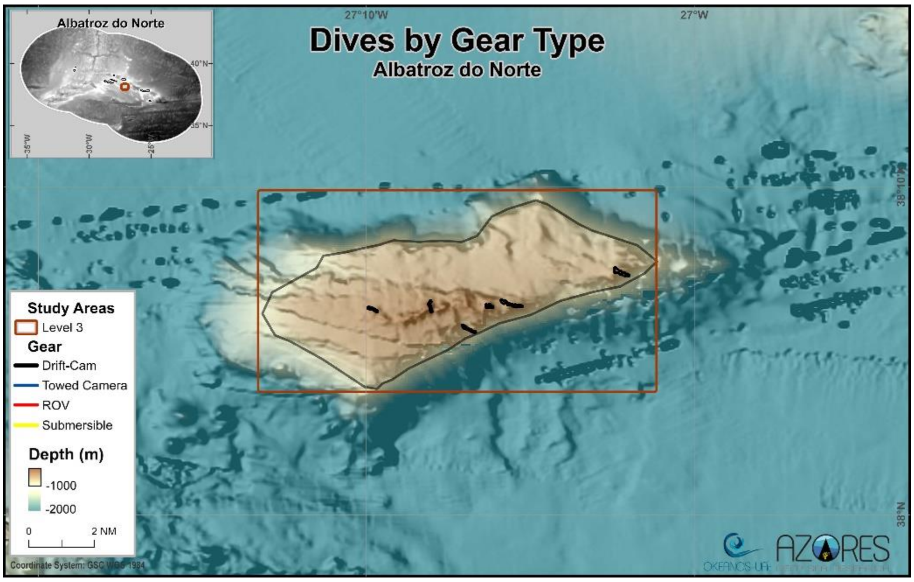



**Figure 356.** Map displaying the 6 underwater dives performed in the Albatroz do Norte area between 550 and 980 meters depth.

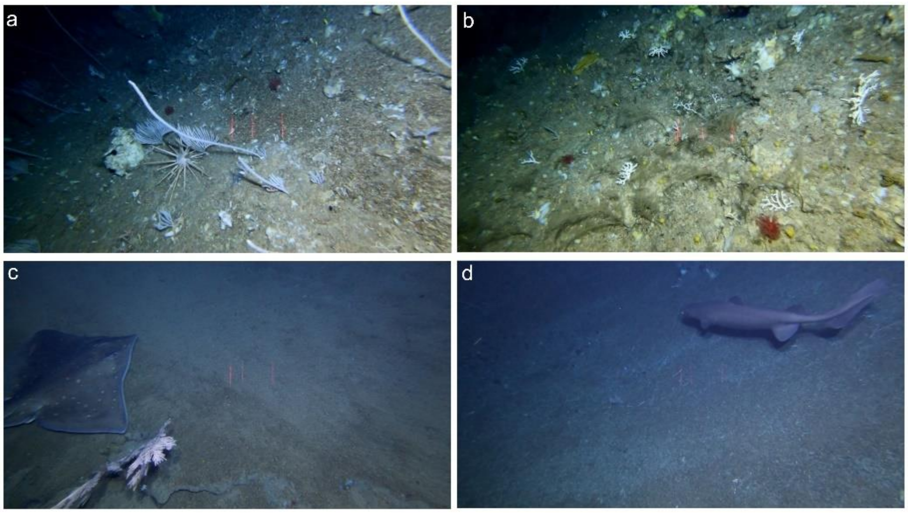



Figure 357 Selected images representative of the main structuring species and benthic communities observed in Albatroz N area. (a) Benthic community created by colonies of *Narella bellissima* and *N. verluysi* and the soft-coral *Anthomastus/Pseudoanthomastus* sp. and the sea urchin *Cidaris cidaris.* (b) Aggregation of *Lytocarpia myriophyllum, Leptopsammia formosa* and *Anthomastus/Pseudoanthomastus* sp. (c) A *Dipturus intermedius* passing by a colony of *Callogorgia verticillata* (d) Deep-sea shark *Dalatias licha.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

Study area | Dom João de Castro

*Alcatraz seamount*

In the Alcatraz area, 5 underwater video transects were conducted between 400 and 2,160 m depth (Figure 358). A total of 23 taxa were identified from the images, with 10 determined at the species level, revealing that this area supports a low diversity of deep-sea megabenthic species. Noteworthy taxa based on weighted occurrences include Galatheoidea (n= 4), *Petrosia* sp. (n= 3), and *Desmacella grimaldii* (n= 2).

Alcatraz is a relatively deep seamount located only 18 nm east of Dom João de Castro, with the shallowest point of its elongated summit at 360 m depth. Several large sponge species were observed on its rocky outcrops, which include the litisthids *Leiodermatium* sp., *Neophrissospongia nolitangere* and *Petrosia* cf. *crassa* (Figure 359a), as well as the giant sponge *Characella pachastrelloides* (Figure 359b). Sparse colonies of the whip coral *Viminella flagellum* were spotted among the sponges, some reaching very large sizes. Monospecific patches of this octocoral were also reported on the shallowest part of the seamount, although never in high densities (Figure 359c). Some large solitary colonies of *Callogorgia verticillata* were reported in Alcatraz, but always scattered along the seabed (Figure 359d). Alcatraz seamount was also characterized by the large number of fishing lines laying over the seabed.

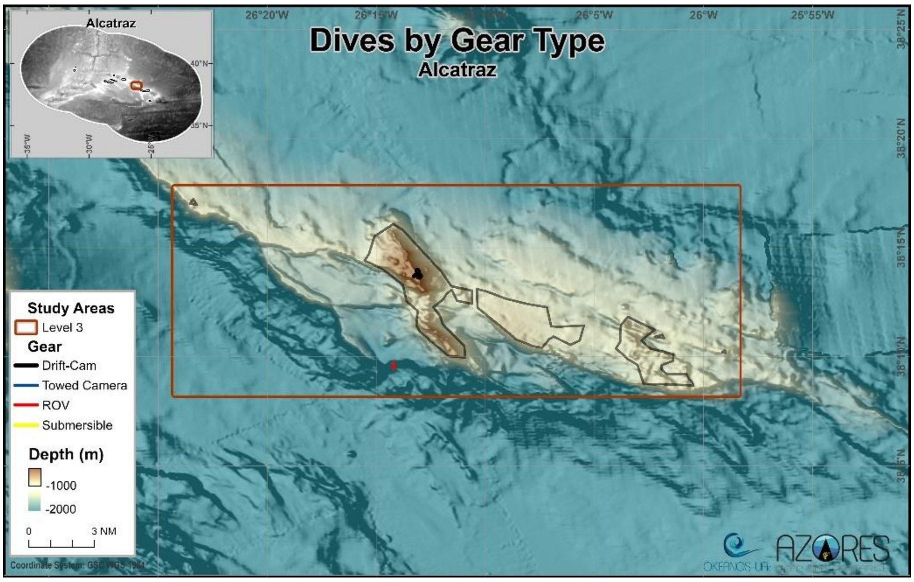



**Figure 358** Map displaying the 5 underwater dives performed in the Alcatraz area between 400 and 2,160 meters depth.

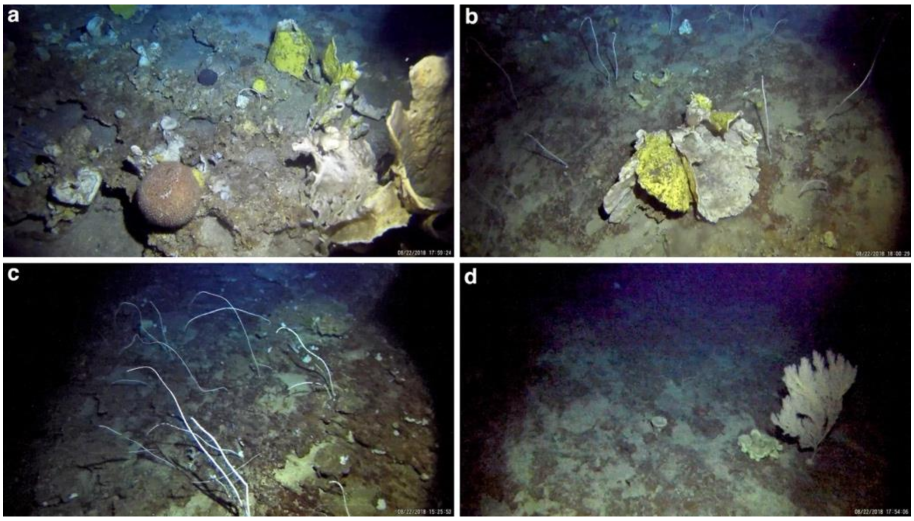



**Figure 359.** Selected images representative of the main structuring species and benthic communities observed in Alcatraz seamount. (a-b) Areas of hard substrates of the summit with large Porifera, including *Characella pachastrelloides*. (c). Some colonies of the species *Viminella flagellum*. (d) One of the few scattered colonies of the primnoid *Callogorgia verticillata*. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Dom João de Castro seamount*

The seamount Dom João de Castro was surveyed via 8 underwater video transects, covering depths ranges between 220 and 830 m (Figure 360). The video annotation resulted in 63 taxa identified revealing that this area supports a medium diversity of deep-sea megabenthic species. From these, 24 were determined at the species level. Dominant taxa based on weighted occurrences include *Viminella flagellum* (n= 7), Petrosia (n= 6), and Hydrozoa (n= 5).

Dom João de Castro is a volcanic seamount located between the islands of Terceira and São Miguel. This seamount was formed after a volcanic eruption that occurred in 1720, generating a small island of 150 m height. Erosional processes made the island disappear, and the top of the seamount is currently found below sea surface, at 13 m depth. Its deepest part explored, at around 500 m depth, was dominated by the white coral *Pleurocorallium johnsoni*, accompanied by the soft coral *Anthomastus/Pseudoanthomastus* sp., found mostly on rocky outcrops. In contrast, the composition of the benthic communities dwelling a little shallower, between 300 and 450 m depth, was dominated by the primnoid *Callorgorgia verticillata* found forming relatively dense aggregations with some very large colonies (Figure 361a-b). Not many coral colonies showed signs of fishing impacts, although a considerable number of small fishing lines were observed laying over the seabed or entangled around rocks (Figure 361c). The whip coral *Viminella flagellum* and large hydrozoans could also be observed as accompanying species, never forming dense patches. In the shallower areas of the summit, the mixed substrates have a very different species composition, with a large number of small Porifera, such as an erect repent sponge (Figure 361d) and some sparse individuals of larger sizes of the species *Petrosia* spp. and *Leiodermatium* spp.

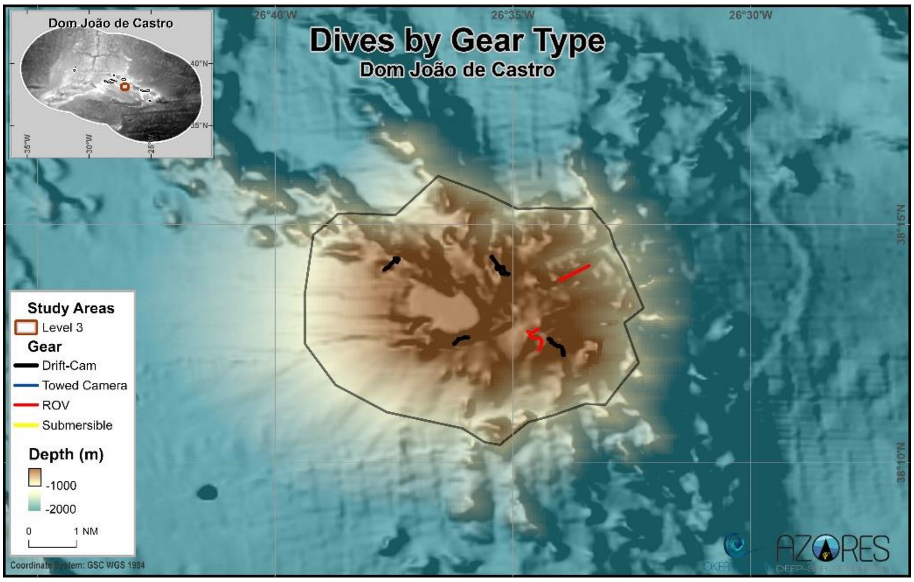



**Figure 360** Map displaying the 8 underwater dives performed in the Dom João de Castro area between 220 and 830 meters depth.

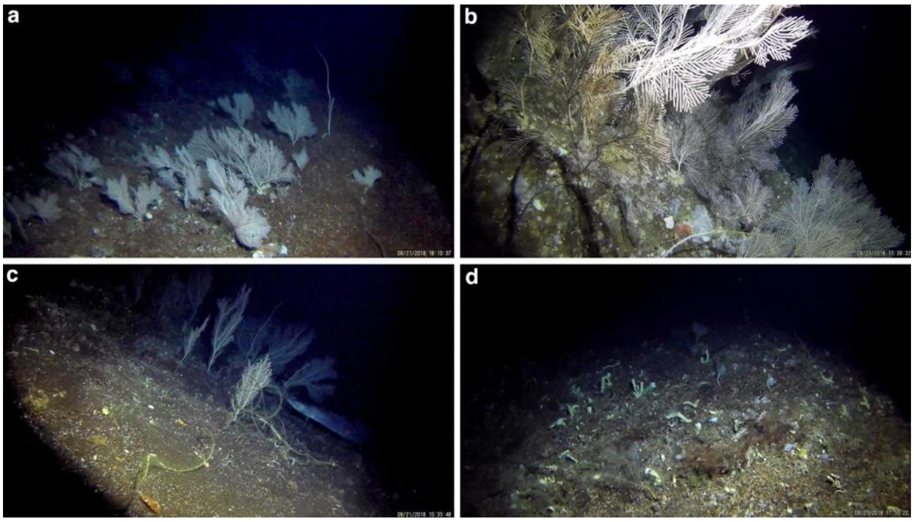



Figure 361. Selected images representative of the main structuring species and benthic communities observed in Dom João de Castro seamount. (a-b) Aggregations of the primnoid coral *Callogorgia verticillata*, which reach very large sizes. (c) One of the many fishing lines found in this seamount. (d) Small sponges on the mixed substrates of the summit. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Ferraria Norte*

In the Ferraria Norte area, 3 underwater video transects were completed between 680 and 1090 m depth (Figure 362). A total of 37 taxa were identified from the images, with 20 determined at the species level, revealing that this area supports a low diversity of deep-sea megabenthic species. Prominent taxa based on weighted occurrences include *Errina atlantica* (n= 19), *Asconema fristedti* (n= 18), and *Narella bellissima* (n= 16).

The Ferraria Norte geomorphological unit is a deep seamount located in the area of the Dom João de Castro seamount complex. The geomorphological features of Ferraria Norte were explored mostly at relatively deep areas, being the substrate mostly composed of sedimentary rocky areas with some coral rubble. The deepest areas explored showed a generally low benthic diversity with mostly the presence of encrusting sponges attached to some rocky outcrops, and some other examples of the same phylum like for example the bird's nest sponge *Pheronema carpenteri*, *Asconema* sp. and *Regadrella phoenix*. However, some coral species were observed at these lower sectors of the slope such as the bamboo coral *Acanella arbuscula* (Figure 458), *Chrysogorgya* sp., punctual aggregations of Stylasterids (cf. *Errina atlantica*) (Figure 458) and some black corals *Leiopathes* cf. *expansa*, *Parantipathes hirondelle* and *Bathypathes* sp. At shallower areas surveyed, and when the rock outcropped, the highlights go to the extensive gardens of the primnoids *Narella bellissima*, *N. versluysi* (Figure 458) and the gorgonian *Candidella imbricata*, sometimes together with *Acanthogorgia* spp. Sponge biodiversity increased with the depth decrement and was possible to spot large extensions of *Poecillastra compressa* (Figure 458), *Phakellia robusta*, *Desmacella grimaldi*, *Neophrisospongia nolintangere*, *Petrosia sp.,* and one exemplar of *Craniella longipilis*. Regarding mobile fauna we could spot both *Hoplostethus atlanticus* (Figure 458) and *H. mediterraneus, Neocyttus helgae*, *Mora moro, Chaunax spp., Molva macrophthalma* and other eel-like fishes and Macrouridae; and some deep-sea sharks such as *Centroscymnus* cf. *owstonii*, *Deania* sp. and *Galeus murinus*.

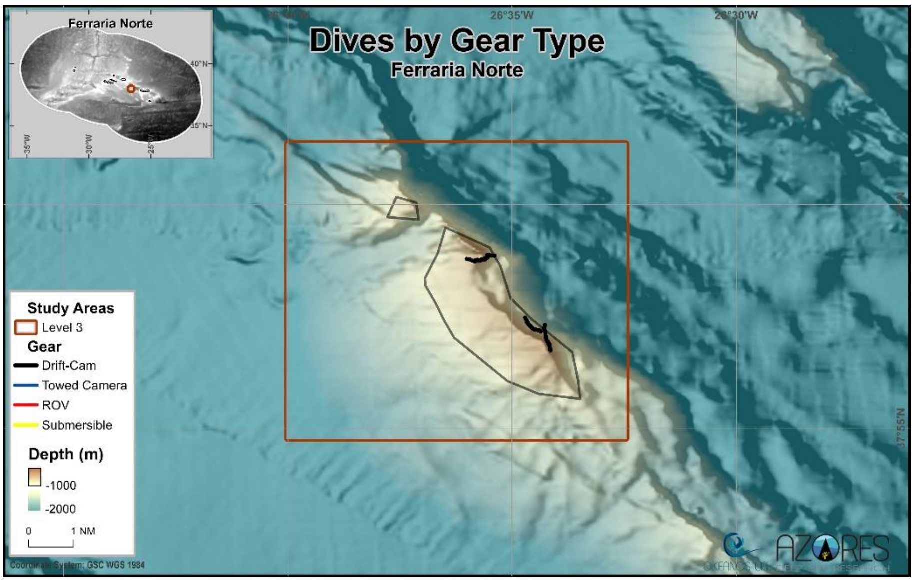



**Figure 362** Map displaying the 3 underwater dives performed in the Ferraria Norte area between 680 and 1,090 meters depth.

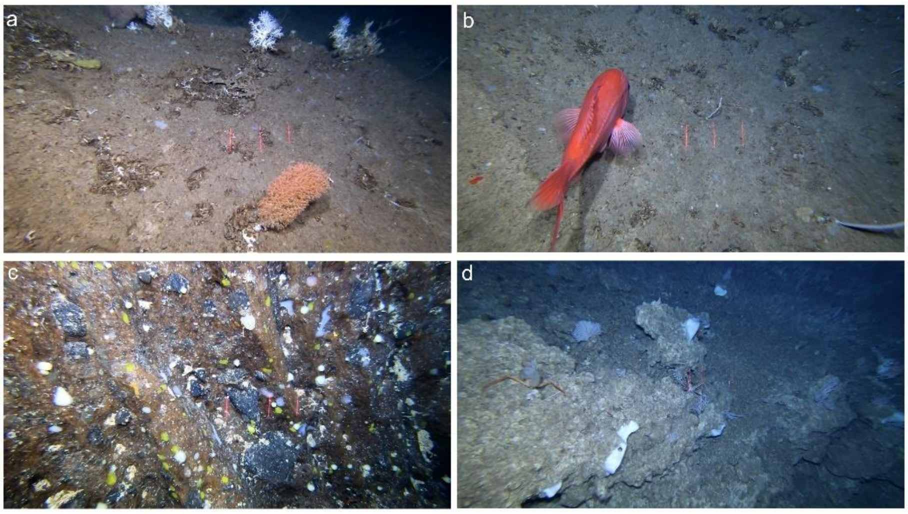



**Figure 363** Selected images representative of the main structuring species and benthic communities observed in Ferraria North seamount. (a) *Acanella arbuscula* and *Errina atlantica* on hard substrate. (b) Commercial fish *Hoplostethus atlanticus.* (c) Assemblage of a wide variety of small and encrusting sponges together with bryozoans. (d) Hard substrate colonized by the gorgonian *Narella bellissima* and the sponge *Poecillastra compressa.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Ferraria Mar*

Ferraria Mar area was explored through the performance of 7 underwater video transects, conducted in a depth range between 700 and 1,010 m (Figure 364). The results obtained from video analysis revealed that this area supports a low diversity of deep-sea megabenthic species. A total of 43 taxa were identified from the images, with 22 determined at the species level. Noteworthy taxa based on weighted occurrences include *Narella versluysi* (n= 23), *Pheronema carpenteri* (n= 22), and Crinoidea (n= 20).

The seamount Ferraria mar is a seamount located on the area complex of the Dom João de Castro seamount, on the northern central group of geomorphological units of the Azorean archipelago. This is a deep seamount where the bottom is mainly soft sediment with the sparse presence of rocky outcrops and patches of coral rubble. The deepest areas explored exhibited relatively high diversity and density of benthic megafauna. Main coral species inhabiting these lower sectors of the slope were the bamboo *Acanella arbuscula* (Figure 365), the black corals *Leiopathes* cf. *expansa*, *Parantipathes hirondelle*, *Bathypathes* sp., and some extensions of small Stylasterids (Figure 365). Large aggregations of the primnoid coral *Narella versluysi* (Figure 365) were also spotted, together with some of the remaining fauna described. Regarding sponges, the bird's nest *Pheronema carpenteri* (Figure 365), *Regadrella phoenix*, *Asconema* sp. and *Farrea occa* were frequently present. On a bit shallower depth, the community didn't change much, with the continuity of the primnoid corals, this time with aggregations of *Narella versluysi*, *N. bellissima* and the gorgonian *Candidella imbricata* (Figure 365) occurring at the hard substrates, and still with the presence of a few individuals of *Pheronema carpenteri*. Another gorgonian coral (*Acanthogorgia* spp.) appeared at these shallower depths. The lamellate sponge *Characella pachastrelloides* also started to be spotted. Motile fauna was a constant with the record of a varied of animals such as, *Hoplostethus mediterraneus*, *Beryx splendens*, *Helicolenus dactylopterus, Trachyscorpia* sp., *Mora moro*, *Molva macrophthalma*, and some deep-sea sharks such as *Deania Calcea* and *Dalatias licha*.

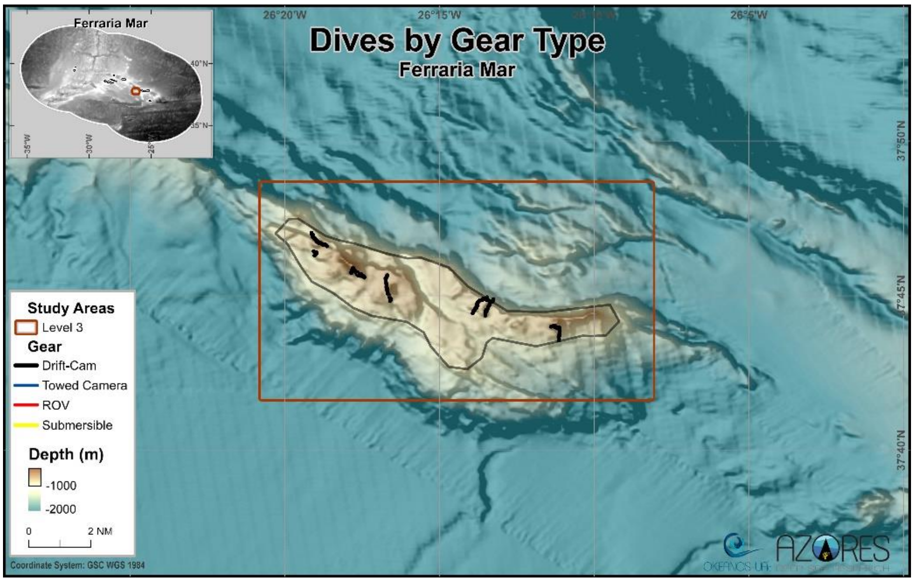



**Figure 364** Map displaying the 7 underwater dives performed in the Ferraria Mar area between 700 and 1,010 meters depth.

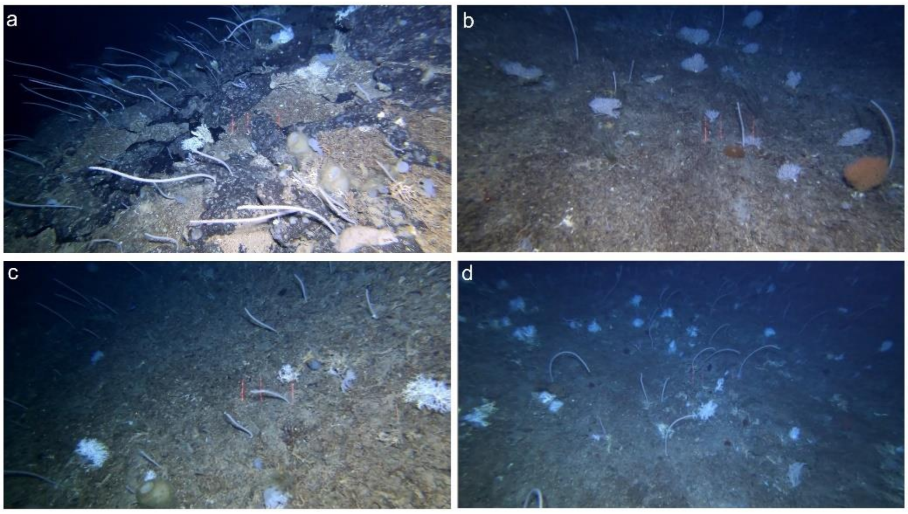



Figure 365 Selected images representative of the main structuring species and benthic communities observed in Ferraria N area. (a) Aggregation of *Narella versluysi* and stylasterids together with several sponges, including *Pheronema carpenteri* and other glass sponges. (b) Bamboo coral *Acanella arbuscula* and *Candidella imbricata* on hard substrate. (c) Assemblage of stylasterids together with *N. versluysi* and sponges, including *P. carpenteri*. (d) Aggregation of *N. versluysi, C. imbricata,* stylasterids, *A. arbuscula* and occasional sponges. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Girard*

The exploration of the Girard area resulted in 6 underwater video transects, in a range depth between 780 and 1080 m (Figure 366). A total of 47 taxa were identified from the images recorded, with 29 determined at the species level, revealing a low diversity of deep-sea megabenthic species for the area. Dominant taxa based on weighted occurrences include *Farrea occa* (n= 35), *Errina atlantica* (n= 33), and *Narella versluysi* (n= 32).

The Girard morphological unit is a small ridge complex with relatively deep summits, at around 702m deep, and is located on the Northern central group, close to Ferraria Mar area. The geomorphologic features presented at the slopes of this area were very similar at each dive performed here, with the prevalence of a substrate of the soft type at the deepest sectors, sometimes with extensive areas covered with coral rubble, and harder bottoms, mainly formed by basaltic rocks, however, most of the times it was slightly covered with finer sediment layers. On the deepest areas explored, the extensive areas of dead coral framework were sometimes interrupted with the presence of boulders covered with several small encrusting sponges and on the ground sporadic sylasterids (likely *Errina atlantica*) and the bamboo coral *Acanella arbuscula* (Figure 367), were often observed. Further up the slopes coral gardens that included the gorgonians *Narella versluysi* (Figure 367), *Acanthogorgia* spp., and several more of the same stylasterids were spotted, frequently together with soft corals of the genus *Anthomastus/Pseudoanthomastus*, and the glass sponges *Regadrella phoenix* and *Farrea occa*. Patches of the bird's nest sponge *Pheronema carpenteri* were found close to the crests of the ridges. It was also possible to detect some motile fauna in this area such as the fish species *Trachyscorpia cristulata, Neocyttus helgae, Hoplostethus mediterraneus*, and the rather rare sighting of the deep-water shark *Pseudotriakis microdon*.

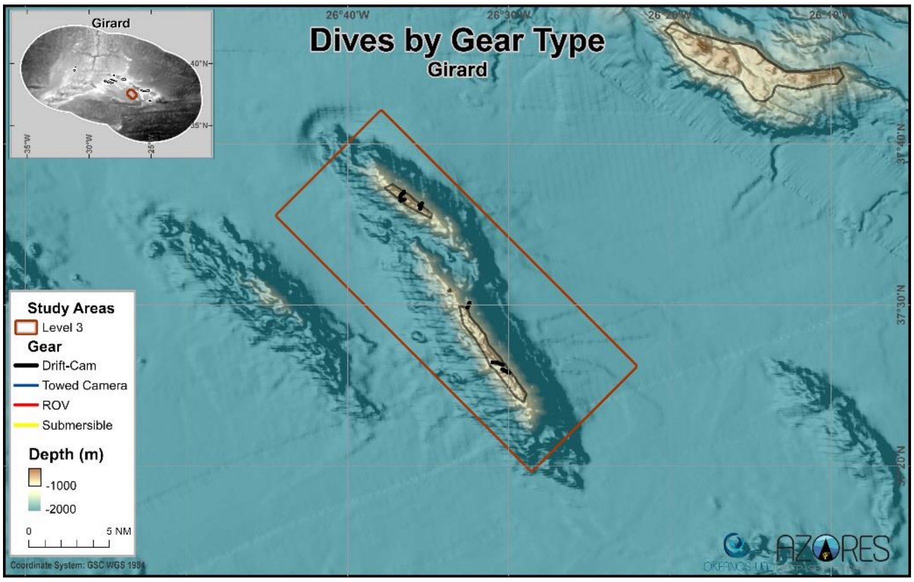



**Figure 366** Map displaying the 6 underwater dives performed in the Girard area between 780 and 1,080 meters depth.

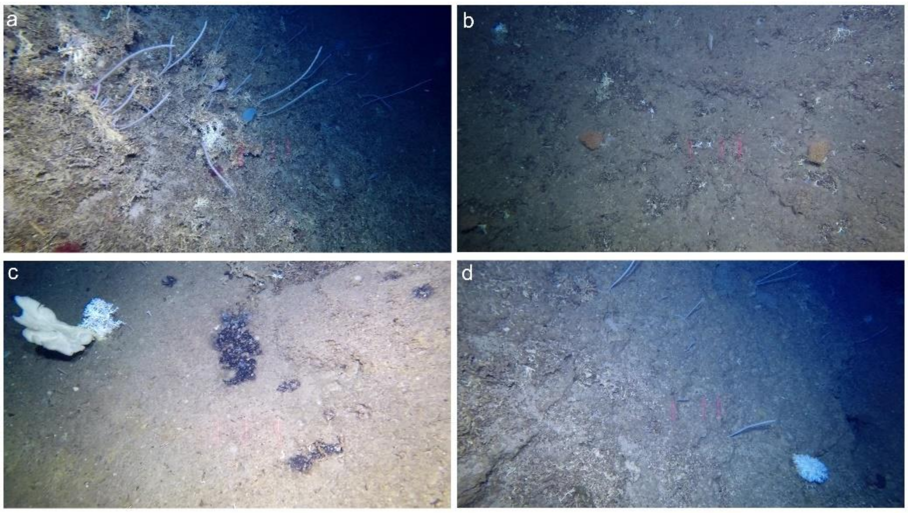



**Figure 367** Selected images representative of the main structuring species and benthic communities observed in Girard area. (a) Dead coral framework colonized by *Narella versluysi,* stylasterids, soft-corals and some sponges. (b) Bamboo coral *Acanella arbuscula* on hard substrate. (c) Large sponge of the genus *Phakellia* together with stylasterid on hard substrate. (d) Area with patches of coral rubble colonized by *N. versluysi* and stylasterids. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

## *10.6 Large area | Southern Central Group*

In the large Southern Central group of the Azores contains two study areas: Faial/Pico islands and Princesa Alice, and a total of 31 sampling areas (Figure 368). These areas have been sampled with the Azor drift-cam during the MapGES 2019, 2021, 2022 and 2023 surveys both with MT Physeter and R/V Arquipélago, the MIDAS 2016 with the NIOZ Hopper tow-cam, in the Blue Azores 2019 with LULA 1000 submersible, during the Blue Azores 2018 with the Luso ROV and during the OceanX 2023 with the ROV Chimaera.

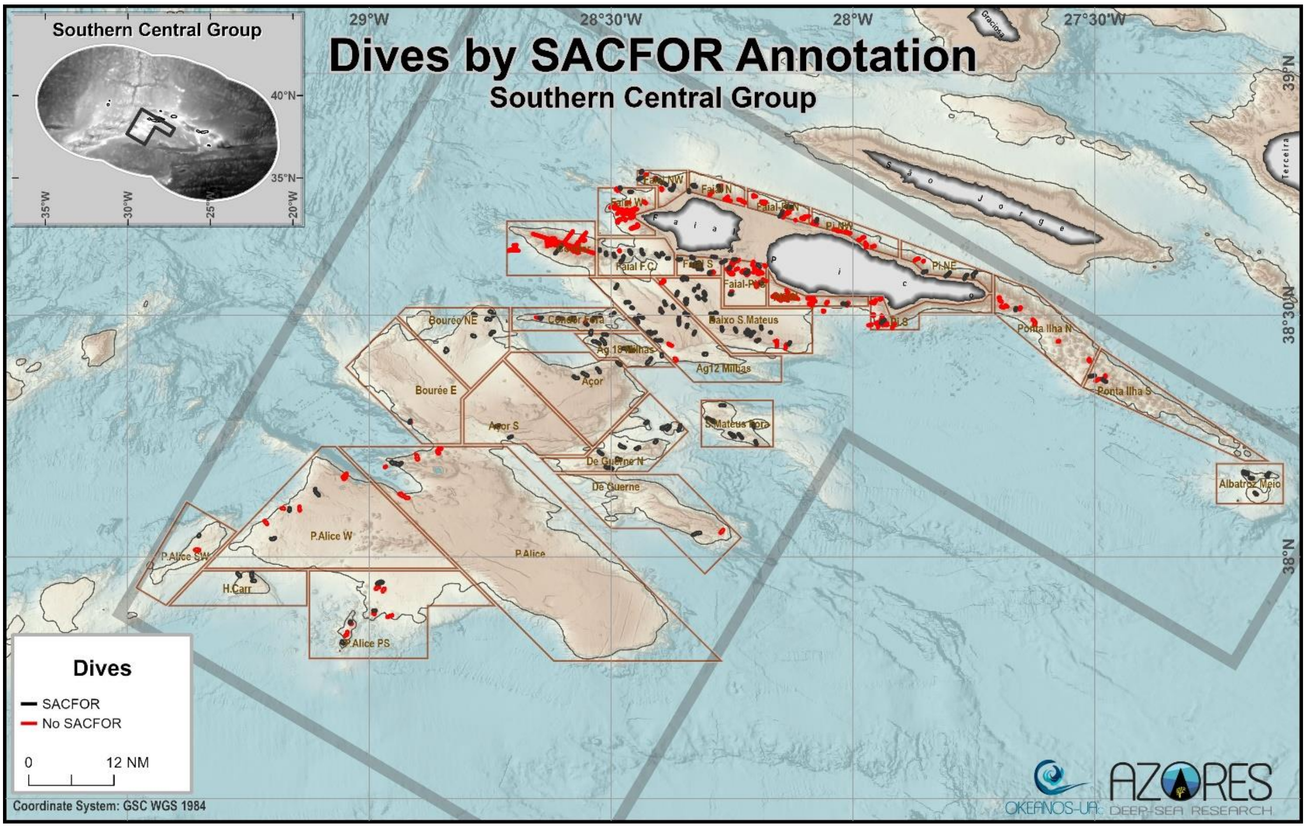



**Figure 368** Southern Central Group sampling areas (Level 3) with or without SACFOR dive locations.

## Study area | Faial/Pico Islands

*Faial NW*

There were completed 11 underwater video transects in Faial Northwest area, covering a depth range between 390 and 1010 m (Figure 369). A total of 93 taxa were identified from video annotation. From these, 54 were determined at the species level, revealing a high diversity of deep-sea megabenthic species for the area. Predominant taxa based on weighted occurrences include *Farrea occa* (n= 30), *Flabellum* sp. (n= 24), and *Pliobothrus symmetricus* (n= 22).

At the deepest areas in this unit, the substrate was composed mainly by sedimentary environments constituted by sand and coral rubble, also including sometimes dead parts of the sea-urchin *Cidaris cidaris* and sporadically interrupted by basaltic boulders. On the lower slope (~1000 to 800m) benthic biodiversity was principally constituted by the extensive and abundant aggregations of the gorgonian *Candidella imbricata* and some coral specimens of the family Stylasteridae, likely *Errina atlantica* (Figure 370). These boulders and rocky outcrops had also the presence of several other coral species such as big exemplars the black coral *Leiopathes* cf. *expansa* attached on the vertical basaltic walls, a few specimens of the scleractinians *Lophelia pertusa*, and the often sighting of the bamboo coral *Acanella arbuscula* (Figure 370) on the soft substrate. On the more upper slope (~800 to 300m) of the Northwest area of Faial Island, the seabed was harder, where the rocky outcrops dominated. Benthic megafauna was composed by different species, this time with an impressive and extensive community of *Narella versluysi*, which is accompanied by the *Narella bellissima* (Figure 370) in a slightly shallower area (~730m) and high abundance of small colonies of *Paragorgia johnsoni* (Figure 370) with a few large speciemens (~600m). The soft coral *Anthomastus/Pseudoanthomastus* sp. (Figure 370), and the hexactinellid sponges *Farrea occa* and *Asconema fristedti* (Figure 370) normally appeared along with this communities. At this depth, patches of soft sediment, had very little existence of benthic sessile fauna, with the occasional sightings of corals of the genus *Flabellum*. On the upper slope, close to the summit, there were still rocky grounds, with boulders covered with encrusting sponges and large white porifera, from the genus *Leiodermatium* and *Characella*. Colonies of whip coral *Viminella flagellum* started appearing and we can highlight shoals of the fish *Pagellus bogaraveo* and the common presence of the commercially important *Helicolenus dactylopterus*.

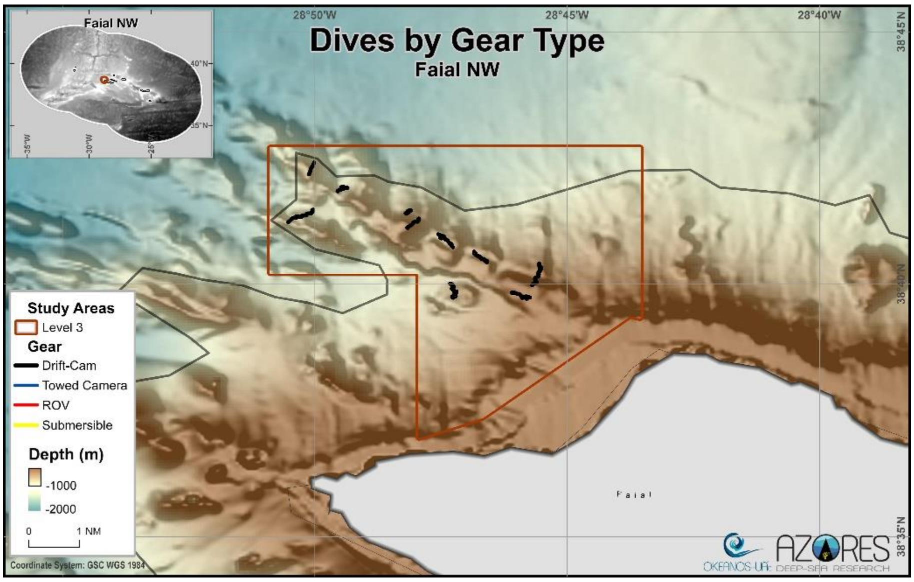



**Figure 369.** Map displaying the 11 underwater dives performed in the Faial NW area between 390 and 1,010 meters depth.

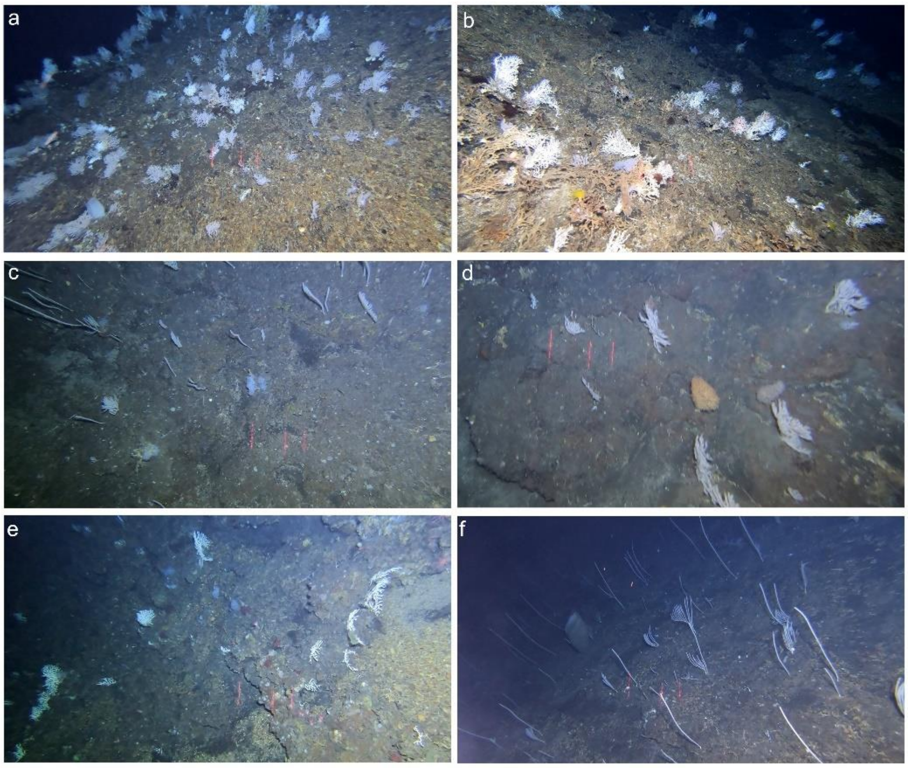



**Figure 370** Selected images representative of the main structuring species and benthic communities observed in Faial Northwest area. (a) Vast aggregation of the primnoid *Candidella imbricata* on dead coral framework. (b) Dead coral framework densely colonized by the stylasterid cf. *Errina atlantica.* (c) Aggregation of the primnoids *Narella versluysi* and *Narella bellissima,* with occasional glass sponges. (d) Small assemblage of gorgonians *C. imbricata* and *Acanella arbuscula.* (e) Coral garden formed by small colonies of *Paragorgia johnsoni* and soft coral *Anthomastus/Pseudoanthomastus* sp. and glass sponges. (f) Aggregation of primnoids from genus *Narella* and a large sponge *Asconema frsitedti.* Image credits: IMAR/Okeanos-UAz

*Faial N*

In the Faial North area, 12 underwater video transects were conducted between 180 and 650 m depth (Figure 371). A total of 47 taxa were identified from the images recorded, with 25 determined at the species level, revealing that this area supports a low diversity of deep-sea megabenthic species. Noteworthy taxa based on weighted occurrences include *Haliclona filholi* (n= 27), *Geodia* sp. (n= 19), and Ceriantharia (n= 17).

The northern island slope of Faial was mostly characterized by soft grounds with occasional boulders on the lower parts progressively changing to rocky outcrops and vertical basaltic walls. The deepest areas (~600 to 500 m) were characterized by the presence of several specimens of the family Echinothuriidae inhabiting the soft sediments and a few boulders covered with encrusting sponges. Noteworthy was the strong presence of motile fauna, at these depths, mainly composed by fishes of the species *Conger conger*, *Helicolenus dactylopterus* and specimens of the genus Macrouridae. As the substrate progressively changed during the ascent along the island slope (~500 to 200 m), the benthic fauna was dominated by sponges, primarily by encrusting type, mainly the *Phlyctaenopora (Phlyctaenopora) bitorquis* and quite some individuals of the genus *Geodia* (Figure 372). Regarding corals, the gorgonian *Acanthogorgia* spp (Figure 372), started to appear, becoming more and more frequent as we approached the top of the slope, making aggregations of rarely seen numbers and sizes. Along with this, close to the summit (~200m), several other specimens were significant such as the whip coral *Viminella flagellum* (Figure 372) or the aggregations of the sponge *Haliclona implexa* (Figure 372) and several other lamellate sponges. On the top of the upper slope, an unusual school of *Pagellus bogaraveo* was detected along with some shoals of *Capros aper*.

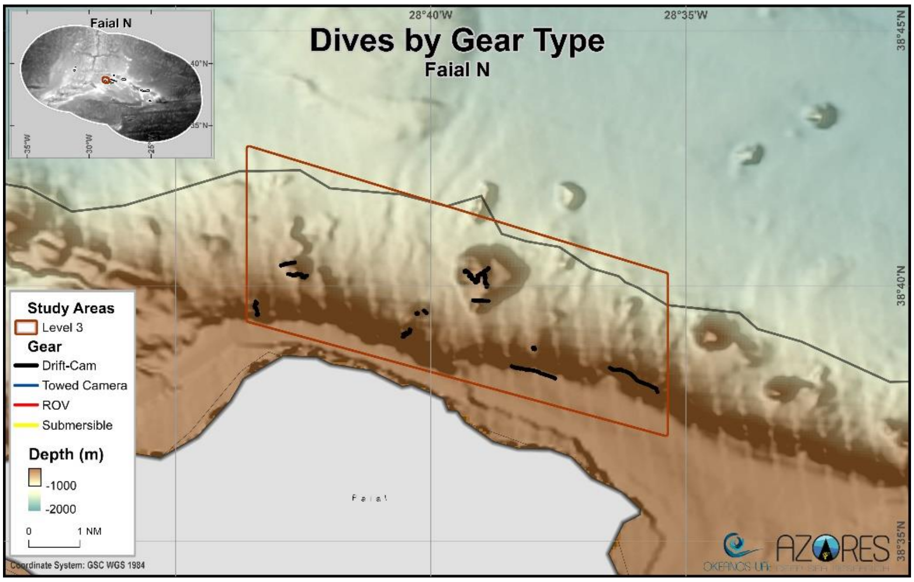



**Figure 371.** Map displaying the 12 underwater dives performed in the Faial N area between 180 and 650 meters depth.

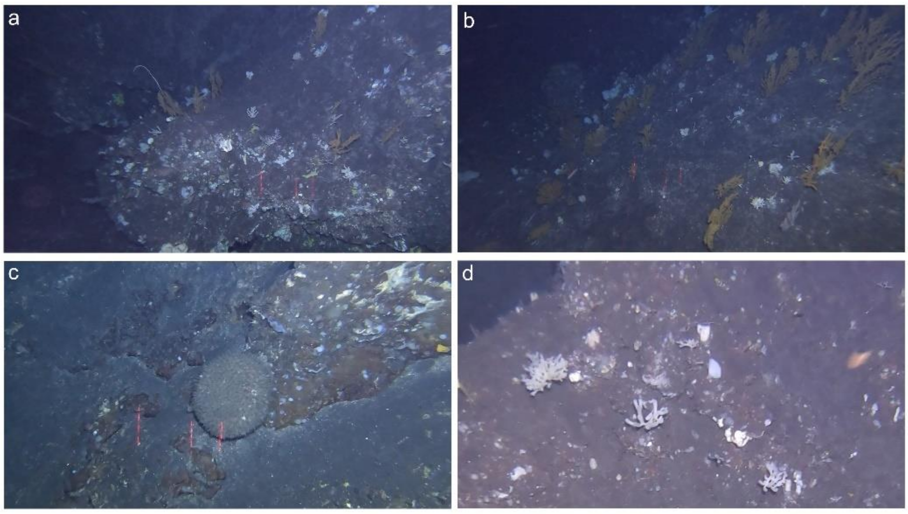



**Figure 372** Selected images representative of the main structuring species and benthic communities observed in Faial North area. (a) Boulder colonized by several sponge species, dominated by *Haliclona implexa,* and the gorgonians *Viminella flagellum* and *Acanthogorgia* spp. (b) Vast aggregation of *Acanthogorgia* spp. (c) Desmosponge *Geodia* sp. (d) Aggregation of the desmosponge *H. implexa.* Image credits: IMAR/Okeanos-UAz

*Faial-Pico N*

There were performed 11 underwater video transects in the Faial-Pico North area, covering a depth range from 230 to 950 m (Figure 373). A total of 35 taxa were identified from the video analysis, with 18 determined at the species level, revealing a low diversity of deep-sea megabenthic species for the area. Dominant taxa based on weighted occurrences include Echinothuriidae (n= 19), *Syringammina fragilissima* (n= 12), and Ceriantharia (n= 11).

Most of the deepest areas explored in Faial-Pico N were quite flat, consisted of soft sediments and were mainly characterized by low levels of benthic biodiversity. A large field of Xenophyophores was recorded at around 950m depth, concomitant with sparse bird's nest sponges *Pheronema carpenteri* (Figure 374). At these depths, sea-urchins were also present, as well as several Macrourid fishes. When rare rocky outcrops appeared, these were usually colonized by the solitary coral *Leptopsammia Formosa,* hydrocorals *Pliobothrus symmetricus* (Figure 374) and some white gorgonian corals yet to be identified. Motile fauna at these depths consisted mostly of the decapod *Aristaeopsis edwardsiana*, and several fish species, including *Conger conger, Beryx* sp., *Mora moro* and *Deania* sp. On steeper areas, where larger rocky outcrops began to be more common, these were mostly colonized by smaller and encrusting sponge species. Occasionally, massive sponges such as *Characella pachastrelloides* and *Geodia* sp., also occurred within this community. Small and sparse colonies of cf. *Errina dabneyi* (Figure 374) were briefly recorded as well. At around 450m depth, basalt vertical walls started to appear, where the sponge diversity began to grow, with larger species such as *Macandrewia azorica* and *Neophrissospongia nollitangere* dominating the substrate. Very few colonies of the whip coral *Viminella flagellum* were also present at these depths.

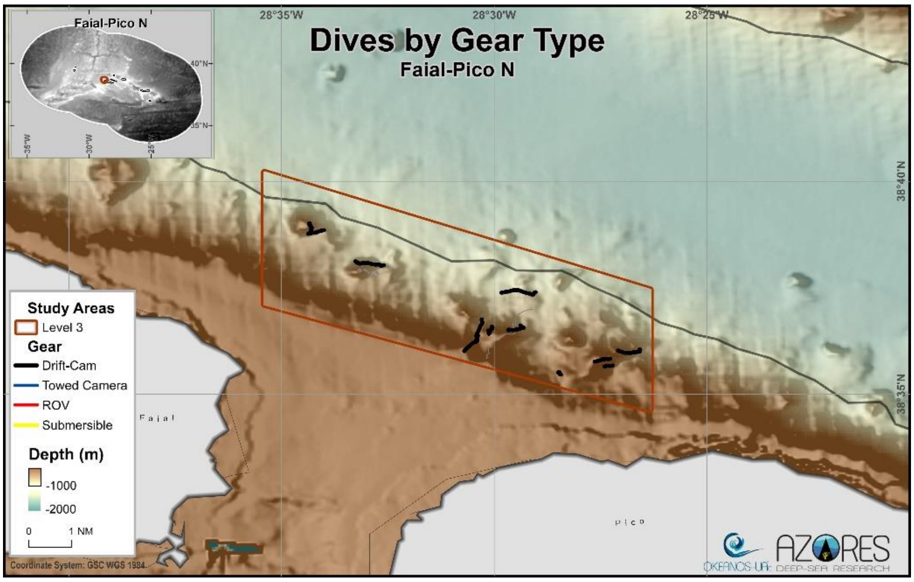



**Figure 373.** Map displaying the 11 underwater dives performed in the Faial-Pico N area between 230 and 950 meters depth.

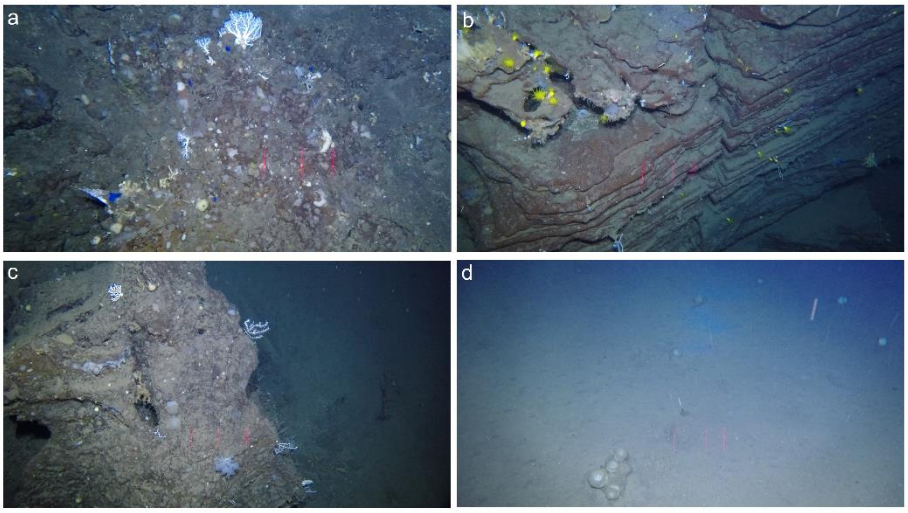



**Figure 374** Selected images representative of the main structuring species and benthic communities observed in Faial-Pico North area. (a) Hard substrate densely colonized by several sponge species, including encrusting sponges and the hydrocoral cf. *Errina dabneyi.* (b) Vertical wall with sparce colonies of *Leptopsammia formosa* and the glass sponge *Farrea occa.* (c) Boulder with small colonies of plexaurids, *Pliobothrus symmetricus* and several small sponges. (d) Aggregation of the sponge *Pheronema carpenteri.* Image credits: IMAR/Okeanos-UAz

*Pico NW*

While surveying Pico Northwest area, 12 underwater video transects were conducted between the depth of 130 and 760 m (Figure 375). A total of 22 taxa were determined from the video analysis, with 10 identified at the species level, indicating a low diversity of deep-sea megabenthic species. The most frequently observed taxa based on weighted occurrences include Ceriantharia (n= 6), Echinothuriidae (n= 5), and *Syringammina fragilissima* (n= 4).

The deeper sections of this area were characterized by soft bottoms dominated by foraminifera (cf. *Syringammina fragilissima*) (Figure 376) and the bird's nest sponge *Pheronema carpenteri.* Assemblages of cf. *Neopycnodonte zibrowii* and cf. *Cyathidium foresti* (a living fossil community) were also present underneath rocky overhangs. From 700 meters up, hydrocorals can be observed (cf. *Errina* sp.) (Figure 376), together with small gorgonians (*Acanthogogria* sp., *Nicella granifera)* as well as the solitary scleractinian *Leptopsammia formosa*.

Shallower sections were also usually characterized by soft bottoms, however, occasional basalt outcrops and vertical walls were also present. These provide substrate for a diverse sponge assemblage to dominate the faunal communities observed. Large sponge species such as *Characella pachastrelloides, Neophrissospongia nollitangere, Macandrewia azorica* and *Phakellia ventilabrum* (Figure 376) compose most of the species observed at these depths. Colonies of the black coral *Antipathella subpinnata* with signs of impacts were also present on the shallowest portions explored, where several bottom-longlines can be seen as well.

The common mora (*Mora moro)* was among the fish species observed at greater depths while the conger eel (*Conger conger)* and the alfonsino (*Beryx splendens)* were on shallower areas.

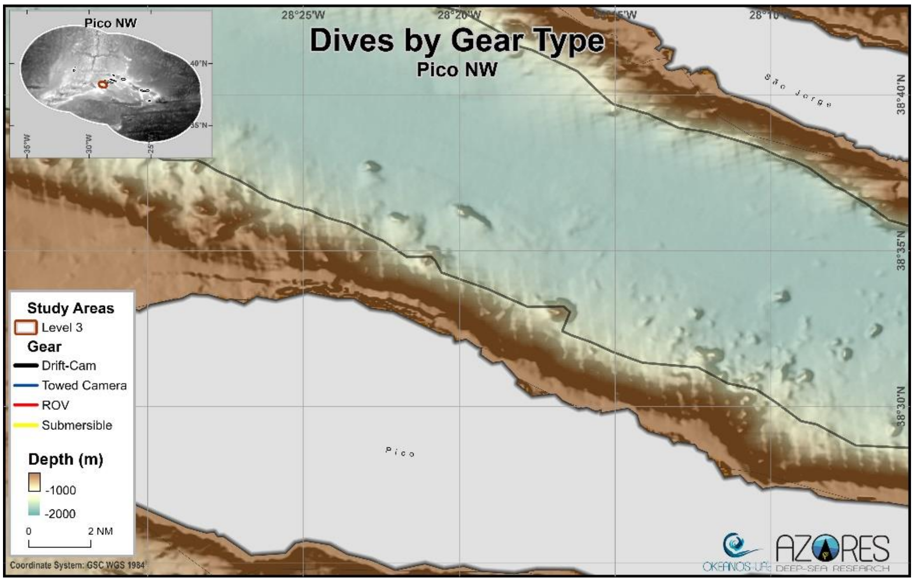



**Figure 375.** Map displaying the 12 underwater dives performed in the Pico NW area between 130 and 760 meters depth.

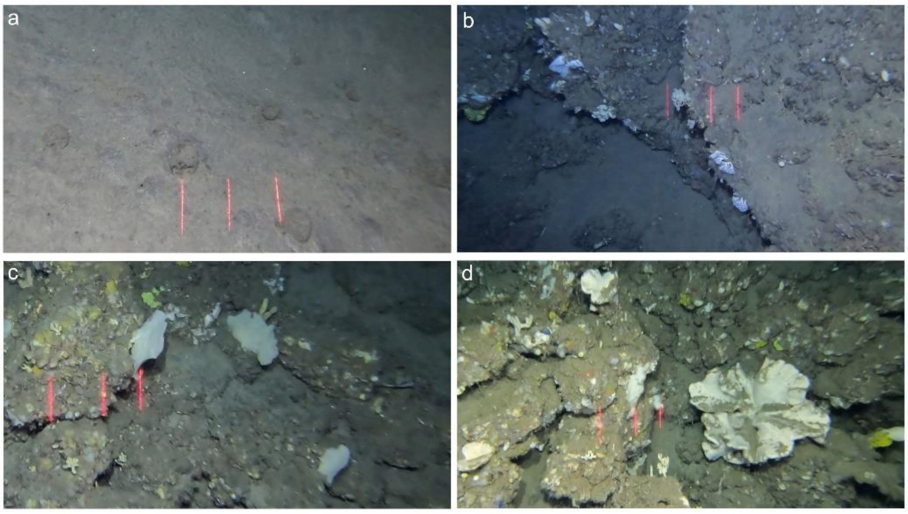



**Figure 376** Selected images representative of the main structuring species and benthic communities observed in Pico Northwest area. (a) Assemblage of the foraminifera *Syringammina fragilissima* (b) Small colonies of stylasterids, cf. *Errina* sp., together with a wide variety of sponges, including *Haliclona implexa.* (c) Small rocks colonized by the demosponge *Phakellia* ventilabrum. (d) Hard substrate densely colonized by several demosponges. Image credits: IMAR/Okeanos-UAz

*Pico NE*

In the Pico Northeast area, 6 underwater video transects were performed between the depths of 190 and 980 m (Figure 377). A total of 64 taxa were identified from the images recorded, with 41 determined at the species level, indicating that this area supports a medium diversity of deep-sea megabenthic species. The most frequently observed taxa based on weighted occurrences include *Plesionika* sp. (n= 29), *Petrosia (Petrosia) crassa* (n= 21), and Galatheoidea (n= 19).

The Northeastern slope of Pico Island is very steep and mainly composed by vertical walls that leads from the deepest bottom to a shelf summit located very shallow. The dives realized on this geomorphological unit covered a high range of depths, and so we were able to detect the different benthic megafaunal communities present at the distinct vertical slope sectors. The substrate at the deepest areas explored was composed by soft sediment mixed with loose pebbles, making kind of a rocky rubble. The fauna at such depths was mainly characterized by the often presence of sea urchins of the family Echinothuriidae and the species *Cidaris cidaris*, and a distinct community of the foraminifera *Syringammina fragillissima*, for its density and extension. We could also observe several hydrozoans of the species *Pliobothrus symmetricus* always growing on hard substrate. The sponges *Pheronema carpenteri* (Figure 378) started to appear at around 850m deep, as well as the laminate *Phakellia ventilabrum* (Figure 378) and *Petrosia crassa*. Climbing up for the upper sectors of the slope, the frequent rocky outcrops found here were densely covered in sediments, which is typical of island slopes. These were mainly colonized by some sponges, principally of the species *Farrea occa*, *Characella pachastrelloides* (Figure 378), and big aggregations of *Macandrewia azorica*, *Haliclona implexa* and *Phakellia ventilabrum* (Figure 378), that progressively increase as the depth decrease. Around 260 m depth, a relatively high abundance of *Pseudotrachya hystrix* was found. The corals recorded were very occasional and mainly composed of the gorgonians *Acanthogorgia* spp. and *Viminella flagellum*. The summit of the slope was totally covered with sand and no benthic fauna was recorded.

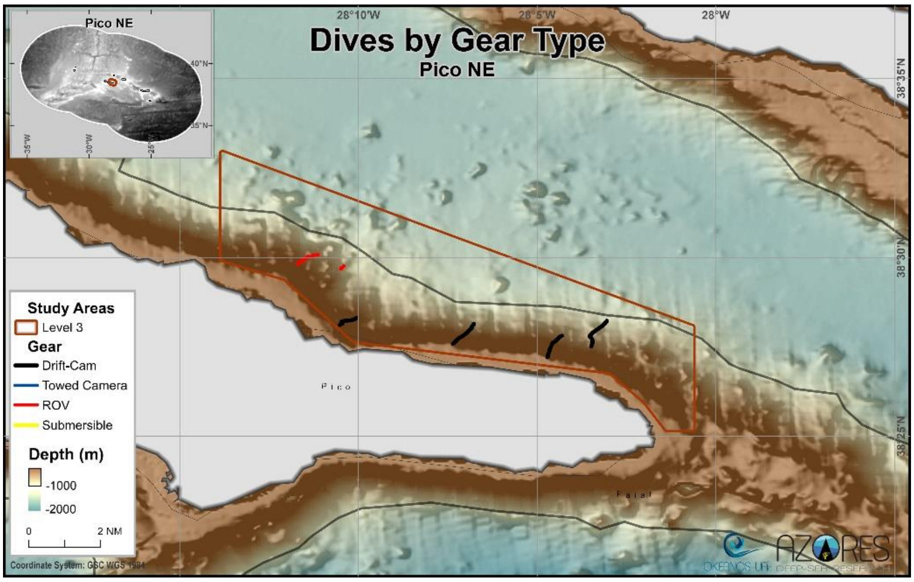



**Figure 377.** Map displaying the 6 underwater dives performed in the Pico NE area between 190 and 980 meters depth.

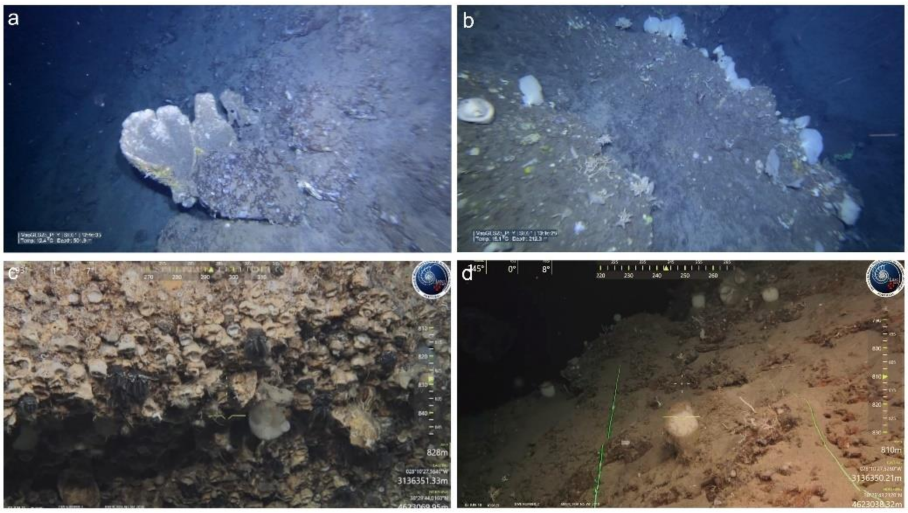



**Figure 378** Selected images representative of the main structuring species and benthic communities observed in Pico Northeast area. (a) Large sponge of the species *Characella pachastrelloides.* (b) Boulder colonized by several sponge species, including *Phakellia ventilabrum* and *Haliclona implexa.* (c) Vertical wall densely colonized by crinoids of the species *Cyanthidium foresti.* (d) Aggregation of the sponge *Pheronema carpenteri.* Image credits: a,b IMAR/Okeanos-UAz, Azor drift-cam; c,d ROV Luso / EMEPC / 2018 Oceano Azul Expedition, organized by Oceano Azul Foundation & partners.

*Pico S Lajes*

In the Pico South Lajes area, 12 underwater video transects were conducted, ranging from 50 to 1,100 m depth (Figure 379). A total of 61 taxa were determined from the video record, with 34 identified at the species level, revealing a medium diversity of deep-sea megabenthic species. The most frequently observed taxa based on weighted occurrences include *Plesionika* sp. (n= 14), *Acanthogorgia* spp. (n= 10), and Ceriantharia (n= 9).

The deepest habitats covered, at around 1000m depth, were large areas covered with coral debris likely from the lace coral *Lophellia pertusa* (Figure 380). These debris were usually colonized by several species, such as the glass sponges *Farrea occa*, *Hertwigia falcifera* and *cf. Phakellia robusta* and the scleractinian coral *Desmophyllum dianthus.* Several other coral species were also observed at this depth such as *Leiopathes* cf. *expansa* (Figure 380)*, Bathypathes* sp.*, Candidella imbricata*, *Acanella arbuscula* and *Leptopsammia formosa.* On soft dominated bottoms, *S. fragilissima*, *Cidaris cidaris*, and *Deltocyathus* cf. *moseleyi* were common. The gorgonian *Candidella imbricata* began to dominate the community in areas where the slope increased, forming occasional patches of relatively high densities. However, long sections of uncolonized coral rubble were quite frequent as well. The bird's nest *Pheronema carpenteri* (Figure 380) often covered the tops of large basalt rocks, until the 800m depth mark, where the primnoids *Narella versluysi* and *Narella bellissima* started to appear as well in high densities, and at around 650m large basalt outcrops begin to dominate the substrate. At these depths, several sponge species compose the community observed, including *Characella pachastrelloides* (Figure 380)*, Macandrewia azorica* and *Petrosia* sp., with many other smaller species present as well. Several bluemouth rockfish *Helicolenus dactylopterus* were observed in these areas. Shallower areas proved to be quite sedimentary, where its soft bottoms were usually colonized by hydrozoans likely from the genus *Lytocarpia*, and the whip coral *Viminella flagellum*, very sparsely distributed on the available rocky outcrops. Small sponges from the species *Haliclona implexa* and the genus *Petrosia* sp. Shoals of *Capros aper* were seen at these shallower spots as well.

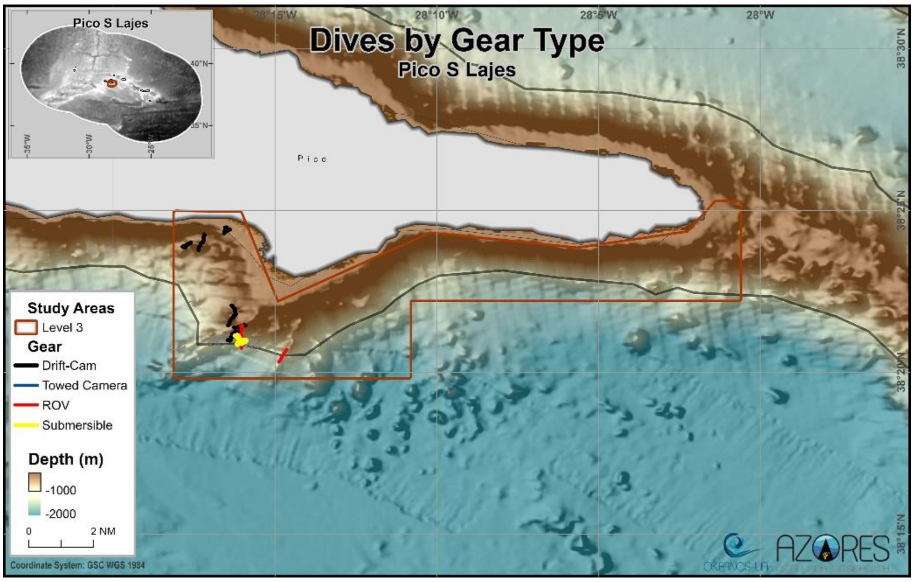



**Figure 379.** Map displaying the 12 underwater dives performed in the Pico S Lajes area between 50 and 1,100 meters depth.


**Figure 380** Selected images representative of the main structuring species and benthic communities observed in Pico South Lajes area. (a) Hard bottom colonized by encrusting and glass sponges, the soft coral *Gersemia* sp. and a dead colony of *Lophelia pertusa* serving as substrate for glass sponges and hydrozoans. (b) Pillow lava bottom with colonies of the black coral *Leiopathes* cf. *expansa,* dead colonies of *Lophelia pertusa* and a wide variety of sponges. (c) Sponge *Characella pachastrelloides* on a hard bottom densely colonized by other small and encrusting sponge species. (d) Large aggregation of the sponge *Pheronema carpenteri.* Image credits: ROV Luso / EMEPC / 2018 Oceano Azul Expedition, organized by Oceano Azul Foundation & partners.

*Pico SW Espartel*

In the Pico Southwest Espartel area, 15 underwater video transects were performed between 560 and 990 m depth (Figure 381). A total of 19 taxa were determined from the video data, with 8 identified at the species level, suggesting a low diversity of deep-sea megabenthic species for the area. The most frequently observed taxa based on weighted occurrences include *Pheronema carpenteri* (n= 10), *Cidaris cidaris* (n= 9), and Bryozoa (n= 4).

The substrate found in this area was interestingly diverse. Apart from the usual soft bottoms found on island slopes and the occasional vertical walls, most the rocky substrate observed was dominated by large pillow lavas, from the deepest areas explored to the shallowest.

On the shallowest areas, soft bottoms with low levels of biodiversity were observed. Small, monospecific aggregations of the whip coral *Viminella flagellum* were present on some pillow lavas at around 400m depth. At around 750m depth, community shifts take place, where a markedly distinct faunal assemblage is present. Dense and vast aggregations of the primnoids *Narella versluysi* and *Narella bellissima* (Figure 382) clearly dominate the substrate along with the bird's nest sponge *Pheronema carpenteri* and other hexactinelids such as *Asconema fridsteti, Regadrella phoenix* (Figure 382) and white lamellate sponges. Other coral species are also present but more sporadically, such as *Hemicorallium niobe* (Figure 382)*, Acanthogorgia* spp., and *Paragorgia johnsoni.* On soft grounds around pillow lavas, dense aggregations of Hydrozoans cf. *Lyocarpia* sp. can be seen and when vertical walls appeared, these were usually colonized by small and encrusting sponges and by a white, white Plexaurid coral. Alfonsinos *Beryx decadactylus* were occasionally spotted, as well as a small aggregation of the echinoderm *Cidaris cidaris.* At greater depths, at around 950m, we observed dead coral framework on areas of soft grounds, providing suitable substrate for the aggregations of Stylasterids seen, likely from the species *Errina atlantica* (Figure 382). Impressive vertical walls were also present, where a diverse benthic community was seen thriving, composed by large colonies of the black coral *Leiopathes* cf. *expansa,* the lace corals *Lophellia pertusa* and *Madrepora occulata* – which formed dense patches of coral framework (Figure 382)- and several other associated species. Interestingly, a large bottom longline weight was also observed, not a usual sighting for such depths.

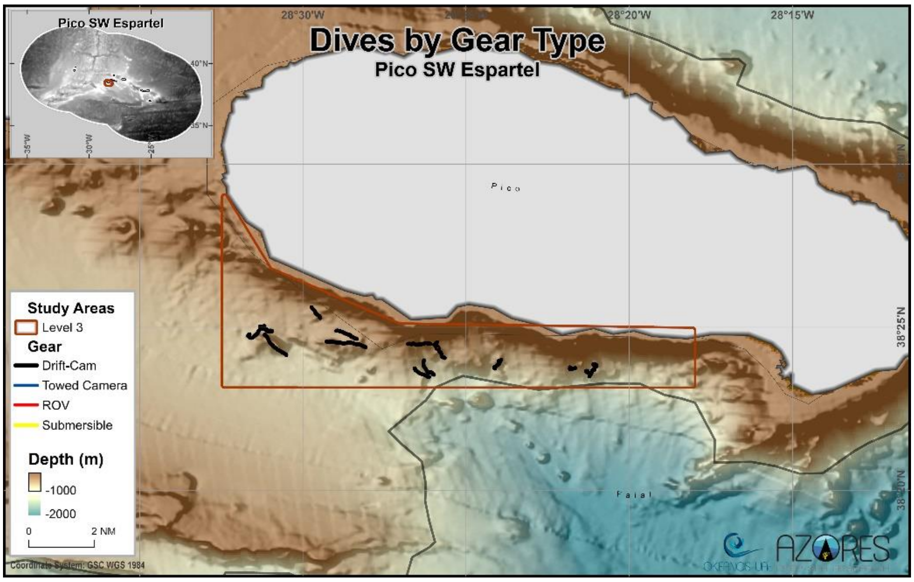



**Figure 381.** Map displaying the 15 underwater dives performed in the Pico SW Espartel area between 560 and 990 meters depth.

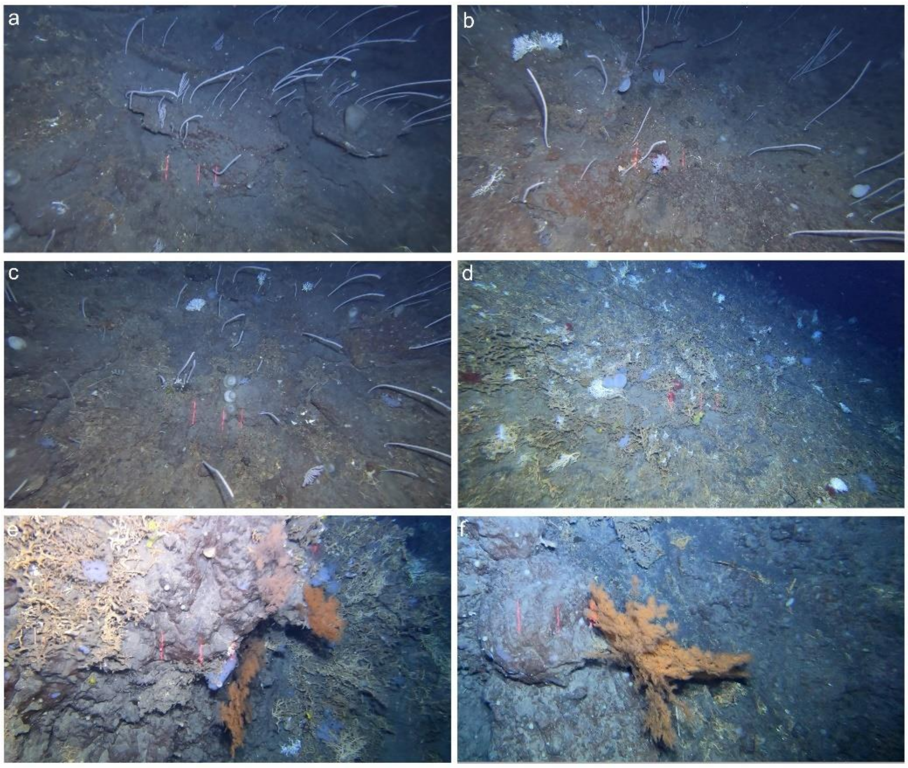



**Figure 382** Selected images representative of the main structuring species and benthic communities observed in Pico Southwest area. (a) Aggregation of the primnoids *Narella versluysi* and *Narella bellissima* with a specimen of the sponge *Asconema fristedti.* (b) Coral garden with corals *N. verluysi* and *Hemicorallium niobe* together with glass sponges *Regadrella phoenix.* (c) Aggregation of primnoids of the genus *Narella,* gorgonian *H. niobe* and "bird nest" sponges *Pheronema carpenteri.* (d) Colonies of the stylasterid *Errina dabneyi* on dead coral framework together with the soft coral *Anthomastus/Pseudoanthomastus* sp. and glass sponge *Farrea occa.* (e-f) Colonies of the black coral *Leiopathes* cf. *expansa* on dead coral framework and hard substrate. Image credits: IMAR/Okeanos-UAz, Azor drift-cam

*Faial-Pico S*

Through Faial-Pico South area were conducted 14 underwater video transects, between the depths of 70 and 840 m (Figure 383). A total of 60 taxa were identified from video analysis, with 32 determined at the species level, indicating that this area supports a medium diversity of deep-sea megabenthic species. The most frequently observed taxa based on weighted occurrences include *Haliclona (Soestella) implexa* (n= 25), *Acanthogorgia* spp. (n= 24), and *Hymedesmia (Hymedesmia) paupertas* (n= 23).

The Faial-Pico South geomorphological unit is an area south of the two Island that give the name to it and is mainly composed by the island slopes and seamounts, which include sites shallower than usual, inside the Faial-Pico channel. In general, the seafloor at this unit is characterized by sedimentary and flat environments with the deposition of high quantity of soft sediments, sporadically interrupted by sparse boulders and basaltic outcrops, that which contained the majority of the benthic fauna observed. The deepest areas recorded, were almost entirely composed by soft grounds and with a very limited abundance and diversity of fauna. Echinoderms of the family Echinothuriidae were the most common sighting on the sandy bottom. At these depths, sporadic small basaltic boulders were found with the presence of a diversity of encrusting sponges and the species of glass sponge *Farrea occa*. On shallower sectors of this area, the substrate was very similar, with a slightly higher occurrence of boulder and hard substrate areas. The fauna was still very scarce, with again some individuals of the genus Echinothuriidae appearing, and when occasional rocky outcrops appeared, these were sparsely colonized by smaller and encrusting sponges. In some of them we also found small colonies of *Hemicorallium niobe* (Figure 384), *Acanthogorgia* spp., and more rarely, larger sponges that comprise the *Characella pachastrelloides* complex (Figure 384). Near the summit and on the top sectors, fauna was more abundant, especially on the rocks appearing occasionally. This diversity of fauna was mainly composed of the sponge species *Haliclona implexa*, *Characella pachastrelloides*, *Macandrewia azorica*, *Pseudotrachya hystrix* and of the genus *Petrosia* and *Leiodermatium*. Coral assemblages were not very common, with nearly only the observation of the whip coral *Viminella flagellum* (Figure 384), although never in high densities. The motile fauna was very present with highlights for the fish species of *Serranus atricauda*, *Mora moro*, *Trachyscorpia cristulata* and shoals of *Anthias anthias*.

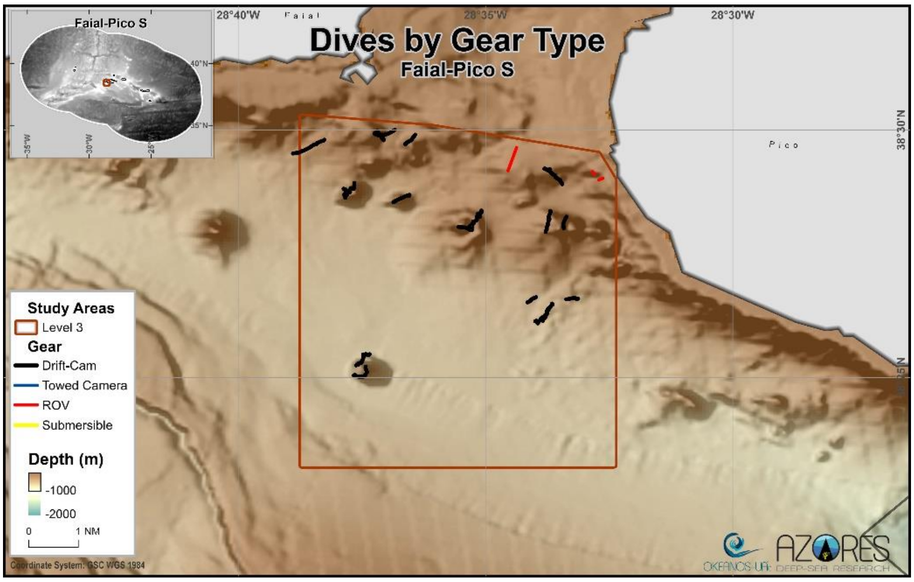



**Figure 383.** Map displaying the 14 underwater dives performed in the Faial-Pico S area between 70 and 840 meters depth.

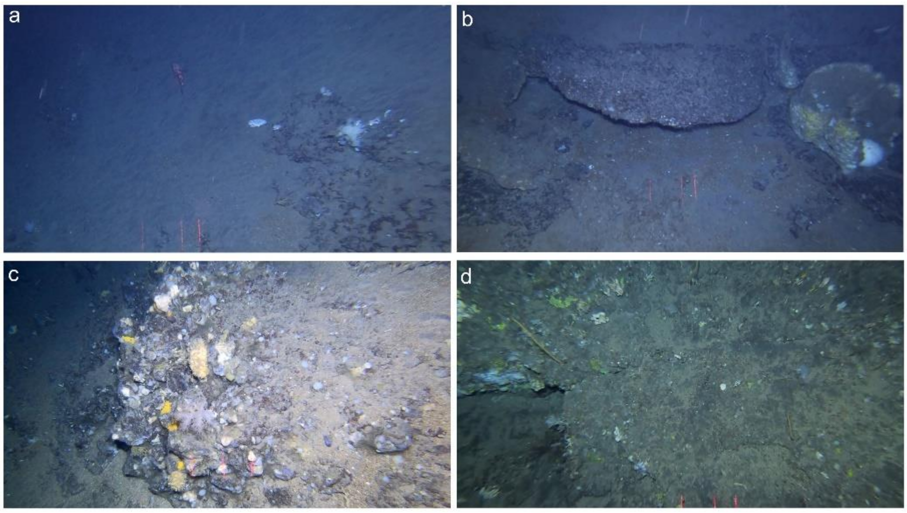



**Figure 384** Selected images representative of the main structuring species and benthic communities observed in Faial - Pico South area. (a) Small colonies of *Hemicorallium niobe* on soft sediments. (b) Large sponge *Characella pachastrelloides.* (c) Small boulder densely colonized by encrusting sponges, *Phlyctaenopora (Phlyctaenopora) bitorquis* and a colony of *Gersemi* sp. (d)Hard bottom with several species of sponges and two small colonies of the yellow morphotype *Viminella flagellum.* Image credits: IMAR/Okeanos-UAç, Azor drift-cam

*Faial S*

In Faial South area, 13 underwater video transects were completed between 220 and 790 m depth (Figure 385). A total of 59 taxa were determined from the images recorded. From these, 38 were identified to the species level, revealing that this area supports a medium diversity of deep-sea megabenthic species. The most frequently observed taxa based on weighted occurrences include *Characella pachastrelloides* (n= 44), Echinothuriidae (n= 42), and *Petrosia (Petrosia) crassa* (n= 34).

Soft grounds colonized by Foraminifera usually characterized the deepest sections explored, at around 800m depth, and on areas of steeper terrain, larger fields of the glass sponge *Pheronema carpenteri* (Figure 386) were recorded. At around the same depths, a large ray *Dipturus intermedius* was observed as well. At 750m these soft grounds began to shift to a sediment essentially composed of dead coral deposits and large basaltic outcrops, usually colonized by large sponges such as *Characella pachastrelloides, Geodia* sp. and *Petrosia* sp. in relatively low abundances (Figure 386), until around 500m depth. However, a strong community shift took place at around 300m depth, where the gorgonian *Acanthogorgia* spp. and the lamellate sponge cf. *Poecillastra compressa* (Figure 386) densely dominated the seafloor for a considerable extension. Occasional colonies of the hydrocoral *Errina dabneyi* were also observed, as well as the smaller sponge *Haliclona implexa* (Figure 386). The forkbeard *Phycis phycis* was recorded at these depths also.

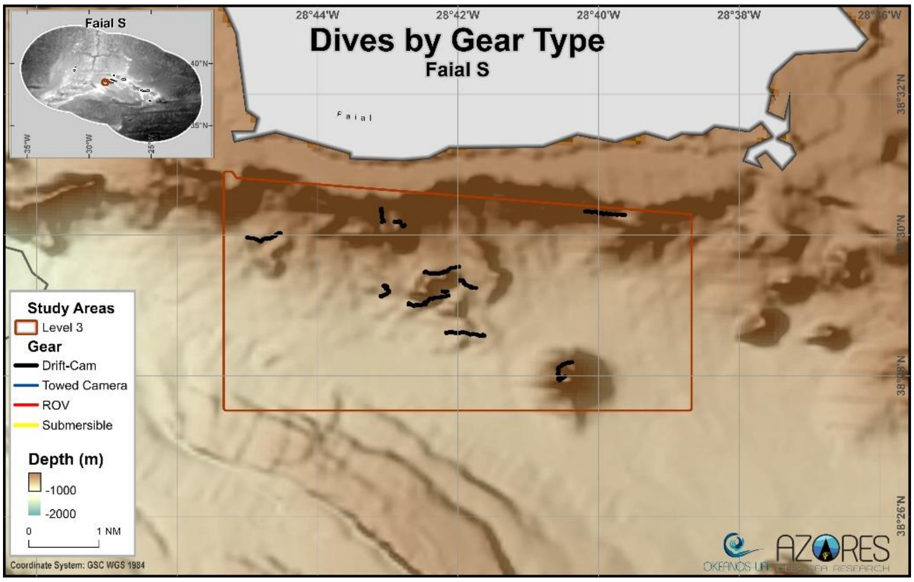



**Figure 385.** Map displaying the 13 underwater dives performed in the Faial S area between 220 and 790 meters depth.

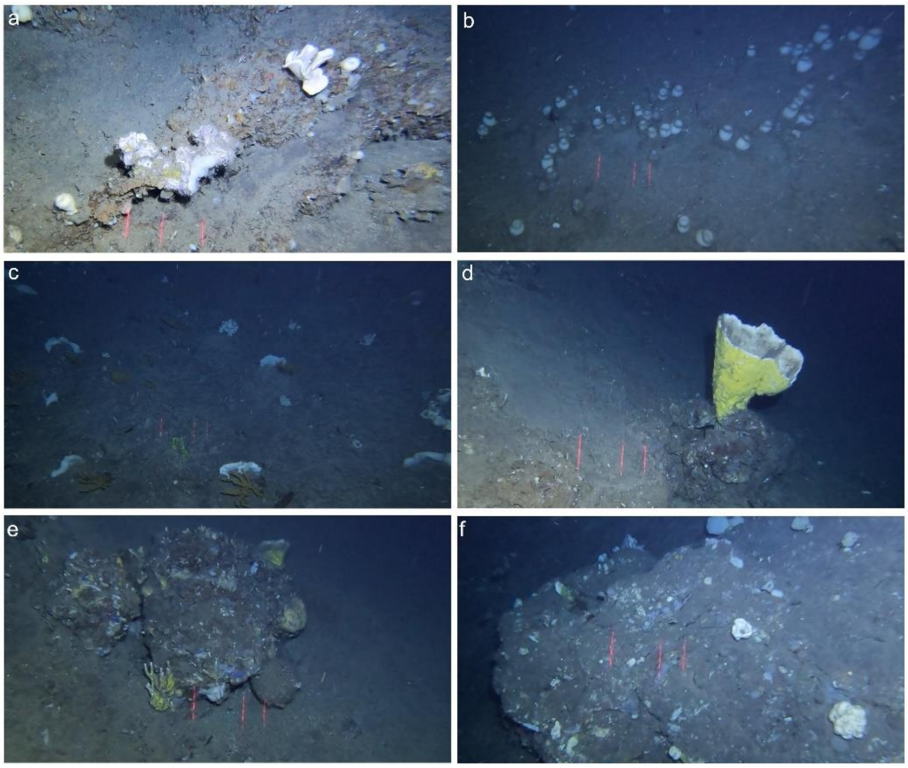



**Figure 386** Selected images representative of the main structuring species and benthic communities observed in Faial South area. (a) Small rock with a wide variety of lithistid, globular and encrusting sponges. (b) Large aggregation of the bird's nest sponges *Pheronema carpenteri.* (c) Vast aggregation of the coral *Acanthogorgia* spp. with the sponges *Poecillastra compressa* and *Haliclona implexa* (d) Massive *Characella pachastrelloides.* (e) Aggregation of desmosponges *Geodia* sp. and *Characella pachastrelloides,* together with other encrusting species. (f) Boulder colonized by several sponge species, including sponges of the genus *Petrosia.* Image credits: IMAR/Okeanos-UAç, Azor drift-cam

*Faial Filhas do Condor*

In the Faial Filhas do Condor area, 11 underwater video transects were conducted between 460 and 1020 m depth (Figure 387). A total of 90 taxa were determined from the video data. From these, 56 were identified to the species level, indicating a high diversity of deep-sea megabenthic species for the area. The most frequently observed taxa based on weighted occurrences include *Farrea occa* (n= 51), Ceriantharia (n= 50), *and Characella pachastrelloides* (n= 40).

The Filhas do Condor is a geomorphological unit composed by a series of seamounts associated to the important and large geomorphological structure of the Condor seamount. The range of depths analysed on this unit were very large, going from the base or lower slopes at around 1000m until the summit at approximately 460m below the sea surface. The different slope areas were distinct, being the seafloor characteristic of a more sedimentary environment at the base with the extensive presence of sand (almost mud) at the deeper areas, where the most common benthic fauna showed to be sea urchins of the genus Echinothuriidae and the species *Cidaris cidaris*, this last one with densities not usually seen, although not incredibly abundant. Patches of individuals of *Syringammina fragilissima* (Figure 388) were also often observed on the soft grounds. When the rock outcropped at the high depths, and progressively to the upper slope, it was possible to observe the appearance of several more species, such as aggregations of *Narella bellissima* (Figure 388)although small sized individuals, and *Candidella imbricata* (Figure 388), this last with colonies growing both on rocks and sand, and a high diversity of sponges which included *Pheronema carpenteri* (Figure 388), and when going up, aggregations of *Macandrewia azorica*, *Farrea occa* (Figure 388), exemplars of the genus *Geodia*, and great abundances of large *Characella pachastrelloides* (Figure 388). Also, to highlight the sporadic presence colonies of the scleractinian *Leptopsammia formosa* (Figure 388) and soft corals of the genus *Gersemia*. At the top, or close to it, the hard seabed (generally rock partially covered with sand) was scarce in benthic fauna with the sighting of a few *Characella pachastrelloides*.

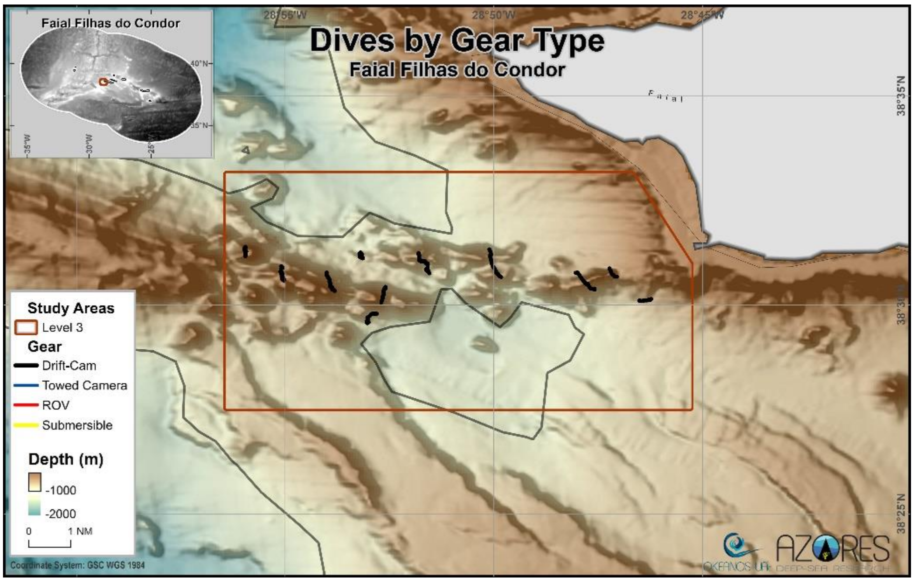



**Figure 387.** Map displaying the 11 underwater dives performed in the Faial Filhas do Condor area between 460 and 1020 meters depth.

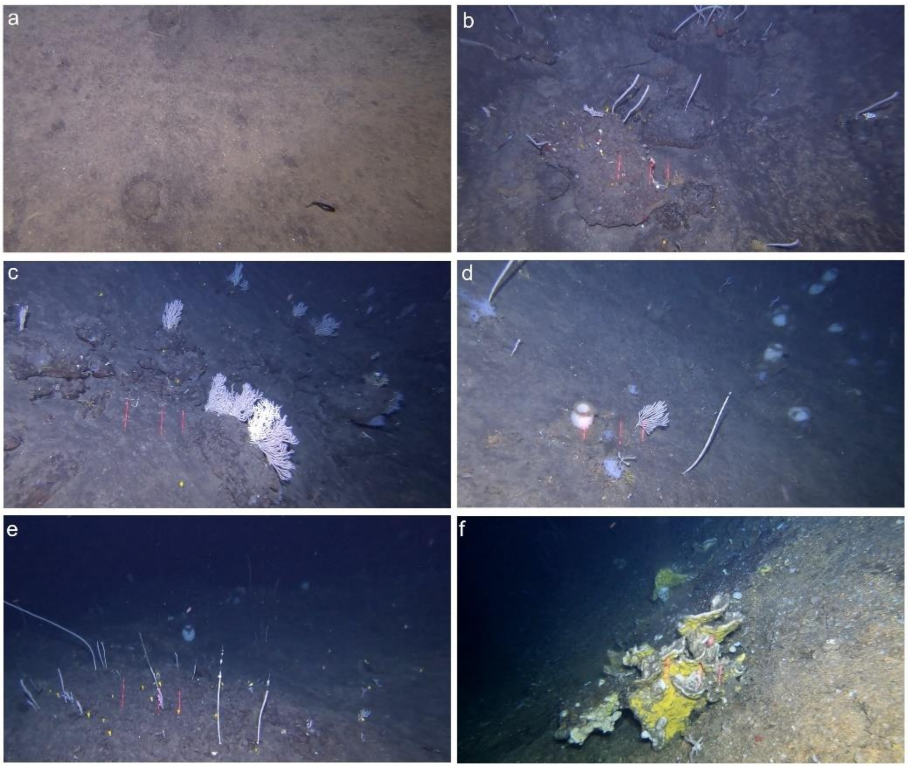



**Figure 388** Selected images representative of the main structuring species and benthic communities observed in Faial Filhas do Condor area. (a) Foraminifera assemblage *Syringammina fragilissima*. (b) Coral garden of the primnoids *Narella versluysi* and *Narella bellissima* together with the scleractinian *Leptopsammia formosa* and the soft coral *Anthomastus/Pseudoanthomastus* sp. (c) Aggregation of *Candidella imbricata*. (d) Soft bottom colonized by *N. verluysi* and *N. bellissima* together with glass sponges *Pheronema carpenteri* and *Farrea occa*. (e) Assemblage of the corals *N. verluysi* with scleractinian *L. formosa* and sporadic sponges *P. carpenteri*. (f)Large sponge *Characella pachastrelloides*. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Faial W Capelinhos*

In Faial West Capelinhos area, 24 underwater video transects were conducted between 110 and 960 m depth (Figure 389). A total of 93 taxa were determined from video analysis, with 35 identified at the species level, indicating a high diversity of deep-sea megabenthic species for the area. The most frequently observed taxa based on weighted occurrences include *Farrea occa* (n= 7), *Syringammina fragilissima* (n= 6), and Bryozoa (n= 5).

The shallowest part of Capelinhos sampling area, closer to shore, hosts a diverse ecosystem, dominated by several invertebrate species that intermix to form benthic communities, sometimes difficult to disentangle one from the other. One of the most striking aggregations is characterized by a soft coral species yet to be identified, reaching very high densities in rocky outcrops at 100-150 m depth (Figure 390a). The number of species associated to this community is large, with numerous colonies of the black coral cf. *Antipathella subpinnata* (Figure 390b), as well as many sponges not identified to species level yet. A wide variety of fishes have also been observed within this community, including *Pontinus kuhlii*, *Phycis phycis*, *Anthias anthias*, *Helicolenus dactylopterus* and *Serranus atricauda*. Moving further deep (200-400 m), aggregations of the yellow sea fan *Acanthogorgia* spp. become very common, in some areas reaching impressive densities (Figure 390c). Although this gorgonian species is observed forming monospecific patches in some areas of Capelinhos, it is generally associated to a few other larger species, such as the octocorals *Callogorgia verticillata*, *Dentomuricea* cf. *meteor* and yellow morphotypes of the whip coral *Viminella flagellum*, as well as the sponge cf. *Haliclona implexa*, which can reach high abundances locally. Also interesting is the aggregation of the primnoid coral *Callogorgia verticillata* (Figure 390d), with some large colonies that show little signs of fishing impact. Until now, these aggregations have only been observed in one spot, covering a very small area. Also relevant are the high abundances of large hydrozoan colonies, found forming some dense monospecific patches as well as in association with a few of the coral species already mentioned. Between 300 and 450 m depth, an impressive aggregation of the hydrocoral *Errina dabneyi* was identified (Figure 390f), possibly with the highest densities of this species reported in the Azores so far. Impressively, this community lasted for several hundreds of meters, with other coral species living in association, including *Callogorgia verticillata*, *Dentomuricea* aff. *meteor* and *Acanthogorgia* spp. The deepest dives, below 500 m, reported the lowest diversity of megafauna of all the areas explored, dominated in most cases by sand and boulders, some of which with a distinctive dark/reddish coloration that could indicate recent volcanic activity. One of the most relevant aspects of Capelinhos area is the large number of sharks that have been encountered, mainly from the species *Galeorhinus galeus*. These sharks are usually observed down to 300 m depth, with a large aggregation reported in shallower areas (150-200 m depth). Further deep, some specimens of the six gill-shark *Hexanchus griseus* have also been observed.

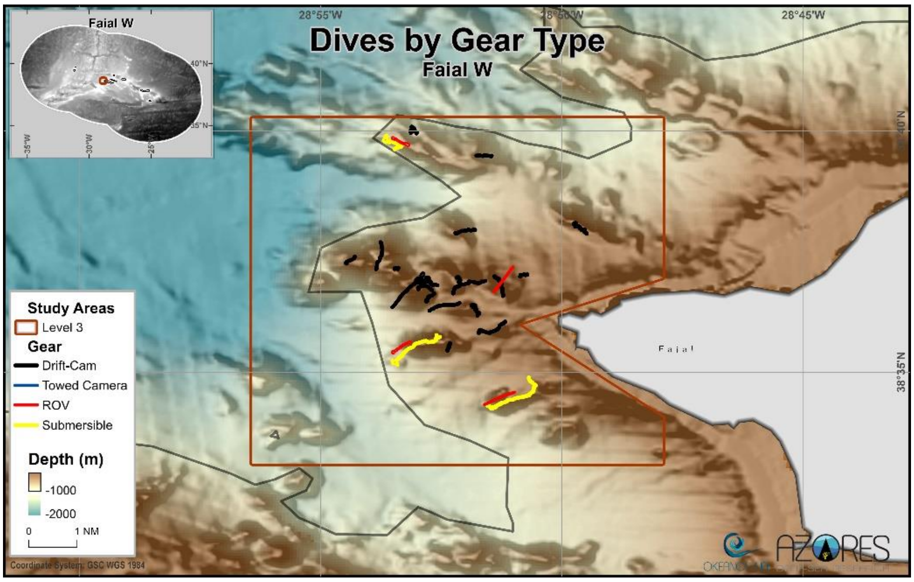



Figure 389. Map displaying the 24 underwater dives performed in the Faial W Capelinhos area between 110 and 960 meters depth.

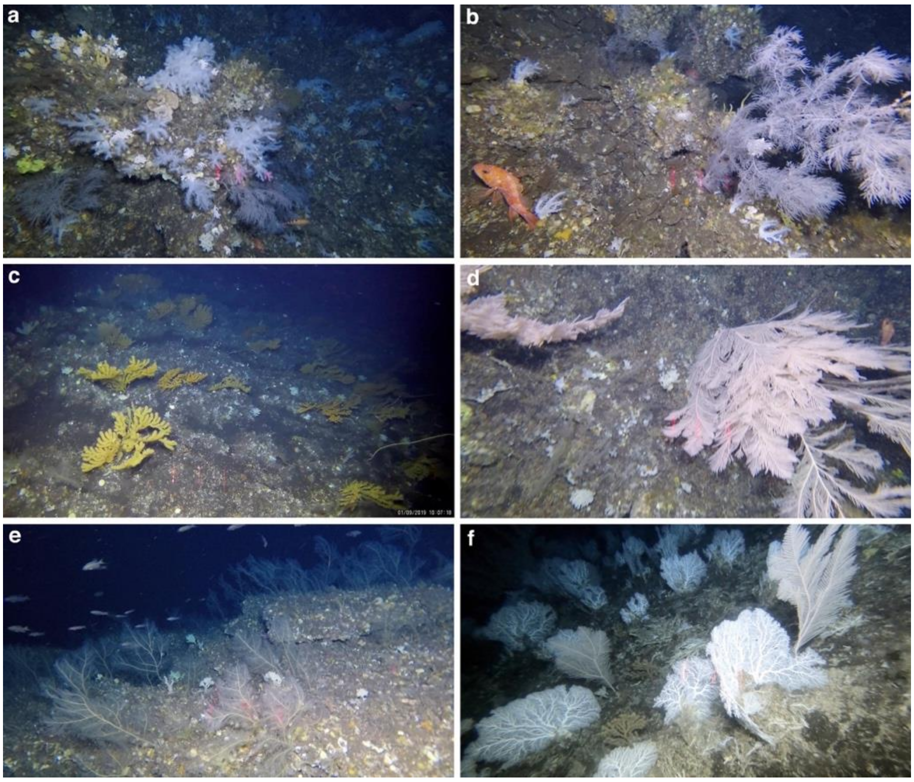



**Figure 390.** Selected images representative of the main structuring species and benthic communities observed in Capelinhos area. (a) Aggregation of soft corals on the shallowest areas explored. (b) A large colony of the black coral *Antipathella subpinnata* in between soft corals. (c) High densities of the yellow sea fan *Acanthogorgia* spp. (d) Some large colonies of the primnoid coral *Callogorgia verticillata*. (e) Aggregation of large hydroids. (f) A dense aggregation of the hydroid coral *Errina dabneyi.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Condor seamount*

While exploring Condor seamount, 44 underwater video transects were performed between the depths of 210 and 1100 m (Figure 391). A total of 122 taxa were identified from the images recorded, with 73 determined at the species level, revealing that this area supports a very high diversity of deep-sea megabenthic species. The most frequently observed taxa based on weighted occurrences include *Petrosia (Petrosia) crassa* (n= 28), *Petrosia* sp. (n= 26), and *Leiodermatium* sp. (n= 23).

Condor is an elongated volcanic seamount located 17 km southwest of Faial Island. Its ridge extends NW-SE for 39 km, with its shallowest point on its flat summit at 185 m depth and its flanks extending with gentle slopes down to 2000 m depth. The benthic communities at Condor show a very clear zonation pattern, strongly linked to depth, with the composition of the communities located on the summit displaying significant differences from those found on the seamount flanks. Coral gardens formed by the octocorals *Viminella flagellum*, *Dentomuricea* aff. *meteor, Paracalyptrophora josephinae* and *Callogorgia verticillata* (Figure 392a-b-c), together with the large hydrozoan cf. *Lytocarpia myriophyllum* dominate the summit of Condor. The three gorgonian species were found both in consolidated and unconsolidated substrates, with the dominance of one species over the others varying throughout the summit. Impressive shoals of several wreckfish *Polyprion americanus* were observed in this area as well. Also at the summit, particularly on the hard substrates of the eastern edge, a dense aggregation of the hexactinellid sponge *Asconema* sp. was found (Figure 392d). A small area of the summit also held a patch of the scleractinian of the genus *Eguchipsammia*, composed mainly of coral rubble with a few living colonies over an area of 100 meters in length (Figure 392e). The flanks of the seamount were characterized by a greater proportion of unconsolidated substrates compared to the summit, with sandy and gravelly areas more common towards its deeper parts. This type of substrate influences on the abundance of sessile organisms, with sandy patches generally colonized by the foraminifera cf. *Syringammina fragillissima*, which can be accompanied by ceriantids and the solitary scleractinian *Flabellum* sp. Areas of coarser substrate on both flanks were dominated by lithistid sponge species, replacing gorgonian corals as depth increased. Some frequent sponge species included *Leiodermatium* sp., *Neophrissospongia nolitangere*, *Macandrewia azorica* and *Petrosia* spp., among many others. Also on the flanks, some aggregations of the hexactinellid sponge *Pheronema carpenteri* were spotted, generally along a limited seabed extension (Figure 392f). Although sponges dominated the flanks, two coral assemblages were found on the deeper areas. On the southern side, gorgonians of the genus *Acanthogorgia* whilst coral gardens formed by of the white gorgonian *Candidella imbricata* in the deepest part of the seamount, in most cases accompanied by the yellow cup coral *Leptopsammia formosa*.

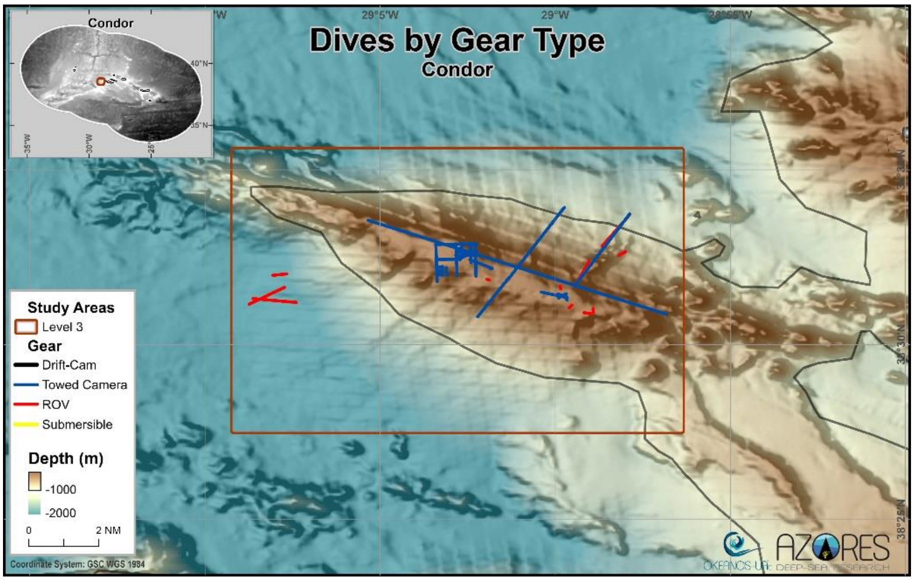



Figure 391. Map displaying the 44 underwater dives performed in the Condor area between 210 and 1100 meters depth.

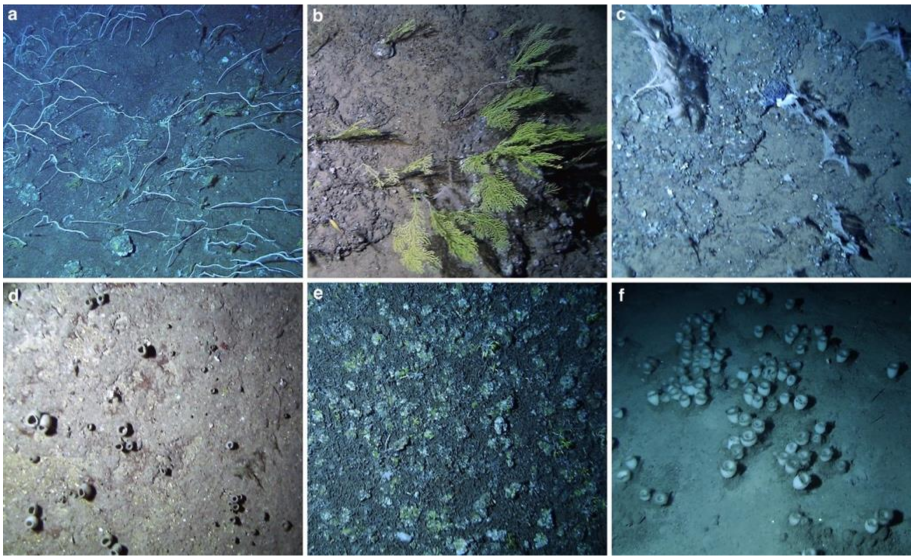



**Figure 392.** Selected images representative of the main structuring species and benthic communities observed in Condor seamount. (a) Dense patch of *Viminella flagellum*. (b) Aggregation of the sea fan *Dentomuricea* aff. *meteor*. (c) Some of the large *Callogorgia verticillata* colonies observed. (d) Aggregation of the glass sponge *Asconema* sp. on the eastern side of the mound. (e) Aspect of the *Eguchipsammia* cf. c*ornucopia* reef found on the middle part of the summit. (f) One of the few aggregations of the hexactinellid *Pheronema carpenteri*. Image credits: Hopper tow-cam, NIOZ.

*Baixo de São Mateus*

A total of 27 underwater video transects were performed in Baixo de São Mateus area, ranging from 380 and 850 m depth (Figure 393). A total of 96 taxa were identified from the videos recorded, with 59 determined at the species level, revealing a high diversity of deep-sea megabenthic species for the area. The most frequently observed taxa based on weighted occurrences include *Characella pachastrelloides* (n= 90), *Haliclona filholi* (n= 89), and *Petrosia (Petrosia) crassa* (n= 88).

Baixo de São Mateus is an elongated feature south of Pico Island that stretches for more than 20 km, with its summit at 350 m depth. Its slopes are of a sedimentary nature, with most of its rocky outcrops covered in a layer of muds and fine sands. The deepest areas explored corresponded to flat soft bottoms, where some foraminifera (cf. *Syringammina fragilissima)* could be observed scattered along the seabed. When the slope began to increase, large deposits of coral rubble started to appear, in some areas constituting a large percentage of the available substrate. Not much fauna was observed on top of the dead coral fragments besides some small sponges and the occasional sea urchin *Cidaris cidaris*. When the rock outcropped, especially in vertical or very slopping areas, the most important community corresponded to that formed by large colonies of the black coral *Leiopathes* cf. *expansa* surrounded by a considerable number of small scleractinian corals of the species *Dendrophyllia cornigera* as well as the glass sponge *Farrea occa* (Figure 394a). It is interesting to point out that many dead colonies of the coral *Lophelia pertusa* still attached to the rock were commonly observed within this community. A closer examination of these colonies revealed that some tips still have living polyps, although their percentage with respect of the dead parts is small. Soft bottom patches around these rocky outcrops were colonized by the glass sponge *Pheronema carpenteri* (Figure 394b), which reached some very high densities locally. In those areas, where the rock has a lower slope, some very large colonies of the coral *Hemicorallium niobe* were spotted (Figure 394c), although never forming aggregations of considerable numbers.

Moving up along the slope, the association between the primnoids *Narella bellissima* and *Narella verluysi* became common, reaching its higher densities at around 750 m depth (Figure 394d). Below 700 m depth, the rock becomes more frequent and experienced a clear change in the composition of its characteristic fauna. Porifera becomes by far the dominant group, with giant sponges of the species *Characella pachastrelloides* (Figure 394e) alongside an extensive list of other erect and encrusting sponges: *Macandrewia azorica*, *Petrosia* cf. *crassa*, *Neophrissospongia nolitangere and Leiodermatium* sp. among many others.

In some areas, the number of sponge species was large impressive, some of which reaching important abundances. At those depths, some vertical walls were home to the living fossil community with the oyster cf. *Neopycnodonte zibrowii* and the crinoid cf. *Cyathidium foresti* (Figure 394f). A large number of other species were observed living attached to the vertical surfaces of those rocks, including the sea fan *Acanthogorgia* spp., soft corals Anthomastus/*Pseudoanthomastus* sp., the cup coral *Desmophyllum dianthus* and several encrusting sponges, both lithistid and hexactinellid.

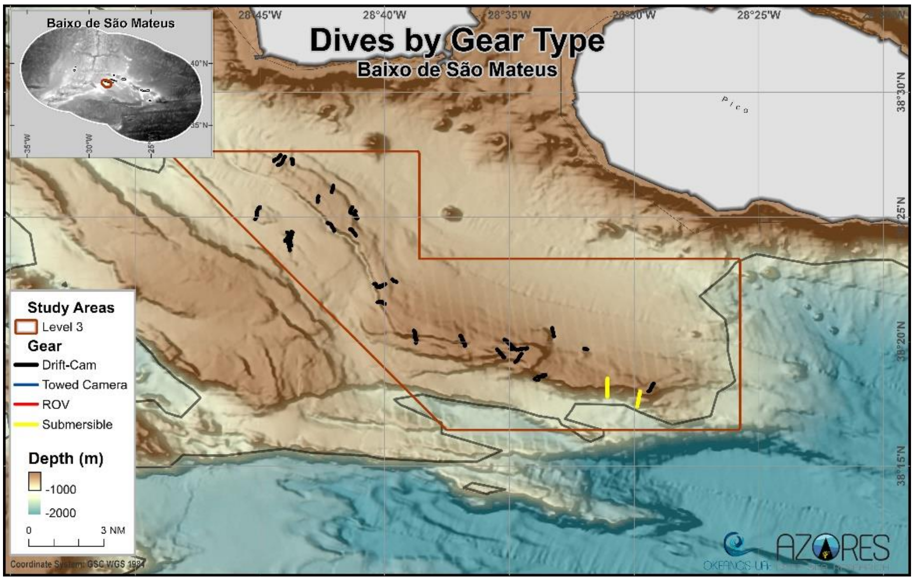



**Figure 393.** Map displaying the 27 underwater dives performed in the Baixo de São Mateus area between 380 and 850 meters depth.

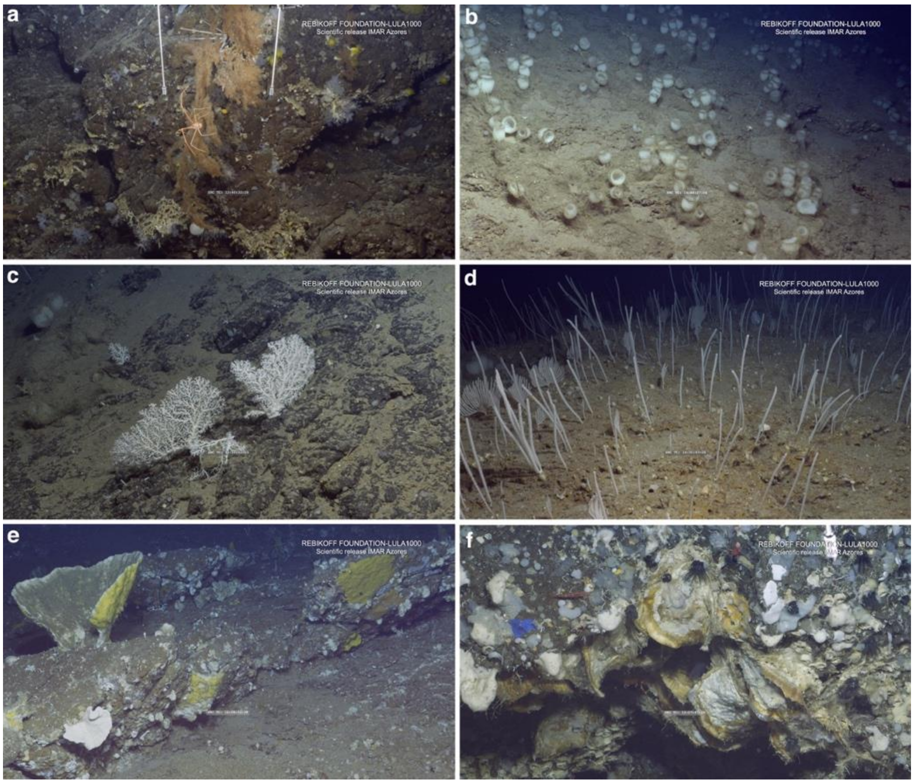



Figure 394. Selected images representative of the main structuring species and benthic communities observed in Baixo de São Mateus seamount. (a) Large black coral *Leiopathes* cf. *expansa* on a vertical wall at 850 m depth. (b) Field of *Pheronema carpenteri* on mixed substrates. (c) Two large colonies of the coral *Hemicorallium niobe*. (d) Dense patch of primnoid corals with a dominance of *Narella verluysi*. (e) Aspect of the sponge-dominated community on the hard substrates of the shallowest areas visited, with the giant sponge *Characella pachastrelloides*. (f) Close up of the living fossil community with oysters and the crinoid cf. *Cyathidium foresti* on a vertical wall at 580 m depth. Image credits: LULA 1000, Rebikoff Foundation.

*Ponta da Ilha N*

In Ponta da Ilha North area, 10 underwater video transects were completed between 250 and 840 m depth (Figure 395). A total of 59 taxa were determined from the video analysis, with 25 identified at the species level, indicating that this area supports a medium diversity of deep-sea megabenthic species. The most frequently observed taxa based on weighted occurrences include *Errina dabneyi* (n= 8), *Hymedesmia (Hymedesmia) paupertas* (n= 7), and *Macandrewia azorica (n= 6).*

The seamounts southeast of Pico Island were divided in two different geomorphological units. At the north tip of the Island, represented by the northernmost part of the chain of sea peaks, the areas explored covered a great part of the slopes of the peaks, and the benthic megafauna represented on of the most diverse and structurally complex benthic areas observed around the Islands of the central group. The presence of colonies of many structural species that intermix at varying densities generated a very diverse seabed habitat. The seafloor substrate was the typical find at the slopes of submarine peaks and close to the Island slopes, with a more sedimentary environment at the deepest areas close to the loser sections of the slope and progressively shifting to harder grounds dominated by basaltic boulders and outcrops, sometimes interrupted with sandy patches that can contain coral rubble deposits. The deepest areas explored (around 800m), had a flat sedimentary bottom and only poorly colonized by some glass sponges *Pheronema carpenteri* and *Regadrella phoenix*, becoming more common and abundant at the least deep areas of the lower slopes, along with several other glass sponges. Several fishes of the species *Hoplosthethus mediterraneus* were quite common at these depths as well as a large *Molva macrophtalma*. Further up the slope, the sediment progressively started to be more and more consolidated, where it was possible to start observing *Macandrewia azorica* in relatively high abundance, together with some *Stylocordila pellita*, *Desmacella grimaldi*, and massive *Characella pachastrelloides* and individuals of the genus *Geodia*. Some corals were already spotted, although scattered through the hard substrate, such as the white and yellow morphotypes of *Viminella flagellum*, *Acanthogorgia* spp., the hydrocoral *Errina dabneyi* (Figure 396) and small individuals of the gorgonian *Callogorgia verticillata*. All these coral biodiversity increased in density further up the slopes to the summit area (around 300 to 200m), where we can highlight very large aggregations of *Errina dabneyi*, which dominated the sea bottom at some points, along with *Acanthogorgia* spp., the appearance of *Paracalyptrophora josephinae* (Figure 396) and the relatively high abundance of the fan shaped *Phakellia ventilabrum* among other sponge species such as *Haliclona implexa* and likely from the genus *Leiodermatium* and *Petrosia.* Finally, one of the most interesting communities observed in the mounds SE Pico corresponds to the reefs formed by large numbers of the azooxanthellate scleractinian coral of the genus *Eguchipsammia* (Figure 396). The frog fish of the genus *Chaunax* and the bluemouth rockfish (*Helicolenus dactylopterus*) were also observed.

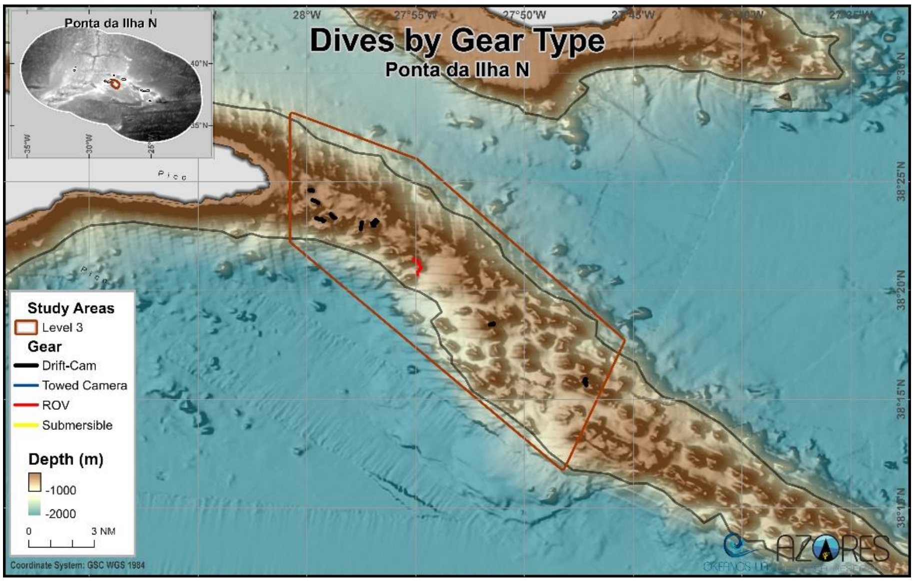



**Figure 395.** Map displaying the 10 underwater dives performed in the Ponta da Ilha N area between 250 and 840 meters depth.

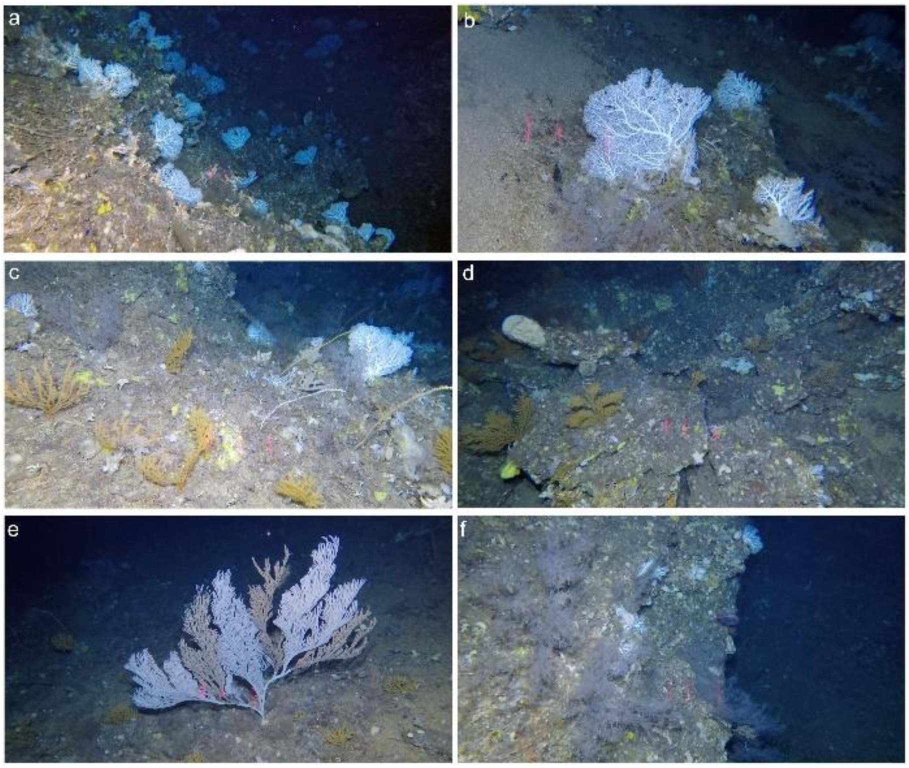


**Figure 396** Selected images representative of the main structuring species and benthic communities observed in Ponta da Ilha North area. (a-b) Vast aggregation of the stylasterid *Errina dabney.* (c) Aggregation of the gorgonian *Acanthogorgia* spp., the black coral *Antipathes subpinata,* the stylasterid *E. dabney* together with several sponge species. (d) Boulders densely colonized by *Acanthogorgia* spp. with a wide variety of sponges. (e) Large colony of *Paracalyptrophora josephinae* with the epibiont *Zibrowius alberti.* (f) Black coral *A. subpinata* Image credits: IMAR/Okeanos-UAz, Azor drift-cam

*Ponta da Ilha S*

In Ponta da Ilha South area, 4 underwater video transects were performed between 370 and 510 m depth (Figure 397). A total of 61 taxa were identified from the video analysis, with 38 determined at the species level, revealing a medium diversity of deep-sea megabenthic species. The most frequently observed taxa based on weighted occurrences include *Hymedesmia (Hymedesmia) paupertas* (n= 29), *Macandrewia azorica* (n= 27), and *Haliclona (Soestella) implexa* (n= 25).

The seamounts southeast of Pico Island were divided in two different geomorphological units. At the south tip of the Island, represented by the southernmost part of the chain of sea peaks, the areas explored belonged mainly to the upper slopes/summits of the peaks, and the benthic megafauna represented on of the most diverse and structurally complex benthic areas observed around the Islands of the central group. The presence of colonies of many structural species that intermix at varying densities generated a very diverse seabed habitat. Generally, the substrate was formed by rocky outcrops mixed with small soft sediment patches, that seemed to be just the basaltic rocks covered with unconsolidated sediment. Some aggregations of the hydrocoral *Errina dabneyi* (Figure 398) were observed covering the basaltic boulders, extensive and dense gardens formed by the gorgonian whip coral *Viminella flagellum* (present in both white and yellow morphotypes), incredibly large yellow octocoral *Dentomuricea* aff. *meteor*, *Callogorgia verticillata* and, although in with less densities compared to the others, *Acanthogorgia* spp. and the primnoid *Paracalyptrophora josephinae* (Figure 398). Other coral species such as the antipatharian *Antipathella* cf. *subpinnata* and soft corals of the genus *Anthomastus/Pseudoanthomastus* sp. area also included in the list of observations at this geomorphological unit. Several sponge aggregations were observed on the slopes of the seamounts, with an extensive species composition, and includes a wide variety of small encrusting and erect sponges. Amont the larger porifera, the most common species was the giant sponge *Characella pachastrelloides* (Figure 398), together with large aggregations of *Macandrewia azorica* (Figure 398) and *Neophrisospongia noplintagere*, as well as the glass sponge *Asconema* sp., *Haliclona implexa*, the fan shaped *Phakellia ventilabrum* and individuals likely of the genus *Leiodermatium* and *Petrosia*. Associated fauna (principally found on top of *Viminella flagellum* and *Callogorgia verticillata*), was also spotted with the sighting of several decapods of the species *Anamathia rissoana*. Small shoals of *Anthias Anthias* were common to see swimming around, as well as some *Hoplostenus mediterraneus*, *Helicolenus dactylopterus* and the record of a *Galeorhinus galeus*.

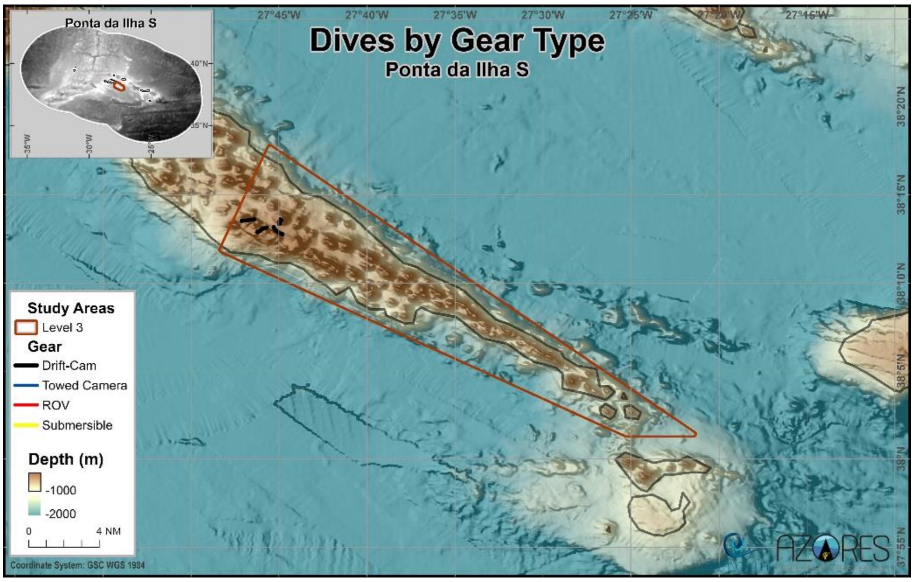



**Figure 397.** Map displaying the 4 underwater dives performed in the Ponta da Ilha S area between 370 and 510 meters depth.


**Figure 398** Selected images representative of the main structuring species and benthic communities observed in Ponta da Ila South area. (a) Extensive aggregation of *Callogorgia verticillata* together with *Acanthogorgia* spp.. (b) Large aggregation of colonies of *Dentomuricea* aff. *meteor* and occasional colonies of *Acanthogorgia* spp. (c) Large colony of the primnoid *Paracalyptrophora josephinae,* with a spider crab *Anamathia rissoana* associated. (d) Vast aggregation of the scleractinian *Eguchipsammia cornucopia* on a dead coral framework. (e) Small aggregation of the stylasterid from the genus *Errina,* on a hard substrate also colonized by the gorgonian *Acanthogorgia* spp. and several sponges. (f) Area densely colonized by several sponge species, including *Macandrewia azorica* and *Characella pachastrelloides* Image credits: IMAR/Okeanos-UAz, Azor drift-cam

*Albatroz do Meio*

In the Albatroz do Meio area, 7 underwater video transects were conducted between 560 and 1000 m depth (Figure 399). A total of 71 taxa were determined from the images, with 45 identified at the species level, indicating a medium diversity of deep-sea megabenthic species. The most frequently observed taxa based on weighted occurrences include *Narella versluysi* (n= 35), *Narella bellissima* (n= 28), and *Farrea occa* (n= 27).

Albatroz do Meio hosted particularly impressive faunal assemblages in the areas explored. Remarkably diverse and abundant coral gardens were present across most of the steep slopes surveyed, which were usually covered by dead coral deposits. The primnoid corals *Candidella imbricata, Narella versluysi* and *Narella bellissima* (Figure 400) were particularly abundant and dominated the benthic community, with other species also present in high numbers, such as the stylasterid *Errina atlantica* (Figure 400), the scleractinian *Leptopsammia formosa* and the black coral *Leiopathes* cf. *expansa* (Figure 400). Several sponge species in relatively high abundances also composed this diverse community, such as *Poecillastra compressa, Desmacella grimaldii, Phakellia ventilabrum, Regadrella phoenix* and, in particular, the bird's nest sponge *Pheronema carpenteri* (Figure 400). We also observed a distinct community dominated by the small gorgonian *Pleurocorallium johnsoni* with *Acanthogorgia* sp. also present as well, colonizing the deep summit explored. The deepest areas explored were essentially covered by soft sediments and sparsely distributed benthic fauna, with the bamboo coral *Acanella arbuscula* and its gorgonian lookalike C*hrysogorgia* sp. being the most representative taxa.

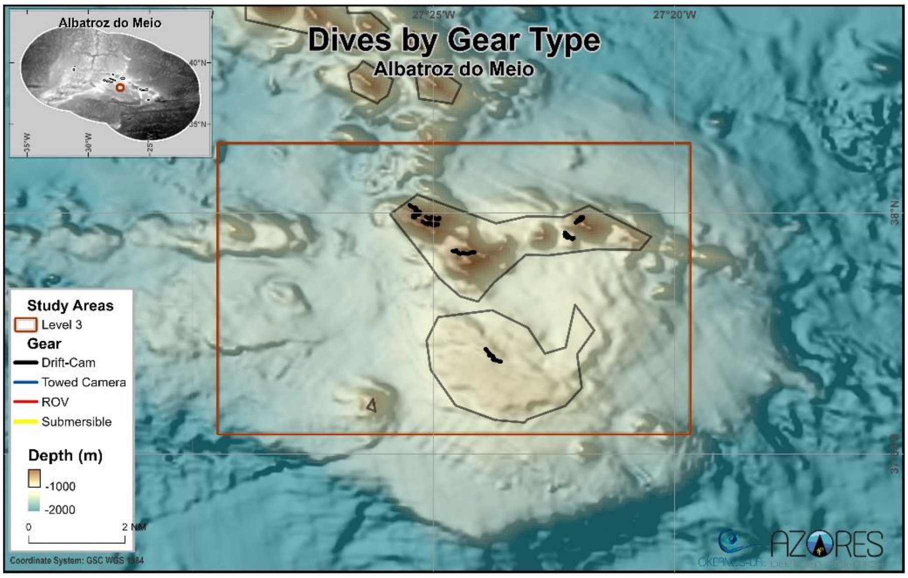



**Figure 399.** Map displaying the 7 underwater dives performed in the Albatroz do Meio area between 560 and 1000 meters depth.

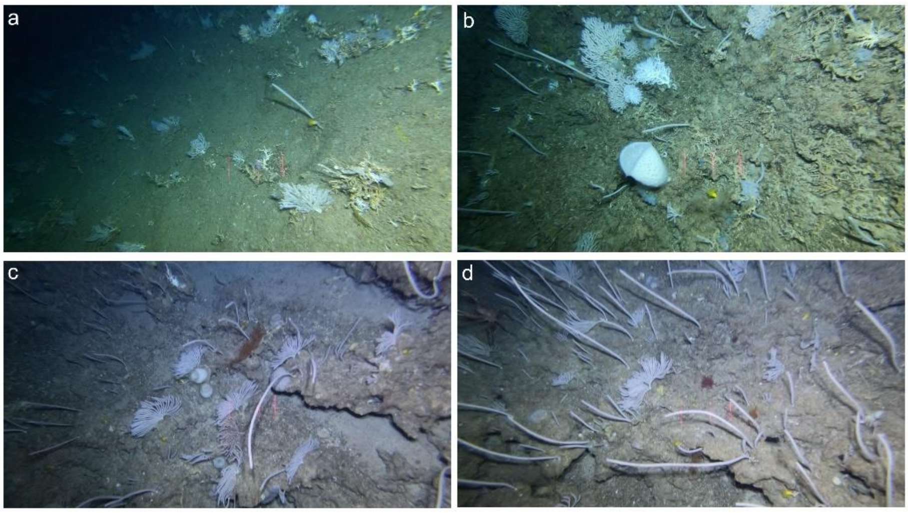


**Figure 400** Selected images representative of the main structuring species and benthic communities observed in Albatroz do Meio area. (a) Extensive aggregation of *Candidella imbricata* together with stylasterids, scleractinians and *Narella versluysi.* (b) Hard substrate with dead coral framework colonized by *N. versluysi, C. imbricata,* stylasterids, scleractinians and glass sponge, including *Regadrella phoenix.* (c) Hard substrate colonized by *N. verluysi, N. bellissima,* a small colony of *Leiopathes* cf. *expansa* and the sponge *Pheronema carpenteri.* (d) Aggregation of *N. versluysi, N. bellissima* with occasional occurrence of soft-corals and scleractinians. Image credits: IMAR/Okeanos-UAz, Azor drift-cam

Study area | Princesa Alice

*Agulhas 12 Milhas*

In the area of Agulhas 12 Milhas a total of 19 underwater video transects were performed, covering a depth range between 530 and 960 m (Figure 447). A total of 90 taxa were determined from the video annotation. From these, 51 were identified at the species level, indicating that this area supports a high diversity of deep-sea megabenthic species. The most frequently observed taxa based on weighted occurrences include *Plesionika* sp. (n= 105), *Farrea occa* (n= 81), and *Haliclona filholi* (n= 73).

The deepest areas surveyed (around 950 to 800m deep) were essentially characterized by the irregular rocky substrate, that was occasionally intercalated with very fine sediment bottoms. At these softer grounds, the occurrence of some scleractinian corals of the species *Leptopsammia Formosa*, the sea urchin *Cidaris cidaris* and deep-sea anemones of the genus *Liponema*. When the rock outcropped, these deeper sectors were home for incredible and vast aggregations of the bird's nest sponge *Pheronema carpenteri* (Figure 402), several times even attached to the basaltic walls in high abundance. These aggregations of *Pheronema*, were normally together with other sponge species, the *Farrea occa* and *Regadrella phoenix*, as well with the primnoid coral *Hemicorallium niobe* (Figure 402). The fish species *Mora moro* was frequently spotted at such depths. A rapid shift on the benthic community was observed when the climbed up to depths around 700-600 meters. The diversity of fauna was expressively higher and mainly growing on or close to the hard substrate. The primnoid coral species *Narella versluysi*, *N. bellissima* (although in small sizes) (Figure 402) were the most common, creating relatively big patches on the ground. The gorgonian *Acanthogorgia* spp., soft corals of the genus *Gersemia*, and the black coral *Sticopathes gravieri* (Figure 402) were observed sometimes but always very scattered. Regarding the phylum Porifera, it was very well represented, with high abundance of *Petrosia crassa*, and other individuals of the same genus, vast aggregations of the lollipop sponge *Stylocordyla pellita* and

*Macandrewia azorica* (Figure 402), and unusual numbers of sponges of the genus *Geodia*. The frog fish of the genus *Chaunax*, a ray *Dipturus intermedius* and shark *Deania* sp. can be considered the highlight in terms of motile fauna observed.

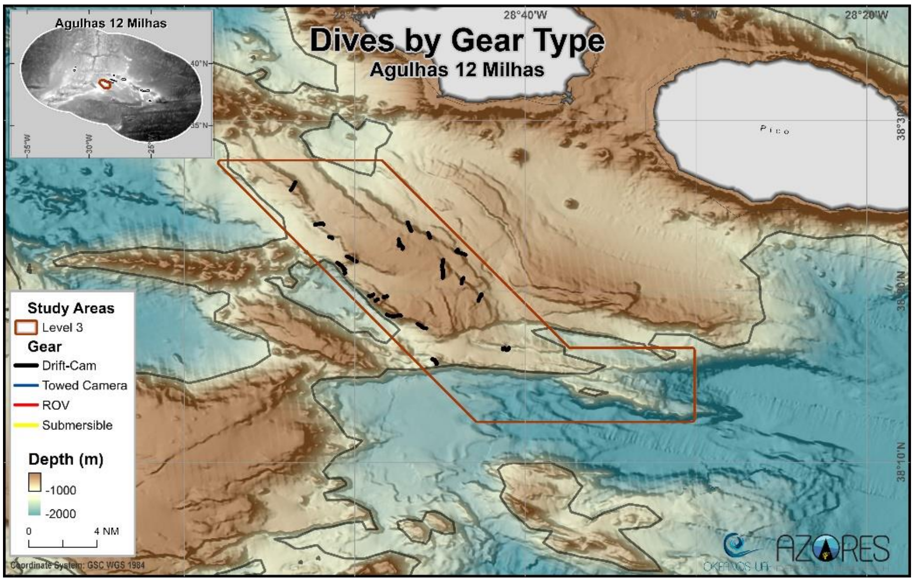



**Figure 401.** Map displaying the 19 underwater dives performed in the Agulhas 12 Milhas area between 530 and 960 meters depth.

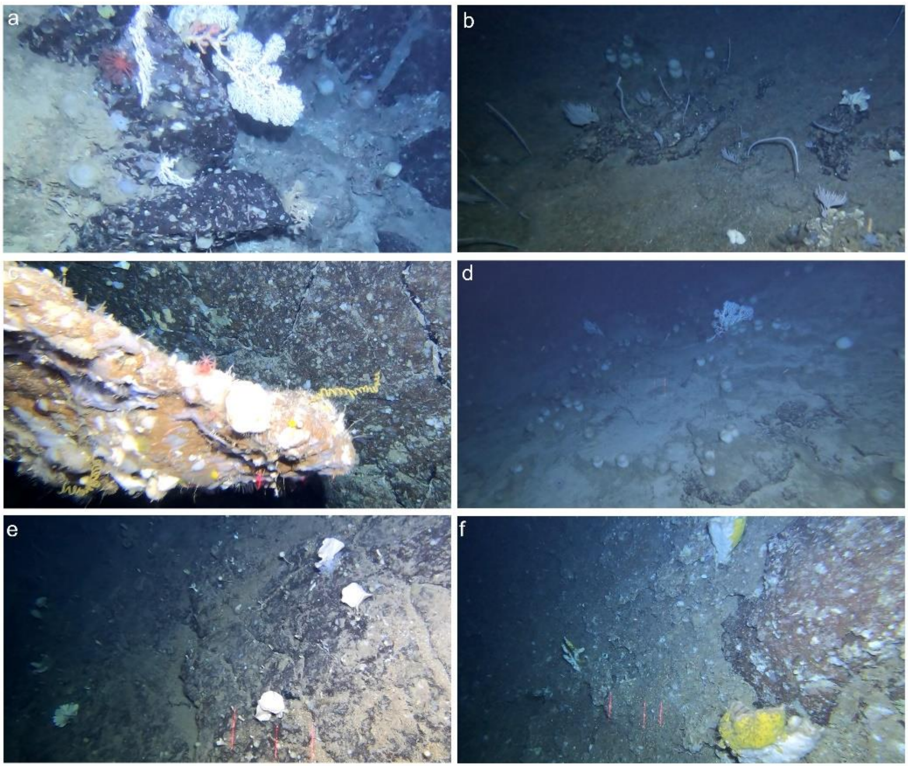



**Figure 402** Selected images representative of the main structuring species and benthic communities observed in Agulhas 12 Milhas area. (a) Small boulder colonized by the gorgonian *Hemicorallium niobe* and the soft coral *Anthomastus/Pseudoanthomastus* sp.. (b) Coral garden formed by the primnoids *Narella verluysi* and *Narella bellissima,* together with the sponges *Pheronema carpenteri* and *Macandrewia azorica.* (c) Two colonies of the black coral *Stichopathes gravieri.* (d) Vast aggregation of the bird's nest sponge *P. carpenteri.* (e) Aggregation of the demosponge *Macandrewia azorica.* (f) Specimens of the sponge *Characella pachastrelloides*. Image credits: IMAR/Okeanos-UAz, Azor drift-cam

*Condor de Fora*

In the Condor de Fora area, 14 underwater video transects were performed between 400 and 1010 m depth (Figure 403). A total of 64 taxa were identified from the images, with 38 determined at the species level, revealing that this area supports a medium diversity of deep-sea megabenthic species. The most frequently observed taxa based on weighted occurrences include *Characella pachastrelloides* (n= 35), *Petrosia (Petrosia) crassa* (n= 34), and *Haliclona filholi* (n= 31).

The deepest sections of this area were characterized by different types of substrates, with each holding different faunal assemblages. Flat rocky bottoms were present at greater depths (around 1000m), colonized by the typical benthic community composed by the bamboo coral *Acanella arbusculla,* the gorgonians *Chrysogorgia* sp. and *Candidella imbricata* (Figure 404) and the scleractinian *Leptopsammia formosa.* Soft grounds, on the other hand, were found to be colonized by several dense patches of *Pheronema carpenteri* (Figure 404)*,* at around 800m, where aggregations of the primnoids *Narella versluysi* and *Narella bellissima* (Figure 404) start to increase in density, reaching its peak at roughly 730m depth. Other coral species are also present, but more sporadically, such as *Acanthogorgia* sp., *Hemicorallium niobe* as well as some hexactinellids (*Regadrella phoenix*, for instance). The common Mora *Mora moro* and a small deep-sea shark *Deania* sp. are present at around these depths too.

Basaltic outcrops begin to appear at 700m, densely colonized by a variety of sponge species, of which *Petrosia crassa, Characella pachastrelloides, Geodia* sp. and, in particularly high abundances, *Macandrewia azorica* (Figure 404)*.* When sandy substrate was present, it was found to be occasionally colonized by tall colonies of *Callogorgia verticillata* (Figure 404)*,* at around 500m depth, and, even more sparsely by the whip coral *Viminella flagellum*. The hydrocoral *Errina dabneyi* was also found on basaltic outcrops. It is also noteworthy the several bottom longlines and fishing lines that were encountered at different depths in this area.

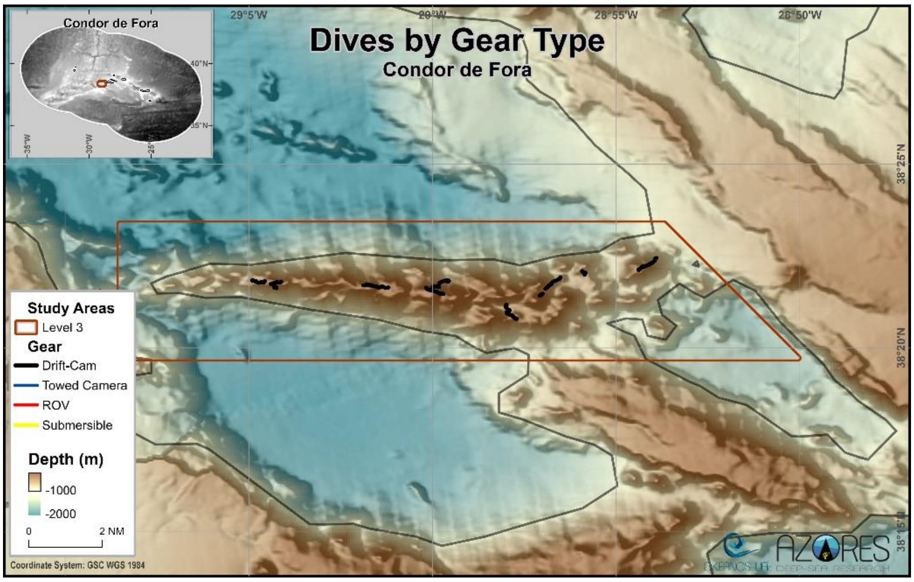



**Figure 403.** Map displaying the 14 underwater dives performed in the Condor de Fora area between 400 and 1,010 meters depth.

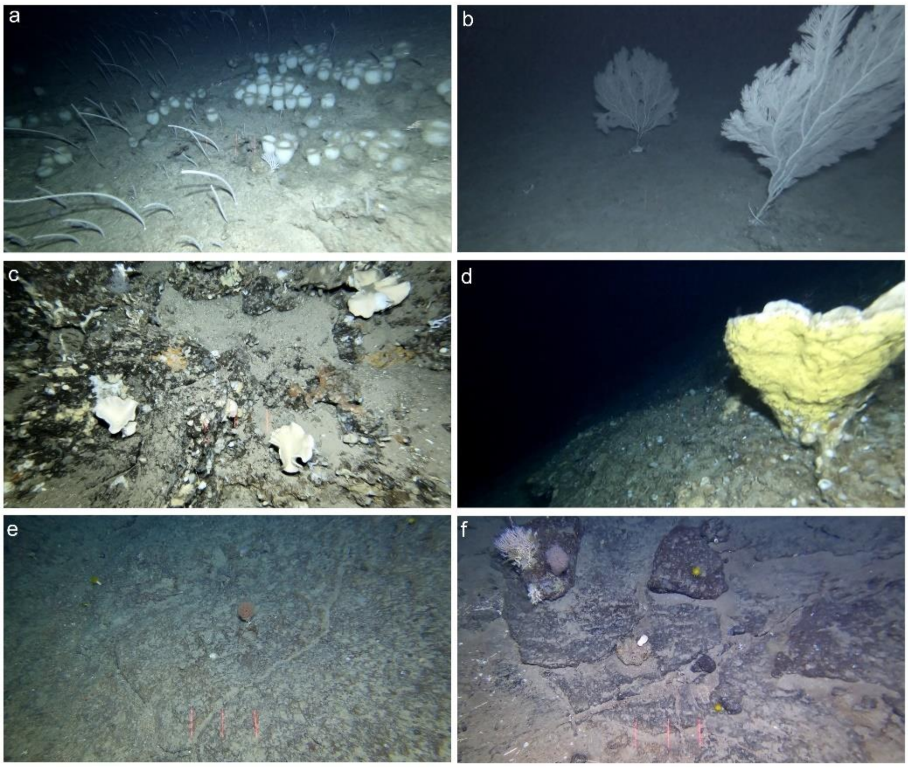



**Figure 404** Selected images representative of the main structuring species and benthic communities observed in Condor de Fora area. (a) Extensive aggregation of *Narella versluysi* and the bird's nest sponge *Pheronema carpenteri.* (b) Large colonies of *Callogorgia verticillata.* (c) Hard substrate colonized by several small and encrusting sponges, glass sponges and desmosponges *Macandrewia azorica.* (d) Large sponge *Characella pachastrelloides* on hard bottom. (e) Bamboo coral *Acanella arbuscula* and the scleractinian *Leptopsammia formosa* on hard bottom. (f) Small rock colonized by *Candidella imbricata* and *Chrysogorgia* sp. Image credits: IMAR/Okeanos-UAz, Azor drift-cam

*Agulhas 18 Milhas*

While exploring Agulhas 18 Milhas, 7 underwater video transects were conducted between 380 and 890 m depth (Figure 405). A total of 88 taxa were determined from video annotation, with 49 identified at the species level, indicating that this area supports a high diversity of deep-sea megabenthic species. The most frequently observed taxa based on weighted occurrences include *Farrea occa* (n= 46), *Pheronema carpenteri* (n= 37), and *Macandrewia azorica* (n= 31).

Agulhas 18 Milhas (as in 18 nautical miles from shore) area, like most of the areas south of Faial and Pico Islands, are extensively used by local bottom longliners and hand liners, making exploration challenging due to potential entanglements on lost fishing lines.

In the shallowest parts of Agulhas 18 Milhas area, between 530 and 370m deep, we observed some lace corals of the species *Errina dabneyi* (Figure 406), which seems to be endemic of the Azores archipelago, and sparse *Callogorgia verticillata* (Figure 406) and *Viminella flagellum* colonies. Apart from this, the benthic community spotted was essentially composed of sponge fauna, containing large specimens of the *Characella pachastrelloides* complex, *Neophrissospongia nolitangere* (Figure 406), and many encrusting sponges colonizing hard basaltic substrates. In some areas at similar depths, a similar faunal assemblage was observed, but poorer in terms of abundances.

In deeper areas, between 515 and 1010 m depth, both soft and hard bottoms were covered, where basaltic outcrops were colonized by different benthic fauna communities. On soft substrate, we observed extensive sponge fields containing *Pheronema carpenteri* (including a large section of dead specimens, and on a relatively steep slope) (Figure 406) and *Hyalonema (Cyliconema) thomsonis*. Hard substrates were frequently colonized by a diverse sponge community composed of *Pheronema carpenteri*, *Macandrewia azorica, Regadrella phoenix, Farrea occa* and *Stylocordilla pellita*. Some large colonies of *Callogorgia verticillata* – some of them dead or damaged – were also present. We also noticed the presence of some cup corals such as *Leptopsammia formosa* and occasionally the foraminifera *Syringammina fragilissima.*

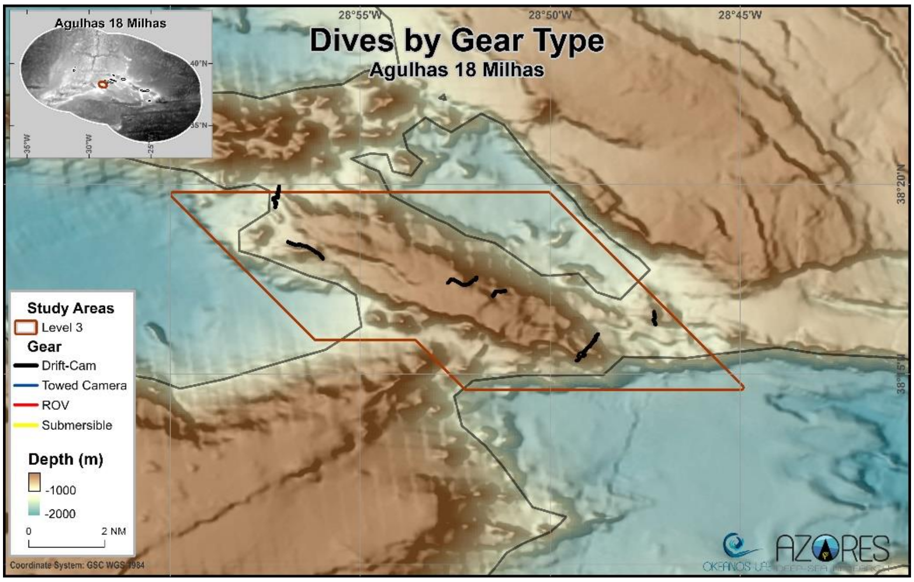



**Figure 405.** Map displaying the 7 underwater dives performed in the Agulhas 18 Milhas area between 380 and 890 meters depth.

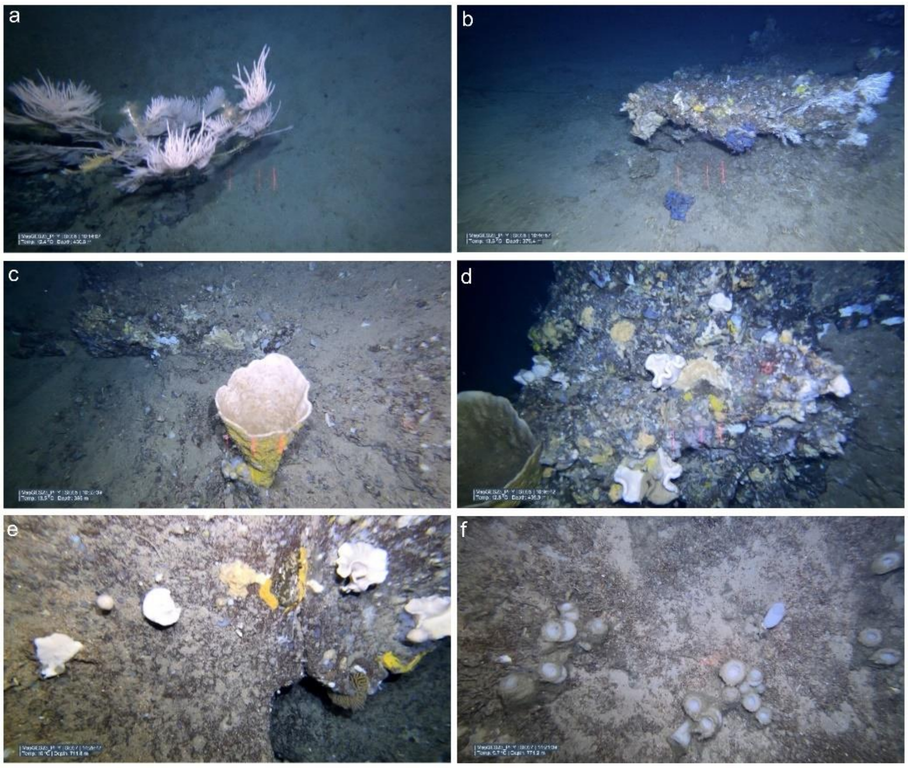



Figure 406 Selected images representative of the main structuring species and benthic communities observed in Agulhas 18 Milhas area. (a) Rock with *Callogorgia verticillata.* (b) Boulder densely colonized by sponges, including two morphotypes of *Leiodermatium* sp., and the hydrocoral *Errina dabneyi.* (c) Large exemplar of sponge *Characella pachastrelloides.* (d) Rocky area heavily colonized by a wide variety of sponges, including encrusting sponges, *Phlyctaenopora (Phlyctaenopora) bitorquis* and *Neophrissospongia nolitangere* and *C. pachastrelloides.* (e) Assemblage of *Macandrewia azorica* together with other sponges and a octocoral. (f) Aggregation of the “bird nest” sponge *Pheronema carpenteri* with a glass sponge. Image credits: IMAR/Okeanos-UAz, Azor drift-cam

*Bourée NE*

In the Bourée Northeast area, 7 underwater video transects were completed between the depths of 590 and 920 m (Figure 407). A total of 64 taxa were identified from the images, with 38 determined at the species level, revealing a medium diversity of deep-sea megabenthic species for the area. The most frequently observed taxa based on weighted occurrences include *Syringammina fragilissima* (n= 44), *Farrea occa* (n= 39), and *Pheronema carpenteri* (n= 32).

Coral communities were essentially found on the shallowest parts explored on basaltic substrates and were composed of *Narella versluysi* and *Narella bellissima* together with other more sporadic species such as *Hemicorallium niobe* (Figure 408) and *Pliobothrus symmetricus*. An aggregation of a small, pink-coloured soft coral was also present at around 600m deep. Outcropped bottoms, as well as basaltic boulders, between 700 and 800 m were mainly characterized by aggregations of the sponge *Pheronema carpenteri* (Figure 408). Sometimes, besides *Pheronema carpenteri* other associated species such as octocorals of the species *Hemicorallium niobe* and a small aggregation of both *Narella belissima* and *N. versluysi* were also observed. The deepest parts explored were characterized by low biodiversity, mostly covering soft sediment and some bare basalt outcrops, in which we drifted over some foraminifera from the species *Syringammina fragilissima* and some echinoderms such as *Cidaris cidaris* and *Peltaster placenta*. The only exception was one large but isolated *Hemicorallium tricolor* (Figure 408) colony. Some of the most frequently spotted sponge species included *Pheronema carpenteri*, *Macandrewia azorica, Regadrella phoenix* (Figure 408)*, Farrea occa, Aphrocallistes beatrix* complex and *Asconema fristedti*, as well as some unidentified medium-sized demosponges. We also noticed several bluemouth rockfish *Helicolenus dactylopterus*.

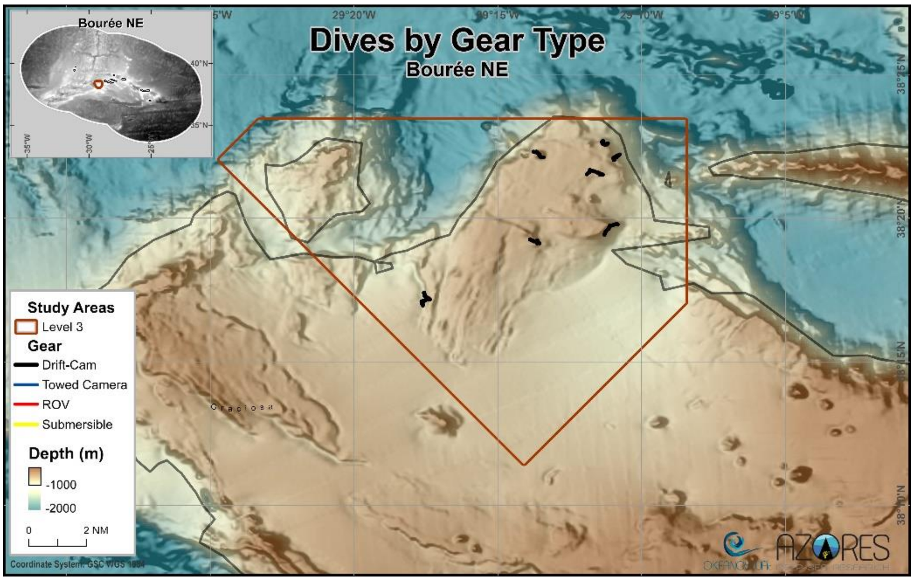



**Figure 407.** Map displaying the 7 underwater dives performed in the Bourée NE area between 590 and 920 meters depth.

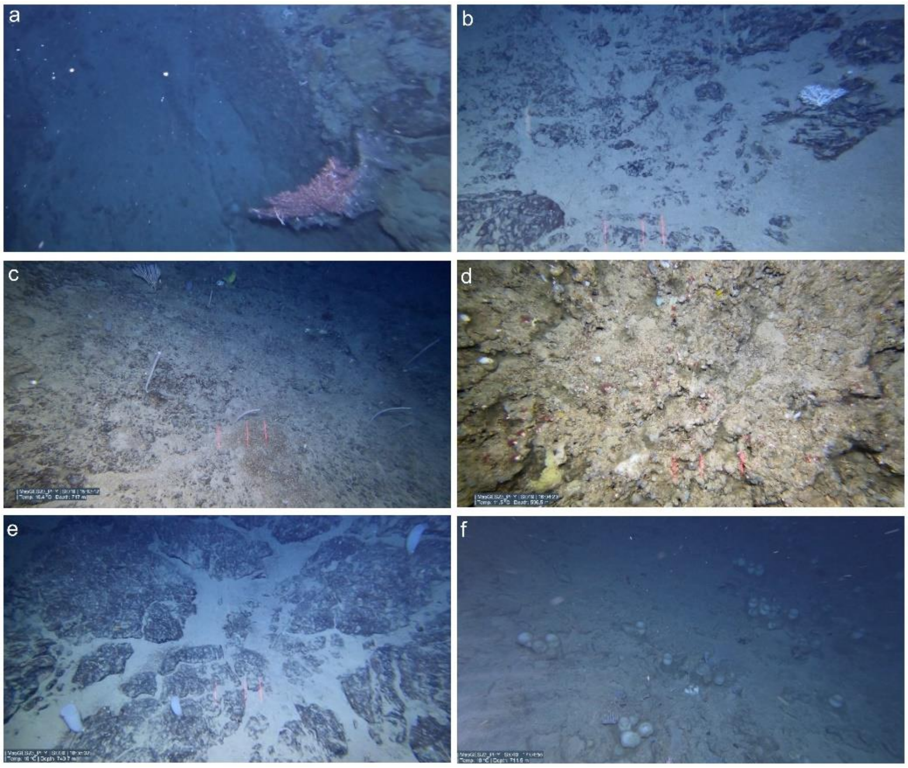



**Figure 408** Selected images representative of the main structuring species and benthic communities observed in Bourée Northeast area. (a) Colony of *Hemicorallium tricolor* (b) Colony of *Hemicorallium niobe.* (c) Assemblage of *Narella versluysi* and *Narella bellissima* with occasional occurrence of sponges. (d) Aggregation of an unidentified pink coloured soft coral. (e) Rocky bottom with glass sponges *Regadrella phoenix.* (f) Aggregation of the bird's nest sponge *Pheronema carpenteri*. Image credits: IMAR/Okeanos-UAz, Azor drift-cam

*Bourée E*

Navigating through the Bourée East area, 3 underwater video transects were performed between 750 and 1000 m depth (Figure 409). The findings suggested a medium diversity of deep-sea megabenthic species, with 65 taxa determined from the videos analysed. Of these, 37 were identified at the species level. The most frequently observed taxa based on weighted occurrences were *Pheronema carpenteri* (n= 14), Plexauridae (n= 10), and *Farrea occa* (n= 8).

The geomorphological unit located at the easternmost section of the Bourée seamount was surveyed with the help of an ROV, which allowed us to survey the deepest areas of the features in this area. The deepest sectors explored were quite barren, with occasional large basalt vertical walls and outcrops only colonized by a few glass sponges of the species *Farrea occa* (Figure 410), some Brachipods and a few *Leptosammia formosa*. We also hovered over lots of dead bivalves, possibly belonging to the species *Acesta excavata*. Only a few meters up, the biggest highlight of this unit appeared when we started to observe large vertical walls covered in surprisingly large and lush black coral colonies of the species *Leiopathes* cf. *expansa* (Figure 410), which looked extremely long-lived, probably several thousand years old, densely covering large extensions of these outcrops with lots of associated biodiversity. On the shallower depths explored, at the peak of these large rocks, it was often possible to detect aggregations of the bird's nest *Pheronema carpenteri* (Figure 410). Apart from this we also covered an extensive, flat, and sedimentary area colonized by the glass sponges *Hyalonema thomsonis* and, again, *Pheronema carpenteri*.

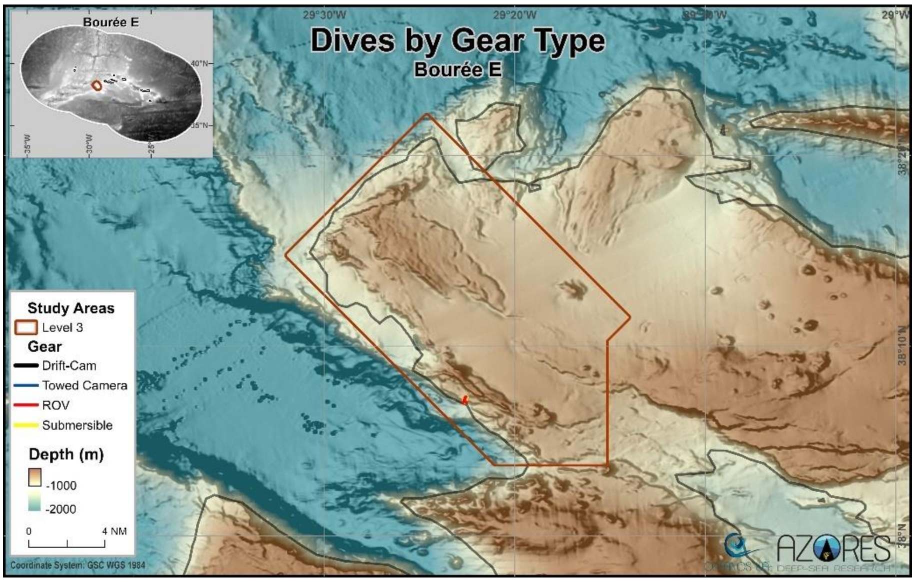



**Figure 409.** Map displaying the 3 underwater dives performed in the Bourée E area between 750 and 1000 meters depth.

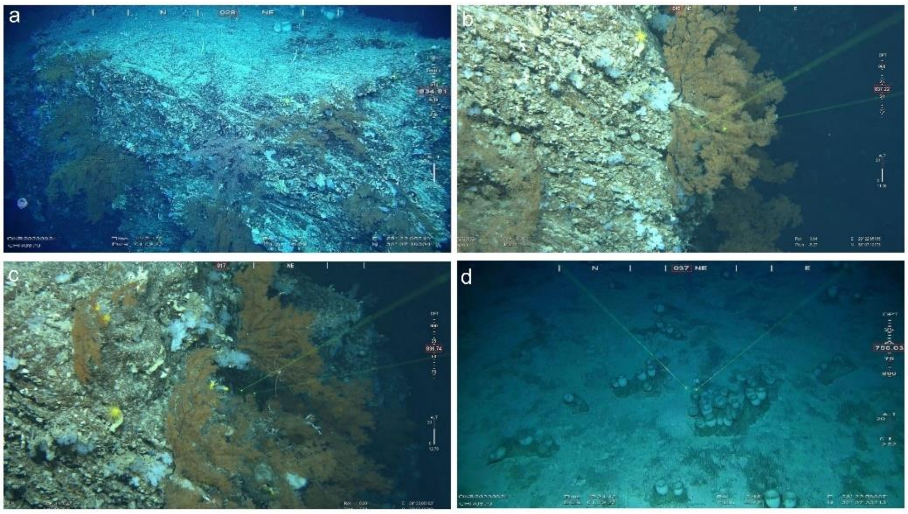



**Figure 410** Selected images representative of the main structuring species and benthic communities observed in Bourée East area. (a) Vertical wall colonized by black corals *Leiopathes* cf. *expansa.* (b-c) Colonies of black coral *Leiopathes* cf. *expansa*, one with *Sternostylus formosus* associated with, on a vertical wall together with scleractinians and glass sponges. (d) Aggregation of the bird's nest sponge *Pheronema carpenteri*. Image credits: OceanX, Okeanos-UAç

*Açor*

In the Açor area, 4 underwater video transects were conducted between 290 and 690 m depth (Figure 411). A total of 116 taxa were determined from the video analysis. From these, 67 were identified at the species level, indicating that this area supports a very high diversity of deep-sea megabenthic species. The most frequently observed taxa based on weighted occurrences include *Plesionika* (n= 30), *Flabellum* sp. (n= 24), and *Haliclona (Soestella) implexa* (n= 18).

In the shallowest explored areas, at around 300m deep, the substrate was mainly composed of basaltic outcrops with a considerable number of sponge species like: *Characella pachastrelloides*, *Leiodermatium*, *Pachastrella* spp. and *Phakellia ventilabrum*. Between 315 and 483m deep, the substrate was characterized by outcropped areas covered with sediment, in which we observed a big variety of sponges such as *Haliclona implexa*, *Neophrissospongia nolitangere* (Figure 412), *Pachastrella* spp., *Phakellia ventilabrum* and other. These last two appeared associated with the whip coral *Viminella flagellum*. An interesting association of the black coral *Elatopathes abietina* with the whip coral *Viminella flagellum* (Figure 412), at around 428 m deep was also recorded. A big and dense aggregation of *Cidaris cidaris* (Figure 412) was also observed between 350 and 582 m deep. At around 550 m depth, several fish were recorded, such as *Arnoglossus rueppeli*, *Coelorinchus caelorhincus* and *Capros aper*. The deepest areas at around 740 m were characterized by soft sediment covered with coral rubble, in which only small or encrusting sponges were spotted.

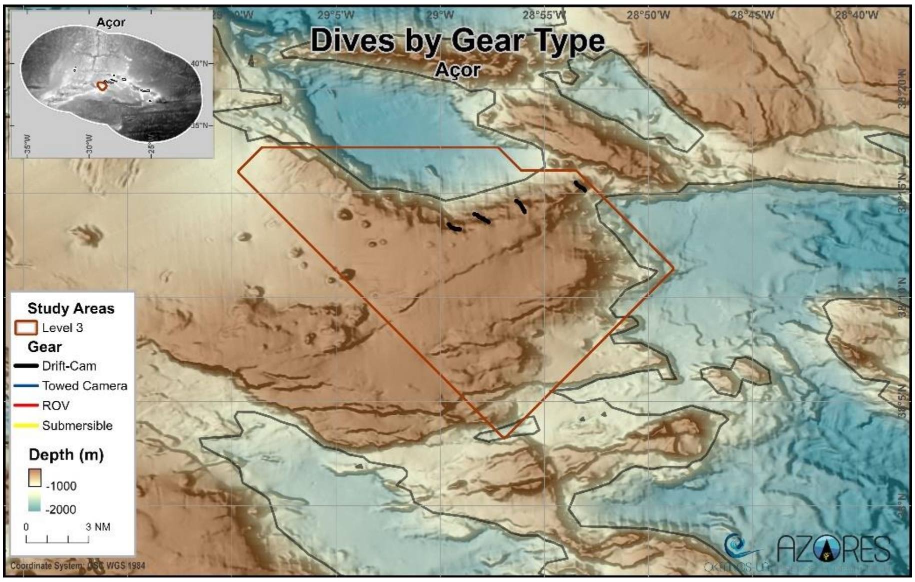


**Figure 411.** Map displaying the 4 underwater dives performed in the Açor area between 290 and 690 meters depth.

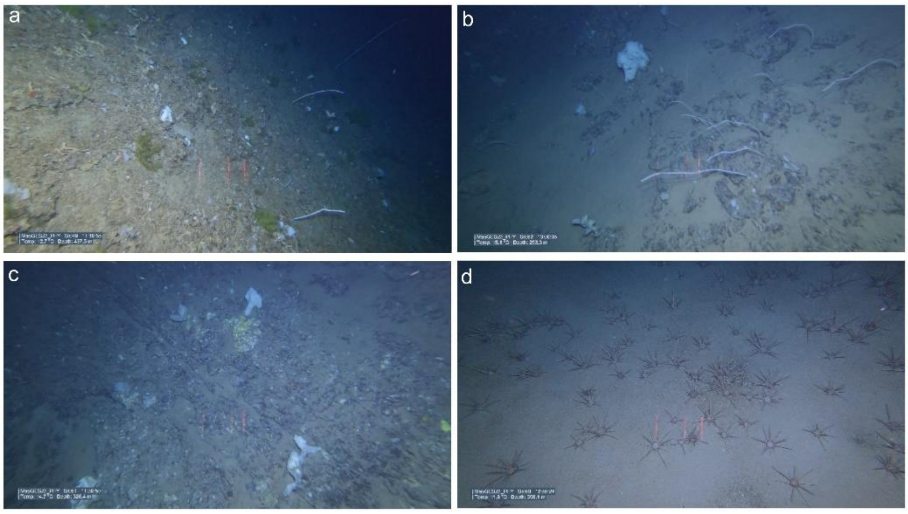



**Figure 412** Selected images representative of the main structuring species and benthic communities observed in Açor seamount. (a) Hard substrate colonized by sparce colonies of *Viminella flagellum* and the black coral *Elatopathes abietina* and several small sponges. (b) Dispersed aggregation of *Viminella flagellum* and sponges. (c) Hard bottom colonized by several sponge species, including *Poecillastra compressa* and *Neophrissospongia nolitangere.* (d) Large aggregation of the sea urchin *Cidaris cidaris.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam

*Açor S*

Through the Açor South area, 2 underwater video transects were performed between 200 and 920 m depth (Figure 413). The results revealed a high diversity of deep-sea megabenthic species, with 85 taxa determined from the video analysis. Of these, 53 were identified at the species level. The most frequently observed taxa based on weighted occurrences were *Echinus melo* (n= 9 weighted occurrences), *Characella pachastrelloides* (n= 8), and *Errina dabneyi* (n= 6).

Even though this area is an important fishing ground, being subject to high degrees of fishing effort, a considerable variety of benthic communities was observed. On the deepest areas explored, unconsolidated sediments dominate the substrate, where Xenophyophores from the species *Syringammina fragilissima* and tube-dwelling anemones can be frequently seen colonizing these soft grounds. Within the same depth range (1,000m – 800m), vast and dense aggregations of the bird's nest sponge *Pheronema carpenteri* (Figure 414) can also be found dominating the substrate. At around 750m, the first community shifts begin to take place. Tall basalt outcrops with jagged overhangs begin to appear, providing a suitable substrate to which the large bivalves *Neopycnodonte zibrowii* and crinoids *Cyathidium foresti* (Figure 414) can attach. The common association between these two species creates a space-confined but distinct and thriving benthic community, which is composed of several other species, including a wide variety of deep-sea sponges. On the shallowest plateaus explored, numerous lost bottom longlines can be seen stretching across and around the summit, caught in the overhangs hundreds of meters below. Despite the clear signs of human activities, the benthic communities found were distinct. From large fields colonized by the massive sponges *Characella pachastrelloides*, displaying its common array of morphologies, to dense patches of the whip coral *Viminella flagellum* in an unusual association with the lace coral *Errina dabneyi* (Figure 414), these communities were found to be in a relatively good environmental status. Wrekfish *Polyprion americanus* and large shoals of Atlantic horse mackerel *Trachurus trachurus* were also observed at these shallower depths.

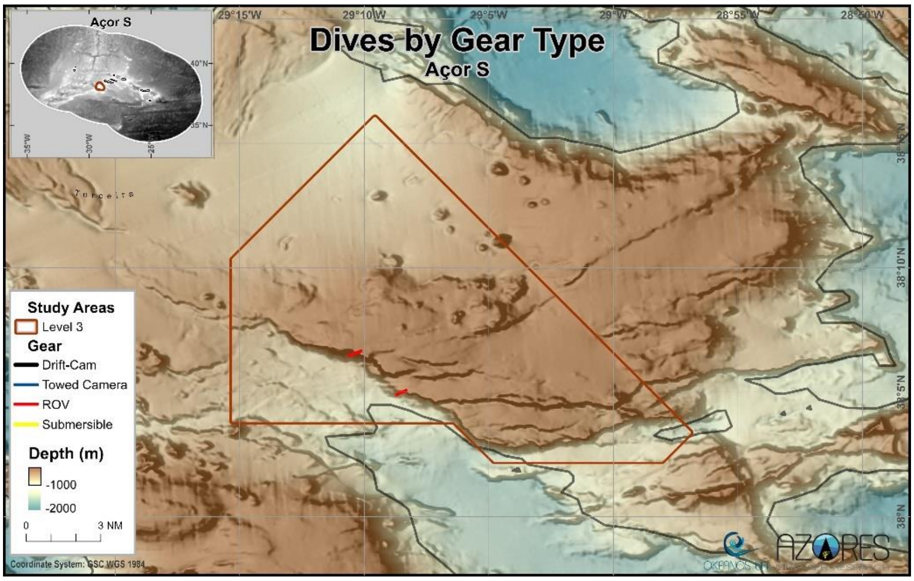



**Figure 413** Map displaying the 2 underwater dives performed in the Açor S area between 200 and 920 meters depth.

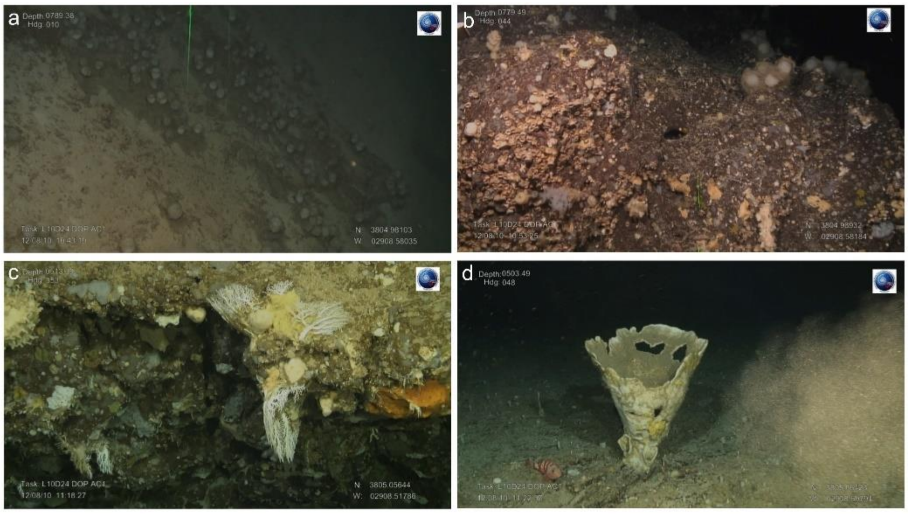



**Figure 414** Selected images representative of the main structuring species and benthic communities observed in Açor seamount. (a) Aggregation of the bird's nest sponge *Pheronema carpenteri.* (b) Living fossil community of the crinoidea *Cyathidium foresti* (c) Vertical wall with small colonies of the stylasterid *Errina dabneyi* with several sponge species. (d) Large sponge *Characella pachastrelloides* with a specimen of the fish *Helicolenus dactylopterus.* Image credits: ROV Luso / EMPEC.

*De Guerne N*

While surveying De Guerne North area, 10 underwater video transects were completed between 530 and 960 m depth (Figure 415). A total of 93 taxa were determined from the images, with 54 identified at the species level, indicating that this area supports a high diversity of deep-sea megabenthic species. The most frequently observed taxa based on weighted occurrences include *Farrea occa* (n= 72), Ceriantharia (n= 59), and Plesionika (n= 41).

Most of the area surveyed was characterized by basaltic outcrops covered with sediment and coral rubble. The basaltic outcrops and vertical walls were colonized by small or encrusting sponges such as *Macandrewia azorica* and *Geodia* sp. In some of them, occasional *Leiopathes* cf. *expansa* (Figure 416) and *Hemicorallium niobe* colonies were found. At 600m some lamellate sponges *Desmacella grimaldi,* sponges belonging to the genus *Geodia* and a decapod *Paromola cuvieri* were also observed. Aggregations of *Narella belissima* with *Narella versluysi* and *Asconema fristedti* (Figure 416) were present, colonizing extensive areas of the seafloor at around 700m deep. The benthic communities observed at greater depths were dominated by some aggregations of *Pheronema carpenteri* and *Acanella arbuscula* (Figure 416), *Leptopsammia formosa* and some *Hemicorallium tricolor*. Black coral colonies of *Leiopathes* cf. *expansa* with associated decapods *Sternostylus formosus* (Figure 416) were sighted, as well as the wreckfish (*Polyprion americanus*), between 740 and 580 m deep.

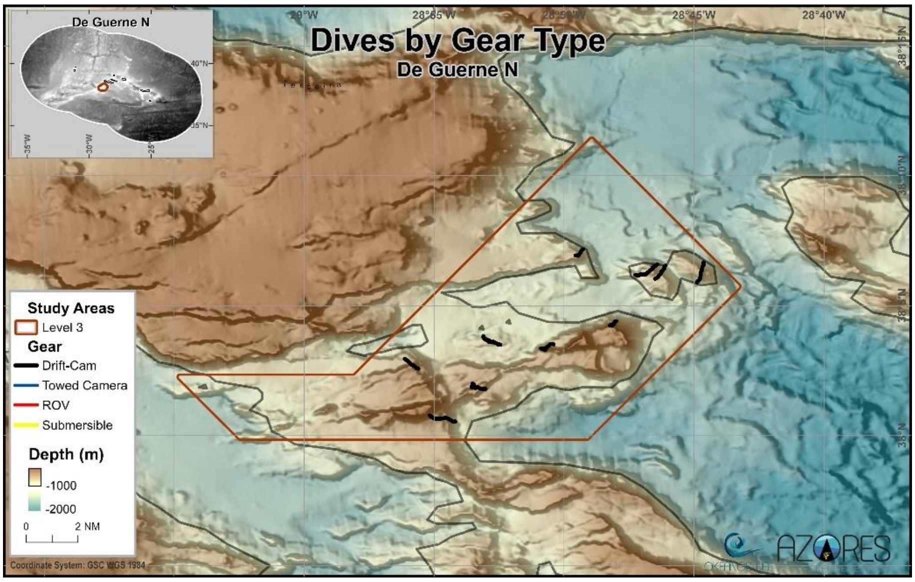



**Figure 415** Map displaying the 10 underwater dives performed in the De Guerne N area between 530 and 960 meters depth.

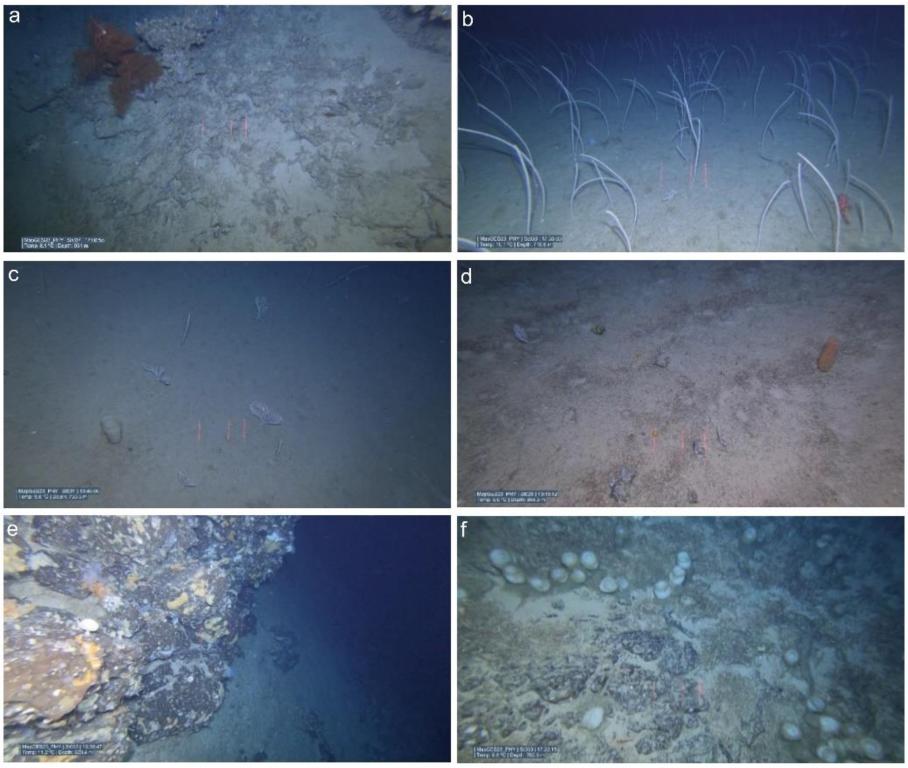



Figure 416 Selected images representative of the main structuring species and benthic communities observed in De Guerne North area. (a) *Leiopathes* cf. *expansa* with the crab *Sternostylus formosa* associated with. (b) Aggregation of *Narella versluysi* and *Narella bellissima.* (c) Dispersed aggregation of *N. versluysi* with *N. bellissima* and the sponge *Asconema fristedti.* (d) Bamboo coral *Acanella arbuscula.* (e) Boulder densely colonized by small and encrusting sponges, including *Macandrewia azorica.* (f) Aggregation of the hexactinellid sponge *Pheronema carpenteri.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*De Guerne*

In the De Guerne area, 2 underwater video transects were conducted between 400 and 900 m depth (Figure 417). The analysis disclosed a medium diversity of deep-sea megabenthic species, with 59 taxa determined from the video data. From these taxa, 33 were identified at the species level. The most frequently observed taxa based on weighted occurrences were *Pheronema carpenteri* (n= 9 weighted occurrences), *Crypthelia* spp. (n= 8), and Plexauridae (n= 7).

The geomorphological unit called De Guerne is a seamount located inside the Princesa Alice seamount complex, in the southern central group of the Azorean archipelago. The range of depth explored with the Azor drift-cam dives, was relatively large which allowed us to describe the communities of benthic megafauna present essentially at parts of the lower and upper slope of the seamount. In general, the areas surveyed were characterized by sand bottom with some gravel and basaltic outcrops covered by soft substrate. There were also sporadic vertical walls. The soft substrate present was normally colonized with patches of the bird's nest sponge *Pheronema carpenteri* (Figure 418) small aggregations, exemplars of the genus *Asconema* (Figure 418) and some foraminifera *Syringammina fragilissima*. Coral biodiversity was generally low, with only some occasional gorgonians of the species *Narella versluysi* and *N. bellissima* (Figure 418) together with cf. *Muriceides* sp. A few bamboo corals *Acanella arbuscula* were also spotted. On the shallower areas, the biodiversity and abundance of sponges was once again greater than that of corals. It was frequent to observe large *Characella* *pachastrelloides* (Figure 418), *Macandrewia azorica*, massive tubular shaped sponges and individuals of the genus *Geodia*. Also present but in smaller sizes were the species *Stylocordyla pellita*, *Aphrocallistes beatrix* and the usually found *Farrea occa*. The corals were essentially composed by the presence of a few black corals of the species *Parantipathes hirondelle* and *Elatopathes abietina*, and gorgonians of the genus *Acanthogorgia*. We also managed to record several fish and deep-sea shark species, such as *Hoplostethus mediterraneus*, *Helicolenus dactylopterus*, *Chaunax pictus, Mora moro*, and several Macrouridae. Regarding other mobile fauna, we drifted over some shrimps *Aristaeopsis edwardsiana*.

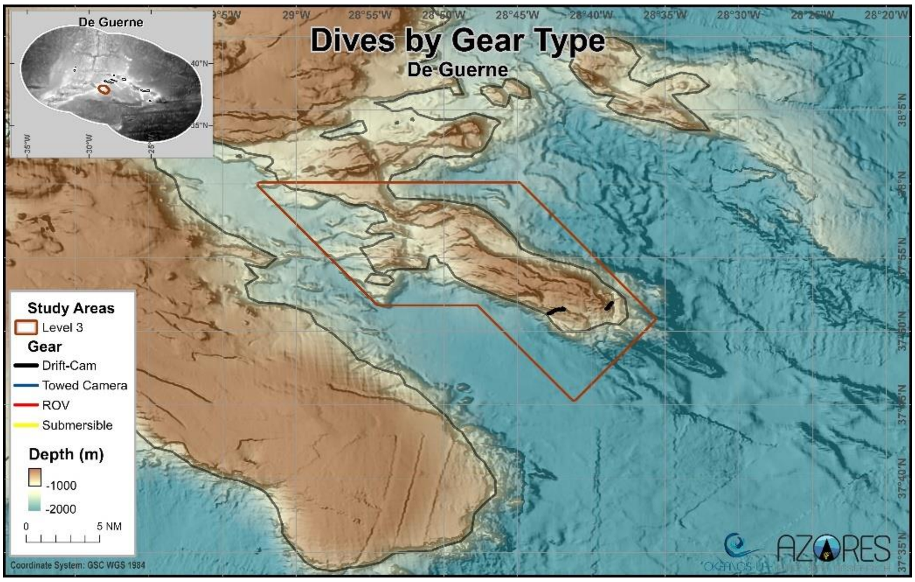



**Figure 417** Map displaying the 2 underwater dives performed in the De Guerne area between 400 and 900 meters depth.

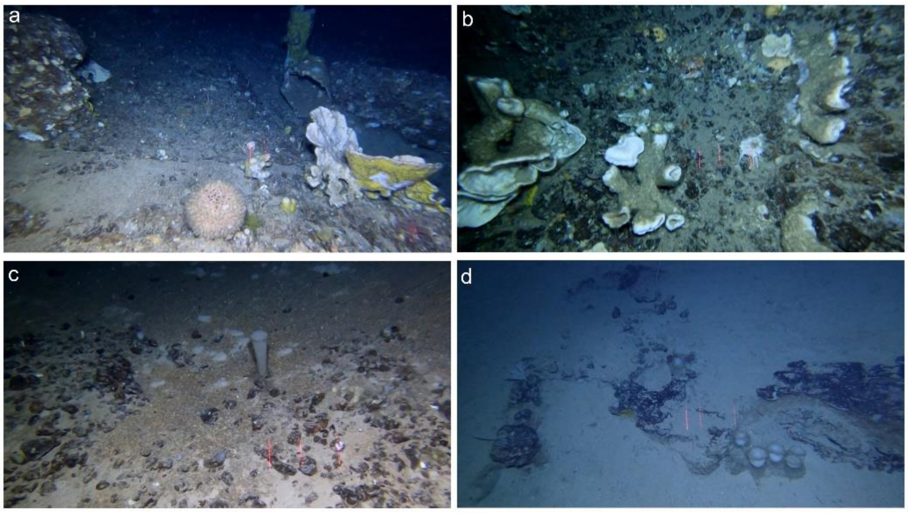



**Figure 418** Selected images representative of the main structuring species and benthic communities observed in De Guerne seamount. (a) Large specimens of the sponge species *Characella pachastrelloides* and *Geodia* sp. in an area densely colonized by a wide variety of small and encrusting sponges. (b) Dense aggregation of several species of sponges. (c) Large sponge *Asconema fristedti.* (d) Area covered with soft sediments and a small aggregation of *Pheronema carpenteri* and the corals *Narella versluysi* and *Narella bellissima.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*São Mateus de Fora*

There were performed 9 underwater video transects in São Mateus de Fora area, between the depths of 440 and 950 m (Figure 419). A total of 88 taxa were identified from the video images, with 57 determined at the species level, revealing a high diversity of deep-sea megabenthic species. The most frequently observed taxa based on weighted occurrences include *Farrea occa* (n= 60), *Haliclona filholi* (n= 44), and *Pheronema carpenteri* (n= 34).

The São Mateus de Fora seamount was mostly characterized by soft bottoms covered with coral rubble and rocky outcrops in uphill sectors, with a variety of benthic communities observed. At around 700 m, the seabed held an assemblage of benthic fauna mostly comprised of *Narella versluysi, Narella bellissima* (Figure 420) and some colonies of *Hemicorallium niobe* (Figure 420) and the glass sponge *Pheronema carpenteri* (Figure 420). Other, more occasional sponge species (e.g., *Characella pachastrelloides* complex, *Regadrella phoenix, Farrea occa, Macandrewia azorica*) were also sighted. A vast section near the top of a crest explored was colonized by a large field of *Asconema fristedti*, between 688 and 744 m deep. On the deepest areas explored, at around 930 m, some bamboo corals *Acanella arbuscula* were found colonizing the seafloor, along with some glass sponges (e.g., *Regadrella phoenix*). However, this community was clearly dominated by the primnoid cf. *Candidella imbricata* (Figure 420), which formed large and dense coral gardens, with some *Narella versluysi* colonies as well. On softer sediments, the faunal assemblage was poorer and mainly consisted of the common bird's nest sponge *Pheronema carpenteri*.

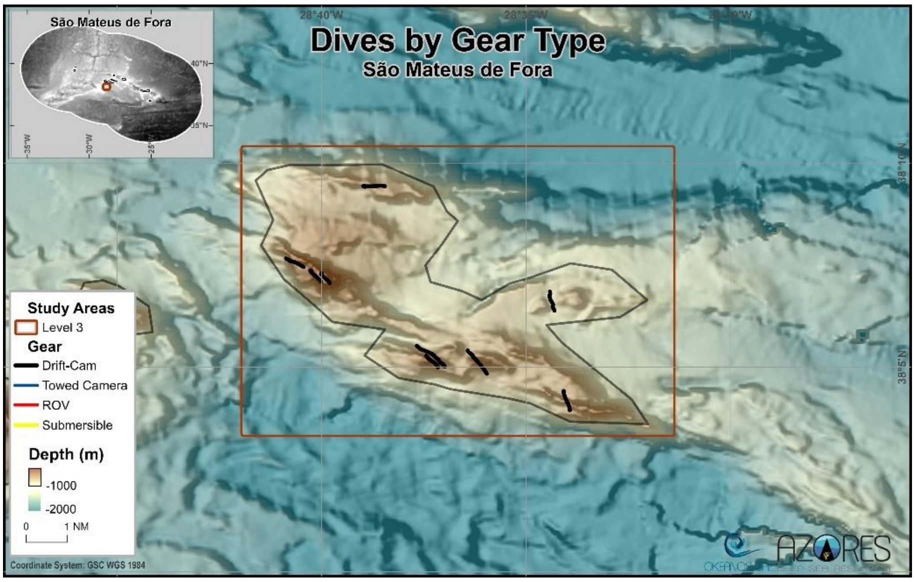



**Figure 419** Map displaying the 9 underwater dives performed in the São Mateus de Fora area between 440 and 950 meters depth.

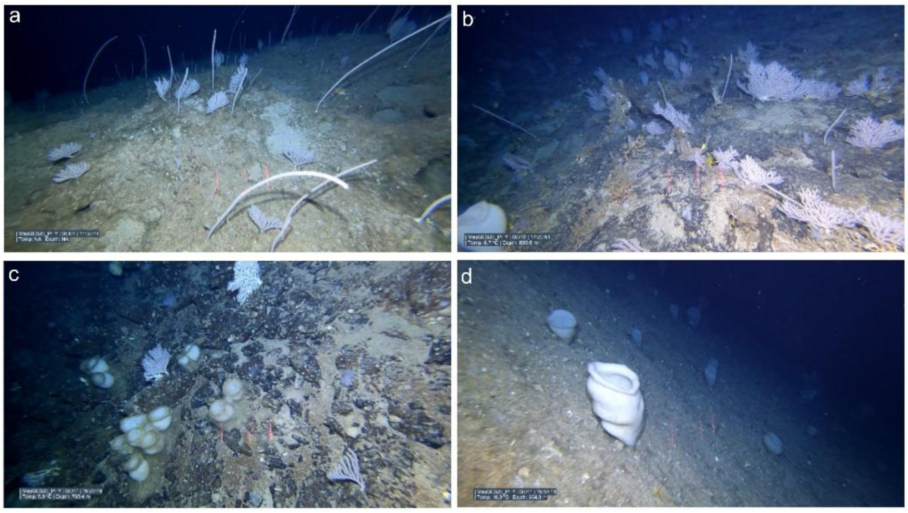



**Figure 420** Selected images representative of the main structuring species and benthic communities observed in São Mateus de Fora area. (a) Large aggregation of *Narella versluysi* and *Narella bellissima.* (b) Rocky bottom covered with patches of soft sediments with an aggregation of the coral species *Candidella imbricata, N. versluysi, Leptopsammia formosa* and glass sponges. (c) *Hemicorallium niobe, N. bellissima* and the sponge *Pheronema carpenteri* on hard substrate. (d) Sparse aggregation of the sponge *Asconema fristedti.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam

*Princesa Alice.*

In the area defined as Princesa Alice, 7 underwater video transects were conducted between the depths of 410 and 1,590 m (Figure 421). A total of 140 taxa were determined from the video analysis. From these, 80 were identified at the species level, indicating a very high diversity of deep-sea megabenthic species. Based on weighted occurrences, the most frequently observed taxa were *Farrea occa* (n= 37 weighted occurrences), *Pheronema carpenteri* (n= 35), and *Desmacella grimaldii* (n= 33).

The Princesa Alice geomorphological unit is a large seamount, divided in several flanks. Some of these flanks were tried to be covered, mainly with the deploying of an ROV. The depth range of the dives performed, allowed us to observe the benthic communities of megafauna present at the slope of these flanks. The topography mainly consisted of large hills, where the substrate of the peaks was consistently tall, vertical basalt walls, while their bases were composed of consolidated sedimentary rock. It was interesting to compare the contrast of faunal compositions associated to each type of substrate. The relatively barren mixed substrate of rock and sand of the deepest areas explored were characterized by a diverse community, mostly of sponge species of *Farrea occa*, *Aphrocallistes beatrix* and *Asconema* sp., *Regadrella phoenix* and sometimes dense patches of the bird's nest sponge *Pheronema carpenteri* (Figure 422) dominating the seafloor. To refer that three large cf. *Haliclona magna* were also observed at these lower sections of the slopes. At these same depths, on the basalt outcrops, several corals were possible to see, mainly of the species of hydrozoa *Pliobothrus symmetricus*, *Leiopathes* cf. *expansa*, *Paragorgia johnsoni*, patches of *Leptopsammia formosa*, *Hemicorallium niobe*, *Acanella arbuscula* and some of the family Paramuricea and genus Plexauridae. At the deepest areas it is also noteworthy to mention the record of oysters *Neopycnodonte zibrowi* under overhangs, together with *Cyathidium foresti*. At slightly shallower areas, a general shift in the communities was observed, now with the predominance of the sponges *Characella pachastrelloides* (Figure 422), along with some others such as *Petrosia crassa*, *Macandrewia azorica*, *Desmacella grimaldii*, *Stylocordyla pellita* and *Phakellia ventilabrum*. The sea urchin Echinus melo start to appear at this level. Large aggregations of the "living fossil" *Neopycnodonte zibrowii* with *Cyathidium foresti* were still present at these areas. The primnoid corals *Narella* spp. and the gorgonian *Pleurocorallium johnsoni* were also recorded. At the shallower depths the sea bottom was composed by large sections of dead coral framework, mostly of *Errina dabneyi* (Figure 422), with some alive colonies as well. The flat tops were colonized by a few large colonies of *Callogorgia verticillata* and very large and in all sorts of morphologies (vase shape, conical, tubular, etc) sponges *Characella pachastrelloides*. Along the slopes explored, several bluemouth rockfish *Helicolenus dactylopterus*, *Mora moro*, *Hoplostethus mediterraneus*, some elasmobranchs e.g., *Dipturus* sp., *Hexanchus griseus* and the monkfish *Lophius piscatorius* were also spotted.

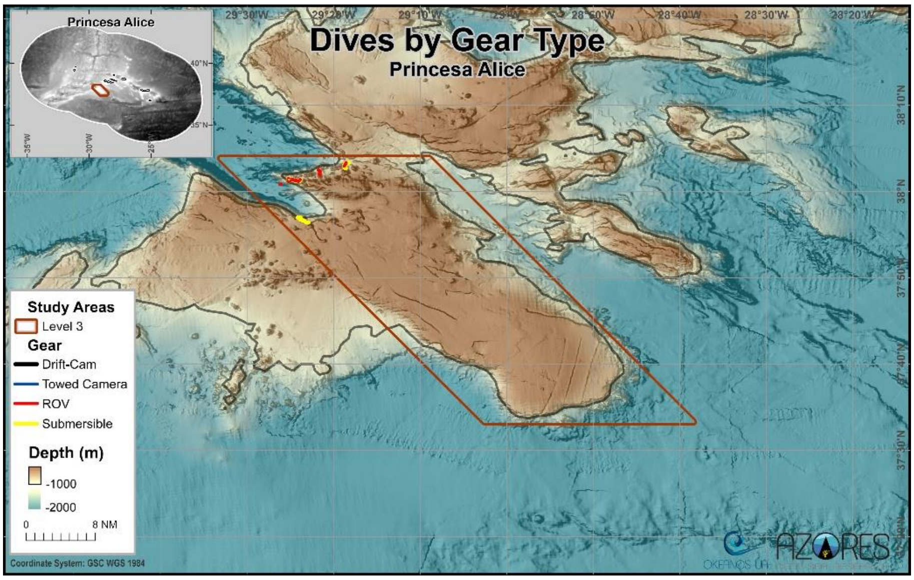



**Figure 421** Map displaying the 7 underwater dives performed in the Princesa Alice area between 410 and 1,590 meters depth.

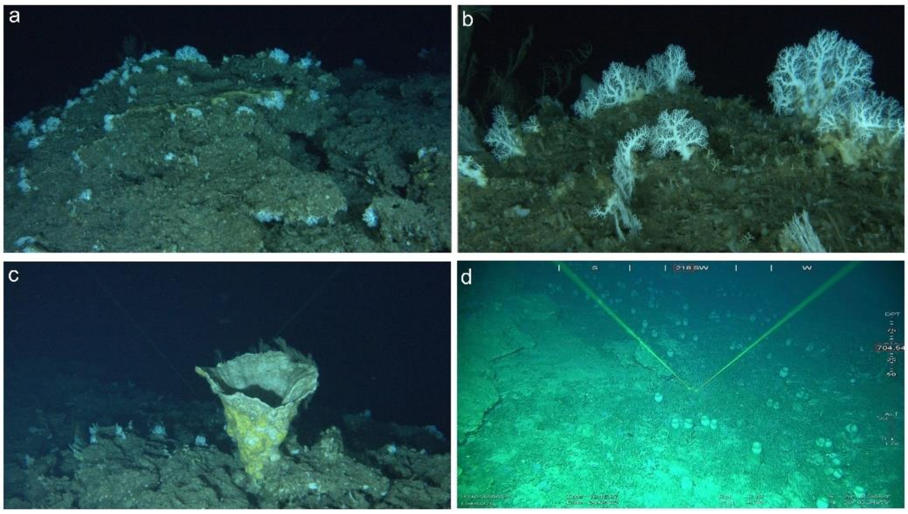



**Figure 422** Selected images representative of the main structuring species and benthic communities observed in Princesa Alice seamount (a-b) Aggregation of the hydrocoral *Errina dabneyi,* together with other hydrozoans and several sponge species. (c) Large sponge *Characella pachastrelloides* in a hard bottom with small colonies of *E. dabneyi*. (d) Aggregation of the hexactinellid sponge *Pheronema carpenteri.* Image credits: OceanX, Okeanos-UAç

*Princesa Alice W*

In the Princesa Alice West area, 8 underwater video transects were performed between 340 and 1010 m depth (Figure 423). From the video data, a total of 94 taxa were determined, with 55 identified at the species level, revealing a high diversity of deep-sea megabenthic species. The most frequently observed taxa, based on weighted occurrences, were *Hymedesmia (Hymedesmia) paupertas* (n= 18 weighted occurrences), *Farrea occa* (n= 13), and *Macandrewia azorica* (n= 12).

The geomorphological unit situated on the western area of the Princesa Alice seamount complex is formed by features that includes small ridges and slopes. The depths covered on these slopes were wide and had given us the general composition of the benthic megafauna present at most of the vertical gradients. In general, the substrate was composed of soft bottoms often covered with coral rubble deposits and with only a few sporadic outcrops and boulders. The deepest areas explored on this unit (around 900-700m), showed both areas with soft and hard substrate. The bottoms with unconsolidated sediments hosted a few foraminifera and some individuals of the glass sponges *Hyalonema thomsonis*, while in the hard ground we were able to observe a variety of coral species such as some colonies of *Hemicorallium niobe*, *Pliobothrus symmetricus,* and *Leiopathes* cf. *expansa* (Figure 424), this last with associated fauna including shark eggs cages, and some fish *Neocyttus helgae* and *Helicolenus dactylopterus*. Still at the lower areas of the slope, but with smaller depths, the substrate was still bare rock with several species of sponges (e.g., *Farrea occa*, *Regadrella phoenix*, *Asconema sp.*, *Stylocordilla pellita, Pheronema carpenteri* (Figure 424)), sparse colonies of cf. *Errina atlantica, Narella versluysi, Narella bellissima, Acanella arbuscula* (Figure 424) and more *Leiopathes* cf. *expansa*. At these depths it was also possible to record a kite fine shark *Dalatias licha* swimming around. On the upper sectors of the slopes and with a decrease in depth we continued observing several sponges dominated communities (e.g., *Characella pachastrelloides*, *Neophrissospongia nolitangere*, *Leiodermatium* sp., *Macandrewia azorica*, among many other smaller sponges and many dead lithistid sponges) and spotted several *Helicolenus dactylopterus*, two wreckfish (*Polyprion americanus*), a conger eel (*Conger conger*). On the shallowest areas explored, the sighting of some colonies of *Callogorgia verticillata* (Figure 424), one crossed by a fishing line, and *Acanthogorgia* spp. was frequent. Curiously a school of *Apogon* sp. living on the crevice was spotted.

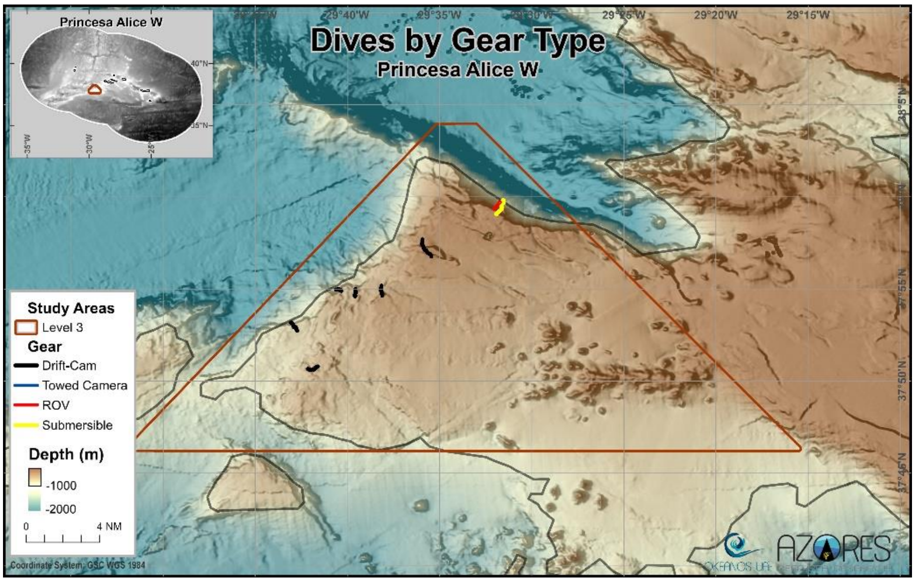



**Figure 423** Map displaying the 8 underwater dives performed in the Princesa Alice W area between 340 and 1,010 meters depth.

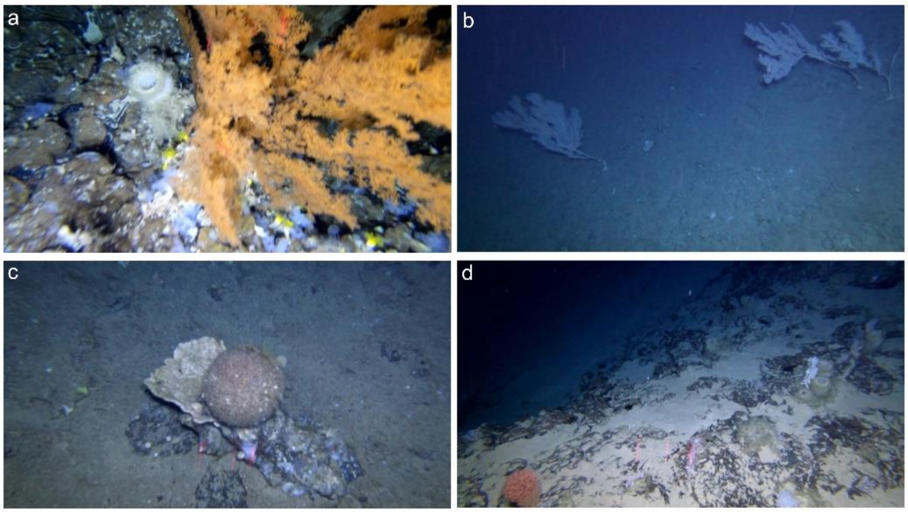



**Figure 424** Selected images representative of the main structuring species and benthic communities observed in Princesa Alice West area. (a) Colony of the black coral *Leiopathes* cf. *expansa* on hard substrate together with several sponge species. (b) Colonies of *Callogorgia verticillata.* (c) Small rock with a large sponge of the genus *Pachastrella* and *Geodia* and other encrusting sponges. (d) Bamboo coral *Acanella arbuscula* with *Pheronema carpenteri* sponges on rocky bottom covered with soft sediments. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Princesa Alice Picos S*

A total of 13 underwater video transects were performed in the Princesa Alice Picos South area, covering a range depth between 600 and 1,020 m (Figure 425). A total of 60 taxa were determined from the videos, with 37 identified at the species level, indicating a medium diversity of deep-sea megabenthic species in this area. The most frequently observed taxa, based on weighted occurrences, were *Pheronema carpenteri* (n= 42 weighted occurrences), *Farrea occa* (n= 35), and *Regadrella phoenix* (n= 29).

This geomorphological unit, located in the enormous complex of the Princesa Alice seamount, is described as a series or a chain of little submarine peaks southern of Princesa Alice. The slopes several of these deep peaks were explored and in general showed to be mostly covered by soft sediments, with abundant coral rubble deposits and a few rocky areas at the upper sectors of the slopes. On the deepest areas surveyed, although with generally low biodiversity, some areas of hard substrate hosted high densities of the primnoid corals *Narella versluysi* and *N. bellissima* and the sporadic spots of other species of corals such as the bamboo *Acanella arbuscula*, and *Hemicorallium* (*H. niobe and H. tricolor*) (Figure 426). Some other deep areas were dominated by patches of the sponge *Pheronema carpenteri*, among others such as *Asconema* sp. (Figure 426), and *Farrea occa*. A bit upper on the slopes, the benthic community didn't differ, with only the sightings of more individuals of the gorgonian coral *Acanthogorgia armata*, and again some patches of dense aggregations of *Narella versluysi* and *N. Bellissima,* and large sponges *Characella* sp. and *Haliclona magna*. It was also possible to observe at these slopes, some of bluemouth rockfish (*Helicolenus dactylopterus*), monkfish (*Lophius piscatorius*), a deep-sea kitefin shark (*Dalatias licha*), and one arrowhead dogfish (*Deania* cf. *profundorum*), pink frogmouth fish (*Chaunax pictus*), *Mora moro*, *Hoplostethus mediterraneus*, *Molva macrophthalma*, and the deep-sea crabs *Chaceon affinis* and *Paromola cuvieri*.

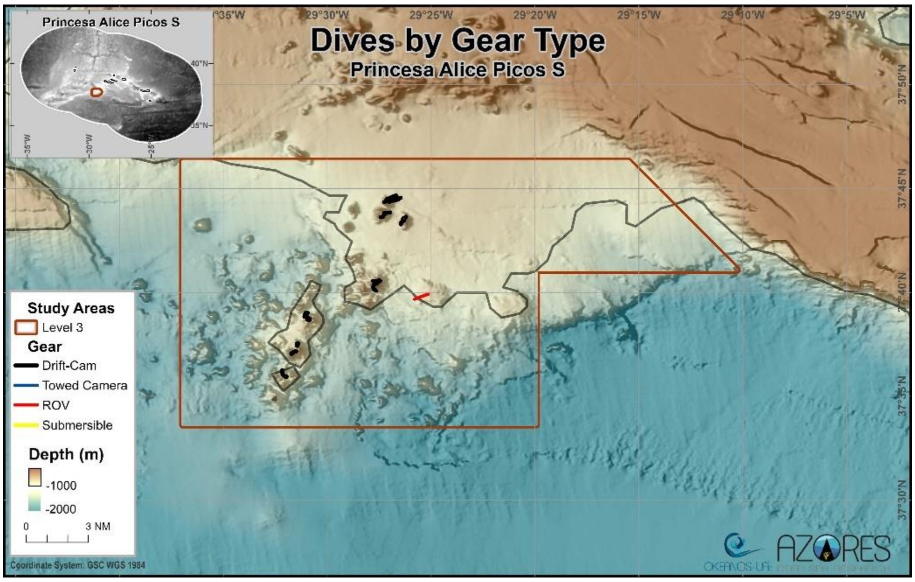



**Figure 425** Map displaying the 13 underwater dives performed in the Princesa Alice Picos S area between 600 and 1,020 meters depth.

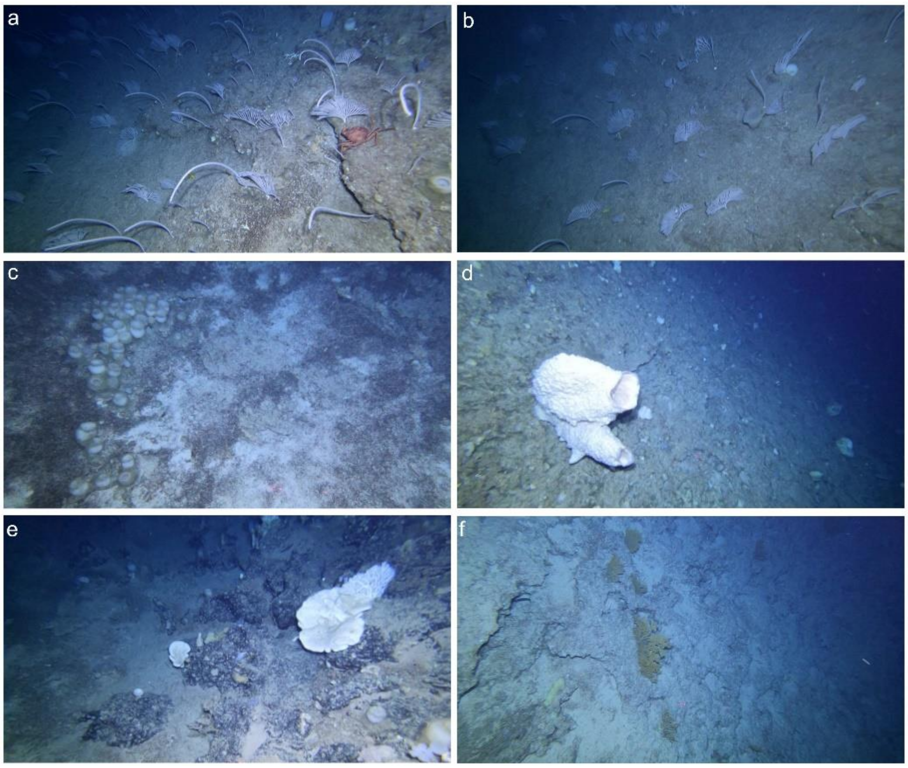



**Figure 426** Selected images representative of the main structuring species and benthic communities observed in Princesa Alice Picos Sul area. (a-b) Aggregation of the primnoids *Narella versluysi* and *Narella bellissima* with sporadic occurrence of sponges *Pheronema carpenteri, Regadrella phoenix* and *Asconema fristedti.* (c) Small aggregation of *Pheronema carpenteri.* (d) Large specimens of the sponge cf. *Haliclona magna* (e) Assemblage composed by the gorgonian *Hemicorallium niobe* together with sponges from genus *Petrosia* and others. (f) Small aggregation of *Acanthogorgia* sp. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Henry Carr*

Exploring Henry Carr area resulted in 3 underwater video transects completed between 770 and 1120 m depth (Figure 427). The results of video data indicated a low diversity of deep-sea megabenthic species, with 47 taxa determined. Among these, 27 were identified at the species level. The most frequently observed taxa based on weighted occurrences were *Leptopsammia formosa* (n= 18), *Regadrella phoenix* (n= 17), and *Acanthogorgia* spp. (n= 13).

It was on the Henry Carr geomorphological unit that we performed one of our deepest dives with the Azor drift-cam., reaching 1120m depth. This is a deep plateau in the Southwestern area of Princesa Alice, and in general the substrate was covered by sand, characteristic of sedimentary environments and with a low and scattered biodiversity of megabenthic fauna. The dives realized at this area, covered always very deep sectors of the slopes of Henry Carr, and the bottom has the same aspect for a depth range that went from around 1120 to 758 m. On the vast extensions of sand, with occasional boulders, that covered the deepest areas, we could find very sporadic colonies of the bamboo coral *Acanella arbuscula*, and the gorgonian *Chrysogorgia* spp., as well as some small aggregations of small individuals of the primnoid corals *Narella versluysi* and *N. bellissima*, normally together with *Hemicorallium Niobe* (Figure 428). The sponges that were present, were usually big individuals, from which we can highlight the observation of the fan shaped *Phakellia ventilabrum*, aggregations of *Pheronema carpenteri* (Figure 428), *Regadrella phoenix*, and very large individuals of *Geodia megastrella* and *Chonelasma choanoides*. At slightly shallower depths, the scleractinian coral *Leptopsammia formosa* was spotted forming a few colonies and we were able to record a frog fish of the genus *Chaunax* and of the species *Mora moro*.

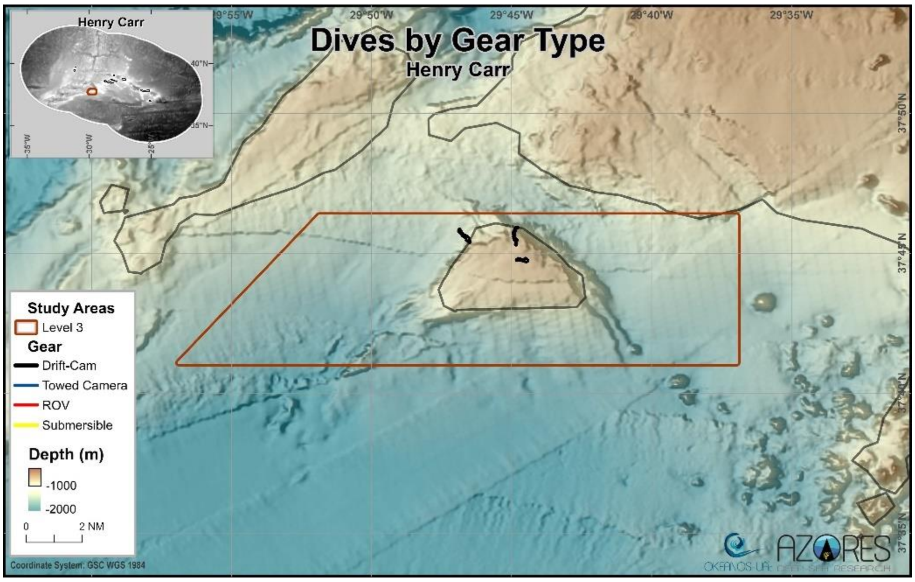



**Figure 427** Map displaying the 3 underwater dives performed in the Henry Carr area between 770 and 1120 meters depth.

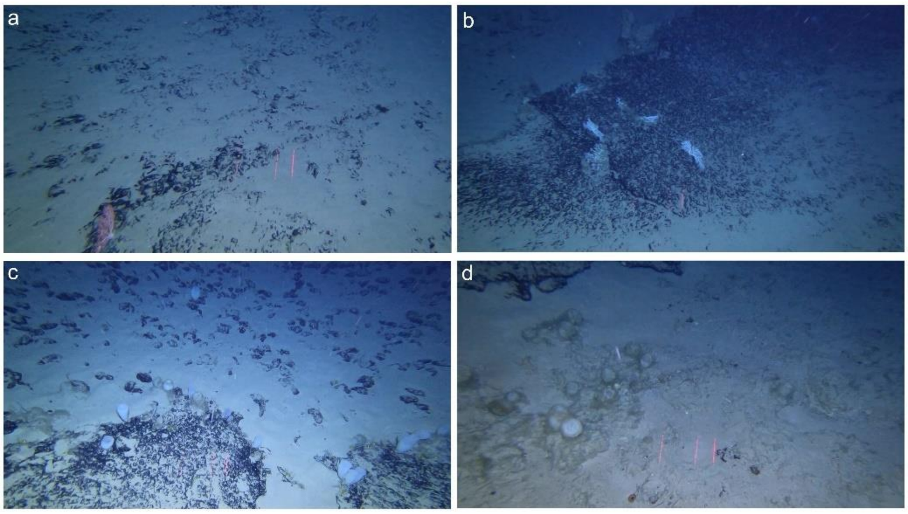



**Figure 428** Selected images representative of the main structuring species and benthic communities observed in Henry Carr area. (a) Colony of *Hemicorallium tricolor.* (b) Basaltic bottom with colonies of *Hemicorallium niobe.* (c) Soft sediments dominated by hexactinellid sponges. (d) Aggregation of the sponge *Pheronema carpenteri.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Princesa Alice SW*

In the Princesa Alice Southwest area, 2 underwater video transects were conducted between 890 and 970 m depth (Figure 429). A total of 21 taxa were determined from the footages, with 14 identified at the species level, indicating a low diversity of deep-sea megabenthic species in this area. The most frequently observed taxa, based on weighted occurrences, were *Farrea occa* (n= 9 weighted occurrences), *Leptopsammia formosa* (n= 8), and Plesionika (n= 6).

The southwestern sector the of seamount complex of Princesa Alice is a geomorphological unit, known for being a deep plateau, along the Albert of Monaco ridge. The dives performed at this area were mostly deep, covering the lower sectors of the area. The biodiversity of megabenthic species was not incredible, but showed to be constant along the transects explored. The rocky bottom, sometimes slightly covered with a layer of sediments, usually found on deep areas, had mainly the presence of some sparse cold-water corals *Narella versluysi*, *N. bellissima*, *Candidella imbricata* (usually forming aggregations together), *Hemicorallium niobe*, *H. tricolor* and the scleractinian *Leptopsammia formosa*, these last three in less abundance (Figure 430). Sponges present were mainly of the species *Farrea occa*, *Pheronema carpenteri*, *Phakellia ventilabrum*, *Desmacella grimaldi* and large *Regadrella phoenix* (Figure 430). It was also possible to spot some shrimps *Aristaeopsis edwardsiana*, some urchins *Cidaris cidaris* and some deep-sea fishes *Mora moro* and of the genus *Chaunax*.

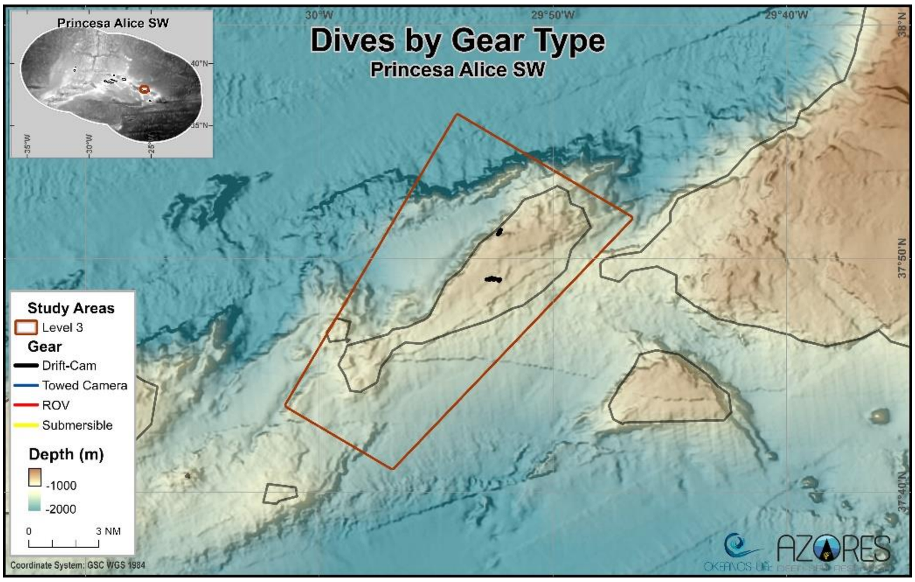



**Figure 429** Map displaying the 2 underwater dives performed in the Princesa Alice SW area between 890 and 970 meters depth.

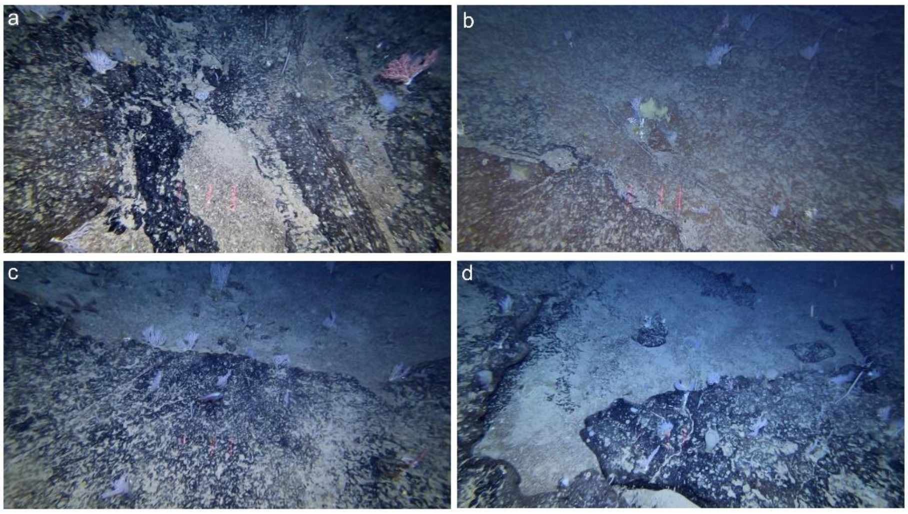



Figure 430 Selected images representative of the main structuring species and benthic communities observed in Henry Carr area. (a) Aggregation of *Candidella imbricata, Narella versluysi* and *Hemicorallium tricolor* together with glass sponges. (b) Basaltic bottom with dispersed colonies of *C. imbricata, Hemicorallium niobe, Leptopsammia formosa* and the lamellate sponge *Desmacella grimaldi.* (c) Assembage of the gorgonian *C. imbricata* on hard and soft bottom. (d) Rock bottom colonized by sponges of the species *Regadrella phoenix, Asconema fristedti* and small primnoids *C. imbricata* and *N. versluysi.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

## *10.7 Large area | Eastern Group*

In the large Eastern Group of the Azores there are four study areas: São Miguel, Mar da Prata, Formigas and Santa Maria, and a total of 23 sampling areas (Figure 431). These areas have been sampled with the Azor drift-cam during the MapGES 2018, MapGES 2022 and 2023 surveys both with MT Physeter and R/V Arquipélago, and during NOAA Expedition using the ROV Deep Discoverer, and the EMEPC (2009) and the Medwaves (2016) surveys.

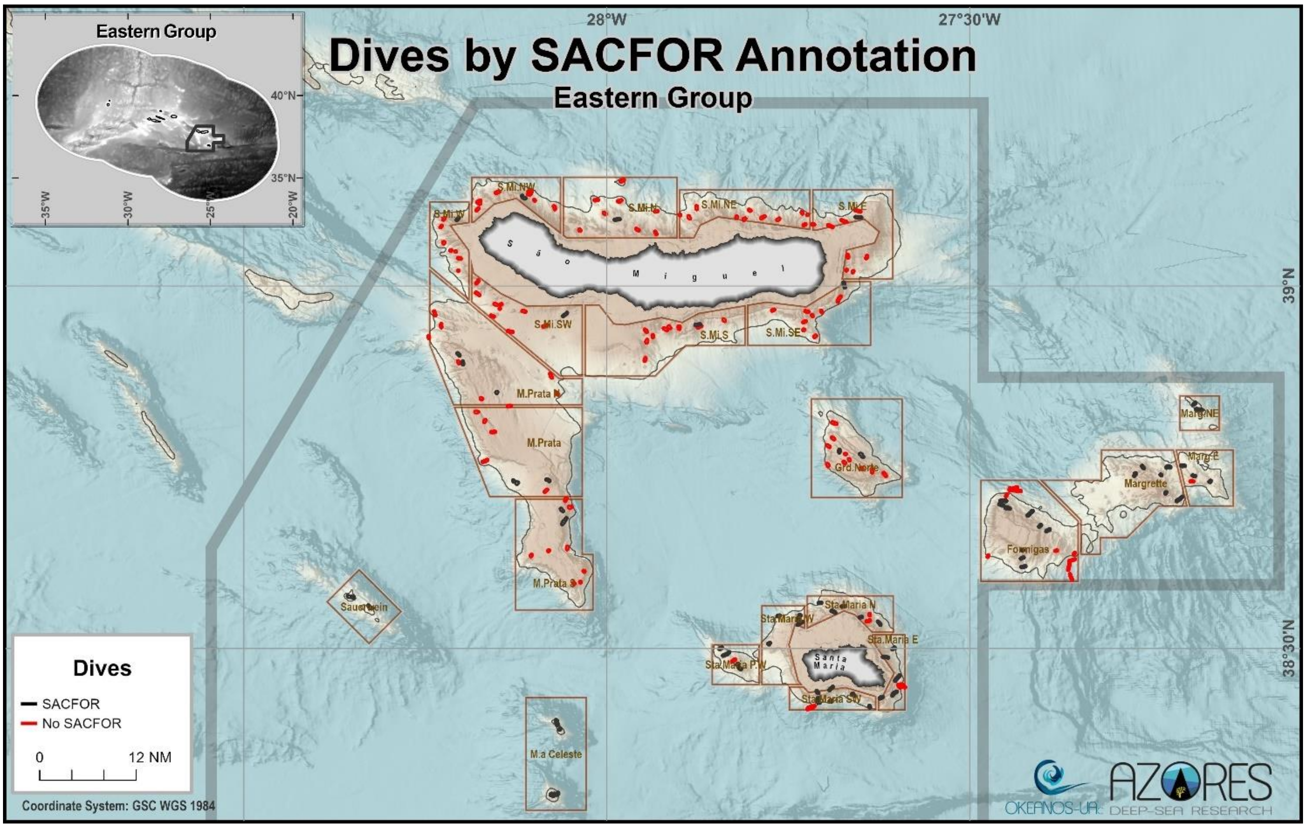



**Figure 431** Eastern Group sampling areas (Level 3) with or without SACFOR dive locations.

Study area | São Miguel

*São Miguel NW*

Surveying São Miguel Northwest area resulted in 9 underwater video transects performed, covering a depth range between 390 and 950 m (Figure 432). The video analysis revealed a total of 37 taxa determined, with 13 identified at the species level, indicating a low diversity of deep-sea megabenthic species in this area. The most frequently observed taxa, based on weighted occurrences, were *Viminella flagellum* (n= 11 weighted occurrences), *Haliclona (Soestella) implexa* (n= 4), and Galatheoidea (n= 3).

The Northwestern area of the slopes of São Miguel Island were characterized by its rocky outcrops and deposits of coral rubble with high aggregations of benthic coral fauna, but very scattered and different among the sites where the Azor drift-cam was deployed. The deepest areas of the slope that were filmed, showed to have a substrate composed mainly by sand and a few horizontal outcrops, hard grounds that made possible to a few aggregations of the gorgonian coral *Candidella imbricata* and some individuals of the family Stylasteridae. At shallower depths the highlight goes to the astonishingly dense and vast colonies of *Narella versluysi* and N. *Bellissima* and two different morphotypes (red and white) of the rarely spotted species *Paragorgia johnsoni* were encountered in specular densities and sizes, which shows an apparently good state of conservation (Figure 433). With the progressively decrement of depth, a shift of benthic biodiversity was observed. The substrate stayed the same, with basaltic outcrops coming out of the soft bottom, in which some individuals of the genus *Flabellum* were found. On the hard substrate colonies of the octocorals *Viminella flagellum*, *Acanthogorgia* spp., and large exemplars of *Callogorgia verticillata* were recorded. Sponges of the species *Farrea occa*, *Macandrewia* *azorica*, *Desmacella grimaldi*, the lamelate *Phakelia ventilabrum* and the genus *Geodia*, were commonly seen through the dives performed on the shallower depths of this geomorphological unit. Is also possible to highlight the sighting of a ray of the species *Dipturus intermedius* swimming above sedimentary grounds and the possible observation of a fish species never seen before in the Azores archipelago, likely of the genus *Halosaurus*.

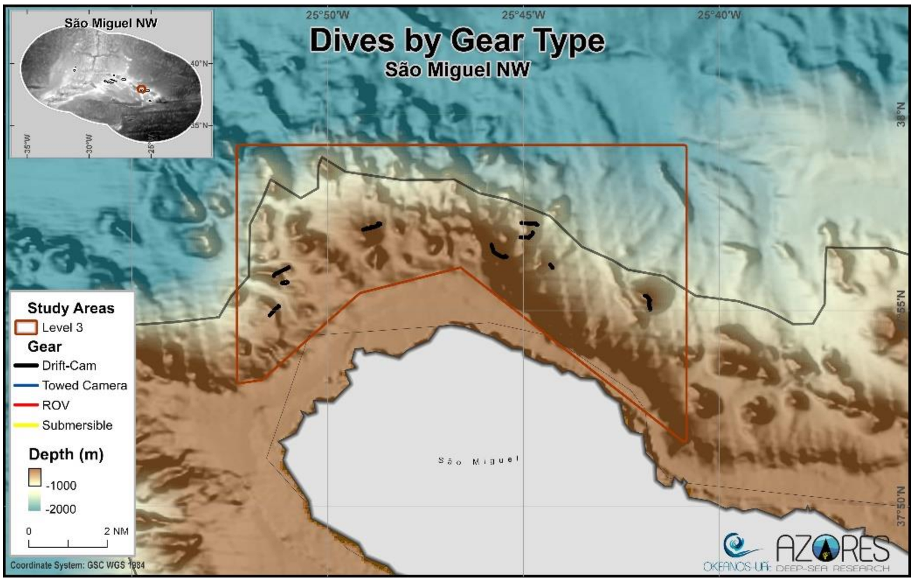



Figure 432 Map displaying the 9 underwater dives performed in the São Miguel NW area between 390 and 950 meters depth.

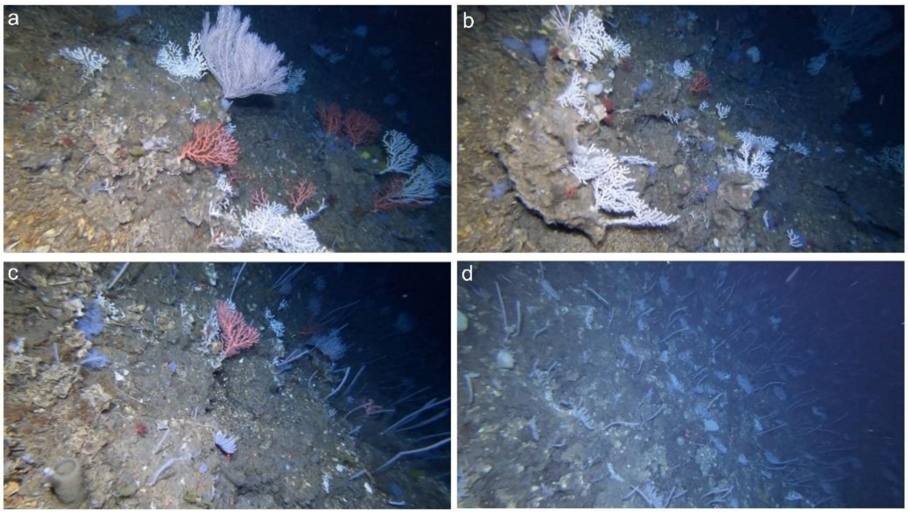



Figure 433 Selected images representative of the main structuring species and benthic communities observed in São Miguel Northwest area. (a-b) Large aggregation of two morphotypes of the coral *Paragorgia johnsoni* together with one colony of *Callogorgia verticillata* with occasional occurrences of the soft-coral *Anthomastus/Pseudoanthomastus* sp. and glass sponges. (c) Basaltic bottom covered with soft sediments colonized by *Narella versluysi* and *N. bellissima* with small colonies of *P. johnsoni* and glass sponges. (d) Dense aggregation of *N. versluysis* and *N. bellissima* and occasional sponge of the genus *Phakellia.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*São Miguel N*

In the São Miguel North area, 10 underwater video transects were conducted between 310 and 980 m depth (Figure 434). A total of 46 taxa were determined from the video analysis, with 23 identified at the species level, indicating a low diversity of deep-sea megabenthic species in this area. The most frequently observed taxa, based on weighted occurrences, were *Plesionika* sp. (n= 16 weighted occurrences), *Lytocarpia myriophyllum* (n= 14), and *Acanthogorgia* spp. (n= 6).

The North area of the São Island showed to be very rich in benthic megafauna, which is curious due to the strong fishing effort known to happen at this area right off the harbour of the widely knew Rabo de Peixe harbour. This geomorphological unit was characterized by a relatively gentle slope and several small seamounts. At the deepest areas explored in this part of the Island the substrate was characterized from sedimentary environments, with the widely presence of soft sediments. The fauna encountered growing on the sandy bottom were mainly composed by a limited biodiversity, with the sightings of hard corals of the genus Flabellum and sparse individuals of the hydrozoan cf. *Lytocarpia myriophyllum* and the bamboo coral *Acanella arbuscula*. At the same depths in the range of 900 to 700m, when basaltic boulders and outcrops were not covered with sand, we were able to record aggregations of the primnoid corals (Figure 435) *Narella versluysi* and *N. Bellissima*, a few individuals of the black coral *Leiopathes* cf. *expansa* and the scleractinian *Leptopsammia formosa*, even if this last have had a slightly more extensive distribution. At the lower areas of the slope, (including the summit) some *Pheronema carpenteri* were also spotted. At shallower depths, the benthic communities shifted, and we were able to record gardens of the gorgonians *Viminella flagellum*, *Acanthogorgia* spp., *Callogorgia verticillata* and unusually large and apparently well-preserved colonies of *Dentomuricea* aff. *meteor* (Figure 435). Porifera diversity and abundance was also substantially higher at the upper slope levels, with the presence of several species such as *Characella pachastrelloides*, *Macandrewia azorica*, white morphotypes of the genus *Leiodermatium* and *Petrosia*, and the glass sponge *Regadrella phoenix*. Motile fauna was widely present with the shark species Deania sp., a Lophius *piscatorius*, the frogfish of the genus *Chaunax* and several exemplars of the commercially important bluemouth rockfish (*Helicolenus dactylopterus*).

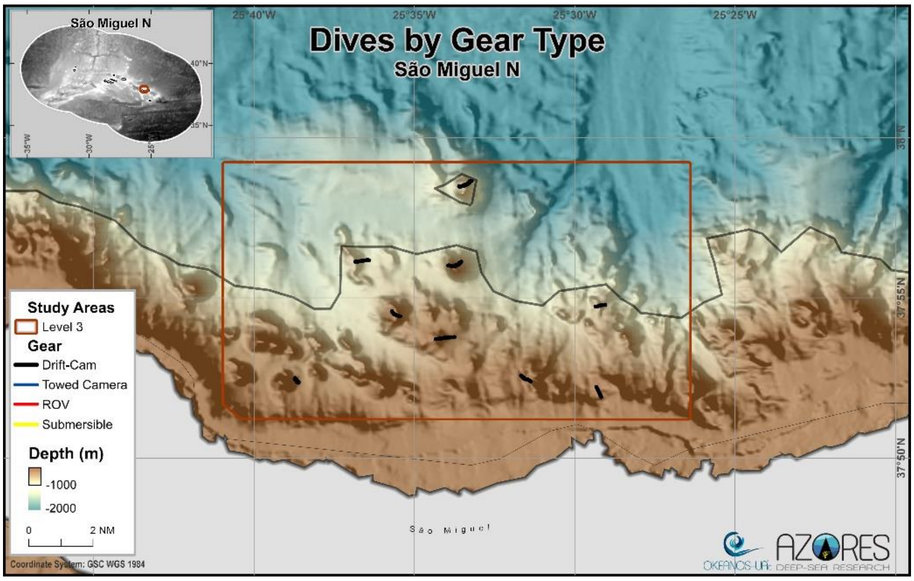



**Figure 434** Map displaying the 10 underwater dives performed in the São Miguel N area between 310 and 980 meters depth.

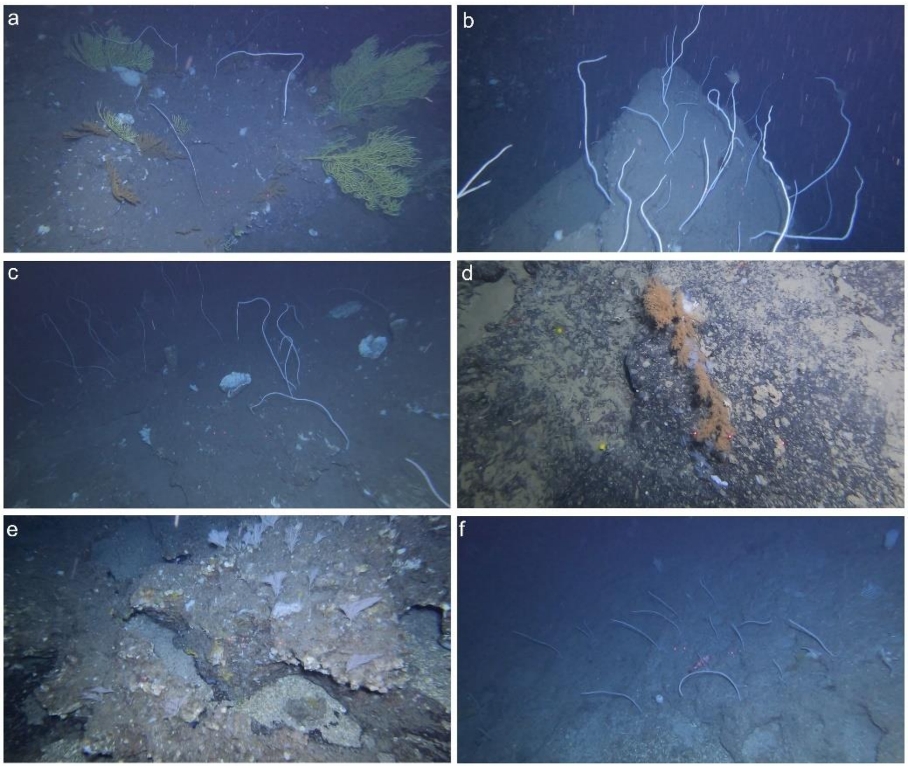



**Figure 435** Selected images representative of the main structuring species and benthic communities observed in São Miguel North area. (a) Rocky area covered by soft sediments with large colonies of *Dentomuricea* aff. *meteor, Viminella flagellum* and *Acanthogorgia* sp. and several species of sponges. (b) Large aggregation of *V. flagellum*. (c) Outcrops with large colonies of *V. flagellum* and sponges of the genus *Characella* and others. (d) Colony of *Leiopathes* cf. *expansa* and glass sponge *Farrea occa* on basaltic bottom. (e) Aggregation of small colonies of *Callogorgia verticillata* on hard substrate covered with some encrusting sponges. (f) Sparse aggregation of *Narella versluysi* and *Narella bellissima* together with few species of sponges. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*São Miguel NE*

In São Miguel Northeast area, 11 underwater video transects were performed between 270 and 940 m depth (Figure 436). A total of 26 taxa were determined from the video data, with 13 identified at the species level, indicating a low diversity of deep-sea megabenthic species in this area. The most frequently observed taxa, based on weighted occurrences, were *Flabellum* sp. (n= 9 weighted occurrences), Ceriantharia (n= 4), and *Phlyctaenopora (Phlyctaenopora) bitorquis* (n= 2).

The northeastern area of São Miguel Island did not present high densities or diversity of benthic megafauna. The type of substrate related from the deeper sectors of the explored slopes, showed to be principally composed of sand and clay, sometimes with the occurrence of coral rubble, more characteristic of the deeper sites (around 900-800m). The fauna observed at these deeper levels was very limited, since it was essentially corals of the species cf. *Lytocarpia myriophyllum* and the genus *Flabellum*, and individuals of the class Ceriantharia showed a noteworthy amount. On the shallower sectors of the slopes analysed, the presence of fauna was more notorious, where it was possible to record basaltic boulders and outcrops covered with relatively large aggregations of the octocorals *Acanthogorgia* spp., *Callogorgia verticillata, Viminella flagellum, Dentomuricea* aff. *meteor,* being these last two composed of large individuals (Figure 437). The sponges *Characella pachastrelloides* (Figure 437), *Leiodermatium* sp., the fan shaped *Phakellia ventilabrum* and *Geodia* sp., were often found during the dives performed and usually showing big sizes. Regarding motile fauna, the shallower areas were place for often sights of specimens from Macrouridae family, individuals of the species *Capros aper, Helicolenus dactylopterus,* the crustacean *Paromola cuvieri* and the highlight that is the second sighting of a possibly new species for the Azorean archipelago, *Gaidropsarus* sp.

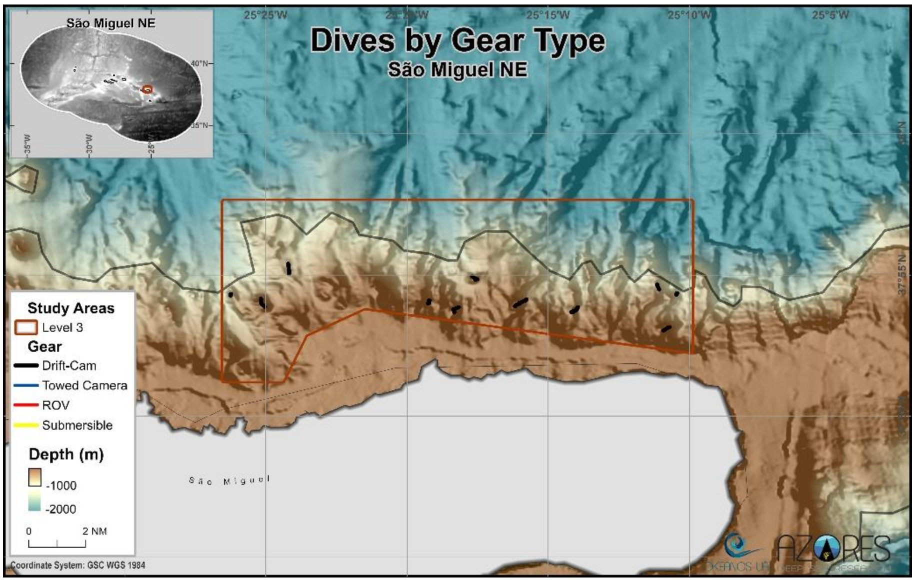



**Figure 436** Map displaying the 11 underwater dives performed in the São Miguel NE area between 270 and 940 meters depth.

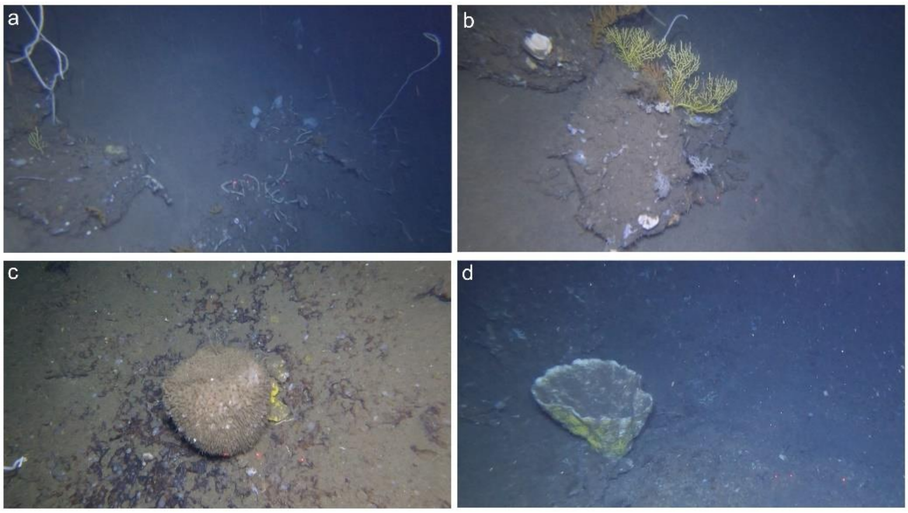



**Figure 437** Selected images representative of the main structuring species and benthic communities observed in São Miguel Northeast area. (a) Area covered by soft sediments colonized by large colonies of *Viminella flagellum,* small colonies of *Dentomuricea* aff. *meteor, Acanthogorgia* sp. and several species of sponges. (b) Boulder colonized by colonies of *D.* aff. *meteor* and *Acanthogorgia* sp. and a wide variety of sponges, *Haliclona implexa* and others. (c) Basaltic bottom with soft sediments covered with encrusting sponges and a *Geodia* sp. (d) Large *Characella pachastrelloides.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*São Miguel E*

While exploring São Miguel East area, 9 underwater video transects were conducted between 320 and 910 m depth (Figure 438). The analysis unveiled a low diversity of deep-sea megabenthic species, with 35 taxa determined from the video data. Of these, 19 were identified at the species level. The taxa most frequently observed based on weighted occurrences were *Plesionika* (n= 12 weighted occurrences), Ceriantharia (n= 8), and Bryozoa (n= 7).

For the exploration of the geomorphological unit situated on Eastern sector of the São Miguel Island slopes, the bathymetric range was very wide, allowing for a benthic community analysis at the different vertical levels of the slope. The most remote bathymetrical areas surveyed showed to have a mostly soft substrate, distinguished by their lack or low density and diversity of benthic megafauna, with almost only the presence of the foraminifera cf. *Syringammina fragillissima* (Figure 439), small shrimps and fishes (mainly *Lophius piscatorius*) and of the Macrouridae family. Some of the scattered boulders at these depths contained some encrusting sponges growing on. On the higher areas of the slopes, the ground was widely covered with rocky outcrops and fauna was progressively more present. Coral species such as the whip *Viminella* flagellum, *Acanthogorgia* spp., and large colonies *Callogorgia verticillata* dominated, with occasional aggregations (Figure 439). Sponges were very common, and mostly appeared when the rock outcropped, being possible to highlight the occurrences of species such as the very usual glass sponge *Farrea occa*, *Characella pachastrelloides*, *Macandrewia azorica* and animals likely of the genus *Geodia* and *Petrosia*. The crustacean, that usually inhabit soft grounds, *Aristaeopsis edwardsiana*, was commonly seen at on the sandy patches. The sightings of a Kaup's arrowtooth eel (*Synaphobranchus kaupi*), several Alfonsinos (*Beryx splendens*), *Cyttopsis rosea* and of a *Gaidropsarus* sp. (possibly the first observation in the Azorean archipelago) constituted the highlights of motile fauna present.

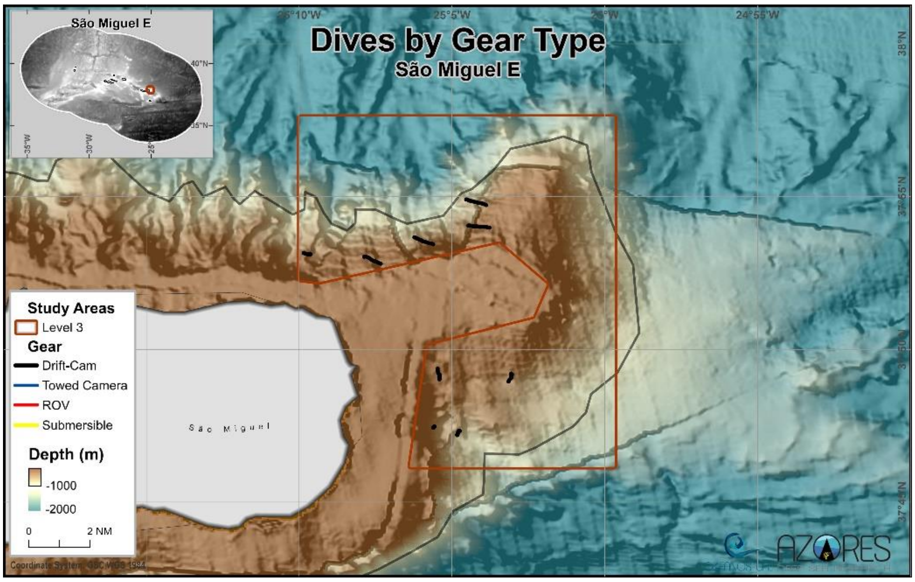



**Figure 438** Map displaying the 9 underwater dives performed in the São Miguel E area between 320 and 910 meters depth.

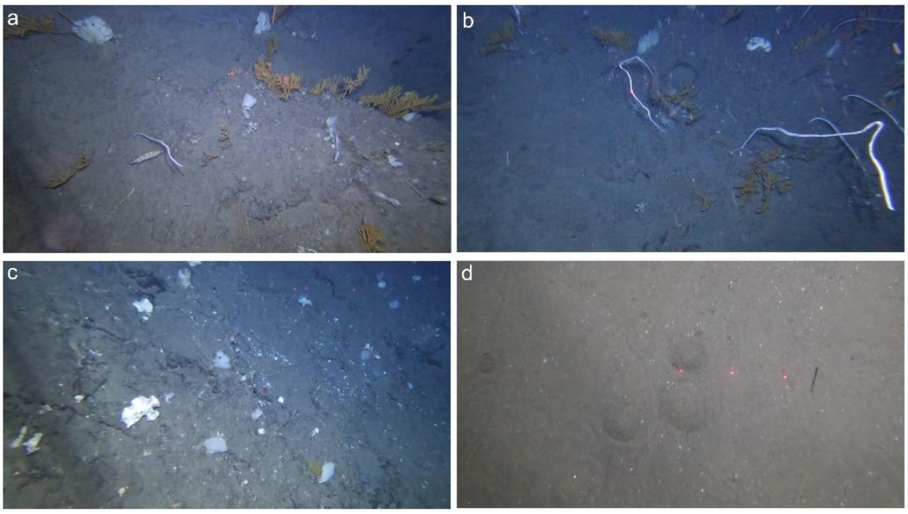



Figure 439 Selected images representative of the main structuring species and benthic communities observed in São Miguel East area. (a-b) Area covered by soft sediments colonized by the corals *Acanthogorgia* sp. and *Viminella flagellum* and the sponges *Haliclona implexa, Poecillastra compressa* and *Phakellia ventilabrum.* (c) Basaltic bottom covered with small sponges, including *Macandrewia azorica.* (d) Foraminifera *Syringammina fragilíssima.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam

*São Miguel SE*

In total, 10 underwater video transects were performed across the São Miguel Southeast area, between 270 and 880 m depth (Figure 440). The results obtained through video analysis indicate a low diversity of deep-sea megabenthic species, with a total of 39 taxa determined. Among these, 24 were identified at the species level. The most frequently observed taxa based on weighted occurrences include *Viminella flagellum* (n= 14 weighted occurrences), *Acanthogorgia* spp. (n= 12), and Bryozoa (n= 10).

This Southeast area of the São Miguel Island slope showed a terrain characterized by starting to be soft at the lower depths, in the deepest parts of the slope, and with some patches of coral rubble, to progressively harder substrate when the depth decreases, with the presence of some basaltic boulders and rocky outcrops (sometimes even forming very steep vertical walls) at some areas almost entirely covered with a thin layer of sand, when the bottom geomorphology allowed it. For this geomorphological unit the areas explored with the Azor drift-cam covered a wide range of depths, allowing us to have a good understanding of the benthic communities present in almost each depth stratum. At the deepest sectors explored, the fauna observed was limited, where we could record some scattered foraminifera of the species *Syringammina fragillissima*, and punctual aggregations of corals likely from the species *Errina atlantica* and of the genus *Anthomastus/Pseudoanthomastus* (Figure 441). On the shallower part of the slopes the diversity of fauna increased, so we could observe the often present of the black coral *Parantipathes hirondelle*, and relatively dense coral aggregations mainly with colonies of the gorgonians *Viminella flagellum*, *Acanthogorgia* spp., and *Dentomuricea* aff. *meteor*. Sponge abundance also had an increment, being the species *Farrea occa*, *Macandrewia azorica*, *Regadrella phoenix* and of the genus *Geodia*, the most common. It was also very usual, the presence of the sea urchin *Cidaris cidaris* and some fishes such as the species *Helicolenus dactylopterus*, *Lepidorhombus whiffiagonis,* shoals of *Caprus aper* and many of the family Macrouridae.

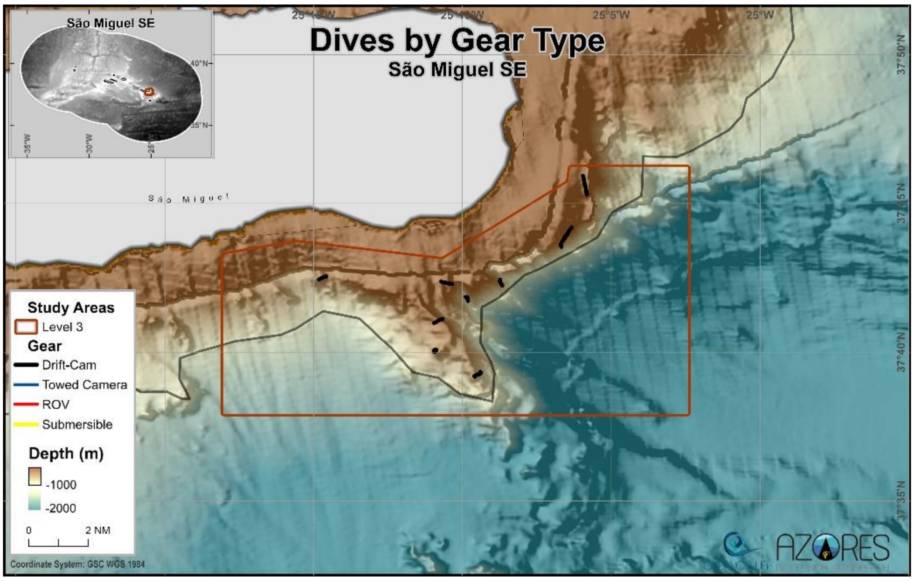



**Figure 440** Map displaying the 10 underwater dives performed in the São Miguel SE area between 270 and 880 meters depth.

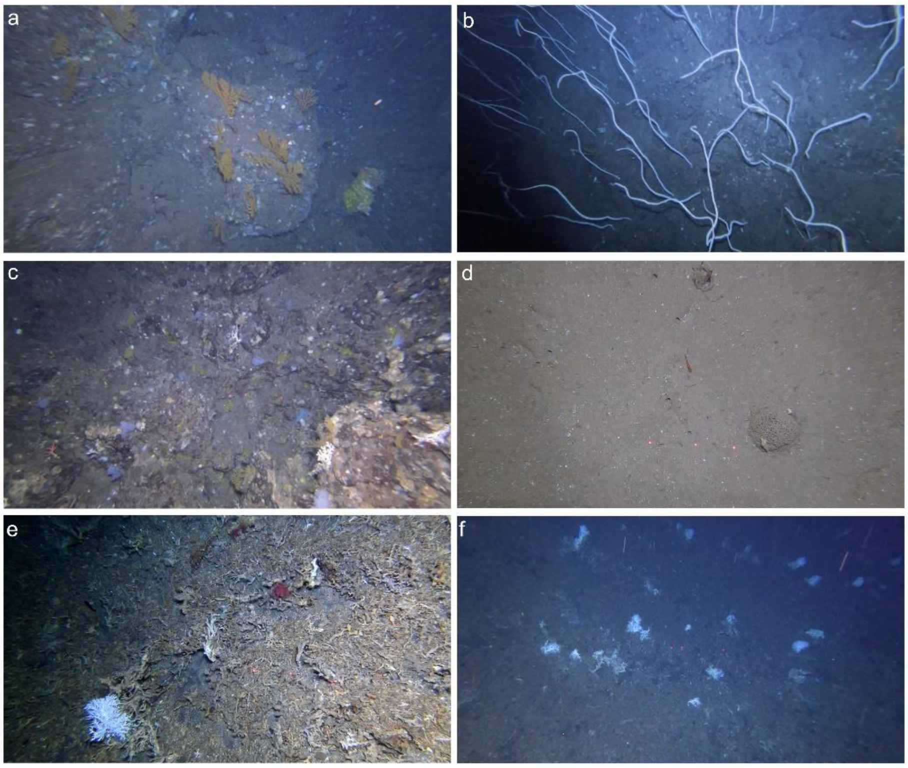


**Figure 441** Selected images representative of the main structuring species and benthic communities observed in São Miguel Southeast area. (a) Hard substrate colonized by *Acanthogorgia* sp. and the sponge *Characella pachastrelloides* and other small sponges. (b) Large colonies of *Viminella flagellum.* (c) Basaltic bottom covered with small sponges, including *Farrea occa* and small colonies of *Acanthogorgia* spp. and *Pleurocorallium johnsoni.* (d) Foraminifera *Syringammina fragilíssima.* (e-f) Large area of dead coral framework colonized by *Errina atlantica* and *Anthomastus/Pseudoanthomastus* sp. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*São Miguel S*

In São Miguel South area, 12 underwater video transects were completed between 280 and 690 m depth (Figure 442). The results suggest a low diversity of deep-sea megabenthic species, with 18 taxa determined from the video analysis. Of these, 11 were identified at the species level. The taxa most frequently observed based on weighted occurrences were *Plesionika* (n= 9 weighted occurrences), *Flabellum* sp. (n= 5), and *Hymedesmia (Hymedesmia) paupertas* (n= 4).

The most southern area of the São Miguel was entirely surveyed with the help of the Azor drift-cam, and even if the depth range of the areas explored was not very wide, it was possible to observe different benthic communities of megafauna at both lower and upper sections of this part of the Island slopes. The deepest areas explored (around 600m) were characterized for its sedimentary environment, and not very abundant and diverse benthic fauna, with the present of very sporadic boulders, where a few gorgonians of the species *Pleurocorallium johnsoni*, were growing (Figure 443). The remaining shallower areas of the slope can be distinguished for the more often hard seafloor (with several basaltic outcrops and steep walls) and with it, higher densities of benthic megafauna. Dense patches of the octocoral *Callogorgia verticillata* (usually large specimens and particularly between 320 and 240m) were frequently attached to the boulders. Also recorded, but in less densities, were the gorgonians *Viminella flagellum*, *Acanthogorgia* spp., and *Dentomuricea* aff. *Meteor* (Figure 443). However, the most represented phylum at this geomorphological unit was the porifera, with the widely presence of encrusting species and the frequent sightings of *Petrosia crassa*, *Phakellia ventilabrum*, *Characella pachastrelloides* and the very common *Farrea occa* (Figure 443). The commercially important bluemouth rockfish (*Helicolenus dactylopterus*) was very frequent, as well as shoals of *Caprus aper*, and individuals of the family Macrouridae. To also denote that seafloor patches covered by fragments of the invasive alga *Rugulopteryx okamurae* were very common.

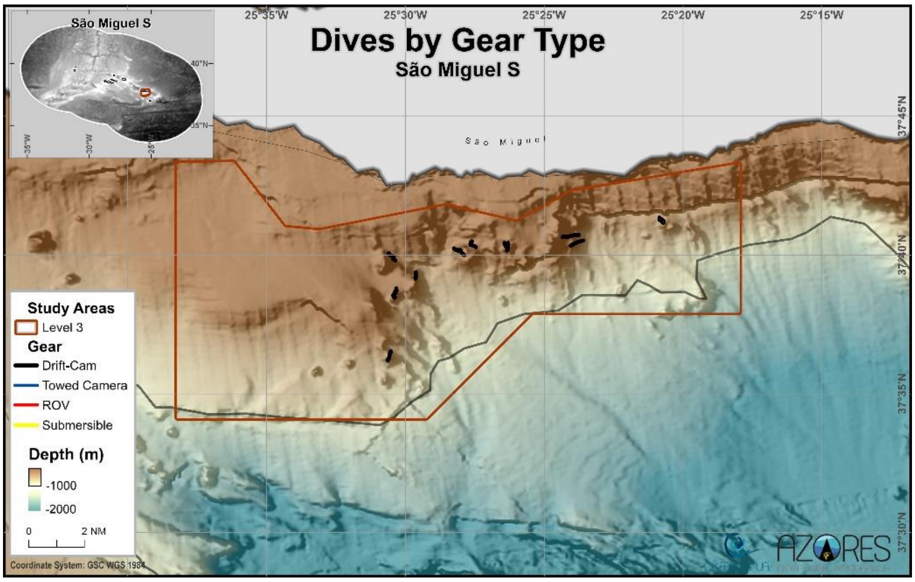



**Figure 442** Map displaying the 12 underwater dives performed in the São Miguel S area between 280 and 690 meters depth.

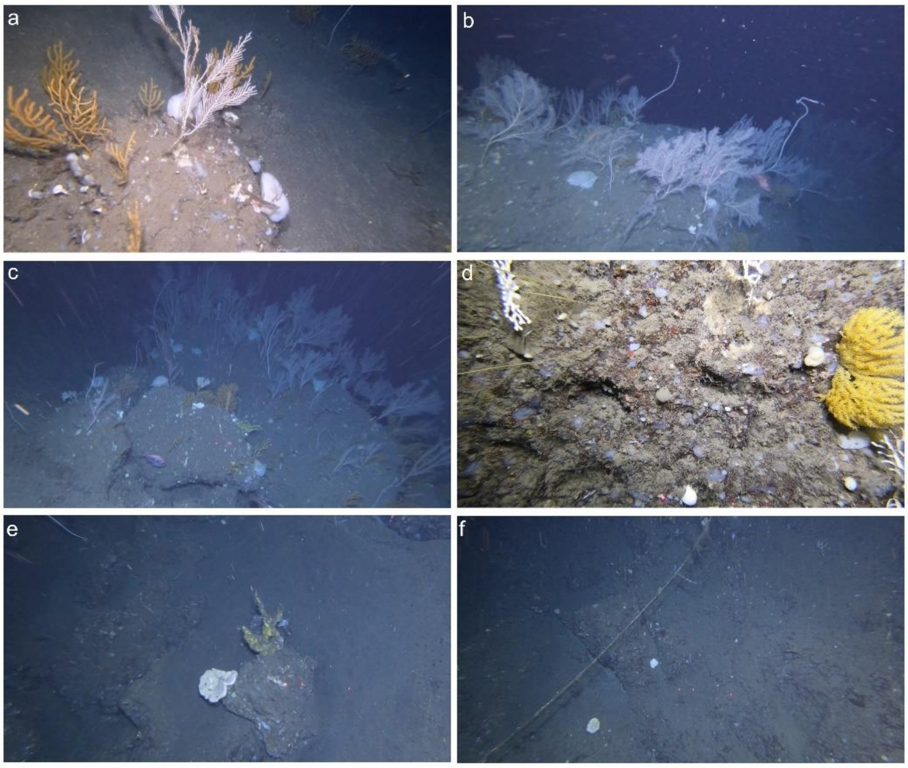



**Figure 443** Selected images representative of the main structuring species and benthic communities observed in São Miguel South area. (a) Hard substrate colonized by the corals *Acanthogorgia* sp. and *Callogorgia verticillata* together with

sponges of the genus *Phakellia, Macandrewia azorica* and other small species. (b) Aggregation of large *C. vertcillata, Viminella flagellum* and *Acanthogorgia* sp. and a sponge of the species *Petrosia crassa.* (c) Large aggregation of the corals *C. verticillata, V. flagellum, Acanthogorgia* sp. and *Dentomuricea* aff. *meteor* with sponges of the genus *Phakellia.* (d) Vertical densely colonized by encrusting sponges, colonies of *Acanthogorgia* sp. and *Pleurocorallium johnsoni.* (e) Two of the sponges frequently observed in the area, *Petrosia crassa* and *Characella pachastrelloides* (f) One of the several lost fishing lines observed in this area. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*São Miguel SW*

During the survey in São Miguel Southwest area, 10 underwater video transects were conducted between 260 and 800 m depth (Figure 444). The results showed low diversity of deep-sea megabenthic species, with a total of 42 taxa determined from the video analysis. Among these, 24 were identified at the species level. The most frequently observed taxa based on weighted occurrences include *Callogorgia verticillata* (n= 9 weighted occurrences), *Acanthogorgia* spp. (n= 8), and *Neophrissospongia nolitangere* (n= 7).

The Southwestern area of the São Miguel Island was mainly characterized by the several small seamounts very close to it. This is where the dives were mainly performed with the Azor drift-cam, covering a relatively wide range of depths. The deepest areas explored on this side of São Miguel Island, had the sea bottom very similar to the rest of the areas around the Island, being more composed of strong sedimentation and coral rubble deposits with sporadic basaltic boulders and outcrops that progressively become more frequent with the decrement of depth, and when the slope is steeper. On the deeper sectors explored, the benthic megafauna was essentially composed by the occasional patches of the bird's nest sponge *Pheronema carpenteri*, normally together with the glass sponge *Farrea occa* and, a few individuals of the black coral *Parantipathes hirondelle*. When the Azor drift-cam drifted over shallower areas of this geomorphological unit, the benthic communities almost entirely differed. The contrast was impressive, with the observation of massive coral gardens growing on the hard substrate and formed by the gorgonian coral *Callogorgia verticillata* (Figure 445). Other coral species showed to be present in large numbers, sometimes creating massive aggregations such as the case of *Acanthogorgia* spp., corals of the family Paramuriceidae, and the reef formed by several colonies of the scleractinian *Eguchipsammia cornucopia* (Most of it growing in a dead coral framework). Mostly of the sponges observed at these depths (around 500 to 300m), were large and included species such as *Macandrewia azorica*, *Neophrissospongia nolintangere*, *Characella pachastrelloides*, and individuals of the genus *Leiodermatium* (present in both white and blue morphotypes) (Figure 445). The motile fauna can be highlighted with the sighting of a *Paromola cuvieri* carrying a piece of the coral *Callogorgia verticillata*, and the record of a ray of the genus *Dipturus* and a shark of the genus *Deania*.

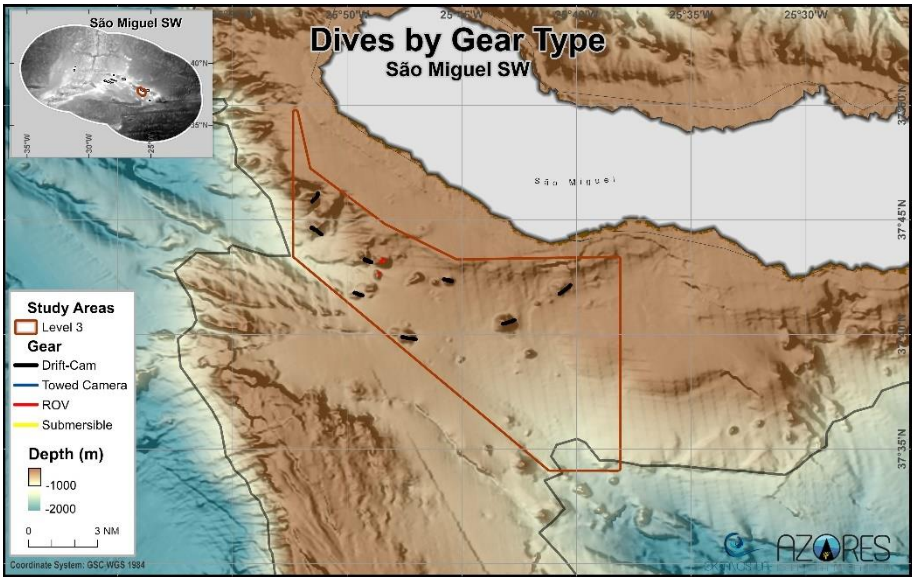



**Figure 444** Map displaying the 10 underwater dives performed in the São Miguel SW area between 260 and 800 meters depth.

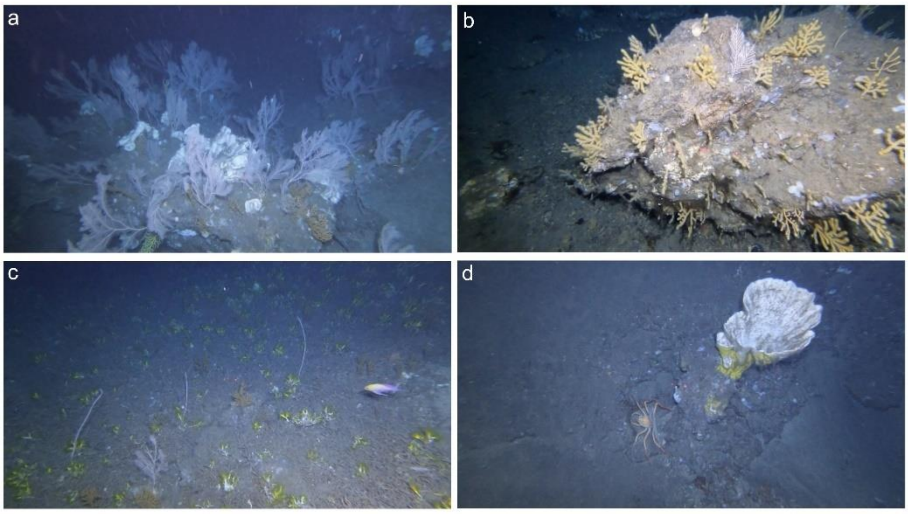



**Figure 445** Selected images representative of the main structuring species and benthic communities observed in São Miguel Southwest area. (a) Large aggregation of the coral *Callogorgia verticillata, Acanthogorgia* sp. and occasional colonies of *Dentomuricea* aff. *meteor* and the sponge *Neophrissospongia nolitangere*. (b) Boulder colonized by the corals *Acanthogorgia* sp. and a small colony of *C. verticillata* and encrusting sponges. (c) Vast area with an aggregation of the scleractinian *Eguchipsammia cornucopia* with occasional colonies of small *C. verticillata, Viminella flagellum* and *Acanthogorgia* sp. (d) Big specimen of the sponge *Characella pachastrelloides.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*São Miguel W*

A total of 8 underwater video transects were performed São Miguel West area, between 330 and 910 m depth (Figure 446). The results reveal a medium diversity of deep-sea megabenthic species, with 55 taxa determined from the video data. Of these, 30 were identified at the species level. The taxa most frequently observed based on weighted occurrences were *Acanthogorgia* spp. (n= 14), *Farrea occa* (n= 10), and *Haliclona (Soestella) implexa* (n= 8).

The geomorphological unit that is located on the most westernmost sector of the slopes of São Miguel Island, is distinguished by the steep nature of its features and the presence of several small ridges. Sandy bottoms were predominant at the deepest areas explored, with the occurrence of harder substrates as the slope goes up and the depth goes down. The deepest areas surveyed had mainly the occasional presence of the hard coral of the genus Flabellum at the soft bottom, and a few occurrences of soft corals of the genus *Anthomastus/Pseudoanthomastus*, the black corals *Antipathella subpinnata* and *Parantipathes hirondelle* and some Stylasterids. At these deepest spots the most frequent sponge was *Farrea occa* (also present in the upper part of the slope). In the shallower areas recorded, there was the presence of very robust corals of the octocoral species *Callogorgia verticillata*, several colonies of *Acanthogorgia* spp., aggregations of the whip coral *Viminella flagellum* and a few corals belonging to the family *Paramuriceidae* (Figure 447). The species of sponges observed did not differ much from the other areas around São Miguel Island, since it was possible to detect *Characella pachastrelloides*, *Poecillastra compressa*, *Phakellia ventilabrum*, an individual of *Haliclona magna* and several other litisthids (Figure 447). It was often seen fishes of the species *Hoplostethus mediterraneus* and a sixgill shark (*Hexanchus griseus*) swimming around.

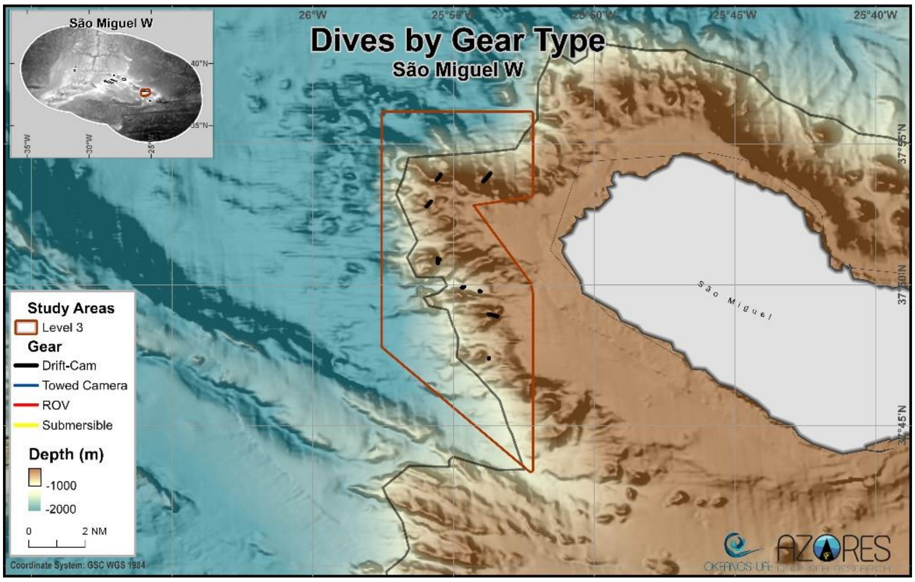



**Figure 446** Map displaying the 8 underwater dives performed in the São Miguel W area between 330 and 910 meters depth.

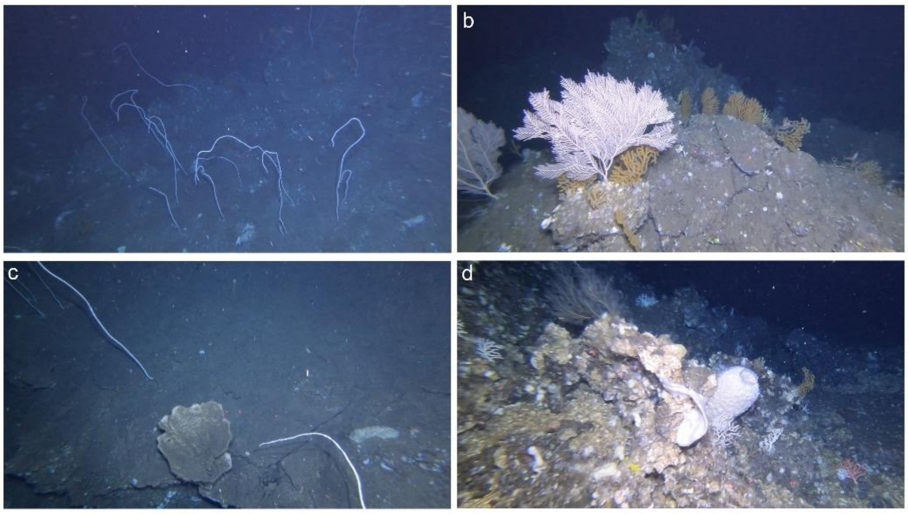



**Figure 447** Selected images representative of the main structuring species and benthic communities observed in São Miguel West area. (a)Aggregation of *Viminella flagellum* on hard substrate. (b) Aggregation of *C. verticillata, Acanthogorgia* sp., occasional colonies of *Dentomuricea* aff. *meteor* and diverse sponges, including *Macandrewia azorica.* (c) Large sponge of the species *Characella pachastrelloides.* (d) Rocky bottom densely colonized by small sponges, the lamelate *Poecillastra compressa,* a sponge from the family Chalinidae and a wide variety of coral species, including *Paragorgia johnsoni, Placogrgia* sp and hydrozoans. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

Study area | Mar da Prata

*Mar da Prata N*

While surveying the Mar da Prata North area, 11 underwater video transects were conducted between 170 and 1010 m depth (Figure 448). The results showcase a high diversity of deep-sea megabenthic species, with a total of 77 taxa determined from the video analysis. Among these, 46 were identified at the species level. The most frequently observed taxa based on weighted occurrences include *Viminella flagellum* (n= 14), Hydrozoa (n= 11), and *Dentomuricea* aff, *meteor* (n= 10).

Between 175 and 390 m deep, the areas surveyed were mainly characterized by sedimentary bottom, with some basaltic outcrops. Benthic megafauna was very dense and diverse, with large gardens of *Viminella flagellum*, sometimes associated with *Callogorgia verticillata* and other times with frequent and large *Dentomuricea* aff. *meteor* colonies (Figure 449). Other corals also spotted in lower densities were *Parantipathes hirondelle* and *Acanthogorgia* spp. Regarding sponges, high densities of *Phakellia ventilabrum*, big aggregations of *Neophrisospongia nolitangere*, and some occasional *Leiodermatium sp*. from both blue and white morphotypes were spotted. A big sixgill shark from the species *Hexanchus griseus* was also observed, as well as large shoals of *Capros aper*, *Anthias anthias*, and *Trachurus trachurus*.

From 500 to 600 m deep, the bottom was mainly characterized by outcrops covered with soft sediments and some coral rubble. In shallower areas, we spotted big aggregations of *Viminella flagellum*, sometimes with *Callogorgia verticillata* and other times with occasional *Dentomuricea* aff. *meteor*. While in the deeper areas, aggregations of both *Narella versluysi* and *N. bellissima, Acanthogorgia* spp. and *Pliobothrus symmetricus* were found (Figure 449). Regarding sponges, the most common species were both *Phakellia robusta* and *P. ventilabrum*, also there were some frequent *Characella pachastrelloides*, *Neophrisospongia nolitangere* and *Petrosia crassa*, occasional *Leiodermatium sp.* from both blue and white morphotypes, *Geodia sp.* and some aggregations of *Pheronema carpenteri*. We also filmed several fish species such as *Helicolenus dactylopterus*, *Mora moro, Hoplostehtus mediterraneu*s, some flatfish and one *Hexanchus griseus* deep-sea shark.

Between 600 and 850 m deep, the substrate observed was diverse. Some areas were mostly characterized with sandy bottoms, with the presence of basaltic boulders and outcrops, sporadic in some areas, extensive in other areas. The basaltic outcrops and boulders hosted a relatively high abundance of benthic fauna. Relatively big coral gardens of *Narella bellissima* and *N. versluysi* were observed, along with some other coral species (Figure 449), mainly on rocky substrate, such as *Acanthogorgia* spp., *Callogorgia verticillata*, *Hemicorallium tricolor*, *Anthomastus/*Pseudoanthomastus *spp,* cf. *Swifitia dubia* and many corals of the family Stylasteridae. Many sponges were also observed, with records of *Phakellia ventilabrum*, *Desmacella grimaldi*, *Regradella phoenix*, *Asconema fristedti,* and the common deep-sea sponge *Pheronema carpenteri*, composing vast fields (Figure 449). A considerable number of the echinoderms cf. *Zoroaster fulgens* was also observed at some basaltic outcrop slopes. The fishes *Chaunax* sp., and *Hoplostethus mediterraneus*, *Molva macrophthalma* and a ray of the species *Dipturus intermedius*. Several *Helicolenus dactylopterus* also appeared regularly. The presence of many lost fishing lines between 600 and 830 m deep must also be noted.

Between 920 and 1000 m deep, we performed a dive starting at the base of a deep crest. The bottom was composed only of sandy and coral rubble bottoms, and a very low presence of benthic megafauna. Nevertheless, it was possible to notice some *Cidaris cidaris*, the anemone of the genus *Liponema,* and the fishes *Lepidopus caudatus*, and some individuals from the Macrouridae family.

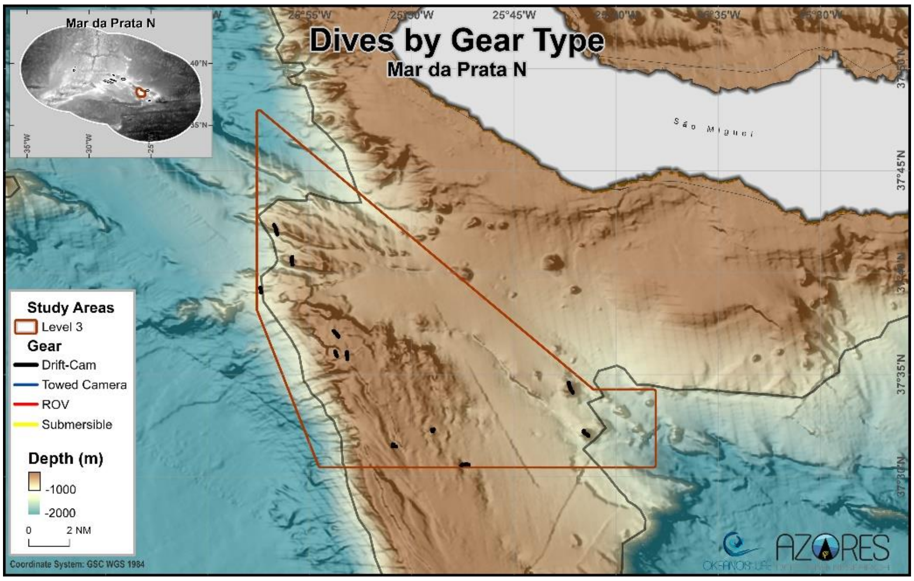



**Figure 448** Map displaying the 11 underwater dives performed in the Mar da Prata N area between 170 and 1,010 meters depth.

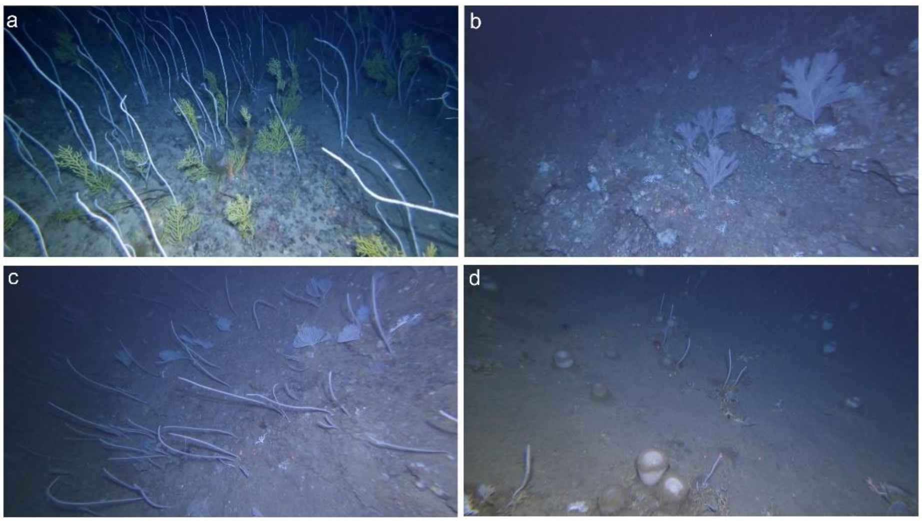



**Figure 449** Selected images representative of the main structuring species and benthic communities observed in Mar da Prata North area. (a) Dense aggregation of *Viminella flagellum* and *Dentomuricea* aff. *meteor.* (b) Aggregation of small-sized *Callogorgia* verticillata and occasional *Acanthogorgia* sp. and *Pliobothrus symmetricus.* (c) Aggregation of primnoids *Narella bellissima* and *N. verluysi.* (d) Scattered aggregation of the “bird nest” sponge *Pheronema carpenteri* and the corals *N. versluysi* with small *N. Bellissima* and occasional *Anthomastus/Pseudoanthomastus* sp.. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Mar da Prata*

In Mar da Prata area, 7 underwater video transects were performed between 230 and 930 m depth (Figure 450). The analysis implies a low diversity of deep-sea megabenthic species, with 48 taxa determined from the video data. Among these, 35 were identified at the species level. The taxa most frequently observed based on weighted occurrences include *Narella versluysi* (n= 20), *Farrea occa* (n= 14), and *Asconema fristedti* (n= 11).

The bottom was mainly sedimentary with coral rubble, with some rocky outcrops covered with soft sediments and some coral rubble. In the shallower areas, large aggregations of *Viminella flagellum* were observed, sometimes with *Callogorgia verticillata,* with occasional *Dentomuricea* aff. *meteor*, or *Paracalyptrophora josephinae* (Figure 451). In deeper areas, aggregations of both *Narella versluysi* and *N. bellissima* were present, together with *Acanthogorgia* spp., and *Pliobothrus symmetricus;* smaller and dispersed aggregations together with *Callogorgia verticillata, Acanthogorgia* sp., and *Leiopathes expansa* were observed as well. The most common sponges recorded in Mar da Prata were *Characella pachastrelloides, Petrosia* sp.*, Neophrisospongia nolitangere* and *Asconema* sp. In other parts of the seamount, the same species were also observed but the most common were both *Poecillastra compressa* and *Phakellia ventilabrum.* Occasional *Leiodermatium sp*. in its and white morphotypes*, Geodia* sp. and some aggregations of *Pheronema carpenteri* were also observed. In term of mobile fauna, we also filmed several fish species such as *Helicolenus dactylopterus, Mora moro, Hoplostehtus mediterraneus* (Figure 451)*,* some flatfish and one *Hexanchus griseus* deep-sea shark, among others.

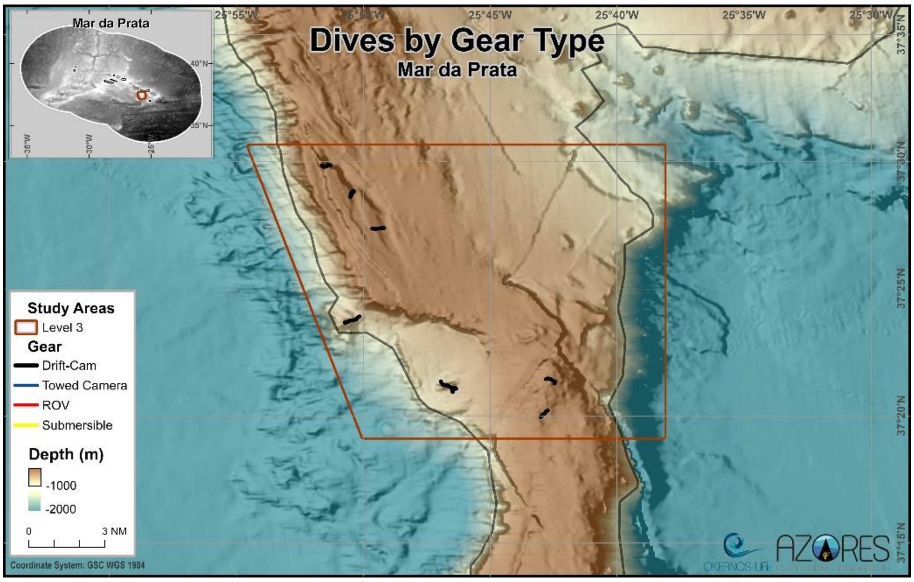



**Figure 450** Map displaying the 7 underwater dives performed in the Mar da Prata area between 230 and 930 meters depth.

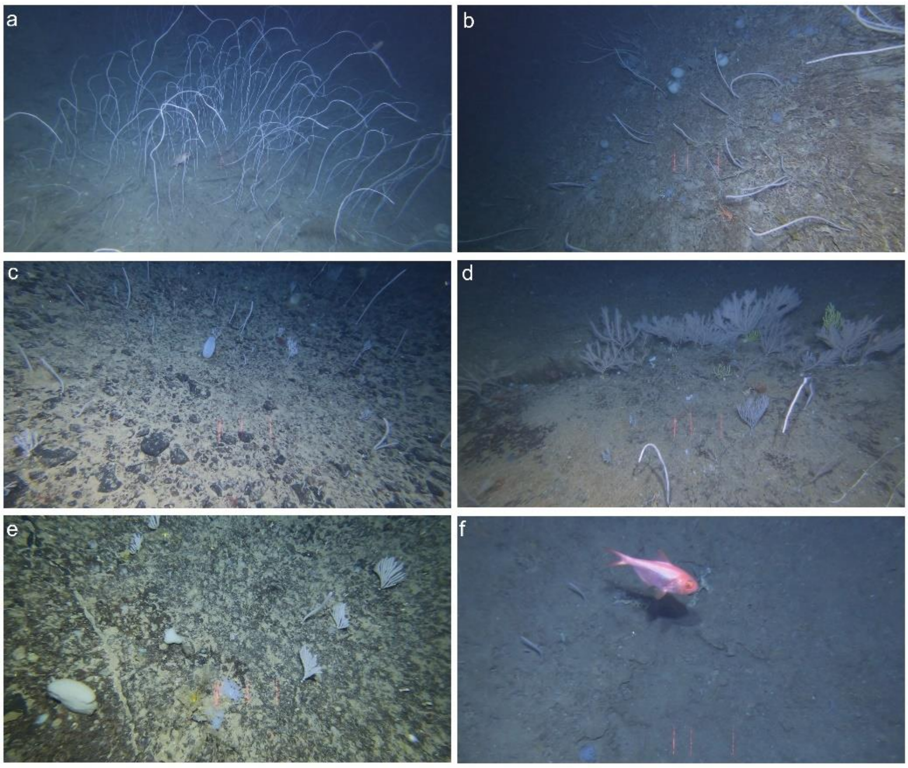



Figure 451 Selected images representative of the main structuring species and benthic communities observed in Mar da Prata area. (a) Dense aggregation of *Viminella flagellum.* (b) Aggregation of *Narella versluysi* and sparse *Pheronema carpenteri.* (c) Aggregation of small *Narella bellissima* and *N. verluysi* and one glass sponge *Regadrella phoenix*. (d) Benthic community formed by *Callogorgia verticillata, Viminella flagellum, Dentomuricea* aff. *meteor* and one *Paracalyptrophora josephinae*. (e) Small aggregation of *Narella bellissima* and *N. versluysi* along with the sponges *Farrea occa*, *Phakellia ventilabrum* and some encrusting sponges. (f) a specimen of *Hoplostehtus mediterraneus.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Mar da Prata S*

On the south part of Mar da Prata area, 10 underwater video transects were conducted, covering a range depth from 300 to 980 m (Figure 452). The video analysis revealed a high diversity of deep-sea megabenthic species, with a total of 86 taxa determined. From these, 52 were identified at the species level. The most frequently observed taxa based on weighted occurrences were *Regadrella phoenix* (n= 14), *Farrea occa* (n= 13), and Bryozoa (n= 9).

Mar da Prata is a large elongated underwater feature located between the islands of São Miguel and Santa Maria and known for its historic fishing pressure. Only the summit of the southern sector was explored with information currently available for a limited depth range. The flat areas of the summit were characterized by sand and fine gravels, with very little invertebrate fauna reported. When boulders started to appear in between patches of sand, the community was characterized by several lithistid sponges, some of which of relatively large sizes (Figure 453). Common Porifera included *Leiodermatium* spp., *Macandrewia azorica* and *Petrosia* cf. *crassa*, as well as a white lamellate sponge that resembles *Phakellia* sp., but for which further identifications are needed. The only large octocoral species observed in the mixed substrates of Mar da Prata were *Viminella flagellum,* always observed as scattered colonies. Conversely, on the southeastern side of the mount, the hard substrates of the upper slopes hosted a very well-structured community characterized by the yellow sea fan *Dentomuricea* aff. *meteor* in very high densities, accompanied by *Viminella flagellum* (Figure 453). Areas of high relief in this seamount had a large number of abandoned fishing lines.

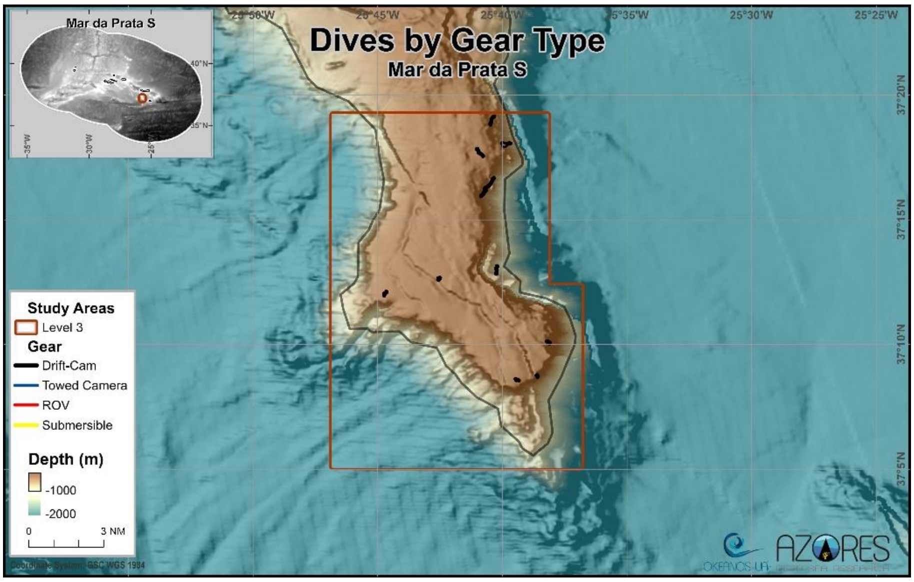



**Figure 452** Map displaying the 10 underwater dives performed in the Mar da Prata S area between 300 and 980 meters depth.

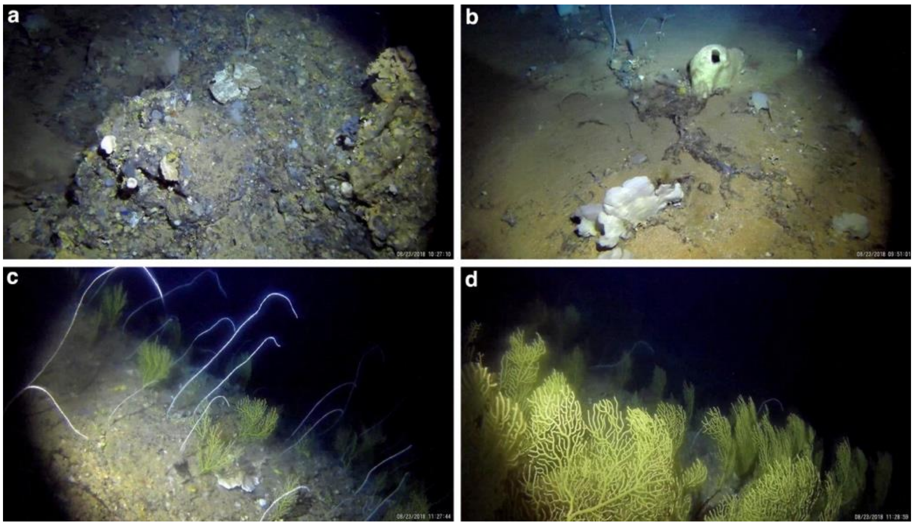



Figure 453 Selected images representative of the main structuring species and benthic communities observed in South of Mar da Prata seamount. (a) Some lithistid sponges on hard substrates. (b) Other unidentified Porifera of the summit. (c-d) Dense aggregation of the sea fan *Dentomuricea* aff. *meteor* on the southwestern flank. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Maria Celeste*

In Maria Celeste area, 5 underwater video transects were performed between 670 and 1000 m depth (Figure 454). The results indicated a medium diversity of deep-sea megabenthic species, with 64 taxa determined from the video analysis. Among these, 36 were identified at the species level. The most frequently observed taxa based on weighted occurrences were *Acanthogorgia* spp. (n= 42), *Pliobothrus symmetricus* (n= 40), and *Cidaris cidaris* (n= 38).

Maria Celeste is an area with two perfectly star-shaped seamounts, with their bases at around 2,500 m depth and their summits at depths as shallow as 580 m. Usually, these seamount-like structures originate quite strong currents circling around their peaks.

On the southern seamount of Maria Celeste (between 900 and 650 m deep), we found some quite large colonies of *Callogorgia verticillata* serving as shelter for small unidentified fishes (Figure 455). This seamount is also inhabited by some of the typical communities found at those depths, including aggregations of *Narella versluysi* and *N. Bellissima,* as well as *Acanthogorgia* spp., and the glass sponges *Pheronema carpenteri* and *Regadrella phoenix* (Figure 455). A few colonies of the black coral *Leiopathes expansa* were also observed. The demosponge *Macandrewia azorica* also appeared in high numbers within this community. On the northern seamount, in the southern part of the summit (between 814 and 768 m deep), and in its northern side (between 992 and 868 m deep), we mostly observed soft sediments, and the bare rock hosted sparse fauna.

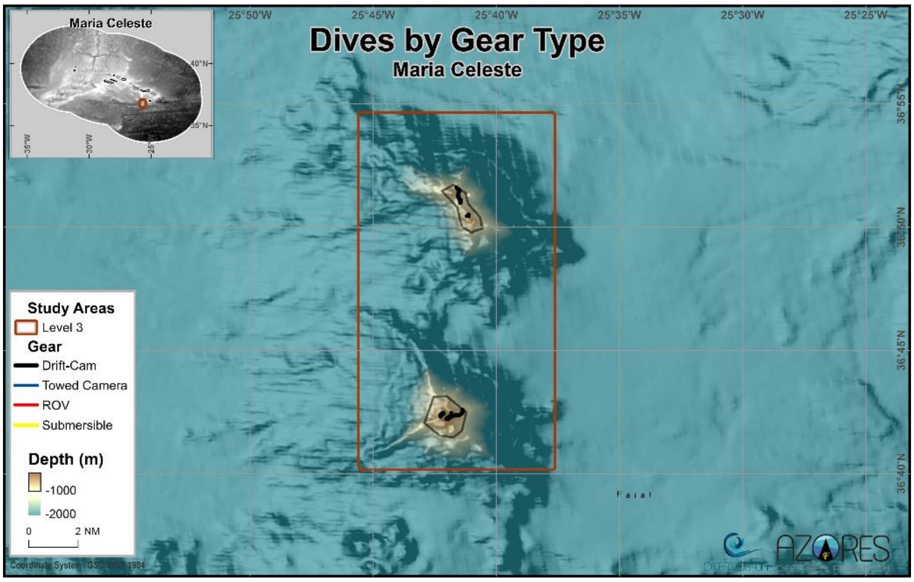



**Figure 454** Map displaying the 5 underwater dives performed in the Maria Celeste area between 670 and 1,000 meters depth.

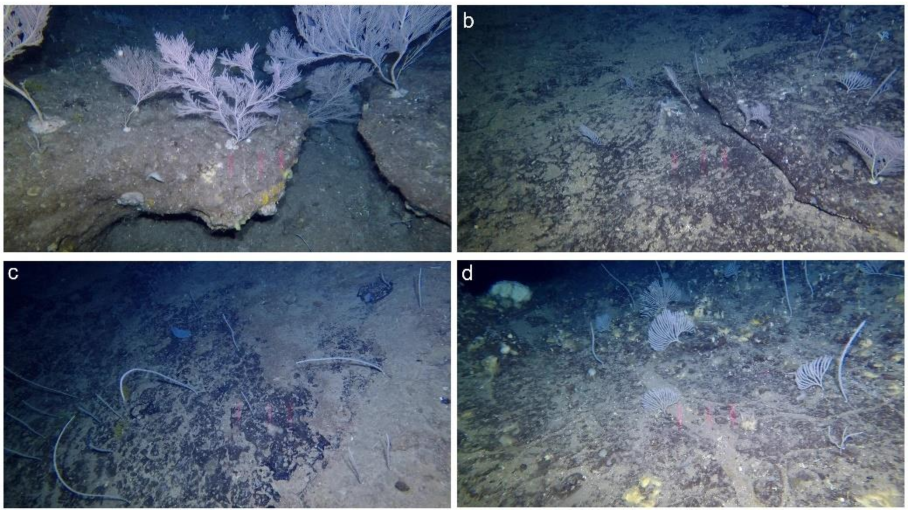



**Figure 455** Selected images representative of the main structuring species and benthic communities observed in Maria Celeste area. (a) Aggregation of *Callogorgia verticillata*. (b) Aggregation of *Narella versluysi*, *N. bellissima* and small-sized *Callogorgia verticillata*. (c) Aggregation of small *Narella verluysi*, one glass sponge *Regadrella phoenix* and occasional *Acanthogorgia* sp.. (d) Rocky bottom colonized by some sparse encrusting sponges and the corals *Narella bellissima* and *N. versluysi*. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Sauerwein*

While exploring the Sauerwein area, 2 underwater video transects were completed between 960 and 1010 m depth (Figure 456). The findings unveiled a low diversity of deep-sea megabenthic species, with a total of 30 taxa determined from the images. Of these, 22 were identified at the species level. The most frequently observed taxa based on weighted occurrences were *Acanella arbuscula* (n= 23 weighted occurrences), *Pheronema carpenteri* (n= 19), and *Javania* (n= 15).

The Sauerwein geomorphological unit is a deep seamount located southern of the São Miguel Island, and on the eastern group of the Azorean archipelago. The geomorphological features evaluated, part of the Sauerwein seamount were mainly part of the upper slope, even if the depth range was very deep (around 900 to 1,000m) and having a deep summit located at an approximate depth of 800m. Based on the two dives performed at this unit, the substrate at the shallower areas of this seamount was mainly hard, composed by basaltic rock generally covered with fine sediment, or partially covered. The benthic communities present were very constant throughout this area and growing on both soft and hard bottom. From these we can highlight the bamboo coral *Acanella arbuscula*, the black coral *Leiopathes expansa*, and the gorgonians *Hemicorallium niobe*, *H. tricolor* and *Chrysogorgia* spp. (Figure 457). There were patches of rock, where all these corals were growing together. Some individuals of the scleractinian *Lophelia pertusa* were also observed. Regarding sponges, there were sporadic records of *Pheronema carpenteri* patches (Figure 457), cf. *Aphrocallistes* Beatrix and *Regadrella phoenix*. The fishes of the species *Mora moro*, *Neocyttus helgae* and several anguilliform of the genus *Synaphobranchus* were observed.

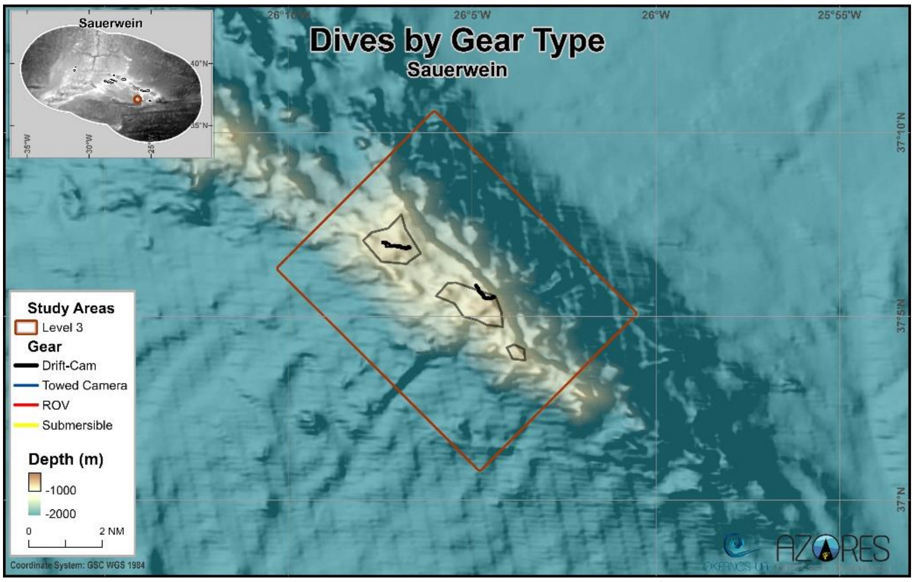



**Figure 456** Map displaying the 2 underwater dives performed in the Sauerwein area between 960 and 1,010 meters depth.

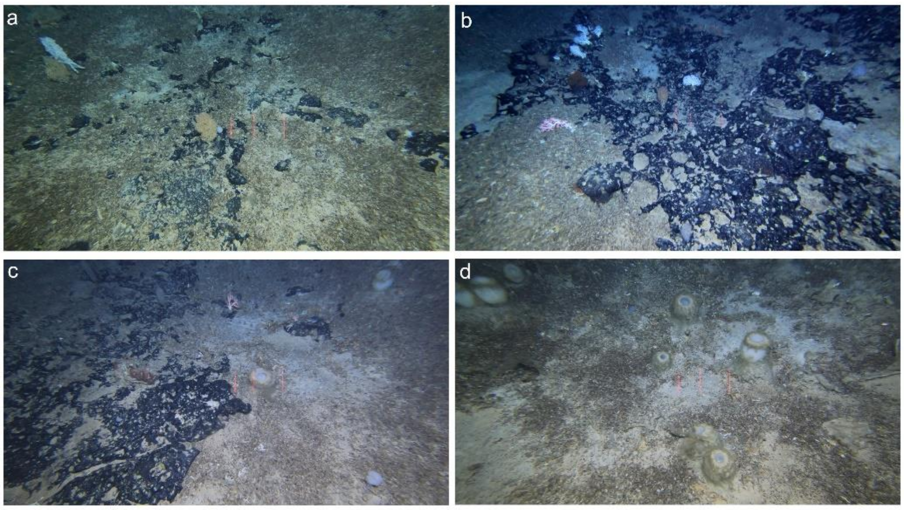



Figure 457 Selected images representative of the main structuring species and benthic communities observed in Sauerwein seamount. (a) *Acanella arbuscula.* (b) Small aggregation of *Acanella arbuscula,* a small-sized *Leiopathes expansa, Hemicorallium tricolor* and *H. niobe.* (c) Scattered aggregation of the sponge *Pheronema carpenteri* and the coral *H. tricolor*. (d) Aggregation of the sponge *P. carpenteri.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

Study area | Formigas

*Grande Norte*

There were performed 12 underwater video transects in Grande Norte area, between 130 and 1050 m depth (Figure 458). The results suggested a low diversity of deep-sea megabenthic species, with 30 taxa determined from the video annotation. Among these, 19 were identified at the species level. The most frequently observed taxa based on weighted occurrences were *Flabellum* sp. (n= 9), *Leiodermatium* sp. (n= 8), and *Echinus melo* (n= 7).

The deeper areas, mainly characterized by consolidated soft sediment showing aggregations of large *Callogorgia verticillata,* some black corals of the genus *Bathypathes* sp. and extensive aggregations of the birdnests sponge *Pheronema carpenter* (Figure 459). While moving further up slope, different types of substrates were observed, going from areas with soft sediments, to areas covered in coral rubble or rocky outcrops. Aggregations of *Callogorgia verticillata* were still observed in association with the gorgonians *Acanthogorgia* spp.*,* the cup coral *Leptopsammia formosa* and the glass sponge from the species *Farrea occa*. We also found large coral aggregations of the whip coral *Viminella flagellum,* together with some *Paracalyptrophora josephinae*, and *Dentomuricea* af. *meteor,* and one small unidentified species of Plexauridae, along with some large sponges such as *Phakellia ventilabrum*, *Poecillastra compressa, Macandrewia azorica*, and *Neophrissospongia nolitangere* (Figure 459). On the shallower areas, an extensive garden of the shallow species of the genus *Candidella* was found in a vertical wall, together with some large sponges from the genus *Characella* and *Geodia*. It was also in the shallow depths of this area that a large aggregation of sea-urchins probably from the species cf. *Centrostephanus longispinus*, was recorded for the first time *in situ*. Regarding mobile fauna we spotted some deep-sea fishes such as *Hoplostenus mediterraneus*, *Helicolenus dactylopterus*, a shoal of *Anthias anthias*, specimens from the Macrouridae family, a big school of *Trachurus picturatus*, two exemplars of the ray *Tetronarce nobiliana* and one *Hexanchus griseus*.

Although this was clearly an intense fishing area, the Grande Norte still presented high diversity and abundance.

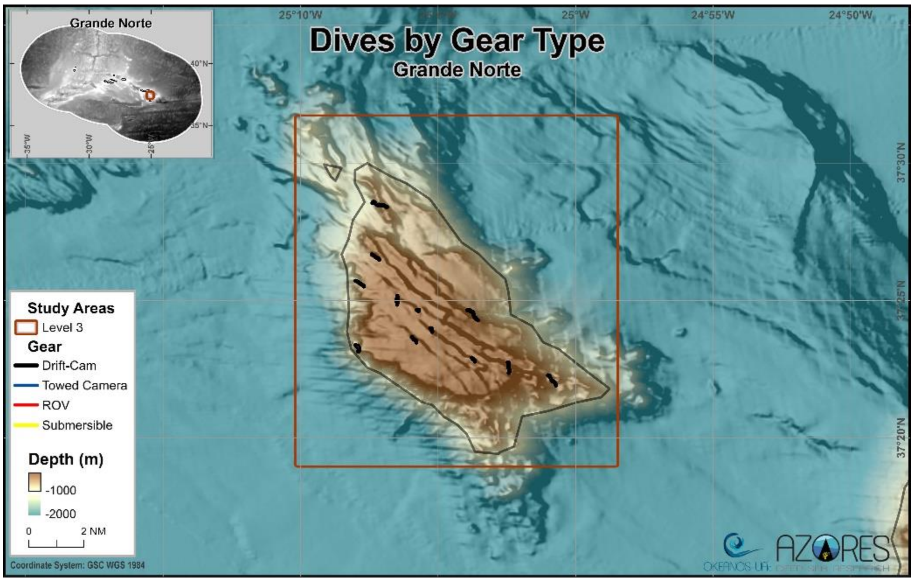



**Figure 458** Map displaying the 12 underwater dives performed in the Grande Norte area between 130 and 1,050 meters depth.

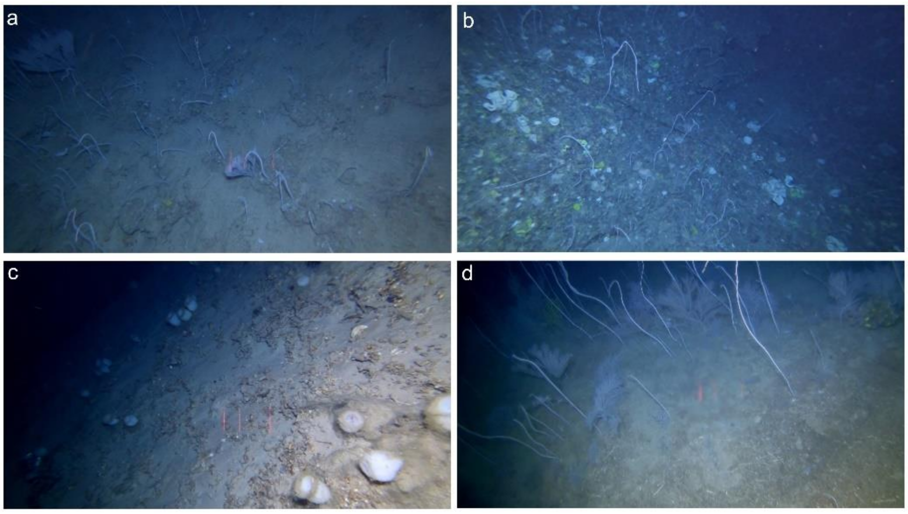



**Figure 459** Selected images representative of the main structuring species and benthic communities observed in Grande Norte seamount. (a) Coral aggregation of *Viminella flagellum* and *Paracalyptrophora josephinae.* (b) Aggregation of *Viminella* flagellum together with the sponge *Neophrissospomgia nolitangere* and other encrusting sponges. (c) Aggregation of the sponge *Pheronema carpenteri*. (d) Aggregation of large *Viminella flagellum, Dentomuricea* aff. *meteor, Paracalyptrophora josephinae* and *Callogorgia verticillata.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Formigas seamount*

A total of 20 underwater video transects were performed in Formigas seamount, covering the depths between 310 and 1580 m (Figure 460). The video analysis resulted in a high diversity of deep-sea megabenthic species, with a total of 101 taxa determined. Of these, 61 were identified at the species level. The most frequently observed taxa based on weighted occurrences were *Acanthogorgia* spp. (n= 71), *Leptopsammia formosa* (n= 50), and *Characella pachastrelloides* (n= 47).

Formigas seamount, including the Dollabarat bank, is located 34 miles south-west of São Miguel Island, in the easternmost part of the Terceira Rift, at the western end of the Eurasian–Nubian plate boundary. It is known to be under the influence of the Mediterranean Outflow Water (MOW), which provides a particular oceanographic setting to the configuration of its water masses. The deepest areas explored, at 1,400-1,600 m depth, were mostly flat with soft sediments, where sand forms discernible ripples. Not much fauna was observed in these soft bottoms besides some scattered sea urchins *Cidaris cidaris* and the orange bamboo coral *Acanella arbuscula*, especially on the southern side (Figure 461). More abundant is the mobile fauna, which includes the crustacean *Aristaeopsis edwardsiana* and several eel-like and macrourid fishes. Moving towards shallower depths, when the rock starts to outcrop, the number of species increased rapidly, leading to a very diverse mixed community of corals and sponges, generally with low densities. Very common were the black corals *Bathypathes* sp*., Antipathes* sp. and *Parantipathes hirondelle,* as well as *Leiopathes* cf. *expansa*, some of which reached large sizes. Also common were the octocorals *Acanella arbuscula, Chrysogorgia agassizii, Iridogorgia* sp. and several Plexauridae species still to be identified, together with the bamboo coral from the family Keratoisididae, with some colonies of impressive heights. Some alive colonies of the scleractinians *Lophelia pertusa* and *Desmophyllum dianthus* were observed, although always found scattered and in low numbers. Regarding the sponge fauna, some hexactinellid species were found on the rocks, including *Pheronema carpenteri*, as well as large demosponges. The highest structural complexity of this community was observed in the large rocky outcrops on the southern flank at 1,000 m depth. Most coral species reached their maximum sizes and densities in this area, conforming the highest diversity patches identified so far. At those depths, the octocoral *Candidella imbricata* became very common, both as part of the coral community or as the dominant species together with *Hemicorallium niobe* and an orange Plexauridae. Around 1200 m depth, in an area of compact soft sediments of the southern flank, a large aggregations of the lollypop sponge *Stylocordyla pellita* was encountered. This pedunculate sponge was found in association with the corals *Acanella arbuscula* and *Chrysogorgia* sp*.,* which develop both on hard and soft substrates. In fact, these two species were the most widespread corals of the deep areas of Formigas, found in low densities from 1,400 m all the way to 700 m depth. The quantity of coral rubble deposited over the seabed started to increase below 1,000 m, with areas fully covered by pieces of dead corals. Most of these pieces seem to be originated by the fractioning of large colonies of the scleractinian coral *Lophelia pertusa,* but some fragments are also as remnants of solitary cup corals and even colonies of lace corals (Stylasteridae) (Figure 461). In some sloping and vertical walls, some dead colonies were clearly visible due to their size, serving as substrate for other invertebrate species. Also, on the vertical walls of the southern flank, at around 900 m depth, the 'living-fossil community' of the crinoid cf. *Cyathidium foresti* was identified (Figure 461), together with several brachiopods and encrusting sponges. The shallowest areas (650-800 m) hosted a community characterized by high densities of the primnoid corals *Narella versluysi* (Figure 461), and *Narella bellissima*, which appeared associated to a wide array of other species, including the octocorals *Acanthogorgia* spp. and *Hemicorallium tricolor*, and the sponges *Pheronema carpenteri.* The shallowest areas explored showed fewer structuring species and were dominated by sponges, mainly encrusting and digitate of a small size.

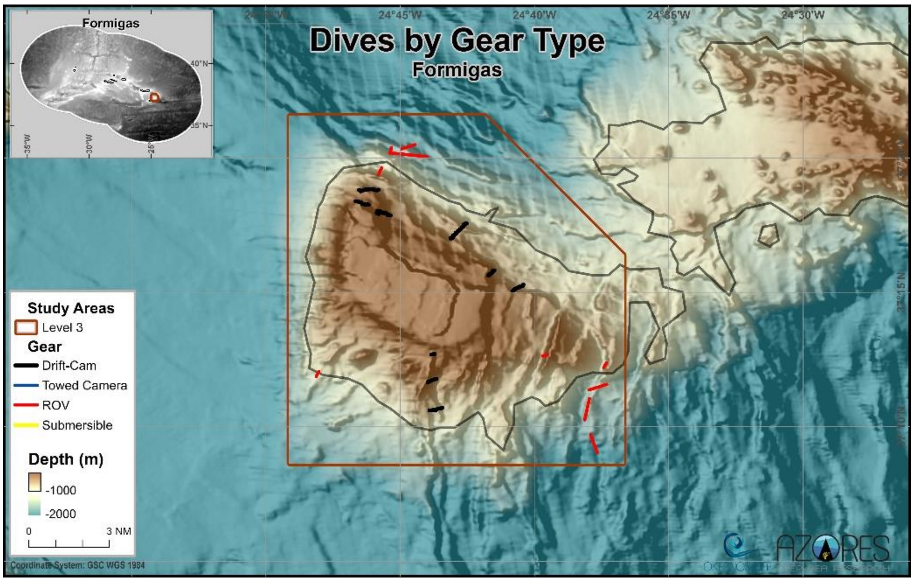



**Figure 460** Map displaying the 20 underwater dives performed in the Formigas area between 310 and 1580 meters depth.


**Figure 461** Selected images representative of the main structuring species and benthic communities observed in Formigas seamount. (a) Ripples on the soft bottoms of the deepest areas explored, at 1,500 m depth. (b) The bamboo coral *Acanella arbuscula* on soft sediments. (c) A large Keratoisidinae in areas of a high diversity of corals. (d) Aspect of the large rocky outcrops colonized by several species of scleractinians, octocorals, black corals and bamboo corals. (e) Association between *Candidella imbricata*, *Hemicorallium niobe* and *Chelidonisis aurantiaca*. (f) Aggregation of the sponge *Stylocordyla pellita*. (g) Dead colonies of the scleractinian coral *Lophelia pertusa*. (h) Ancient community found in vertical walls with oysters and cf. *Cyathidium foresti*. (i). Dense aggregation of the Primnoid *Narella versluysi* with a few other corals and glass sponges. Image credits: Medwaves, ATLAS project.

*Margrette*

In the Margrette area, 8 underwater video transects were conducted between 330 and 1040 m depth (Figure 462). The results obtained through video analysis suggested a medium diversity of deep-sea megabenthic species, with 70 taxa determined. Among these, 48 were identified at the species level. The most frequently observed taxa based on weighted occurrences were *Leptopsammia formosa* (n= 36), *Hymedesmia (Hymedesmia) paupertas* (n= 33), and *Plesionika* (n= 31).

On the deepest areas (800-1000m depth) of the Margrette, the unconsolidated substrates showed the typical fauna of such depths (Figure 463), including the corals *Acanella arbuscula* and *Chrysogorgia* sp., the sea urchin *Cidaris cidaris* and the oreo fish *Neocyttus helgae*. Moving further up the slope (650-800 m depth), several species of octocorals like *Hemicorallium tricolor* and *H. niobe* started to be common, followed by some *Acanthogorgia* spp. and aggregations of both *Narella versluysi* and *N. belissima,* together with the cup coral *Leptopsammia formosa* (Figure 463). The glass sponges *Farrea occa* and *Pheronema carpenteri,* were also observed as well as *Stylocordilla pellita*. The shallower areas (400-500 m depth) revealed a high number of sponge species, including those from the genus *Characella, Petrosia, Geodia* and *Haliclona*, in some sectors accompanied by the whip coral *Viminella flagellum* or by large colonies of the primnoid *Callogorgia verticillata* (Figure 463). Some of these colonies appeared dead lying flat over the seabed, others showed some individuals with broken branches, likely signs of fishing activity. Some crabs of the species *Paromola cuvieri* were observed carrying corals on their back. Several fishes were recorded including the deep-sea shark *Dalatias licha* and some large wreckfish *Polyprion americanus*.

Several long lines were observed on this seamount, some of which with epibionts growing on top of them, indicating that they could have been there for a long time.

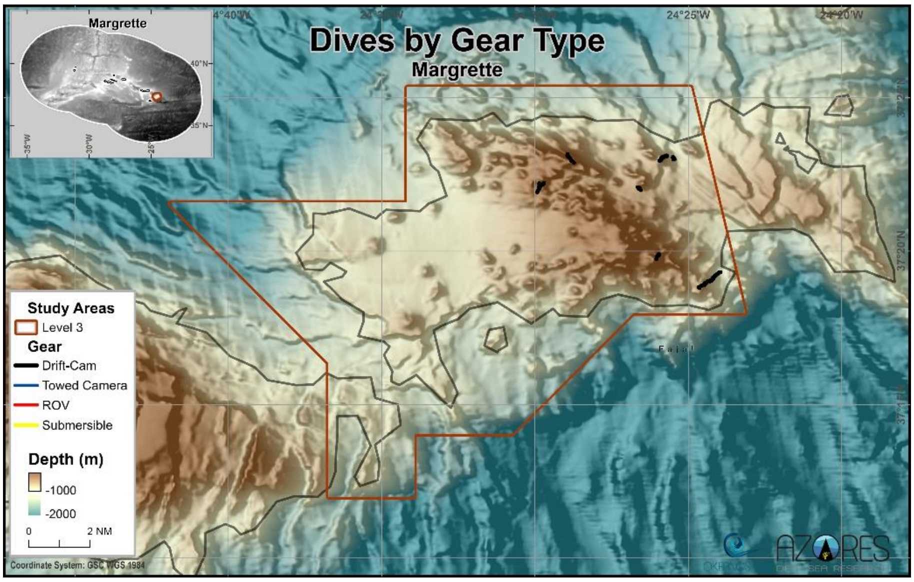



**Figure 462** Map displaying the 8 underwater dives performed in the Margrette area between 330 and 1,040 meters depth.

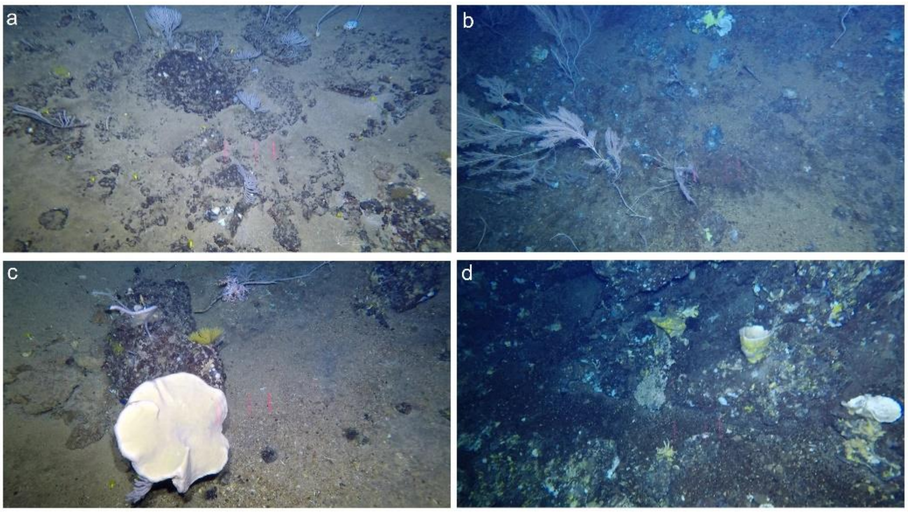



**Figure 463** Selected images representative of the main structuring species and benthic communities observed in Margrette area. (a) Small coral aggregation of *Narella bellissima* and *N. versluysi, Leptopsammia formosa* and occasional *Acanthogorgia* sp. (b) Aggregation of *Viminella* flagellum together *Callogorgia verticillata.* (c) Small rock colonized by *N. versluysi, Acanthogorgia* sp. and some encrusting sponges and one *Petrosia crassa*. (d) Massive *Characella pachastrelloides on basaltic outcrops.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Margrette E*

In the area Margrette East, 5 underwater video transects were conducted between 690 and 930 m depth (Figure 464). The video analysis revealed a low diversity of deep-sea megabenthic species, with a total of 45 taxa identified. Of these, 28 were identified to the species level. The most frequently observed taxa based on weighted occurrences were Plesionika (n= 16), *Acanthogorgia* spp. (n= 14), and *Bathynectes maravigna* (n= 10).

The eastern part of Margarette seamount is an area with several flat terraces and very high vertical walls. The seafloor was distinct by its complexity and sometimes irregular geomorphology, but overall, the seafloor was hard and with a simple relief and coral rubble patches. The benthic megafauna encountered on the deepest areas filmed were mainly composed of corals, from which we can feature the vast aggregations mainly composed by the primnoid corals *Narella versluysi*, *Narella bellissima* and often accompanied by large individuals of *Hemicorallium tricolor* and not so big *H. Niobe* (Figure 465). Relatively large and vast patches of the gorgonian *Acanthogorgia* spp., were spotted and with a large depth range. Sponges were also very common to observe, like *Desmacella grimaldi* and an encrusting sponge from the family Euretidae, normally attached to the basaltic boulders, the frequent glass sponges *Farrea occa, Asconema fristedti* (Figure 465) and mainly at the top of the outcrops, the fan-shaped *Phakellia ventilabrum*. The benthic megafauna was generally the same at the depths explored, not showing a clear shift from one area of the slope to another, only the density increased in slightly shallower sectors.

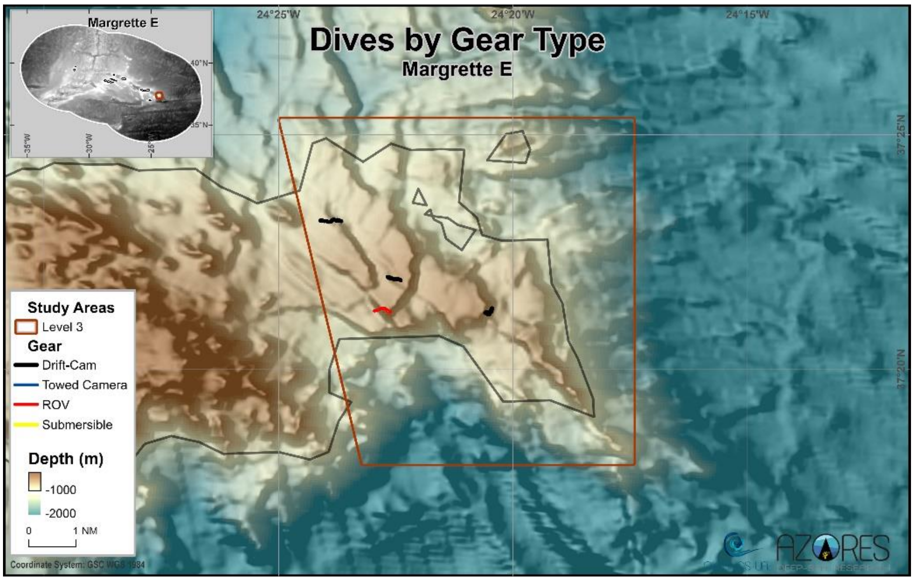



**Figure 464** Map displaying the 5 underwater dives performed in the Margrette E area between 690 and 930 meters depth.

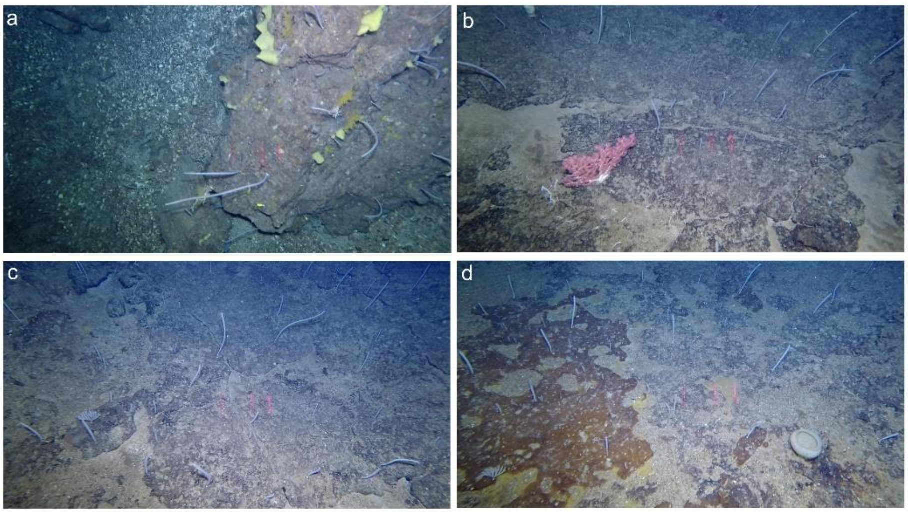



**Figure 465** Selected images representative of the main structuring species and benthic communities observed in Margrette East area. (a) Rock colonized by the corals *Narella versluysi, Leptopsammia formosa* and *Acanthogorgia* sp*.* along with the sponge *Desmacella grimaldi.* (b-c) Aggregation of *N. versluysi* with one *Hemicorallium tricolor* (b) and *Narella bellissima* (c). (d) Aggregation of *N. versluysis, N bellissima and the sponge* Asconema *fristedti.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Margrette NE*

In total, 2 underwater video transects were performed in the Margrette Northeast area between 780 and 970 m depth (Figure 466). The results obtained through video analysis revealed a low diversity of deep-sea megabenthic species, with a total of 42 taxa identified. Of these, 26 were identified at the species level. The most frequently observed taxa based on weighted occurrences were *Plesionika* (n= 19), Crinoidea (n= 18), and *Errina atlantica* (n= 15).

Margrette NE is a relatively deep ridge, with only a few areas with their summit above 800 m depth. The deepest areas of this ridge (around 910m) are characterized by consolidated rock, covered with coral rubble. The rocky areas showed sparse octocorals of the genus *Hemicorallium* (*H. tricolor* and *H. niobe*), as well as some occasional and small primnoids of the species *Narella versluysi* (Figure 467). The bird's nest sponge *Pheronema carpenteri* also appeared, forming small and sparse aggregations. Moving further up slope (850m), the coral rubble showed aggregations of Acanthogorgia spp. sometimes together with gardens of small *Narella versluysi* and *N. belissima.* On the hard substrate, the most abundant species were the stylasterids likely from the species *Errina atlantica* with the same octocorals already described on the deepest areas, from the genus *Hemicorallium,* together some white lamellate sponges and the yellow lamellate sponge *Desmacella grimaldi*. All these shallower species extended to what seemed like the summit of this ridge (around 780m), where an aggregation of large plexaurids (likely of the genus *Placocorgia*) was also observed (Figure 467).

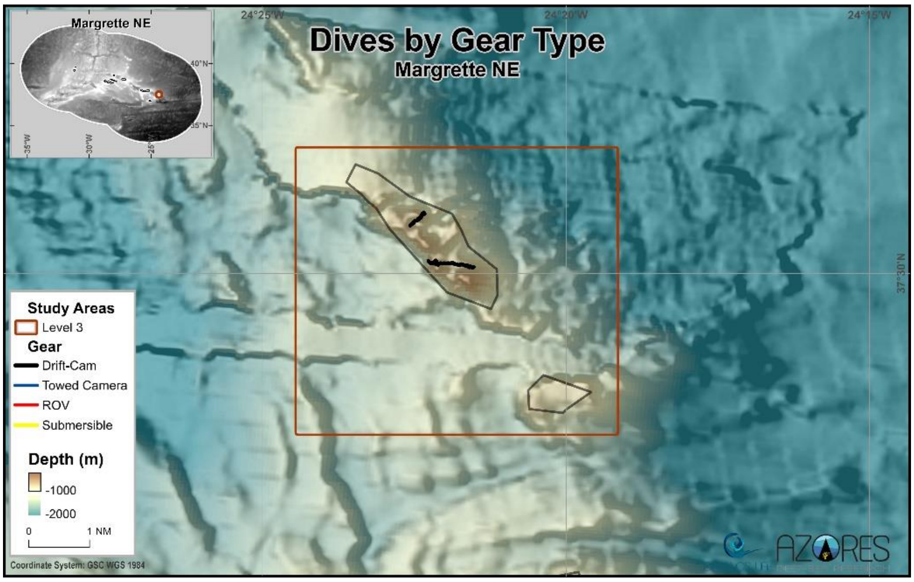



**Figure 466** Map displaying the 2 underwater dives performed in the Margrette NE area between 780 and 970 meters depth.

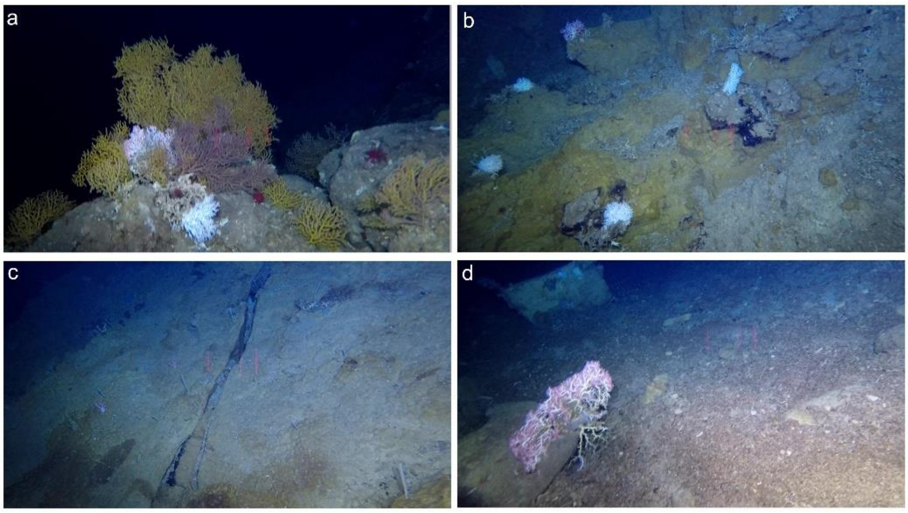



**Figure 467** Selected images representative of the main structuring species and benthic communities observed in Margrette Northeast area. (a) Coral aggregation of large plexaurids, likely the genus *Placogorgia*, the hydrozoan *Errina atlantica* and the soft-coral *Anthomastus/Pseudoanthomastus* sp.. (b) Sparsed colonies of *Errina atlantica*. (c) Dispersed colonies of *Narella versluysi.* (d) Colony of *Hemicorallium tricolor.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

### Study area | Santa Maria

*Santa Maria N*

The survey in Santa Maria North area included 7 underwater video transects, between 360 and 1070 m depth (Figure 468). The video analysis indicated a medium diversity of deep-sea megabenthic species, with 66 taxa determined. Among these, 42 were identified at the species level. The most frequently observed taxa based on weighted occurrences were *Leptopsammia formosa* (n= 35 weighted occurrences), *Lytocarpia myriophyllum* (n= 26), and *Petrosia* spp. (n= 20).

The deepest areas were generally of a sandy/muddy nature, with eel-like and macrourid fishes and little epifauna besides *Acanella arbuscula* and pedunculated glass sponges. However, when the rock outcropped, the diversity increased rapidly, with several of the common species observed at depths of 1000 m (Figure 469), which included black corals of the genus *Leiopathes*, octocorals of the genus *Hemicorallium*, cup corals of the species *Leptopsammia formosa* and several species of glass sponges. Moving towards shallower areas, the diversity and abundance of sessile species increased, with hard substrates characterized by high abundances of sponges, most of them of a small size and encrusting, but also with several erect species, such as *Characella pachastrelloides* and *Stylocordilla pellita*. One of the dives hosted a very dense aggregation of the octocoral *Candidella imbricata* (Figure 469), in most cases attached to the edges of the rock, likely in the search of better feeding conditions. The whip coral *Viminella flagellum* was also relatively common, generally accompanied by other octocorals such as the primnoid *Callogorgia verticillata* or a white ramified plexauridae not yet identified to species level. The soft sediments were generally colonized by large hydrozoans not yet identified to species level, as well as by scleractinians of the genus *Flabellum*, this last species generally in low abundances. Several abandoned fishing lines were observed, especially in shallower areas.

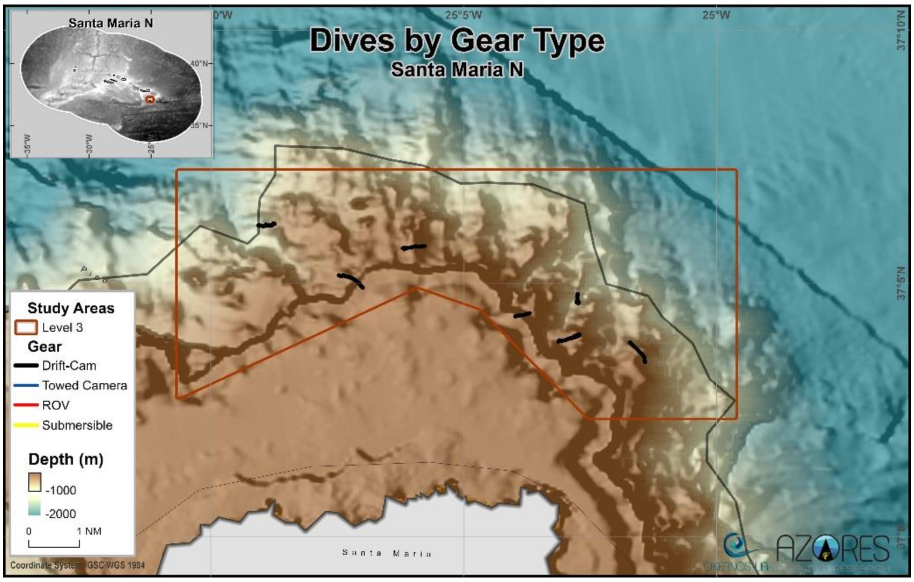



**Figure 468** Map displaying the 7 underwater dives performed in the Santa Maria N area between 360 and 1,070 meters depth.

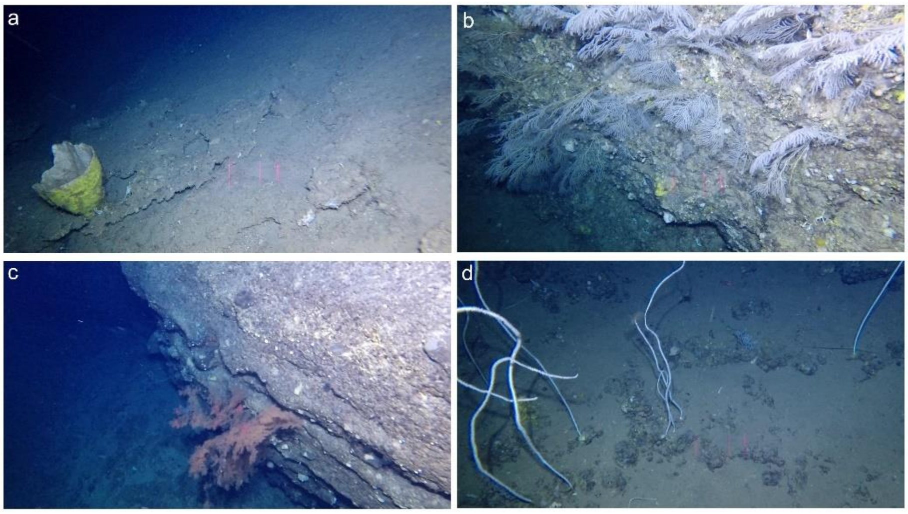



**Figure 469** Selected images representative of the main structuring species and benthic communities observed in Santa Maria North area. (a) Large sponge *Characella pachastrelloides* on soft sediments. (b) Dense aggregation of *Candidella imbricata*. (c) Colonies of *Leiopathes* cf. *expansa* on hard substrate. (d) Large colonies of *viminella flagellum.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Santa Maria E*

While exploring the Santa Maria East area, 5 underwater video transects were completed between 220 and 980 m depth (Figure 470). The results suggested a medium diversity of deep-sea megabenthic species, with 57 taxa determined from the video analysis. Among these, 35 were identified at the species level. The most frequently observed taxa based on weighted occurrences were *Leptopsammia formosa* (n= 35 weighted occurrences), *Lytocarpia myriophyllum* (n= 32), and *Acanthogorgia* spp. (n= 30).

The deepest areas were characterized by soft sediments with plenty of sand ripples, covered by some sponges of the genus *Hyalonema*, the cup corals *Leptopsammia formosa* and the occasional appearance of the sea urchins *Cidaris cidaris.* Considering mobile fauna, we found frequent shrimps *Aristaeopsis edwardsiana* and one ray *Dipturus batis*. While going up the island slope, the terrain started to get steeper with a lot of vertical walls showing small aggregations of the gorgonians *Acanthogorgia* sp., and patches of one unidentified white Plexauridae (Figure 471c). Sponges were also common, with *Macandrewia azorica*, *Characella spp.* (Figure 471d), *Pheronema carpenteri, Stylocordilla pellita* and some large cf. *Stryphnus*, being the most observed species. The fishes silver roughy (*Hoplostethus mediterraneus*) and several rattails (*Macrouridae*) were frequently observed on the upper slope. The shallower areas, close to the summit, were packed with large *Viminella flagellum* together with some big *Callogorgia verticillata* (Figure 471a,b) and at least one *Paracalyptrophora josephinae*. On these areas we also spotted some mobile fauna such as a school of boar fish (*Capros aper*) and some *Anthias anthias* (or *Calanthias ruber*).

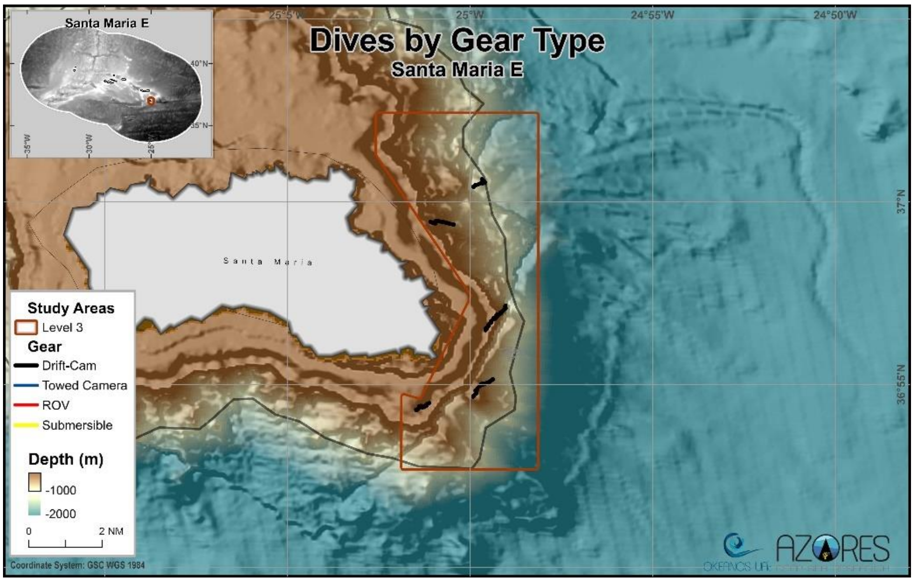



**Figure 470** Map displaying the 5 underwater dives performed in the Santa Maria E area between 220 and 980 meters depth.

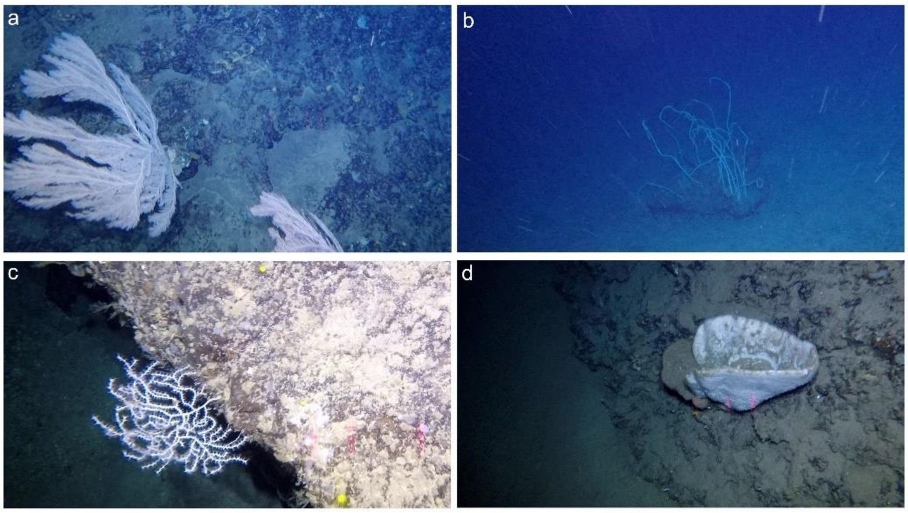



**Figure 471** Selected images representative of the main structuring species and benthic communities observed in Santa Maria East area. (a) Large *Callogorgia verticillata.* (b) Boulder densely colonized by *Viminella flagellum.* (c) Colony of unidentified white plexaurid. (d) Massive *Characella spp.* Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Santa Maria SW*

In Santa Maria Southwest area, 7 underwater video transects were completed between 230 and 1020 m depth (Figure 472). The video analysis uncovered a high diversity of deep-sea megabenthic species, with a total of 80 taxa determined. Of these, 50 were identified at the species level. The most frequently observed taxa based on weighted occurrences were *Leptopsammia formosa* (n= 37), Bryozoa (n= 30), and *Farrea occa* (n= 23).

The fauna observed in the deepest areas was typical from those depths, including the bamboo coral *Acanella arbuscula* and a variety of eel-like fishes in soft sediments. Hard substrates hosted a more diverse faunistic composition, with black corals (e.g., *Leiopathes sp*.), stylasterids, cup corals (e.g., *Leptopsammia formosa*) and glass sponges (e.g., *Hyalonema sp.* and *Farrea occa*). Going up the island slope, the intermediate depths were characterized by a large diversity of sponges, from small encrusting species to large erect individuals, such as *Macandrewia azorica, Stylocordilla pellita* and *Petrosia sp*. (Figure 473).At those depths, aggregations of octocoral species were also observed, including those formed by the primnoids of the genus *Narella* and by *Acanthogorgia spp*. The shallowest areas were relatively poor in terms of fauna, besides some areas with the whip coral *Viminella flagellum*, aggregations of hydroids in soft sediments, and accumulations of dead algae in the shallowest depths surveyed, probably transported from littoral areas.

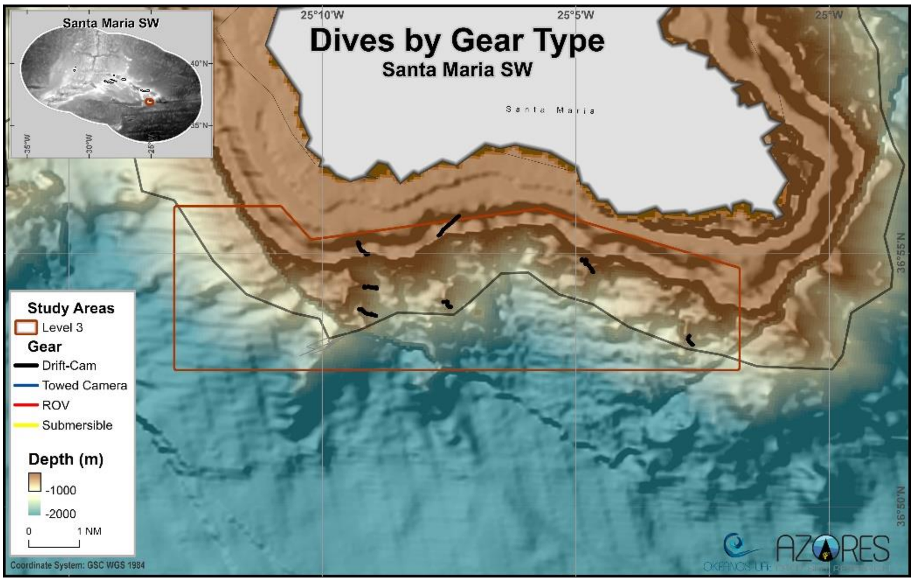



**Figure 472** Map displaying the 7 underwater dives performed in the Santa Maria SW area between 230 and 1,020 meters depth.

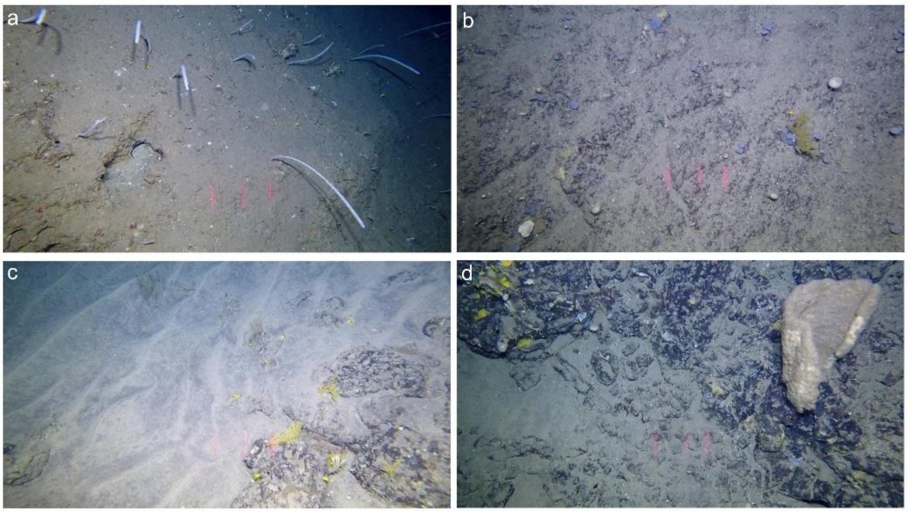



**Figure 473** Selected images representative of the main structuring species and benthic communities observed in Santa Maria Southwest area. (a) Aggregation of *Narella versluysi.* (b) Basaltic bottom covered with soft sediments and colonized by *Acanthogorgia* sp. with the sponges *Macandrewia azorica* and glass sponges. (c) *Acanthogorgia* sp. on rocky patches sideways with soft sediments with cf. *Lytocarpia myriophyllum.* (d) *Characella* spp. on a rocky bottom together with other encrusting sponges. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Santa Maria W*

Through the Santa Maria West area were performed 6 underwater video transects, between 210 and 1090 m depth (Figure 474). The results indicated a medium diversity of deep-sea megabenthic species, with 66 taxa determined from the video annotation. Among these, 47 were identified at the species level. The most frequently observed taxa based on weighted occurrences were *Flabellum* sp. (n= 29), *Lytocarpia myriophyllum* (n= 24), and Hydrozoa (n= 18).

When our research team explored Santa Maria W Island slope, the lack of detailed bathymetry prevented us from finding adequate sites for deployment, although we proceeded our exploration which allowed the biological description of this geomorphological unit. Here we managed to conduct the first dive deeper than the maximum reached before with the Azor drift-cam (1185m).

The deepest areas (1000-1190m) of the Santa Maria W were mainly composed of soft sediment with dense patches of *Candidella imbricata*, there were also some occasional bamboo corals of the species *Acanella arbuscula,* and the black coral *Antipathes erinaceus*, especially colonizing the basaltic boulders (Figure 475b-c), and some unidentified Plexauridae on the rocky crest. The lower upper slope areas, characterized by soft substrate were covered with corals of the genus *Acanthogorgia* spp. and sponge aggregations of cf. *Hyalonema* and *Pheronema carpenteri* (Figure 475d). While moving shallower we found a dense patch of *Callogorgia verticillata*, with the hydrocoral *Pleurocorallium johnsoni* (Figure 475a) and the cup coral *Leptopsammia formosa,* followed by a community with the sponges *cf. Poecillastra compressa, cf. Haliclona magna* and *Characella* spp. In this ridge, we managed to get a close-up of a *Paromola cuvieri* carrying a *Callogorgia verticillata* on its back. On the lower depths shallow-water fish were the main observed fauna, such as *Pontinus khulii*, *Scorpaena scrofa* and *Serranus cabrilla*, among others.

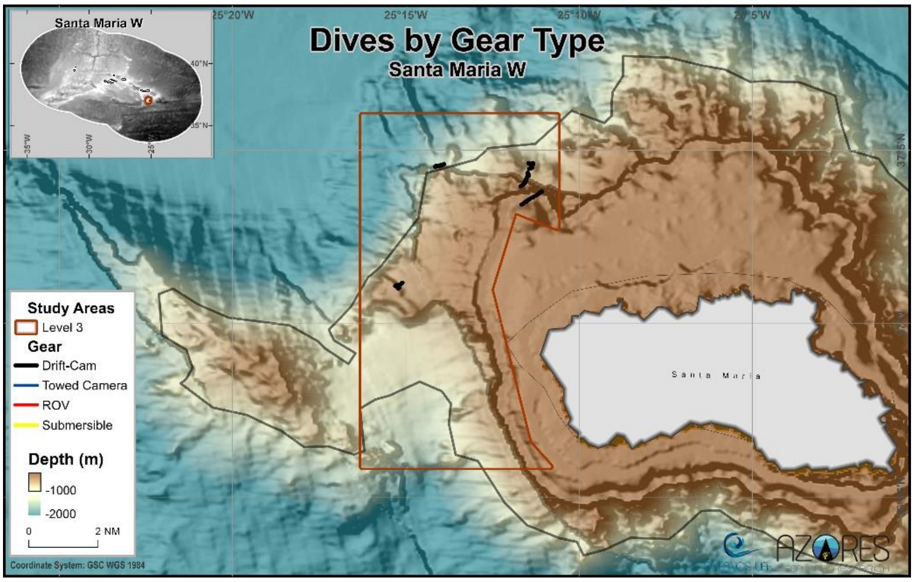



**Figure 474** Map displaying the 6 underwater dives performed in the Santa Maria W area between 210 and 1,090 meters depth.

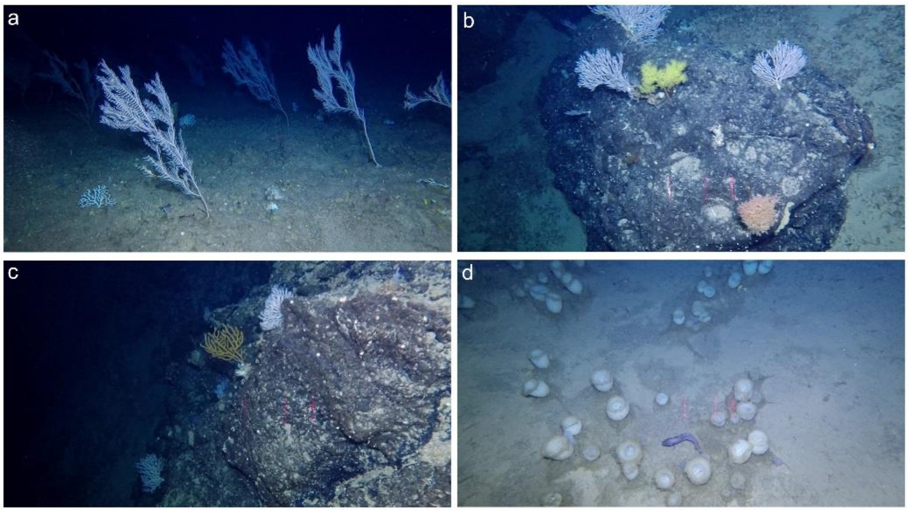



**Figure 475** Selected images representative of the main structuring species and benthic communities observed in Santa Maria West area. (a) Aggregation of large *Callogorgia verticillata* and *Pleurocorallium johnsoni.* (b) Boulder colonized by *Acanella arbuscula,* the black coral *Antipathes erinaceus* and *Candidella imbricata.* (c) Boulder with the gorgonians *Candidella* imbricata and cf. *Placogorgia* sp. and small sponges. (d) Aggregation of *Pheronema carpenteri* on soft sediments. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

*Santa Maria Pico W*

Surveying the Santa Maria Pico West area, 5 underwater video transects were conducted between 580 and 1060 m depth (Figure 476). The findings revealed a medium diversity of deep-sea megabenthic species, with 61 taxa determined from the video analysis. Of these, 39 were identified at the species level. Curiously, no weighted occurrences were recorded for any specific taxa in this area.

The deepest areas of the Santa Maria Pico W Island slope were composed by basaltic outcrops, covered with soft sediment. These rocky substrates were colonized by high densities of the gorgonians *Hemicorallium tricolor* together with cf. *Hemicorallium niobe* and stylasterids (Figure 477a). When moving to shallower depths rocky substrates appeared colonized by a few sponges and large, dense coral gardens of both *Narella versluysi* and *N. bellissima*, were observed, together with aggregations of *Acanthogorgia spp*. and of the glass sponge *Asconema sp*. (Figure 477b,c). Aggregations of large sponges such as *Characella* spp. were also recorded on the shallower areas, as well as some mobile fauna such as the silver roughy (*Hoplostethus mediterraneus*), one bluntnose sixgill shark (*Hexanchus griseus*), a monkfish (*Lophius piscatorius*) (Figure 477d), and a bluemouth rockfish *(Helicolenus dactylopterus*).

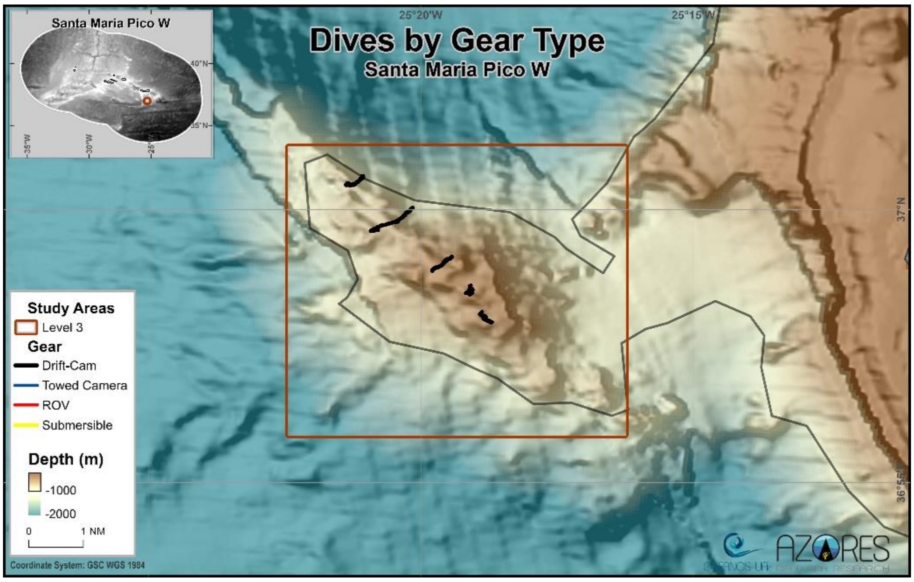



**Figure 476** Map displaying the 5 underwater dives performed in the Santa Maria Pico W area between 580 and 1,060 meters depth.

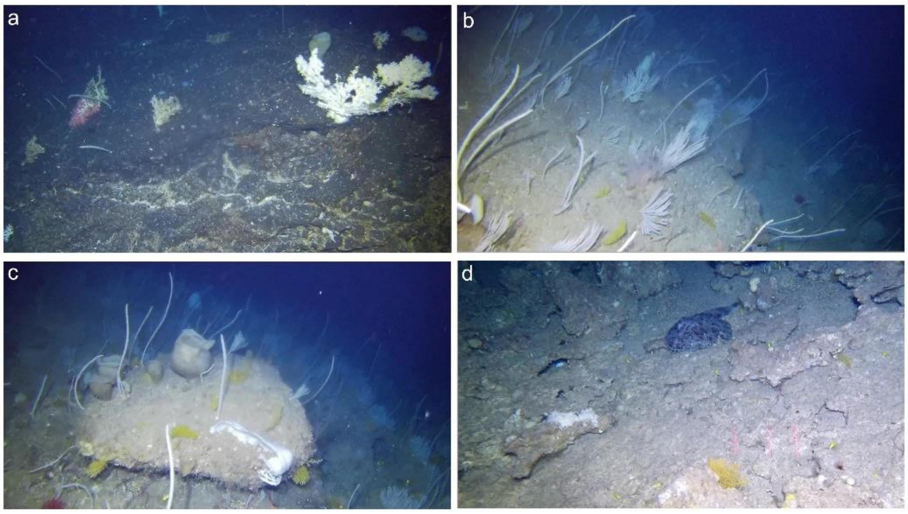



**Figure 477** Selected images representative of the main structuring species and benthic communities observed in Santa Maria Pico West area. (a) Basaltic bottom with colonies of *Hemicorallium tricolor* and *H. niobe* together with *Narella verluysi.* (b) Large area covered by *N. versluysi* and *N. bellissima* and some occasional *Acanthogorgia* sp. and the sponge *Asconema fristedti* (c) Aggregation of the corals *N. versluysi* and *N. bellissima* and occasional *Acanthogorgia* sp. with a boulder in the middle with large sponges *A. fristedti* and *Poecillastra compressa* (d) Monkfish *Lophius piscatorius*. Image credits: IMAR/Okeanos-UAz, Azor drift-cam.

## 11. Policy recommendations

The final report also aims to present recommendations for the protection of these ecosystems and obtaining or maintaining their good environmental status, in accordance with the requirements of the Marine Strategy Framework Directive. This section contains suggestions to 1) identify aiming to Protec deep sea ecosystems, 2) to assess Descriptor 6 of the Marine Strategy Framework Directive for the deep sea, including proposals and suggestions on how to identify reference conditions for reporting purposes, and 3) to assess the pressures and threats from human activities in the deep-sea at sea with the potential to affect these ecosystems.

### *11.1 Protection of deep-sea ecosystems*

For the purposes of this report, and as described in the R0 report, we evaluated the 140 geomorphological structures of the Azores in relation to each of the five FAO criteria to define what constitutes a VME, based on the information compiled, collected and analysed during this project. The evaluation was based on the species and communities found in each geomorphological structure as well as a measure of their abundance in the BD2 Georeferenced database containing information of species and habitats (see section 6).

#### Methodologies and definitions

The provision of services refers the need to operationalize the definition of VMEs in the Azores and to the identification of areas that fit the adopted definitions. As described in Section 1.5, the concept of a vulnerable marine ecosystem was initially developed to protect species, communities, or habitats from impacts from fisheries activities. However, even though great efforts have been made to operationalize the VME concept worldwide, it is still not clear how VMEs can be identified and what management measures should be applied. To start operationalizing a better definition of VME in the Azores and to make progress towards the identification of areas that fit those definitions, we reviewed the recent work developed the ICES (e.g., ICES, 2020b; ICES, 2022a,b) and other organizations (e.g., DFO), and scientist (e.g., Watling & Auster, 2021).

Two of the main problems with the identification of VMEs, are 1) the lack of sufficient data to assess the intrinsic vulnerability of bottom dwelling deep-sea species, communities, habitats or ecosystems and 2) the lack of agreement on delimitation of the "*ecosystem*". To overcome some of these and other shortcomings Watling & Auster (2021) made some recommendations to improve the operationalization of the VME concept in seamount-like areas such as those geomorphological units occurring in the Azores. Among others, they suggested to use VME indicator species to identify vulnerable marine communities, similarly to what is presented in Section 8, and to recognize that protecting part of a geomorphological structure is not enough.

To take advantage of the large volume of data produced over the last years on VME indicator species (Section 8), VME communities (Section 9), and their spatial distribution (Section10 ), but also on the efforts to identify VMEs in the Azores, we assessed the 140 geomorphological units described in Section 2 against each of the five FAO criteria for defining what constitutes a VME (section 1.5) using expert judgement (Table 36). The methodology used for the assessment was based on a qualitative scoring adapted from Morato *et al.* (2018) and took into consideration the VME indicator taxa most suitable to address the FAO criteria, and their occurrence and abundance in the different sampling areas. The degree to which sampling areas fit each of the five FAO criteria was scored as 1 (low), 2 (medium), 3 (high) or 4 (very high). The scoring procedure was discussed and agreed by a group of deep-sea scientists using existing informed expert judgment, and the following specific guidelines (Table 36) adapted from Morato *et al.* (2018).

The features were generally assessed in relation to the diversity of species and biological communities, with unique characteristics in terms of the composition of endemic, rare or threatened species (FAO criteria 1), and to the presence and abundance of communities composed of tall, and arborescent species that provide complex habitat for other species (FAO criteria 5). The fragility of the habitat-forming species (FAO criteria 3) was based on evidence of vulnerability to physical contact, such as accidental capture during longline fishing (based on Sampaio *et al.*, 2012; COLETA database), and the capacity of species for retraction, retention or re-growth or natural protection in some way. In general, there is limited information to assess the life history and functional significance of the species and communities (FAO criteria 2 and 4 respectively) due to major knowledge gaps on species reproductive cycles, growth rates, reproductive output, larvae biology and dispersal, recruitment and their role in the functioning of the ecosystems such as nursery areas for other species, nutrient regeneration, and carbon remineralization and sequestration. When available, information on life-history traits for closely related species or same taxa was used as a proxy to score for that criterion, based on the assumption that these traits are phylogenetically conserved (Kraft *et al.*, 2007). As for the functional significance of the habitat, there is information regarding fish and sharks' aggregations in or close to coral gardens, for example the deep-water kitefin shark *Dalatias licha* and the orange roughy *Hoplostethus atlanticus*. However, it is difficult to infer a direct link between habitat-forming species such as corals or sponges and their role as nursery grounds, especially based on observed adult fish and shark species. Because of limited knowledge, in most cases it was assumed that those features that presented the highest diversity of species and communities had a potentially higher functional significance. This is based on studies that show a direct relationship between biodiversity and ecosystem functioning for deep-sea ecosystems (Snelgrove *et al.*, 2014; Zeppilli *et al.*, 2016) and how habitat heterogeneity increases the number of niches for associated species, ecological interactions, and food web complexity (Buhl-Mortensen *et al.*, 2010; Zeppilli *et al.*, 2016). Though, as new scientific knowledge is gathered in the future, a better assessment of these criteria will be possible.

**Table 36** FAO criteria for defining what constitutes a VME (FAO, 2009; 2016) and the methodology used for assessing each sampling area against each of the five FAO criteria; scored as 1 (low), 2 (medium), 3 (high) or 4 (very high) (adapted from Morato *et al.*, 2018).

| FAO criteria | Description of the criteria | Scoring guidelines | Potential scale for expert judgement) |
|---|---|---|---|
| 1<br>Uniqueness or rareness | An area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems | According to presence on IUCN red list, and if the VME indicator species and/or communities are known to be endemic, rare, threatened or declining | E.g.: 1 for areas with VME indicator species and/or communities with a global distribution, 2 for large ocean basis distribution, 3 for regional distribution, and 4 for local distribution and for isolated or endemic indicators |
| 2<br>Functional significance | Discrete areas or habitats that are necessary for the survival, function, spawning/reproduction or recovery of fish stocks, particular life-history stages (e.g., nursery grounds or rearing areas), or of rare, threatened or endangered marine species | Evaluating if the VME indicator species and/or communities were known to create nursery areas for other species, or known for having higher level ecosystem role, such as nutrient cycling and water filtration | E.g.: 1 for areas with VME indicator species and/or communities with low provision of functional habitat, 2 for medium provision, 3 for high provision, and 4 for very high for provision of functional habitat. |
| 3<br>Fragility | An ecosystem that is highly susceptible to degradation by anthropogenic activities | According to the fragility of the VME indicator species and/or communities against physical contact, the height and complexity of its structure, and the capacity for retraction, retention or re-growth or if being naturally protected in some way | E.g.: 1 for areas with VME indicator species and/or communities with low fragility, 2 for medium fragility, 3 for high fragility, and 4 for very high fragility. |
| 4<br>Life-history | Ecosystems that are characterized by populations or assemblages of species with one or more of the following characteristics: slow growth rates, late age of maturity, low or unpredictable recruitment, or long-lived | Against the longevity of the VME indicator species and/or communities as a proxy for potential recovery after disturbance, fecundity, age at maturity, growth rate, and known frequency of recruitment success | E.g.: 1 for areas with VME indicator species and/or communities with longevities <5 years, 2 if 5-15, 3 if 15-30, 4 if >30 years. |
| 5<br>Structural complexity | An ecosystem that is characterized by complex physical structures created by significant concentrations of biotic and abiotic features | Based on structural habitat created by the VME indicator species and/or communities, and presence of commensal or closely associated species | E.g.: 1 for areas with VME indicator species and/or communities with low provision of structural habitat, 2 for medium provision, 3 for high provision, and 4 for very high for provision of structural habitat. |

Assessment of Vulnerable Marine Ecosystems in the Azores down to 1,000 m depth

The assessment of underwater features against the VME criteria resulted from a semi-quantitative evaluation of the occurrence of VME indicator species and VME indicator communities on the sampling areas. The evaluated sampling areas were, in general, characterized by great diversity of VME indicator species and biological communities, with some examples of endemic, rare or threatened species (FAO criteria 1; Figure 478), namely Kurchatov SE, Agulhas Corvo-Graciosa, Óscar, Gigante, Cavala, Farpas, Espadarte, Sedlo W, Graciosa S, Dom João de Castro, Condor seamount, Ponta da Ilha N, Ponta da Ilha S, Albatroz do Meio, Álvaro Martins, entre outros (score = 4). Several of these areas also scored very high (i.e., 4) for structural complexity mostly because of the high densities of tall and arborescent species and communities that provide habitat for other species (FAO criteria 5), namely Estrela, Kurchatov N, Kurchatov SE, Agulhas Corvo-Graciosa, Farpas, Sedlo W, Graciosa S, Ponta da Ilha N, Ponta da Ilha S, Albatroz do Meio, entre outros (Figure 479).

The Assessment of Vulnerable Marine Ecosystems in the Azores down to 1,000 m depth identified 41 out of the 140 areas that fit the criteria that defines a VME (Table 37; Figure 479): Hard-Rock Café, Flores NE, Chaucer S, Estrela, Kurchatov N, Isolado, Kurchatov SE, Kurchatov S, Kurchatov SW, Agulhas Corvo-Graciosa, Óscar, Gigante N, Gigante, Gigante Agulhas NW, Gigante Agulhas SW, Cavala, Beta, Sardinha, Voador, Farpas, Espadarte, Sedlo W, Gaillard, Graciosa S, Ilha Azul SE, São Jorge W Rosais, Álvaro Martins, Dom João de Castro, Ferraria Norte, Ferraria Mar, Girard, Pico S Lajes, Faial W Capelinhos, Condor, Ponta da Ilha N, Ponta da Ilha S, Albatroz do Meio, Açor S, Princesa Alice Picos S, Sauerwein, and Formigas.

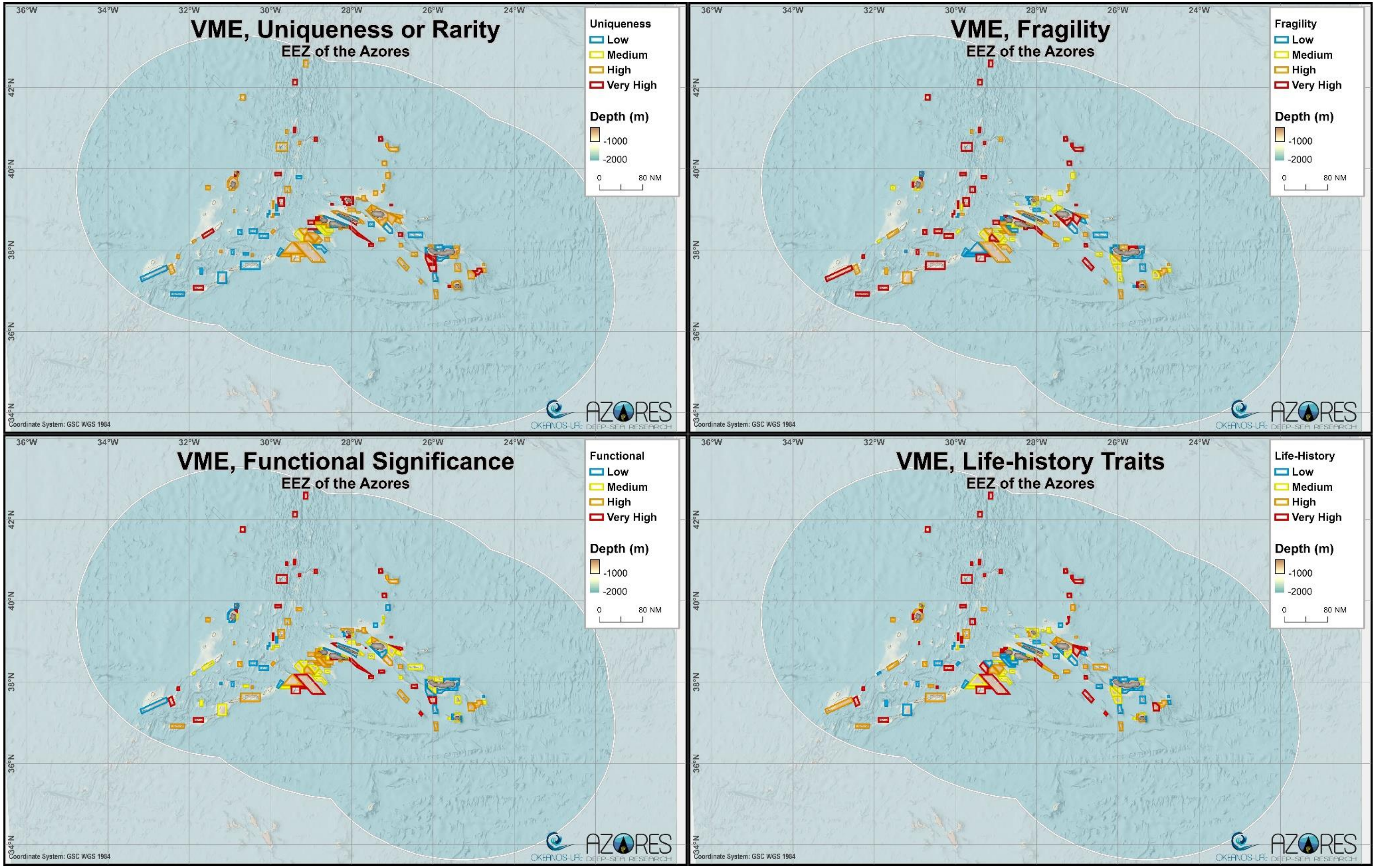



**Figure 478** Assessment of each sampling area against 4 out of the 5 FAO criteria; scored as 1 (low), 2 (medium), 3 (high) or 4 (very high) (adapted from Morato *et al.*, 2018).

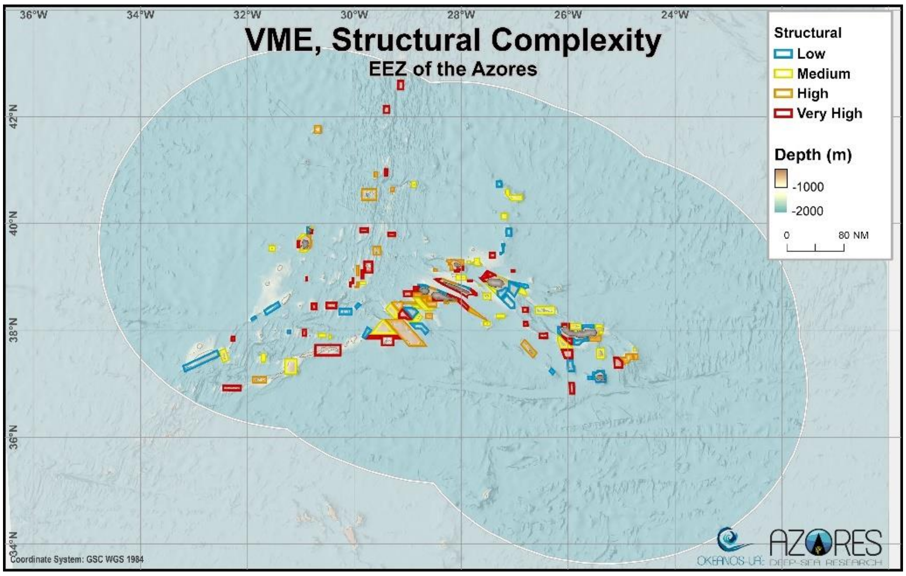



**Figure 479** Assessment of each sampling area against the FAO criteria Structural complexity; scored as 1 (low), 2 (medium), 3 (high) or 4 (very high) (adapted from Morato *et al.*, 2018.

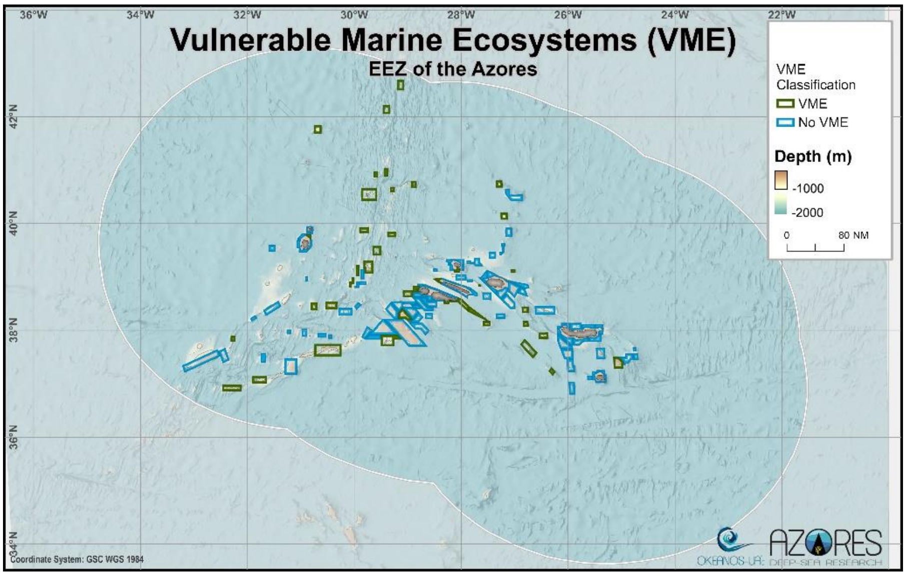



**Figure 480** Final evaluation of each underwater feature against the FAO criteria for defining what constitutes a Vulnerable Marine Ecosystem (FAO, 2009). Features identified as potential VMEs are highlighted in green.

**Table 37** Assessment of underwater features against five criteria for defining what constitutes a Vulnerable Marine Ecosystem (FAO, 2009). Low fit to a criterion is coloured in light blue, medium in dark blue, high in pink, and very high in red. Features identified as potential VMEs are highlighted in *bold* and grey.

| Large Area | Sampling Area | *VME* | *Unique* | *Functional* | *Fragility* | *Life history* | *Structural* | General description |
|---|---|---|---|---|---|---|---|---|
| W group | Hard Rock Café | Y | 3 | 4 | 4 | 4 | 3 | Orange roughy (*Hoplostethus atlanticus*) in large abundances. Diverse community composed by several species such as *Hemicorallium niobe*, *Lophelia pertusa*, *Leiopathes expansa*, *Bathypathes* sp., *Antipathes dichotoma*, *Acanthogorgia* spp., and *Parantipathes hirondelle* and some individuals belonging to the complex cf. *Paramuricea/Placogorgia*. Sponge communities were characterized by the presence of lamellate sponges such as *Desmacella grimaldi* and *Phakellia* spp. |
| W group | Corvo NW | N | 3 | 1 | 1 | 3 | 1 | Several foraminifera (*Syringammina fragillissima*) and tube-dwelling anemones. The black-coral *Elatopathes abietina* formed dense aggregations along most of the slope explored, with the whip-coral *Viminella flagellum* and the sea fan *Acanthogoria* spp. also composing part of the faunal assemblage. |
| W group | Corvo NE | N | 4 | 1 | 1 | 2 | 2 | Large gardens particularly formed by the whip-coral *Viminella flagellum* (with both white and yellow morphotypes) and the sea fan *Acanthogorgia* spp. Dense aggregations of the black-coral *Elatopathes abietina*. The sponge assemblages were mainly characterized by the presence of *Phakellia ventilabrum* and *Haliclona implexa*. |
| W group | Corvo SE | N | 3 | 1 | 1 | 3 | 4 | The rocky outcrops were poorly colonized. Presence mainly of the Antipatharian *Elatopathes abietina* and the octocorals *Viminella flagellum*, and *Acanthogorgia* spp. |
| W group | Corvo SW | N | 4 | 1 | 1 | 2 | 1 | Dense coral gardens dominated by the primnoids *Narella versluysi* and *N. bellissima*. On flat terrains, large colonies of the black-coral *Leiopathes glaberrina*, together with sponge species such as *Haliclona implexa* and *Phakellia ventilabrum*. Extensive and dense bed of the scleractinian and CITES listed *Eguchipsammia cornucopia*. |
| W group | Flores NW | N | 3 | 1 | 2 | 3 | 2 | The bottom was mainly colonized by dense coral gardens dominated by the red and white morphotypes of the bubble gum coral *Paragorgia* cf. *johnsoni* in reasonably good conditions, although some colonies showing signs of impact. Aggregations of soft corals and the black-coral *Elatopathes abietina*. |
| W group | Flores NE | Y | 3 | 4 | 4 | 4 | 3 | Dense patches of large colonies of corals belonging to the family Paramuriceidae. Large patches of the bubble gum coral *Paragorgia johnsoni* and extensive gardens of the sleractinian *Madrepora oculata*, several corals of the family Stylasteridae, and some Antipatharians of the genus *Leiopathes*. Sponge communities were mainly characterized by the presence of *Pheronema carpenteri*. |
| W group | Flores E | N | 3 | 2 | 3 | 3 | 3 | The fauna present mostly included the bamboo coral *Acanella arbuscula*, some patches of *Viminella flagellum* and the sponge *Pheronema carpenteri*. |
| W group | Flores S | N | 3 | 1 | 2 | 3 | 2 | Large aggregations of the whip coral *Viminella flagellum* (present in both white and yellow morphotypes), often together with some other corals such as *Acanthogorgia* spp. Smaller assemblages of the octocorals *Dentomuricea* aff. *meteor* and *Paracalyptrophora josephinae*. Dense aggregations of *Elatopathes abietina*. |
| W group | Flores W | N | 3 | 1 | 4 | 4 | 4 | Patches of relatively dense patches of the octocoral *Viminella flagellum*. Some colonies of the black coral *Elatopathes abietina* and the scleractinian *Dendrophyllia cornigera*. Sponges were not very abundant. |

| Large Area | Sampling Area | *VME* | *Unique* | *Functional* | *Fragility* | *Life history* | *Structural* | General description |
|---|---|---|---|---|---|---|---|---|
| W group | Cachalote | N | 3 | 3 | 2 | 3 | 2 | Coral communities mainly colonized with the primnoid *Narella versluysi* and *N. bellissma*. Notable presence of the massive sponge *Characella pachastrelloides*. |
| N MAR | Chaucer S | Y | 3 | 4 | 4 | 4 | 4 | Presence of framework-building scleractinian corals *Lophelia pertusa* and *Madrepora oculata*. Large colonies of long-lived black corals (e.g., the CITES listed *Leiopathes* cf. *expansa*, *Bathypathes* spp., and *Tylopathes* sp.) and bamboo corals (e.g., from the Keratoisididae family). Large sponges, such as the hexactinellids *Hertwigia falcifera*, *Asconema* sp., and *Phakellia* sp. |
| N MAR | Estrela | Y | 4 | 4 | 4 | 4 | 4 | The benthic community observed in this area showed an enhanced diversity and complexity. Patches of dead coral framework generated by the scleractinian corals *Lophelia pertusa*, *Madrepora oculata* and *Enallopsammia rostrata*, with some of the tips likely alive. It was common to observe colonies of the CITES listed black coral *Leiopathes* cf. *expansa*, *Parantipathes* spp., *Bathypathes* spp, *Chrysopathes* sp. and *Tylopathes* sp. Other common taxa were the bamboo corals *Acanella arbuscula*, very large individuals of the Keratoisididae family, and the gorgonians *Chrysogorgia* sp., *Iridogorgia* sp., and *Paragorgia johnsoni*. The hexactinellid *Hertwigia falcifera* was present. |
| N MAR | Kurchatov N | Y | 4 | 4 | 4 | 4 | 4 | The outcropping rocks were characterized by the presence of the colonial scleractinian *Madrepora oculata* together with the lace coral *Errina* cf. *atlantica*, forming dense patches. Colonies of the octocoral *Chrysogorgia* sp., the bamboo corals *Acanella arbuscula* and whip/branched Keratoisididae and the CITES listed and long-lived black coral *Leiopathes* cf. *expansa*. The hexactinellid *Hertwigia falcifera* was present. It was also observed the rare orange roughy *Hoplosthetus atlanticus*. |
| N MAR | Isolado | Y | 3 | 4 | 3 | 4 | 3 | The coral community was dominated by bamboo corals of the species *Acanella arbuscula*, as well as *Chrysogorgia* sp. and others from the Keratoisididae family. The long-lived black corals *Antipathes dichotoma, Parantipathes hirondelle* and *Bathypathes* sp. were also observed in the area. |
| N MAR | Kurchatov SE | Y | 4 | 4 | 3 | 4 | 2 | Presence of the long-lived and CITES listed black corals *Leiopathes expansa* and *Parantipathes hirondelle*. Abundant coral gardens of the primnoids *Narella versluysi* and *Narella bellissima*. Presence of extensive aggregations of corals of the genus cf. *Candidella*, *Desmophyllum dianthus*, and *Dendrophyllia cornigera*. |
| N MAR | Kurchatov S | Y | 3 | 4 | 4 | 4 | 3 | Extensive areas showed a high percentage cover of dead coral framework, with the scleractinian corals *Lophelia pertusa* and *Madrepora oculata.* The seafloor was colonized by the bamboo corals *Acanella arbuscula* and *Chrysogorgia* sp. In the overhangs and small vertical walls of the outcropping rocks, the diversity of coral species was high, with the presence of the CITES listed long-lived black corals, especially *Leiopathes expansa*, orange plexaurids from the family Paramuriceidae, together with *Paragorgia johnsoni* and *Hemicorallium niobe*. |
| N MAR | Kurchatov SW | Y | 3 | 4 | 4 | 4 | 3 | Impressive dense coral gardens of large black corals *Leiopathes expansa*, together with other associated arborescent corals such as orange plexaurids of the family Paramuriceidae. The bamboo coral *Acanella arbuscula* was also scattered through the seafloor. Other long-lived Antipatharian were colonizing the seafloor such as *Bathypathes* spp., and *Tylopathes* sp. Under the coral framework, were some live patches of the scleractinians *Lophelia pertusa*, *Madrepora* |

| Large Area | Sampling Area | *VME* | *Unique* | *Functional* | *Fragility* | *Life history* | *Structural* | General description |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | *oculata* and *Leptopsammia Formosa*. |
| N MAR | Agulhas Corvo-Graciosa | Y | 4 | 4 | 4 | 4 | 4 | The area hosts extensive areas colonized by large black corals listed by CITES as long-lived: *Leiopathes expansa*, *Bathypathes* sp. and *Parantipathes hirondelle*, with high abundances in the rocky outcrops where there were also *Madrepora oculata* and various species of stylasterids. Large *Paragorgia johnsoni*, *Hemicorallium tricolor* and diverse plexaurids of the family Paramuriceidae, were also observed. Where softer sediments were observed highly abundant bamboo corals such as *Acanella arbuscula* and *Chrysogorgia* sp. were found, as well as the rarely observed sponge *Hertwigia falcifera.* Shallow areas were dominated by the primnoid *Narella versluysi*. |
| N MAR | Óscar | Y | 1 | 3 | 4 | 3 | 4 | Species with amphi-Atlantic or Atlanto-Mediterranean distribution. High diversity of benthic communities. Dense coral gardens dominated by octocorals, particularly *Callogorgia verticillata* with large colonies (~1.5 m height) not seen in many other areas. *C. verticillata* has low growth rates and low reproductive output (Carreiro-Silva, unpub. data) and is highly susceptible to fishing based on fisheries bycatch data (Sampaio et al., 2012). |
| Central MAR | Gigante N | Y | 3 | 3 | 4 | 4 | 3 | Presence of large and arborescent black corals of the long-lived CITES listed species *Leiopathes expansa*, dense aggregations of *Errina* cf. *atlantica* accompanied by the octocoral *Acanella arbuscula*, a few *Paragorgia johnsoni* and several plexaurids of the Paramuriceidae family. Individuals of the rarely seen hexactinellida *Herwigia falcifera* and the fish orange roughy (*Hoplostethus atlanticus*). |
| Central MAR | Gigante | Y | 4 | 3 | 4 | 3 | 4 | FAO listed VME hydrothermal vent, presence of the potentially endemic species *Dentomuricea* aff. *meteor*. High diversity of species and communities. Hydrothermal vent Luso. Dense coral gardens dominated by octocorals, particularly *Paragogia johnsoni* with large colonies (~1.5 m height) and the potentially endemic *D. meteor*. *P. johnsoni* highly susceptible to fishing based on damaged colonies observed in video surveys. *Paragorgia* species have high longevity (~ 100 years) and slow growth rates (Sherwood & Edinger, 2009). |
| Central MAR | Gigante Agulhas NE | N | 3 | 1 | 1 | 2 | 1 | CITES listed black coral species *Leiopathes*. Diverse coral communities composed by large structuring species such as bamboo corals (*Lepidisis* and *Keratoisis*) and the black coral *Leiopathes* spp. These species are characterized by low growth rates, high longevities (centuries to millennia for bamboo corals and black corals respectively, Andrews et al., 2009; Carreiro-Silva et al., 2013). Presence of several corals of the family Plexauridae, not seen elsewhere and that may be new to science. Communities naturally protected from fishing impacts because of great depths (below 1000 m). |
| Central MAR | Gigante Agulhas NW | Y | 3 | 4 | 4 | 4 | 3 | The rocky outcrops were colonized by large colonies of the CITES listed black coral *Leiopathes expansa* and the bubble gum coral *Paragorgia johnsoni* often together with *Hemicorallium tricolor*, as well as some plexaurids of the family Paramuriceidae. It was common to observe small bioconstructions made by the scleractinian corals *Lophelia pertusa* and *Madrepora oculata*, and patches of *Errina* cf. *atlantica*. Presence of several ophiuroids *Gorgonocephalus caputmedusae*. |
| Central MAR | Gigante 127 | N | 3 | 1 | 1 | 1 | 2 | Low abundance of habitat-building corals and sponges; hard substrates dominated by sponges and widespread octocoral *Viminella flagellum*. |

| Large Area | Sampling Area | VME | Unique | Functional | Fragility | Life history | Structural | General description |
|---|---|---|---|---|---|---|---|---|
| Central MAR | Gigante Agulhas S | N | 3 | 2 | 1 | 2 | 3 | Large aggregations of the octocoral *Viminemlla flagellum* and some black corals of the species *Elatopathes abietina* and the gorgonian *Paragorgia johnsoni*. |
| Central MAR | Gigante Agulhas SW | Y | 3 | 3 | 4 | 1 | 4 | Species with mixed amphi-Atlantic and Atlanto-Mediterranean distribution. Populations of CITES listed scleractinian *Eguchipsammia* cf. *cornucopia*. Dense *Paragorgia johnsoni* gardens with some of the largest colonies recorded so far showing little impact from fishing. |
| Central MAR | Ferradura E | N | 3 | 3 | 2 | 1 | 1 | Aggregations of the *Pheronema carpenteri*. Benthic community was dominated by *Narella bellissima* and *N. versluysi*, together with the white coral *Pleurocorallium johnsoni*. Large colonies of the whip coral *Viminella flagellum*, *Callogorgia verticillata*, *Paragorgia johnsoni*, and *Paracalyptrophora josephinae*. |
| Central MAR | Ferradura | N | 4 | 2 | 2 | 2 | 1 | CITES listed black coral species *Leiopathes*. Dense coral gardens dominated by octocorals, such as *Narella bellissima* and *Narella versluysi.* Presence of the gorgonian coral *Paragorgia johnsoni*. There is some evidence of fishing impacts. |
| Central MAR | Cavala | Y | 4 | 3 | 4 | 3 | 4 | Presence of the potentially endemic species *Dentomuricea* aff. *meteor*. High diversity of species and communities. Dense coral gardens dominated by D. meteor, one of the densest recorded in the Azores so far. Presence of large *Paragorgia johnsoni*, *Pleurocorallium johnsoni* and *Paracalypthrophora josephinae*. Species highly susceptible to fishing based on bycatch data (Sampaio et al., 2012) or evidence of broken colonies in video surveys. Structural species characterized by slow growth and low reproductive output (Sherwood and Edinger, 2009; Perrin et al., 2015, Carreiro-Silva, unpub. data). |
| Central MAR | Beta | Y | 1 | 3 | 4 | 3 | 4 | Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Dense and diverse coral gardens dominated by large octocorals and sponge aggregations. Dense *Paragorgia johnsoni* gardens with some very large colonies. Communities generally well preserved, showing little impact from fishing. |
| Central MAR | Diogo Teive | N | 3 | 3 | 3 | 4 | 4 | Several fields of the deep-sea sponges cf. *Asconema* and *Pheronema carpenteri*. Very large and intact colonies of *Callogorgia verticillata*. |
| Central MAR | Buchanan | N | 4 | 2 | 3 | 3 | 1 | The rarely seen gorgonian coral was spotted (*Iridongorgia fontinalis*), as well as dense aggregations of large octocorals belonging to the family Paramuriceidae. The fan coral *Hemicorallium tricolor*, large aggregations of the primnoid corals of the genus *Narella* and some *Callogorgia verticillata*. Presence of the CITES listed black coral *Leiopathes expansa*. |
| Central MAR | Cabeçote | N | 3 | 2 | 2 | 1 | 1 | Large sponges of the genus *Asconema*, and aggregations of the octocorals *Narella versluysi*, *N. bellissima* and the stylasterid *Errina atlantica*. |
| Central MAR | Sardinha | Y | 3 | 4 | 4 | 4 | 4 | Presence of the rarely observed fish orange roughy (*Hoplostethus atlanticus*). Individuals of the bamboo coral *Acanella arbuscula* and of the long-lived black coral of the genus *Leiopathes* (as listed by CITES) were present. On the shallower areas high densities of stylasterids and aggregations of glass sponges of the genus *Asconema*. |
| Central | Lucky Strike E | N | 1 | 2 | 1 | 2 | 3 | Aggregations of *Viminella flagellum* were generally monospecific with low coral abundance observed. Some small black |

| Large Area | Sampling Area | *VME* | *Unique* | *Functional* | *Fragility* | *Life history* | *Structural* | General description |
|---|---|---|---|---|---|---|---|---|
| MAR | | | | | | | | coral species: *Stichopathes gravieri* and *Parantipathes hirondelle* identified within those patches. |
| S MAR | Menez Gwen | N | 3 | 1 | 1 | 3 | 1 | Low abundance and diversity of benthic megafauna. Small colonies of *Lophelia pertusa*, *Hemicorallium tricolor* and some larger of the CITES listed *Leiopathes expansa*. |
| S MAR | Picoto | N | 4 | 3 | 1 | 2 | 3 | Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Low diversity of benthic communities. Coral gardens dominated by the octocorals *Viminella flagellum* and *Callogorgia verticillata*, with some very tall colonies that showed little impact from fishing. |
| S MAR | Alfa | N | 4 | 3 | 2 | 3 | 1 | Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Low diversity of benthic communities and overall low densities of corals and sponges, generally of small sized specimens. Evidence of fishing impacts. |
| S MAR | Alfa E | N | 3 | 3 | 3 | 4 | 2 | Surprisingly large aggregations of the octocoral *Heicorallium tricolor* and occasional of the primnoid *Narella versluysi*. Several dense patches of the sponge *Pheronema carpenteri* and large lamellate *Poecillastra compressa*. |
| S MAR | Voador | Y | 3 | 4 | 3 | 3 | 3 | Species with amphi-Atlantic or Atlanto-Mediterranean distribution. High diversity of species and communities. Densest coral gardens of the octocoral *Paracalypthrophora josephinae* observed in the Azores so far, with the presence of tall colonies. Species highly susceptible to fishing based on bycatch data (Sampaio et al., 2012); and low growth rates and reproductive output (Carreiro-Silva, unpub. data). Dense aggregation of *Candidella imbricata* at shallow depths. |
| S MAR | Monte Alto | N | 1 | 4 | 1 | 1 | 3 | Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Low number of benthic communities, with low densities overall. |
| S MAR | Farpas | Y | 4 | 4 | 4 | 4 | 3 | Some of the highest densities ever observed in the Azores, of the primnoids *Narella versluysi* and *N. bellissima*. Large aggregations of the octocoral *Candidella imbricata* and medium-sized individuals of the slow-growing, long-lived *Callogorgia verticillata*. The more sedimentary depths were characterized by colonies of the bamboo coral *Acanella arbuscula* and patches of the “bird’s nest” sponge *Pheronema carpenteri*. |
| S MAR | Espadarte | Y | 4 | 3 | 4 | 3 | 2 | Species with amphi-Atlantic or Atlanto-Mediterranean distribution. High diversity of species and communities. Dense coral gardens dominated by octocorals *Narella versluysi* and *N. bellissima*, largest aggregations recorded in the Azores so far. Presence of large colonies of the octocorals *Paragorgia johnsoni* and *Callogorgia verticillata*, which are slow-growing, long-lived species susceptible to fishing (Sampaio et al., 2012). |
| S MAR | Sarda E | N | 3 | 4 | 3 | 4 | 2 | Aggregation of large colonies of the slow growing and possibly long-lived coral *Paragorgia johnsoni* and the large primnoid *Callogorgia verticillata.* As well as other species of octocorals referenced as VME indicators such as both *Narella bellissima*, *N. versluysi*, *Acanthogorgia* spp. and *Viminella flagellum*. |
| S MAR | Sarda | N | 3 | 4 | 3 | 3 | 2 | Species with amphi-Atlantic or Atlanto-Mediterranean distribution. High number of benthic communities observed. Diverse coral and sponge assemblages, although some are very localized in space. Presence of large colonies of *Paragorgia johnsoni* and *Callogorgia verticillata*, which are slow-growing, long-lived species susceptible to fishing (Sampaio et al., 2012). |

| Large Area | Sampling Area | VME | Unique | Functional | Fragility | Life history | Structural | General description |
|---|---|---|---|---|---|---|---|---|
| N central group | Sedlo W | Y | 4 | 4 | 4 | 4 | 1 | The black coral *Leiopathes* cf. *expansa* dominated some areas of the seafloor with relatively large aggregations, normally together with the scleractinian *Lophelia pertusa*. Widespread presence of the bamboo coral *Acanella arbuscula*, individuals of the family Paramuriceidae and the hydrozoan *Pliobothrus archipelagus*. |
| N central group | Sedlo | N | 3 | 3 | 4 | 4 | 2 | Common presence of species of hydrocorals, likely from the genus *Errina*, and octocorals of the species *Paragorgia johnsoni*. Frequent colonies of the long-lived and CITES listed black coral *Leiopathes expansa*, among others such as *Parantipathes hirondelle, Bathypathes* sp., and the scleractinian *Madrepora oculata*. Large barrel sponges of the genus *Characella*. |
| N central group | Gaillard | Y | 3 | 4 | 4 | 4 | 2 | Presence of the long-lived species of black corals listed by CITES: *Leiopathes expansa* and *Parantipathes hirondelle*. The bamboo coral *Acanella arbuscula* as well as the primnoid *Narella bellissima,* together with stylasterids of the genus *Errina* – all listed as VME indicator species. Rarely observed species *Hoplostethus atlanticus*. |
| N central group | Borda | N | 3 | 1 | 2 | 3 | 1 | The hydrocoral *Cryptellia* sp., and sparse black corals of the genus *Leiopathes* (e.g., *Leiopathes expansa*) and *Phanopates* were found scattered through the sea bottom. It is also present some colonies of the scleractinians *Madrepora oculata* and *Eguchipsammia cornucopia*, and the bamboo coral *Acanella arbuscula* on the soft bottoms. |
| N central group | João Leonardes | N | 3 | 2 | 3 | 4 | 1 | Often present of some long-lived orange roughies *Hoplostethus atlanticus.* Scattered occurrences of the bamboo coral *Acanella arbuscula*, and the gorgonians *Cadidella imbricata* and *Chrysogorgia* sp. Widespread presence of the yellow lamellate sponge *Desmacella grimaldii*. |
| N central group | Serreta Mar | N | 3 | 1 | 2 | 1 | 4 | Dense coral gardens dominated by large colonies of species likely belonging to the family Paramuriceidae. Medium-sized colonies of *Callogorgia verticillata* and extensive aggregations of the primnoid corals *Narella versluysi* and *N.bellissima.* |
| N central group | Mar da Fortuna | N | 3 | 3 | 2 | 2 | 2 | Hard substrate frequently colonized with aggregations of the octocorals *Narella versluysi* and *N. bellissima*, often together with *Candidella imbricata*. The gorgonians *Callogorgia verticillata*, *Viminella flagellum* and *Dentomuricea* aff. *meteor*, together with *Acanthogorgia* spp., were widely present, sometimes forming dense aggregations. |
| N central group | Graciosa NW | N | 4 | 3 | 1 | 2 | 3 | Presence of the rare species *Dentomuricea* aff. *meteor.* Extensive gardens of the whip coral *Viminella flagellum,* considerable abundance of *Acanthogorgia* spp. and of the possibly long-lived *Calllogorgia verticillata*, as well as huge aggregations of the black coral *Elatopathes abietina*. |
| N central group | Graciosa NE | N | 4 | 3 | 3 | 2 | 3 | Relatively high abundance of the black coral *Elatopathes abietina* and colonies of the scleractinian *Dendrophyllia cornigera*. Dense aggregations of uncommonly large *Viminella flagellum* and *Callogorgia verticillata*. Community of the foraminifera *Syringammina fragilissima*. High evidence of fishing activities. |
| N central group | Graciosa SE | N | 4 | 2 | 2 | 2 | 4 | Presence of the gorgonian *Acanthogorgia* spp., and the black corals *Stichopathes gravieri*. Enormous benthic biodiversity, with impressive gardens of the whip coral *Viminella flagellum*, together with the gorgonians *Callogorgia verticillata* and *Dentomuricea aff. meteor* and with the black coral *Elatopathes abietina*. Well-preserved individuals of |

| Large Area | Sampling Area | VME | Unique | Functional | Fragility | Life history | Structural | General description |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | the large sponge *Phakellia ventilabrum*. |
| N central group | Graciosa S | Y | 4 | 4 | 2 | 2 | 4 | Unusually high presence of sponges from the genus *Geodia* listed by ICES as a VME indicator. Sporadic presence of *Parantipathes hirondelle* and high abundance of *Elatopathes abietina* both listed as long-lived black corals. Scattered gardens of *Viminella flagellum*, *Callogorgia verticillata*, *Dentomuricea aff. meteor*. |
| N central group | Graciosa SW | N | 4 | 1 | 1 | 3 | 3 | Most common sightings of fauna were the Foraminifera *Syringammina fragilissima* and a few animals of the genus *Flabellum*. Aggregations of *Farrea occa* and *Macandrewia azorica* sponges. Presence of communities of the *Viminella flagellum* and the black coral *Elatopathes abietina.* |
| N central group | Perestrelo Bartolomeu | N | 4 | 2 | 2 | 2 | 3 | Presence of the bamboo coral *Acanella arbuscula*, the hydrocoral *Pliobothrus symmetricus* and the gorgonian *Hemicorallium niobe*. Large aggregations of the primnoid corals *Narella versluysi* and *Narella bellissima*. |
| N central group | Ilha Azul | N | 3 | 2 | 1 | 1 | 2 | Aggregations of the octocorals *Narella versluysi* and *N. bellissima*. Presence of relatively large patches of small-sized black coral *Elatopathes abietina*, and the bubble gum coral *Paragorgia johnsoni*. Extensive colonies of the whip coral *Viminella flagellum*. |
| N central group | Ilha Azul E | N | 3 | 3 | 2 | 2 | 4 | Common sightings of the bamboo coral *Acanella arbuscula* and widespread community of the octocorals *Narella versluysi* and *N. bellissima*. The hard substrate was sometimes densely covered with the encrusting sponge *Haliclona filholi.* |
| N central group | Ilha Azul SE | Y | 3 | 4 | 4 | 4 | 2 | Large aggregations of large individuals of the lamellate sponges *Poecillastra compressa* and *Phakellia robusta*. Colonies of the CITES listed black coral *Leiopathes expansa*, attached to the basaltic walls, along with other Antipatharian such as *Parantipathes hirondelle* and *Bathypathes pseudoalternata*. *Candidella imbricata*, *Metallorgia melanotrichos* and several stylasterids. |
| N central group | São Jorge NW | N | 3 | 1 | 3 | 1 | 3 | Occasional presence of the sponge *Pheronema carpenteri* and more sporadically by the gorgonians *Callogorgia verticillata* and *Acanthogorgia* spp. The massive sponges *Characella pachastrelloides*, *Desmacella grimaldii and Poecillastra compressa* were also observed. |
| N central group | São Jorge NE | N | 1 | 1 | 1 | 1 | 1 | Occasional patches of the bird's nest sponge *Pheronema carpenteri*. Sponges dominated the community with the most relevant being *Characella pachastrelloides*, *Macandrewia azorica*, *Neophrisospongia nolitangere*, and *Leiodermatium* sp. |
| N central group | São Jorge E Topo | N | 3 | 2 | 3 | 2 | 4 | Diverse benthic communities with patches of abundant coral gardens of *Candidella imbricata, Narella versluysi* with some scattered *N. bellissima.* Presence of the bamboo corals *Acanella arbuscula* and *Chrysogorgya* sp., and of the black corals *Bathypathes* sp. and *Elatopathes abietina*. Occasional colonies of the gorgonians *Paracalyptrophora josephinae* and *Dentomuricea cf. meteor.* |

| Large Area | Sampling Area | *VME* | *Unique* | *Functional* | *Fragility* | *Life history* | *Structural* | General description |
|---|---|---|---|---|---|---|---|---|
| N central group | São Jorge SE | N | 4 | 1 | 2 | 3 | 4 | Presence of *Viminella flagellum* (both its white and yellow morphotypes), *Acanthogorgia* sp., and the scleractinian *Dendrophyllia cornigera*. Large black coral colonies likely from the species *Leiopathes glaberrima* were also present. |
| N central group | São Jorge S Urzelina | N | 1 | 1 | 1 | 1 | 4 | Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Low diversity of corals and sponges and mostly of small size. Communities in vertical walls naturally protected from fishing. |
| N central group | São Jorge SW Velas | N | 1 | 1 | 1 | 1 | 4 | Benthic communities dominated by small deep-sea sponges, with aggregations of *Hyalonema (Cyliconema) thomsonis*, and the bird's nest *Pheronema carpenteri*. |
| N central group | São Jorge W Rosais | Y | 3 | 4 | 3 | 3 | 4 | Fields of Xenophyophores on flatter terrain and aggregations of the glass sponges *Pheronema carpenteri* and *Hyalonema* sp. appearing in higher densities. Colonies of the slow growing and likely long-lived *Callogorgia verticillata* as well as large colonies of *Paracalyptrophora josephinae* were present, in between vast aggregations of *Acanthogorgia* spp. The black coral *Leiopathes glaberrima* also appeared. |
| N central group | João de Melo | N | 1 | 4 | 1 | 1 | 3 | Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Although the number of communities identified is high, they are very localized in space and species showing low densities overall. Presence of *Callogorgia verticillata*, slow growing, long-lived species susceptible to fishing (Sampaio et al., 2012). |
| N central group | Terceira N | N | 3 | 3 | 2 | 3 | 4 | In terms of benthic fauna observed, Terceira N was a very interesting area. It was observed an extensive but partially dead reef of the scleractinian *Eguchipsammia cornigera*, and impressive and vast coral gardens composed by many different well-preserved species such as *Viminella flagellum, Acanthogorgia* spp., *Dentomuricea* aff. *meteor*, *Errina dabneyi* and large colonies *Callogorgia verticillata*. A particular highlight of this area was the coral garden dominated by *Dentomuricea* aff. *meteor.* |
| N central group | Terceira NE | N | 3 | 2 | 1 | 3 | 2 | The whip coral *Viminella flagellum* and *Pleurocorallium johnsoni* were found colonizing the sparse basaltic outcrops. Some desmosponges were frequently observed, such as *Desmacella grimaldii*. |
| N central group | Terceira E | N | 3 | 2 | 4 | 4 | 1 | Occurrence of lush colonies of *Leiopathes glaberrima* (most of which entangled by lost bottom longlines), frequently covering the seafloor with *Callogorgia verticillata*, *Dentomuricea* aff. *meteor,* cf. *Candidella imbricata* and some colonies of *Enallopsammia rostrata.* Sparse colonies of *Parantipathes hirondelle*, and the endemic cf. *Errina dabneyi* also composed this diverse community. There were extensive aggregations of the white morphotype of *Paragorgia johnsoni.* |
| N central group | Terceira S | N | 3 | 1 | 4 | 2 | 1 | Thriving benthic communities were found. with impressively abundant coral gardens of *Dentomuricea* aff. *meteor, Callogorgia verticillata, Viminella flagellum, Paracalyptrophora josephinae* and particularly lush colonies of *Acanthogorgia* spp. Vast reef of the scleractinian *Eguchipsammia cornigera*. The black coral *Leiopathes expansa* was also spotted. |
| N central group | Terceira SW Angra | N | 3 | 1 | 4 | 1 | 2 | Species with amphi-Atlantic or Atlanto-Mediterranean distribution Low diversity of species and communities, although the presence of a few large colonies of *Paragorgia johnsoni* and *Pleurocorallium johnsoni*, showing impacts from fishing. |

| Large Area | Sampling Area | *VME* | *Unique* | *Functional* | *Fragility* | *Life history* | *Structural* | General description |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Most of the sediments seemed to be colonized by the foraminifera cf. *Syringammina fragillissima*. |
| N central group | Terceira W Serreta | N | 3 | 2 | 2 | 3 | 4 | Assemblages mainly composed the gorgonians *Acanthogorgia* spp., and *Pleurocorallium johnsoni* (sometimes reaching great diversity). The octocoral *Dentomuricea* aff. *meteor*, and colonies of the scleractinian *Dendrophyllia cornigera,* were also observed. |
| N central group | Maçarico | N | 3 | 4 | 3 | 4 | 1 | Aggregations of large colonies of *Viminella flagellum*. Within these aggregations, some coral species were also found, such as small *Pleurocorallium johnsoni*, and the long-lived species: *Callogorgia verticillata*, and *Paracalyptrophora josephinae*. |
| N central group | Álvaro Martins | Y | 4 | 4 | 4 | 3 | 4 | Bamboo coral *Acanella arbuscula* was very common together with aggregations of the black coral *Leiopathes expansa.* The main highlight regarding corals went to the vast aggregations of the stylasterid *Errina atlantica.* spectacular gardens of *Narella versluysi* and *N. bellissima* covered some areas of the sea bottom with some scattered *Acanthogorgia spp.* |
| N central group | Beirada de Fora | N | 3 | 2 | 1 | 1 | 2 | Presence of a few primnoid coral *Narella versluysi* together with *N. bellissima*, as well as some patches of *Pheronema carpenteri* and some large sponges *Characella pachastrelloides.* Vast aggregations of the whip coral *Viminella flagellum,* with casual colonies of *Paracalyptrophora josephinae.* Few black corals of the species *Parantipathes hirondelle* and *Elatopathes abietina.* |
| N central group | Gastromar | N | 1 | 3 | 1 | 1 | 1 | Sparse colonies such as *Acanella* sp., cf. *Crypthelia* sp., *Leiopathes expansa* and *Chrysogorgia sp.,* and some of them belonging to the Paramuriceidae family. Individuals of the bubble gum *Paragorgia johnsoni* (white and red morphotypes). Large lamellate sponges *Poecillastra compressa* were found. |
| N central group | Albatroz do Norte | N | 3 | 4 | 2 | 3 | 2 | Large colonies, mainly of the black corals *Leiopathes expansa*. *Parantipathes hirondelle* and *Stichopathes graviera* were also observed. Extensive aggregations of the primnoid corals *Narella versluysi* and *N. Bellissima.* Small and dispersed individuals of *Acanthogorgia* spp.*, Callogorgia verticillata* and *Paragorgia johnsoni.* |
| N central group | Alcatraz | N | 1 | 3 | 1 | 2 | 4 | Species with amphi-Atlantic or Atlanto-Mediterranean distribution. Low diversity of species and communities. Presence of large sponges *Characella pachastrelloides*, patches of *Viminella Flagellum* and sparse colonies of *Callogorgia verticillata*. Evidence of fishing impacts. |
| N central group | Dom João de Castro | Y | 4 | 3 | 4 | 4 | 4 | FAO listed VME hydrothermal vent, species with amphi-Atlantic or Atlanto-Mediterranean distribution. Dense coral gardens dominated by octocorals, particularly *Callogorgia verticillata*, with the presence of many large colonies. Few signs of fishing impacts. |
| N central group | Ferraria Norte | Y | 3 | 2 | 4 | 4 | 4 | Presence of the bamboo corals *Acanella arbuscula* and *Chrysogorgya* sp., punctual aggregations of cf. *Errina atlantica* and some long-lived black corals (listed by CITES): *Leiopathes expansa*, *Parantipathes hirondelle* and *Bathypathes* sp. Extensive gardens of the primnoids *Narella bellissima*, *N. versluysi* and the gorgonian *Candidella imbricata*, sometimes together with *Acanthogorgia* sp. Extense aggregations of large sponges *Poecillastra compressa*, *Phakellia robusta*, *Desmacella grimaldi*, *Neophrisospongia nolintangere* and *Petrosia* sp. |

| Large Area | Sampling Area | *VME* | *Unique* | *Functional* | *Fragility* | *Life history* | *Structural* | General description |
|---|---|---|---|---|---|---|---|---|
| N central group | Ferraria Mar | Y | 3 | 4 | 2 | 1 | 4 | Sparse colonies of the black corals *Leiopathes expansa (*as listed in CITES), *Parantipathes hirondelle*, and *Bathypathes* sp. Some extensions of small stylasterids (likely *Errina atlantica*), and the bamboo coral *Acanella arbuscula*. Frequent sighting of the orange roughy (*Hoplostethus mediterraneus*). |
| N central group | Girard | Y | 3 | 3 | 4 | 4 | 3 | Dead coral framework occasionally colonized by sylasterids (likely *Errina atlantica*). The bamboo coral *Acanella arbuscula* is present. Aggregations of the gorgonians *Narella versluysi* and *Acanthogorgia* spp., and several more stylasterids. |
| S central group | Faial NW | N | 3 | 2 | 4 | 4 | 1 | Benthic biodiversity is high, with abundant aggregations of the gorgonian *Candidella imbricata* and some corals from the family Stylasteridae, likely *Errina atlantica.* Large black coral colonies *Leiopathes expansa* colonize vertical basaltic walls, with the scleractinians *Lophelia pertusa*. The bamboo coral *Acanella arbuscula* is also present. Extensive community of *Narella versluysi* and *Narella bellissima* and high abundances of small colonies of *Paragorgia johnsoni.* |
| S central group | Faial N | N | 1 | 1 | 1 | 2 | 1 | The gorgonians *Acanthogorgia* spp. and *Viminella flagellum* are occasionally present. |
| S central group | Faial-Pico N | N | 1 | 1 | 4 | 1 | 3 | Presence of massive sponges such as *Characella pachastrelloides* and *Geodia* sp. Fields of the bird´s nest bird's nest sponges *Pheronema carpenteri.* Colonies of the whip coral *Viminella flagellum* are also present. |
| S central group | Pico NW | N | 1 | 1 | 4 | 1 | 1 | Patches of the bird's nest sponge *Pheronema carpenteri* colonize soft bottoms. Large sponge species such as *Characella pachastrelloides* and *Neophrissospongia nollitangere.* Colonies of the black coral *Antipathella subpinnata* with signs of impacts are present. Several bottom-longlines can be seen. |
| S central group | Pico NE | N | 1 | 2 | 3 | 2 | 4 | Presence of "fossil community" composed of long-lived oysters and cirripeds (cf. *Neopycnodonte zibrowii* and cf. *Cyathidium foresti*) found only in the Azores. High diversity of corals and sponges but sparsely occurring on large boulders and mostly of small sizes. Communities in vertical walls naturally protected from fishing. |
| S central group | Pico S Lajes | Y | 3 | 3 | 4 | 3 | 3 | Diverse communities are present, composed of several coral species such as the black corals *Leiopathes expansa, Bathypathes* sp. and the bamboo coral *Acanella arbuscula,* with high density patches of *Candidella imbricata.* The bird's nest *Pheronema carpenteri* appear in aggregations, as well as the primnoid corals *Narella versluysi* and *Narella bellissima.* Several glass sponges also compose the community such as *Hertwigia falcifera* and cf. *Phakellia robusta.* |
| S central group | Pico SW Espartel | N | 1 | 4 | 2 | 1 | 4 | Monospecific aggregations of the whip coral *Viminella flagellum* as well as dense coral gardens of *Narella versluysi* and *Narella bellissima.* Dead coral framework densely colonized by stylasterids *Errina atlantica.* |
| S central group | Faial-Pico S | N | 3 | 2 | 2 | 2 | 3 | The gorgonians *Hemicorallium niobe* and *Acanthogorgia* spp. are occasionally present. Sponge diversity is high, mainly composed of *Characella pachastrelloides*, *Macandrewia azorica, Pseudotrachya hystrix* and *Petrosia* sp. |
| S central group | Faial S | N | 3 | 3 | 2 | 1 | 3 | Large fields of the glass sponge *Pheronema carpenteri* and large sponges such as *Characella pachastrelloides, Geodia* sp. and *Petrosia* sp. The gorgonian *Acanthogorgia* sp. and the lamellate sponge cf. *Poecillastra compressa* densely dominate the seafloor for considerable extensions. Occasional colonies of the endemic hydrocoral *Errina dabneyi* are |

| Large Area | Sampling Area | VME | Unique | Functional | Fragility | Life history | Structural | General description |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | also present. |
| S central group | Faial Filhas do Condor | N | 3 | 3 | 3 | 1 | 3 | Aggregations of *Narella bellissima* and *Candidella imbricata* and a high diversity of sponges which included *Pheronema carpenteri.* Great abundances of large *Characella pachastrelloides* sponges are also present. |
| S central group | Faial W Capelinhos | Y | 3 | 3 | 4 | 4 | 4 | Populations of the potentially endemic octocoral species *Dentomuricea* aff. *meteor* and stylasterid *Errina dabneyi* and CITES listed black corals *Antipathella subpinnata*, *Leiopathes* sp. and stylasterid *Errina dabneyi*. High diversity of species and communities. Dense coral gardens formed by octocorals, black corals and stylasterids. Dense mesophotic coral gardens dominated by the soft coral cf. *Alcyonium* sp. Presence of large colonies of millennia-old *Leiopathes* sp. Evidence of shark aggregations. Little impact from fishing due to absence of longline fishing. Area important for geology and scientific research. |
| S central group | Condor | Y | 4 | 3 | 4 | 3 | 4 | Populations of the potentially endemic species *Dentomuricea* aff. *meteor* and CITES listed scleractinian *Eguchipsammia* cf. *cornucopia*. High diversity of species and communities. Mixed coral gardens composed of several octocoral species and sponge aggregations. Slow growing, long-lived species susceptible to fishing based on bycatch data (Sampaio et al., 2012). Reefs of *E. cornucopia*, a species not known to form reefs elsewhere in the Atlantic and to represent a potential relict species from geological past (Tempera et al., 2015). Seamount important for scientific research (Morato et al., 2010). |
| S central group | Baixo de São Mateus | N | 2 | 3 | 1 | 1 | 3 | Presence of "fossil community" composed of long-lived oysters and crinoids (cf. *Neopycnodonte zibrowii* and cf. *Cyathidium foresti*) found only in the Azores. Low diversity of species and communities in vertical walls, naturally protected from fishing. Presence of large sponges cf. *Characella pachastrelloides*. Presence of numerous fishing lines indicating high pressure from fishing. |
| S central group | Ponta da Ilha N | Y | 4 | 4 | 4 | 4 | 4 | Presence of the potentially endemic species *Dentomuricea* aff. *meteor* and CITES listed scleractinian *Eguchipsammia* cf. *cornucopia*, black coral *Antipathella subpinnata* and vast aggregations of the stylasterid *Errina dabneyi*. High diversity of species and communities. Dense coral gardens dominated by octocorals and sponges. Species with low growth and reproductive output vulnerable to fishing (Sampaio et al., 2012). Reefs of *E. cornucopia*, a species not known to form reefs elsewhere in the Atlantic and representing a potential relict species from geological past (Tempera et al., 2015). |
| S central group | Ponta da Ilha S | Y | 4 | 4 | 3 | 3 | 3 | Vast aggregations of the endemic coral *Errina dabneyi*. Extensive and dense coral gardens formed by the whip coral *Viminella flagellum* and particularly large colonies of *Dentomuricea* aff. *meteor*, *Callogorgia verticillate, Acanthogorgia* spp. and *Paracalyptrophora josephinae.* |
| S central group | Albatroz do Meio | Y | 4 | 4 | 3 | 3 | 2 | Dense and diverse coral gardens are present, namely from the species *Candidella imbricata, Narella versluysi* and *Narella bellissima.* High numbers of other corals such as the stylasterid *Errina atlantica,* the scleractinian *Leptopsammia formosa* and the black coral *Leiopathes expansa* are also present. Distinct community dominated by the gorgonians *Pleurocorallium johnsoni* and *Acanthogorgia* spp. |

| Large Area | Sampling Area | VME | Unique | Functional | Fragility | Life history | Structural | General description |
|---|---|---|---|---|---|---|---|---|
| S central group | Agulhas 12 Milhas | N | 2 | 3 | 3 | 1 | 2 | Vast aggregations of the bird's nest sponge *Pheronema carpenteri,* and the primnoid corals *Narella versluysi* and *N. bellissima* with occasional colonies of *Acanthogorgia* spp. High abundances of sponges, such as *Petrosia crassa*, vast aggregations of the lollipop sponge *Stylocordyla pellita* and *Macandrewia azorica*. |
| S central group | Condor de Fora | N | 4 | 3 | 2 | 2 | 3 | Benthic community composed by the bamboo coral *Acanella arbusculla,* the gorgonians *Chrysogorgia* sp. and *Candidella imbricata.* Presence of aggregations of the primnoids *Narella versluysi* and *Narella bellissima.* Large colonies of *Callogorgia verticillata* and the endemic *Errina dabneyi* found on basaltic outcrops. Several bottom longlines and fishing lines were encountered at different depths. |
| S central group | Agulhas 18 Milhas | N | 1 | 3 | 3 | 3 | 2 | Patches of some lace corals of the endemic *Errina dabneyi*, and sparse *Callogorgia verticillata* and *Viminella flagellum* colonies. Large specimens of the sponges *Characella pachastrelloides* and *Neophrissospongia nolitangere* and extensive sponge fields containing *Pheronema carpenteri* and *Hyalonema (Cyliconema) thomsonis* |
| S central group | Bourée NE | N | 3 | 2 | 3 | 1 | 3 | Aggregations of *Narella versluysi* and *Narella bellissima* together with other species such as *Hemicorallium niobe* and *Pliobothrus symmetricus.* Frequent fields of the bird´s nest sponge *Pheronema carpenteri* and several other sponge species. |
| S central group | Bourée E | N | 2 | 2 | 2 | 4 | 2 | Large vertical walls colonized by long-lived black coral colonies of the species *Leiopathes* cf. *expansa*, with a lot of associated biodiversity. Aggregations of the bird's nest *Pheronema carpenteri* and *Hyalonema thomsonis* are also present on soft grounds. |
| S central group | Açor | N | 3 | 2 | 2 | 3 | 1 | Large variety of sponges such as *Neophrissospongia nolitangere*, *Pachastrella* sp. and *Phakellia ventilabrum.* Association of the black coral *Elatopathes abietina* with the whip coral *Viminella flagellum.* |
| S central group | Açor S | Y | 3 | 3 | 4 | 3 | 4 | Large bivalves *Neopycnodonte zibrowii* and crinoids *Cyathidium foresti* colonize rocky overhangs. Vast and dense aggregations of the bird's nest sponge *Pheronema carpenteri* can also be found dominating the substrate as well as large fields colonized by the massive sponges *Characella pachastrelloides.* Dense patches of the whip coral *Viminella flagellum* in association with the endemic *Errina dabneyi.* These communities were found to be in a relatively good environmental status, but numerous lost bottom longlines stretch across the summit. |
| S central group | De Guerne N | N | 3 | 2 | 2 | 2 | 2 | Occasional presence of black coral colonies *Leiopathes* cf. *expansa* (with associated decapods *Sternostylus formosus*) and gorgonians *Hemicorallium niobe.* Aggregations of *Narella belissima* with *Narella versluysi* and *Asconema fristedti* are present, colonizing extensive areas of the seafloor, as well as patches of *Pheronema carpenteri* and *Acanella arbuscula*, *Leptopsammia formosa* and some *Hemicorallium tricolor.* |
| S central group | De Guerne | N | 1 | 2 | 3 | 2 | 1 | Occasional gorgonians of the species *Narella versluysi* and *N. bellissima* together with cf. *Muriceides* sp. Occasional bamboo corals *Acanella arbuscula.* Presence of a few black corals of the species *Parantipathes hirondelle* and *Elatopathes abietina*, and gorgonians of the genus *Acanthogorgia.* |
| S central | São Mateus de Fora | N | 3 | 2 | 2 | 2 | 3 | Diverse assemblages of benthic fauna mostly comprised of *Narella versluysi, Narella bellissima* and some colonies of |

| Large Area | Sampling Area | VME | Unique | Functional | Fragility | Life history | Structural | General description |
|---|---|---|---|---|---|---|---|---|
| group | | | | | | | | *Hemicorallium niobe* and the glass sponges *Pheronema carpenteri.* and *Asconema fristedti*. Patches of bamboo corals *Acanella arbuscula* colonizing the seafloor. Presence of a community dominated by the primnoid cf. *Candidella imbricata.* |
| S central group | Princesa Alice | N | 3 | 4 | 3 | 4 | 3 | Presence of several coral species mainly the black coral *Leiopathes expansa*, the bubble gum coral *Paragorgia johnsoni*, patches of *Leptopsammia formosa*, *Hemicorallium niobe*, and *Acanella arbuscula*. Several corals belonging to the family Paramuriceidae are present. Large aggregations of the “living fossil” *Neopycnodonte zibrowii* with *Cyathidium foresti* colonize large rocky overhangs. Large sections of dead coral framework, mostly of *Errina dabneyi*, with some alive colonies as well. Large colonies of *Callogorgia verticillata* are present. |
| S central group | Princesa Alice W | N | 3 | 3 | 1 | 2 | 2 | The hard ground is colonized by a variety of coral species such as some colonies of *Hemicorallium niobe*, *Pliobothrus symmetricus,* and *Leiopathes* cf. *expansa*. Sparse colonies of cf. *Errina atlantica, Narella versluysi, Narella bellissima, Acanella arbuscula.* Colonies of *Callogorgia verticillata*, and *Acanthogorgia* sp. are also frequent. |
| S central group | Princesa Alice Picos S | Y | 3 | 4 | 4 | 4 | 4 | High densities of the primnoid corals *Narella versluysi* and *N. bellissima* and occasional patches of bamboo corals *Acanella arbuscula*, and the gorgonians *Hemicorallium tricolor* and *Hemicorallium niobe.* Some aggregations of the sponges *Pheronema carpenteri* and *Asconema* sp and the presence of particularly large *Characella pachastrelloides* and *Haliclona magna.* |
| S central group | Henry Carr | N | 3 | 2 | 1 | 2 | 4 | Presence of the bamboo coral *Acanella arbuscula*, and the gorgonian *Chrysogorgia* sp., as well as some aggregations of the primnoid corals *Narella versluysi* and *N. bellissima*, usually together with *Hemicorallium niobe.* Sponge assemblage is composed by *Phakellia ventilabrum*, aggregations of *Pheronema carpenteri*, and very large *Geodia megastrella* and *Chonelasma choanoides.* |
| S central group | Princesa Alice SW | N | 1 | 1 | 1 | 1 | 1 | Sparse cold-water corals *Narella versluysi*, *N. bellissima*, *Candidella imbricata* colonize flat rocky bottom. Some *Hemicorallium niobe* and *H. tricolor* colonies and the scleractinian *Leptopsammia Formosa* are occasionally present. |
| E Group | São Miguel NW | N | 3 | 2 | 1 | 1 | 4 | Aggregations of the gorgonian coral *Candidella imbricata* and some individuals of the family Stylasteridae. Dense and vast gardens of *Narella versluysi* and N. bellissima, as well as red and white motphotypes of the bubble gum coral *Paragorgia johnsoni.* Colonies of the octocorals *Viminella flagellum*, *Acanthogorgia* spp., and *Callogorgia verticillata* are present. |
| E Group | São Miguel N | N | 1 | 2 | 3 | 1 | 2 | Aggregations of the primnoid corals *Narella versluysi* and *N. bellissima*, a few individuals of the black coral *Leiopathes* cf. *expansa* and the scleractinian *Leptopsammia formosa.* Gardens of the gorgonians *Viminella flagellum*, *Acanthogorgia* spp. and *Callogorgia verticillata.* |
| E Group | São Miguel NE | N | 1 | 1 | 4 | 1 | 1 | Patches of the octocorals *Acanthogorgia* spp.*, Callogorgia verticillata,* and particularly large colonies of *Viminella flagellum.* The sponges *Characella pachastrelloides*, *Leiodermatium* sp., the fan shaped *Phakellia ventilabrum* and *Geodia* sp., are present. |

| Large Area | Sampling Area | *VME* | *Unique* | *Functional* | *Fragility* | *Life history* | *Structural* | General description |
|---|---|---|---|---|---|---|---|---|
| E Group | São Miguel E | N | 3 | 1 | 1 | 2 | 2 | Coral species such as the whip coral *Viminella* flagellum, *Acanthogorgia* spp., and large colonies *Callogorgia verticillata* dominated, with occasional aggregations. A diverse sponge assemblage is also present. |
| E Group | São Miguel SE | N | 3 | 1 | 1 | 1 | 3 | Relatively dense coral aggregations mainly with colonies of the gorgonians *Viminella flagellum*, *Acanthogorgia* spp., and *Dentomuricea* aff. *meteor*. Occasional patches scleractinians *Errina atlantica.* |
| E Group | São Miguel S | N | 1 | 1 | 1 | 1 | 1 | Sporadic rock bottoms where a few gorgonians of the species *Pleurocorallium johnsoni* growing on. Occasional patches of the octocoral *Callogorgia verticillata.* |
| E Group | São Miguel SW | N | 4 | 2 | 3 | 2 | 4 | Presence of the potentially endemic species *Dentomuricea* aff. *meteor*. Dense coral gardens dominated by octocorals such as *Acanthogorgia* spp., *Callogorgia verticillata,* and corals of the family Paramuriceidae. Vast coral reef formed by the scleractinian *Eguchipsammia cornucopia.* Evidence of fishing impacts. |
| E Group | São Miguel W | N | 1 | 1 | 1 | 1 | 1 | Presence of occasional colonies of *Callogorgia verticillata*, *Acanthogorgia* spp., aggregations of the whip coral *Viminella flagellum* and a few corals belonging to the family *Paramuriceidae.* |
| E Group | Mar da Prata N | N | 4 | 1 | 2 | 2 | 2 | Presence of large gardens of *Viminella flagellum*, often associated with *Callogorgia verticillata* and large colonies of *Dentomuricea* aff. *meteor.* Aggregations of *Narella bellissima* and *N. versluysi*, together with *Acanthogorgia* spp. |
| E Group | Mar da Prata | N | 4 | 4 | 2 | 2 | 4 | Large aggregations of *Viminella flagellum* with *Callogorgia verticillata, Dentomuricea* aff. *meteor*, and *Paracalyptrophora josephinae.* Some colonies of *Leiopathes* cf. *expansa* present as well. |
| E Group | Mar da Prata S | N | 1 | 1 | 2 | 1 | 1 | Presence of scattered colonies of *Viminella flagellum.* Several lithistid sponges colonize hard substrates. |
| E Group | Maria Celeste | N | 3 | 3 | 3 | 3 | 4 | Large colonies of *Callogorgia verticillata* and aggregations of *Narella versluysi* and *N. bellissima,* as well as *Acanthogorgia* spp. Colonies of the black coral *Leiopathes* cf. *expansa* are also present. |
| E Group | Sauerwein | Y | 3 | 4 | 3 | 4 | 1 | Presence of bamboo corals *Acanella arbuscula*, black corals *Leiopathes* cf. *expansa*, and the gorgonians *Hemicorallium niobe*, *H. tricolor* and *Chrysogorgia* sp. Some colonies of scleractinians *Lophelia pertusa* are also present. |
| E Group | Grande Norte | N | 3 | 2 | 1 | 1 | 2 | Aggregations of large *Callogorgia verticillata* colonies and *Viminella flagellum,* together with *Paracalyptrophora josephinae*, *Dentomuricea* aff. *meteor* and *Acanthogorgia* spp. Extensive patches of the glass sponge *Pheronema carpenteri.* |
| E Group | Formigas | Y | 3 | 3 | 2 | 4 | 4 | Diverse assemblage of different black coral species, including *Bathypathes* sp.*, Antipathes* sp. and *Parantipathes hirondelle,* and large colonies of *Leiopathes* cf. *expansa*, together with many bamboo corals from the family Keratoisididae. Presence of the 'living-fossil community' of the crinoid cf. *Cyathidium foresti* on vertical walls. Large colonies of the scleractinian coral *Lophelia pertusa* and aggregations of the primnoids *Narella versluysi* and *Narella bellissima.* |
| E Group | Margrette | N | 4 | 3 | 3 | 3 | 3 | Several species of octocorals including *Hemicorallium tricolor, H. niobe* and *Acanthogorgia* spp. Aggregations of *Narella versluysi* and *N. belissima* and the presence of the whip coral *Viminella flagellum* and of large colonies of the primnoid *Callogorgia verticillata.* |

| Large Area | Sampling Area | *VME* | *Unique* | *Functional* | *Fragility* | *Life history* | *Structural* | General description |
|---|---|---|---|---|---|---|---|---|
| E Group | Margrette E | N | 3 | 2 | 2 | 1 | 3 | Vast aggregations of the primnoid corals *Narella versluysi*, *Narella bellissima,* often accompanied by large individuals of *Hemicorallium tricolor* and *H. niobe.* Relatively large patches of the gorgonian *Acanthogorgia* sp. Lamellate sponges *Desmcella grimaldii* and *Poecillastra compressa* and the vase shaped *Asconema* sp. |
| E Group | Margrette NE | N | 3 | 1 | 3 | 1 | 2 | Presence of aggregations of large plexaurids (likely of the genus *Placocorgia*) and high abundances of stylasterids likely from the species *Errina atlantica.* Sparse patches of the bird’s nest *Pheronema carpenteri* colonize soft grounds. |
| E Group | Santa Maria N | N | 3 | 2 | 3 | 2 | 1 | Colonies of black corals *Leiopathes expansa* colonizing rocky overhangs and octocorals *Hemicorallium* sp. and *Candidella imbricata.* The whip coral *Viminella flagellum*, generally accompanied by other octocorals such as the primnoid *Callogorgia verticillata.* |
| E Group | Santa Maria E | N | 3 | 1 | 3 | 1 | 1 | Presence of large colonies of *Viminella flagellum, Callogorgia verticillata* and *Paracalyptrophora josephinae.* Small aggregations of the gorgonian *Acanthogorgia* sp., and patches of one unidentified white Plexauridae coral. |
| E Group | Santa Maria SW | N | 3 | 2 | 3 | 3 | 1 | Presence of bamboo corals *Acanella arbuscula,* occasional black corals *Leiopathes* cf. *expansa* sp. and stylasterid corals. Aggregations of primnoids of the genus *Narella* and *Acanthogorgia*. |
| E Group | Santa Maria W | N | 3 | 1 | 4 | 3 | 1 | Dense patches of the gorgonians *Candidella imbricata, Callogorgia verticillata,* and some occasional bamboo corals of the species *Acanella arbuscula,* and the black coral *Antipathes erinaceus.* Sponge fields of cf. *Hyalonema* and *Pheronema carpenteri* colonize soft grounds. |
| E Group | Santa Maria Pico W | N | 4 | 2 | 1 | 2 | 1 | High densities of the gorgonians *Hemicorallium tricolor* and *Hemicorallium niobe* and stylasterids. Aggregations of the primnoids *Narella versluysi* and *Narella bellissima* with some sponge species composing the community. |

Inferred Vulnerable Marine Ecosystems (VME index)

Currently, the available data covers the full deep-sea areas of the Azores down to 1000 m depth. Nevertheless, we have updated the multi-criteria assessment described in Morato *et al.* (2018). Here, we did not use the abundance of the VME indicators since no estimates are available for the region, yet. We used georeferenced data on VME indicator taxa described in sections 6.1 and 6.4 (namely, COLETA, ICES, NOAA and OBIS) to estimate the VME index and the confidence index. The VME index was then aggregated to a grid of 5 × 5 km cells using the maximum VME index value per cell and assigned to three classes computed with the Jenks natural breaks classification method (Low "VME index": <2.7; Medium: 2.7–3.5; High: 3.5–4.1). Low confidence was given to confidence scores smaller than 0.31, medium confidence to scores between 0.31 and 0.71, and high confidence to scores > 0.71. The VME index highlighted areas where a VME is more likely to occur (Figure 481) while the associated estimate of confidence indicates how (un)certain that assessment is (Figure 482). The VME index identifies the Azores as an area with high values of VME index.

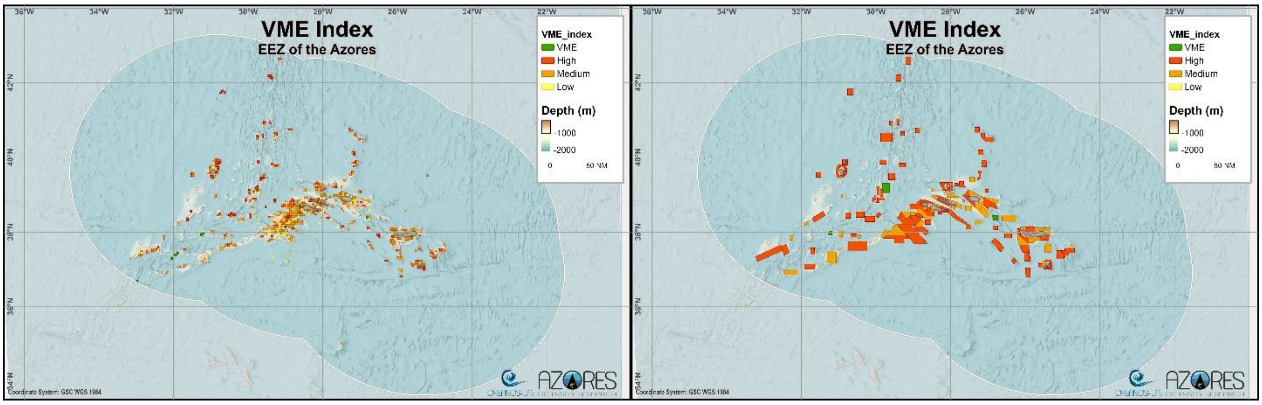



**Figure 481** The VME Index computed using the methodology describe in Morato *et al.* (2018) and data compiled here. Cells coloured in green are known VMEs (hydrothermal vents), in yellow are cells with Low "VME index", orange Medium, and red High.

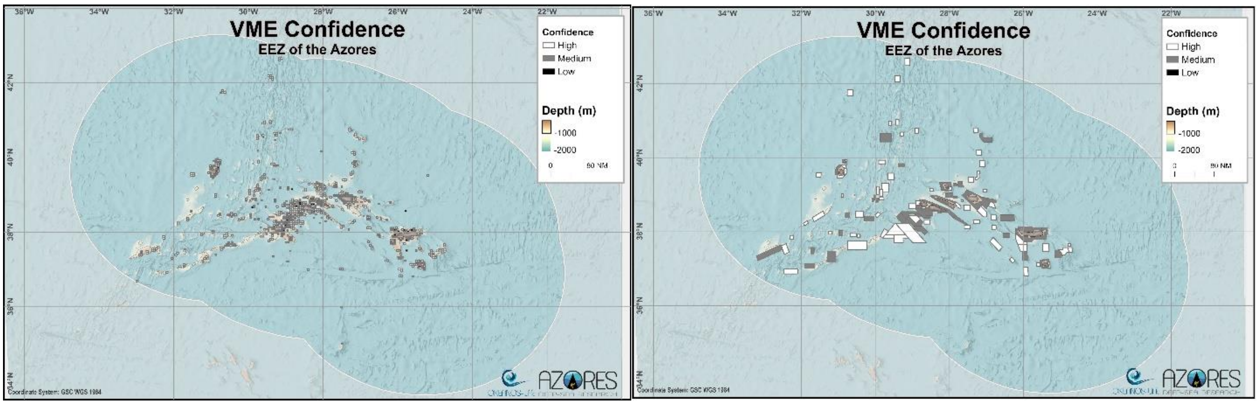



**Figure 482** Confidence index for all cells with data, coloured as low confidence in light grey, medium confidence in dark grey and high confidence in black.

### *11.2 Pressures and Impacts in the Azores deep-sea*

In order to support the assessments of the Descriptor 6 criteria (D6C3 and D6C5), we will carried out an assessment of the degree of pressure and threat relating to human activities. We adopted a standard methodology for this purpose, such as that described in Fernandes et al. (2020) which starts from the characterization and mapping of conservation values (section 10) and pressures arising from activities and potential uses. For this purpose, we compiled the human activities that affect the deep sea of the Azores up to 1,000 m deep, through the analysis of existing Vessel Monitoring System data in the region. We also developed matrices of pressures and threats that allow an objective assessment of impacts and contribute to the assessment of D6C3 and D6C5.

#### Conservation values

For the purposes of the assessment of the pressures and impacts in the Azores deep-sea, we used the results of the evaluation of the 140 geomorphological structures in the Azores in relation to the FAO criteria to define what constitutes a VME (Section 11.1). The analyses produced a "VME index" for each of the areas ranging from 1 to 4. The final "VME index" for each areas was calculated based on the VME indicator score and the abundance based on the annotation of the video images on a SCAFOR scale compiled in BD2 – Georeferenced database containing information of species and habitats. After assigning a VME index to each VME indicator taxa and record, the results were then aggregated to each area.

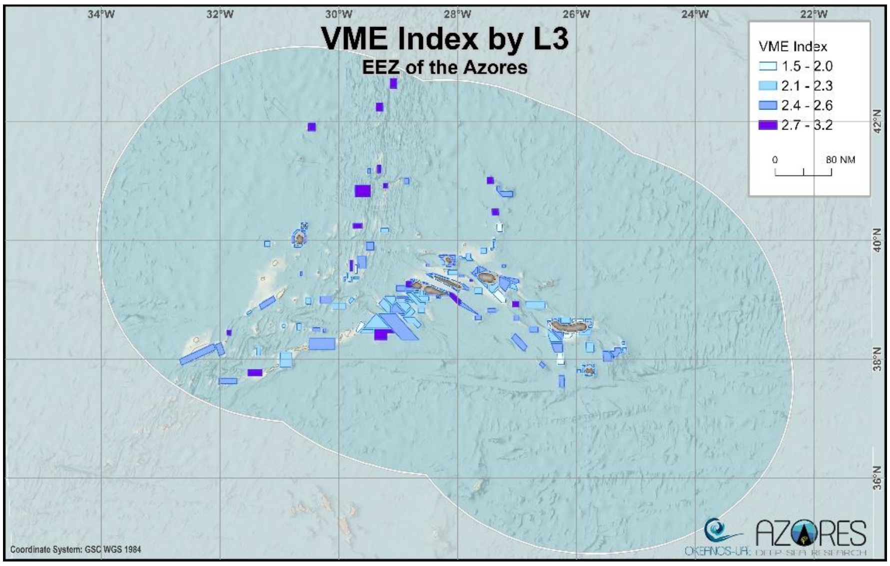



**Figure 483** VME index for each of the 140 geomorphological structures in the Azores.

#### Human pressures

*Fisheries*

As in most oceanic islands, fishing has always been a key driver of the subsistence and economy of the Azores (Carvalho, 2010). The Azores fisheries are typically characterised as being artisanal and small-scale in nature, with a multi-segmented fleet, targeting multiple species with a wide range of fishing gears and methods (Carvalho, 2010). With the absence of a continental shelf and surrounding great depths, modern fishing occurs around the island slopes and the many seamounts present in its vast exclusive economic zone of 1 million km² (Silva & Pinho, 2007; Morato et al., 2008, 2013; Diogo et al., 2015). Dominated by hooks-and-lines, fisheries in the Azores can be categorized as pelagic and deep-sea fishing, with the latter being one of the few human activities currently producing a direct impact in the deep-sea benthic communities. Deep-sea fisheries are currently composed of bottom longline and handline fishery targeting deep-sea demersal fishes such as blackspot seabream (*Pagellus bogaraveo*), wreckfish (*Polyprion americanus*), alfonsinos (*Beryx* spp.) or blackbelly rosefish (*Helicolenus dactylopterus*) with an average total catch of 4,300 t·year$^{-1}$. A drifting deep-water longline fishery for black scabbardfish (*Aphanopus carbo*) has been in experimental phase since 1998 (Machete et al., 2011), but has no catch in recent years (Fauconnet et al., 2019a).

Bycatch from the bottom longline fishery is of concern because they include many deep-water sharks listed in the IUCN Red List of endangered species. According to the European IUCN Red List Assessment 2018, these include the "critically endangered" gulper shark (*Centrophorus granulosus*), blue skate (*Dipturus batis*), the "endangered" kitefin shark (*Dalatias licha*), Portuguese dogfish (*Centroscymnus coelolepis*), leafscale gulper shark (*Centrophorus squamosus*), and birdbeak dogfish (*Deania calcea*); the "near threatened" greenland shark (*Somniosus microcephalus*), and the "least concern" longnose velvet dogfish (*Centroscymnus crepidater*). Despite the fishing prohibition of several species of deep-water sharks set in European fisheries regulations since 2010, occasional bycatch of least ten different species still accounted for 8% of the discards of the bottom longline and handline fishery in the recent years (2010-2014) (Fauconnet et al., 2019a). Yet, handliners had much smaller bycatch of deep-water sharks than bottom longliners. Deep-water sharks caught with handlines are also more likely to survive after release.

Work developed by Pham et al. (2014b) found that deep-sea bottom longline fishing has reduced impact on vulnerable marine ecosystems when compared to bottom trawling. They found reduced bycatch of cold-water corals and limited additional damage to benthic communities, especially compared with bottom trawls. Bycatch of cold-water corals was registered in 44.7% of the longline sets, but with a very small average number of organisms (Pham et al., 2014b). Longlines were found to mostly (91% of the bycatch) impact large organisms with a complex morphology, which is of particular concern because these are generally long-lived species with very slow growth rates (e.g. *Leiopathes* sp.). The most abundant species composing the primary bycatch were the antipatharian, *Leiopathes* spp., the stylasterid, *Errina dabneyi* and the gorgonians, *Callogorgia verticillata, Acanthogorgia armata*, *Paracalyptrophora josephinae* and *Viminella flagellum* (Sampaio et al., 2012). Most of these species are important habitat builders in the region. In total, thirty-nine different taxa of anthozoans and hydrozoans were recorded from longline bycatch, representing 26% of currently known cold-water corals (Sampaio et al., 2012). To provide insights on the level of longline damage not accounted as bycatch, the physical conditions of benthic communities on a fishing ground were also assessed by Pham et al. (2014b). From the colonies observed close to lost fishing lines, 63% were found intact, 15% with minor damage, 20% with major structural damage but with potential for survival, and only 3% of the cold-water corals were found in a critical status with no survival potential. These analyses showed that, although reduced when compared to bottom trawling, deep-sea bottom longline fishing may impact VME indicator taxa mostly those with a complex and large morphology.

We used existing maps of predicted fishing effort in the Azores, namely in what regards bottom longline and handline fisheries (Morato and Fauconnet, unpublished data). The bottom fishing effort was computed from an analysis of the Vessel Monitoring System (VMS) for vessels licensed for bottom longline or handline fishing gears. The fishing licences granted to each vessel per year were used to allocate a gear type to all VMS pings. We acknowledge that not all boats operating in the spatial planning area (beyond 6 nm from island shores) have VMS systems installed. However, a quick comparison of the VMS outputs with the fishing effort maps obtained from fishers' inquiries (Diogo et al., 2015) revealed similar spatial patterns, but much more spatial detail when using the VMS data. In total, VMS data was obtained from 74 anonymous vessels over the period 2002-2018 with an average of 12 vessels per year. This number represents about 25% of the bottom longline fleet if considering an average of 52 vessels per year that declared landings using bottom longline.

After cleaning the VMS database, the derived speed, heading and change in angle were calculated based on the geographic positions of consecutive pings and used for subsequent analysis. The calculated variables better represent the behaviour of fishing vessels over the time between pings than the instantaneous values provided in the original VMS data. From the VMS pings, a new trip was identified if: i) the vessel was in the harbour (i.e. within a distance inferior or equal to 1.5 nm from a harbour), and at a calculated speed inferior or equal to the harbour speed (set to 0.5 knots), but the speed of the next ping was superior to the harbour speed, or if ii) the time difference between 2 consecutive pings was superior to 90 hours, and the next ping was outside of a harbour (i.e. further than 1.5 nm). A new leg was considered when the angle change between 2 consecutive calculated headings was superior to 50°, and the vessel was outside the harbour (distance >1.5 nm from any harbour). Only the major harbours in the Azores were considered.

We used heuristic methods to define the fishing vessels state at any given time using specific rules for speed, course, leg, angle, and distance to harbour. The preliminary results have been validated with a quasi-Bayesian approach. The vessels were considered "fishing" when i) the distance to the closest harbour was greater than 1.5 nm, ii) the leg did not finish or start in a harbour (distance greater than 1.5 nm), iii) the calculated speed was between 0 and 3 knots, iv) the length of the leg was between 0 and 15 nm, and v) it was later than 5 am, but earlier than 1 am. When conditions i to iv were met but between 1 and 5 am, the vessel was considered "resting/night". This time rule was implemented for bottom longliners to reduce the number of false positives and because, contrary to pelagic longlines, the resting state based on low speed was not adequate to distinguish from the fishing state. This is mostly true for those vessels operating with handlines. If the vessel was close to a harbour (i.e., at a distance inferior or equal to 1.5 nm), and at a slow speed (inferior or equal to 0.5 knots) it was considered "in harbour". "Steaming" was considered when i) the vessel speed was above the fishing speed (i.e. superior to 3 knots) or ii) the vessel was close to a harbour (at a distance inferior or equal to 1.5 nm) but at a faster speed than it would have if inside a harbour (i.e. superior to 0.5 knots) or, iii) the vessel was far from any harbour, and within fishing speeds, but a) the leg was starting or finishing in a harbour, or, b) the length of the leg was longer than 15 nm. Fishing effort was estimated as the sum of the time difference between pings associated with the fishing state. Due to the non-normal range of values, including the presence of few cells with very large values fishing activity, the sum of the time difference was log transformed and normalized to a maximum value 1 (Figure 484). For the purposes of the assessment of the pressures and impacts in the Azores deep-sea, we used the results of the VMS analyses and produced a “VMS index” for each of the areas ranging from 1 to 4 (Figure 486).

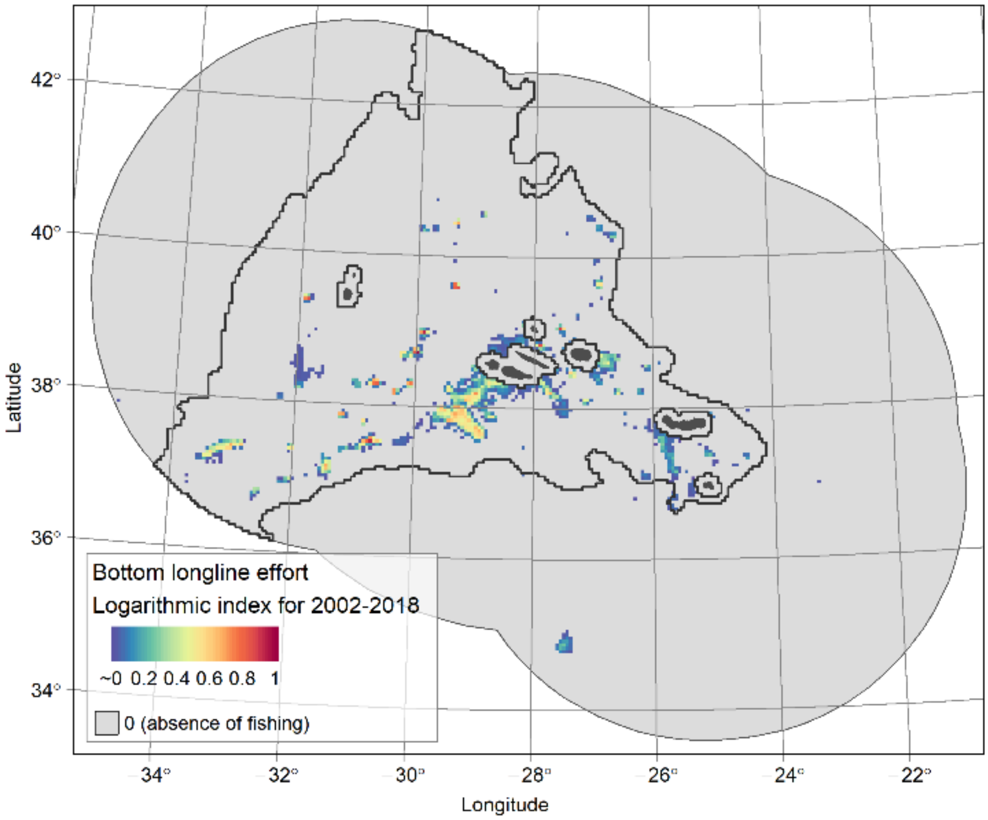



**Figure 484** Bottom longline fishing in the EEZ of the Azores expressed as a logarithmic index of effort within the fishing footprint at the 5km resolution, based on the analyses of VMS data.

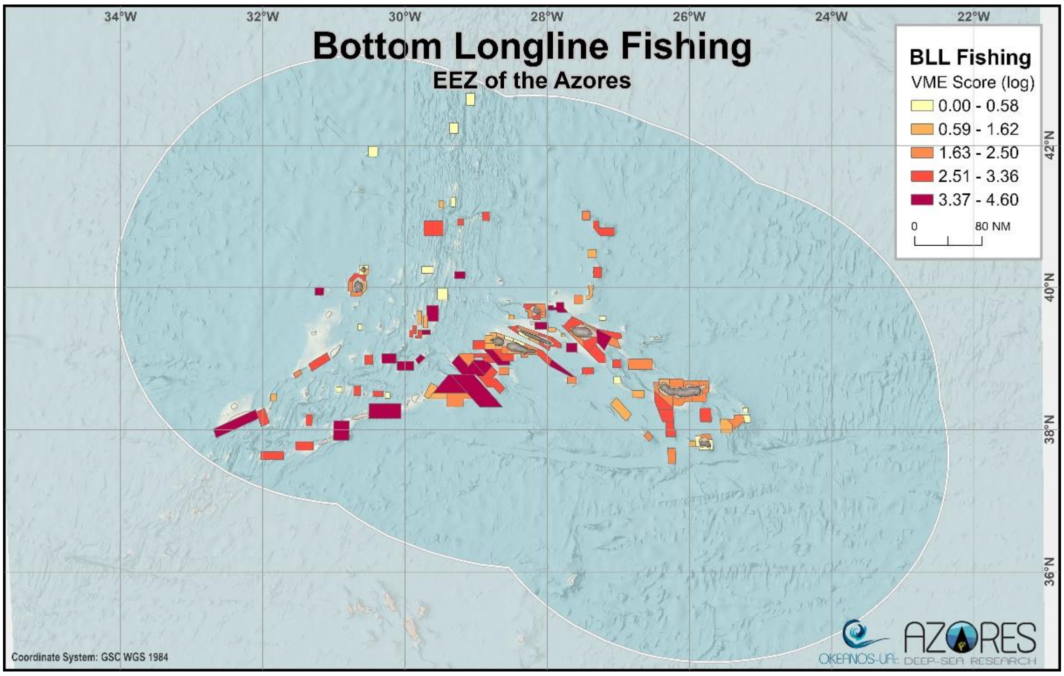



**Figure 485.** Bottom longline fishing in each of the 140 geomorphological structures in the Azores.

*Deep-sea mining*

The recognition that the deep sea could provide a valuable source of scarce metals has become increasingly widespread in recent years (Petersen et al., 2016). To date, no commercial deep-sea mining has occurred in the Azores or anywhere in the world but the activity may happen in the future and is anticipated to cause significant impacts on the marine environment and other human activities (Van Dover, 2011; Boschen et al., 2013; Wedding et al., 2015; Miller et al., 2018). The scale and nature of these impacts remain uncertain but will involve extensive physical destruction of the seabed, alteration in hydrothermal circulation at the active vent sites and production of considerable potentially toxic sediment plumes over both short and prolonged durations, depending on the size and duration of discharge, oceanographic conditions and dilution factors on different environments (Gwyther, 2008; Boschen et al., 2013). Predicted direct impacts on deep-sea ecosystems include the potential reduction in biodiversity, species abundance and ecosystem services, due either to loss of habitat or smothering of benthic communities by sediments in the close vicinity of the mining operations (Gwyther, 2008; Boschen et al., 2013; Van Dover et al., 2017). The organisms that are expected to be most affected by smothering are the benthic sessile fauna and the infauna, with reduced mobility that limits their escape capabilities. However, impacts of pelagic organisms are also expected, since 3-D oceanographic models predict a large horizontal and vertical mining plume dispersion (Morato et al., unpublished data), increasing turbidity and changing grain size and angularity (Lake & Hinch, 1999). Secondary effects include potential uptake of bioavailable trace metals released by sediment particles into tissues of marine organisms resulting in organisms' death and bio-accumulation of these metals through the food web (Brewer et al., 2007, 2012; Koski, 2012), and potential human health risks from fish and shellfish consumption (Reichelt-Brushett, 2012).

In 2006, international companies approached the Azores Government intending to explore minerals resources in the deep sea. In 2012, legislation for mineral exploration and exploitation in the Azores was created as well as legislation for granting access and equitable distribution of scientific results (following the Nagoya Protocol). A dispute with the Portuguese government that has ruled this legislation unconstitutional (ECORYS, 2014) has put things on hold. Nautilus Minerals Inc. submitted the first proposal for exploration rights in several areas, totalling 9272 km2, around the Azores (from North to South): Patorra (between Cavala and Ferradura seamounts), Moreto (south of the Menez Gwen hydrothermal vent field and close to Monte Alto and Voador seamounts), Arinto (south of Lucky Strike area, between Sarda and Farpas seamounts), Famous (in Famous hydrothermal vent field), Saldanha (in Saldanha hydrothermal vent), and Verdelho (around Rainbow hydrothermal vent fields) (Figure 486). Most of these areas were recently included in the Azores Marine Park as part of the PMA13 MPA, but lack effective protection measures (DLR n.º 13/2016/A). In fact, deep-sea mining exploration activities are not prohibited in PMA13, but they require special permits as it would be necessary for any other area.

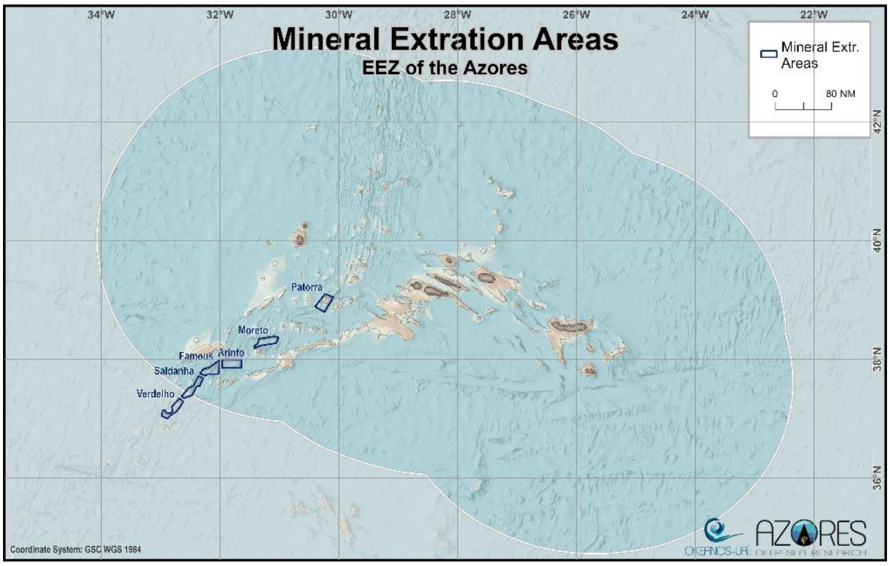



**Figure 486** Location of the areas submitted by Nautilus Minerals Inc. for deep-sea SMS mining exploration in the Azores region.

*Climate change*

Climate change has been recognized as the greatest threat to marine ecosystems in the XXI century (IPCC 2023). Projections of deep-water mass properties suggested that portions of the seafloor in the North Atlantic will experience significant changes as a consequence of the uptake and storage of heat and anthropogenic carbon dioxide in the deep ocean (Gehlen et al., 2014; Sweetman et al., 2017; Perez et al., 2018). These forecasted changes may affect productivity, biodiversity, and distribution of deep-sea fauna, especially VME indicator species compromising key ecosystem services (Levin & Le Bris, 2015; Levin et al., 2019; Xavier et al., 2019; Morato et al., 2020; Puerta et al., 2020). In the Azores, the bottom seawater properties were forecasted to change by 2,100 with a Small increase in seawater temperature, a loss of dissolved oxygen up to 3.7%, a 40-55% decrease in the flux of particulate organic matter to the seafloor, a decrease in pH greater than 0.3 units in most area, and a decreases in the saturation horizon for calcite and aragonite (Figure 487).

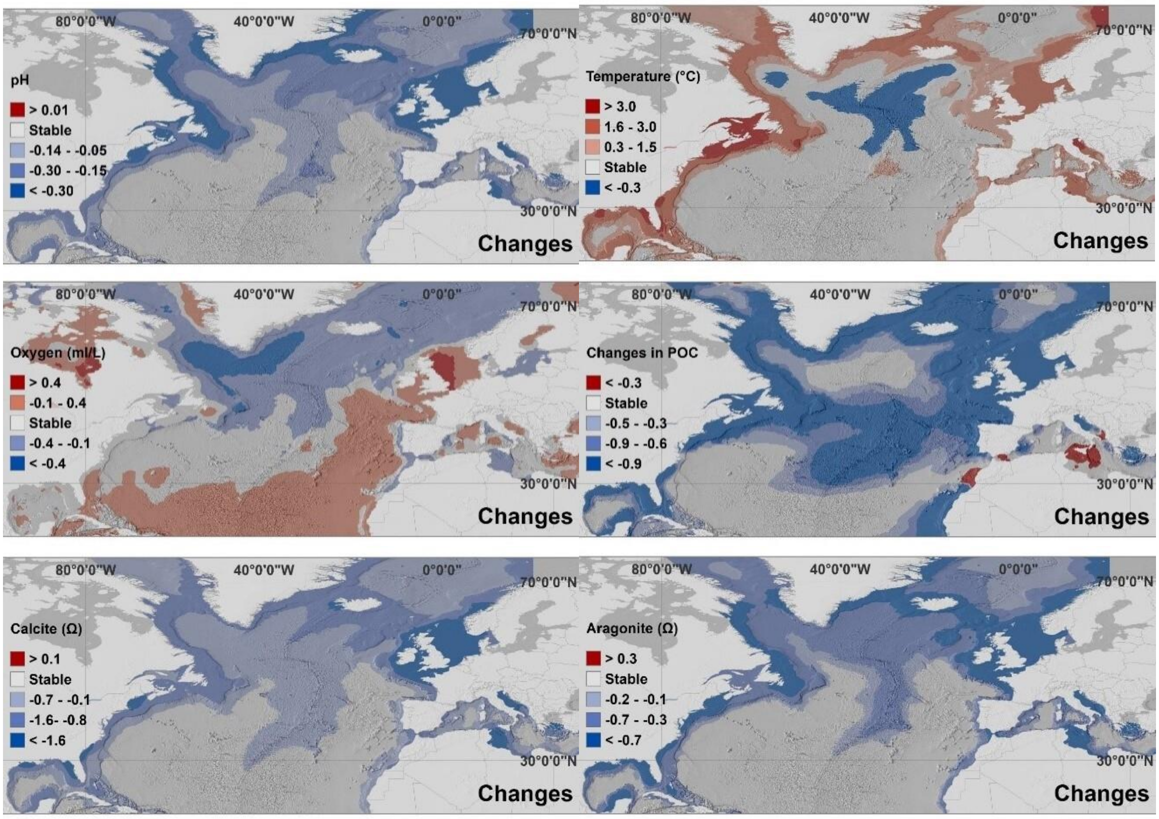


**Figure 487.** Changes in environmental predictors between present and future conditions in the North Atlantic Ocean.

The forecasted changes in the water mass properties of the deep North Atlantic were used to evaluate changes in the habitat suitability for key deep-sea species under future climate scenarios and at large spatial scales (Morato et al., 2020). Model predictions showed that CWCs and commercially important deep-sea fish species could be facing a reduction in their suitable habitat towards 2100 (Figure 488). Prediction showed a marked decrease of 30% to 100% in suitable habitat for cold-water corals and a marked shift in the suitable habitat of deep-sea fishes from 2.0° to 9.9° towards higher latitudes (Morato et al., 2020). The projections forecasted the largest reductions in suitable habitat for the scleractinian coral *Lophelia pertusa* and the octocoral *Paragorgia arborea*, with declines of at least 79% and 99%, respectively. We predicted an expansion of suitable habitat by 2100 for the fishes *Helicolenus dactylopterus* and *Sebastes mentella* by about 20 to 30%, mostly through northern latitudinal range expansion, corroborating the hypothesis of a poleward shift in response to climate change. In the Azores, a significant loss of suitable habitat was forecasted for most species. Experimental studies support these modelling predictions, showing that octocorals in the Azores are more vulnerable than scleractinian corals to predicted ocean acidification (Carreiro-Silva et al., 2014) highlighting the difficulties in making generalisations on the impact of climate change on deep-sea organisms (Xavier et al., 2019).

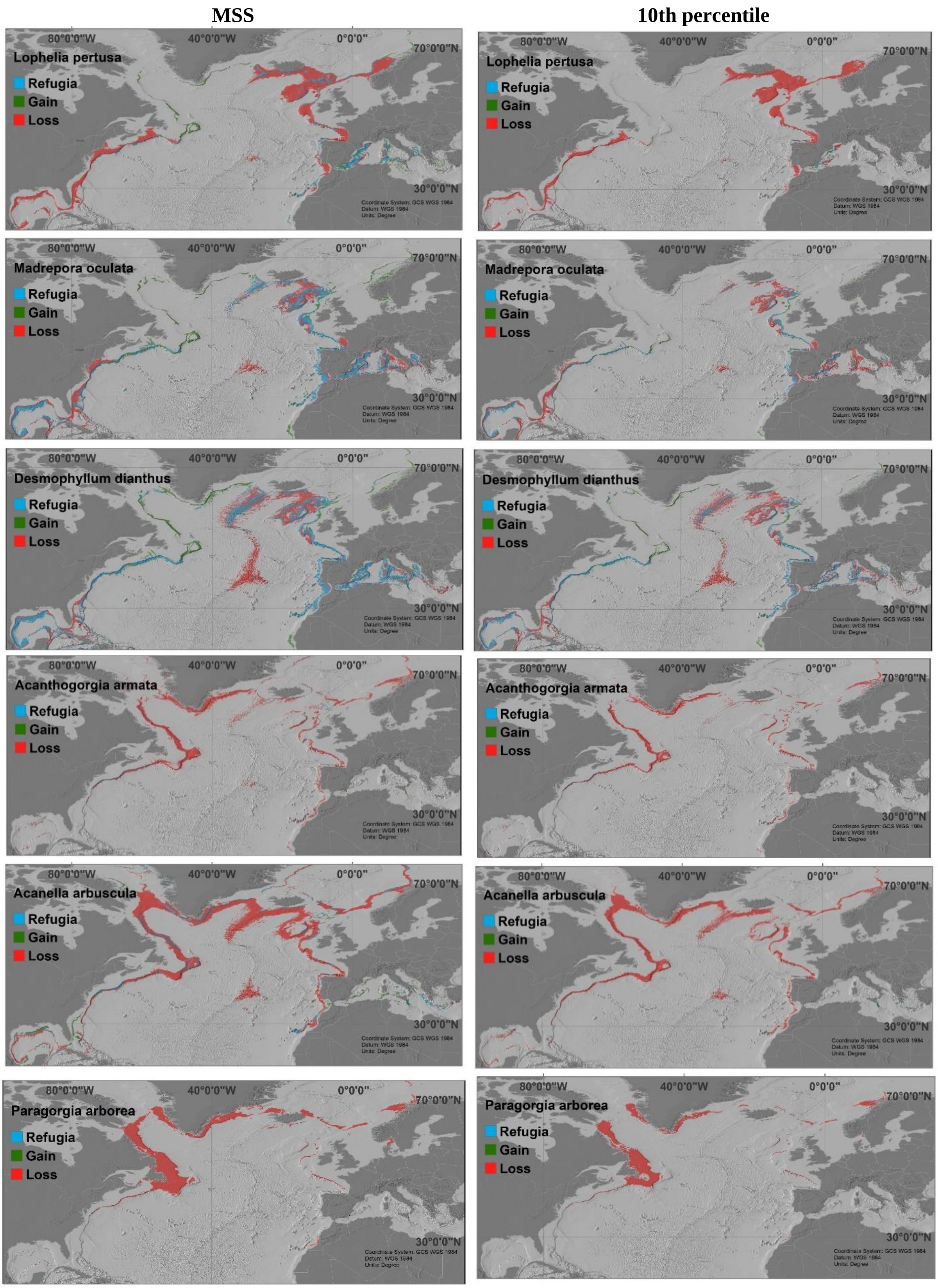



Figure 488. Forecasted present-day suitable habitat loss, gain, and acting as climate refugia areas (sensu Keppel & Wardell, 2012) under future (2081-2100; RCP8.5 scenario) environmental conditions for cold-water corals fish in the North Atlantic Ocean. Areas were identified from binary maps built with an ensemble modelling approach and two thresholds: 10-percentile training presence logistic threshold (10th) and maximum sensitivity and specificity (MSS).

*Litter*

Marine litter has been found in the deep-waters of the Azores highlighting the extent of the litter problem and the need for action to prevent the increasing accumulation of litter in marine environments (Pham et al., 2014a). Abandoned, lost, or discarded fishing gear (ALDFG) was the most common marine litter item in the Condor seamounts, often found entangled on dominant octocorals, indicating a substantial indirect effect of fishing on deep-sea habitats (Pham et al., 2013). We used the videos images obtained from our deep-sea imagery surveys to predict the distribution and abundance ALDFG in the deep sea of the Azores (Ducan et al., 2023). Most ALDFG items observed in the images relate to the local bottom longline fishery operating in the region, and include longlines but also anchors, weights, cables and buoys. A generalized additive mixed model (GAMM) was used to predict the distribution and abundance of ALDFG over the seafloor within the limits of the Azores EEZ using a suite of environmental and anthropogenic variables. Not surprisingly, the resulting model identified potential hotspots of ALDFG in areas with high fishing effort (Figure 489).

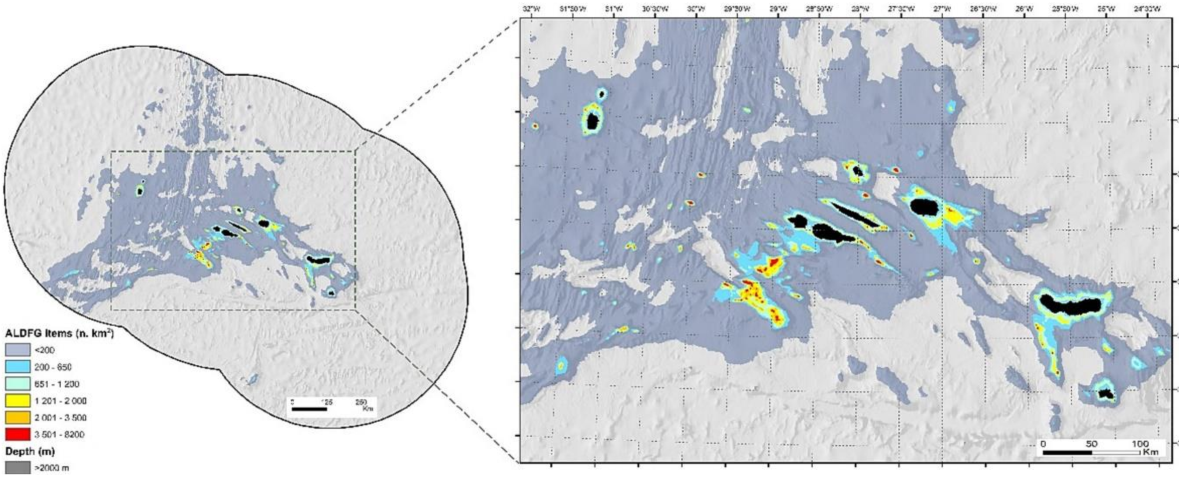
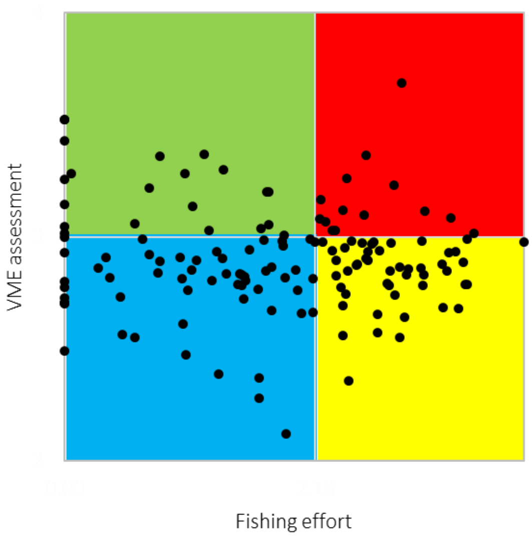



**Figure 489** Predicted abundance of ALDFG items in the Azores EEZ (above 2000 m) resulting from a GAMM modelling approach (Ducan et al., 2023).

Impacts and threats

One of the main advantages of deriving a gridded “VME index” is that it can be directly compared to other spatial data, as for example fishing effort. Fishing intensity data can therefore be used to account for the anthropogenic activities occurring within each of the 140 geomorphological structures in the Azores. We suggest an approach that combines the “VME index” and the level of fishing activity, measured through VMS data. This methodology allows the classification of individual cells into four main categories, which can help in optimizing management efforts toward spatial management: Low VME index-Low fishing; Low VME index-High fishing; High VME index-Low fishing; High VME index-High fishing. “VME index” and fishing intensity for individual cells can therefore be easily summarized and graphically compared. For this, the final outcome of the VME index was presented as two nominal categories of “VME index” scores, indicating the likelihood of an area to contain a VME. Thresholds were computed using the Jenks natural breaks classification method (Jenks, 1967). The categories were: low “VME index” for total scores <=2.39 and high for total scores >=2.39. Similarly, the final outcome of the fishing effort analyses was presented as also two nominal categories of “VMS index”, indicating the likelihood of an area to contain fishing effort likely to produce adverse impact in the deep-sea benthic communities. The threshold was computed using the Jenks natural breaks (Jenks, 1967), as low fishing effort or "VMS index" for total scores <=1.92 and high for total scores >=1.92.

The application of the VME and fishing effort portfolio categories to the VME and VMS indexes was tested in each of the 140 geomorphological structures in the Azores. The outcomes of the framework can be visualized for comparing different areas, allowing to prioritize their choices or policies in terms of closing pristine VME areas, closing disturbed areas for recovery of VMEs, or both (Figure 490). The VME index/Fishing intensity portfolio dataset revealed a larger portion of cells categorized as Low VME index – Low fishing (n= 57) and Low VME index–High fishing (n= 48), with only a small portion being categorized as High VME index–Low fishing (n= 21) and High VME index–High fishing (n= 14). The VME index/Fishing intensity portfolio analyses allowed to identify 22 areas identified as VME that fall in the portfolio category high VME – low VMS, 14 falling in the portfolio category high VME – high VMS, and 3 in the other category (Figure 490). The areas where high fishing effort overlaps with high VME index may be areas of potentially significant adverse impacts in vulnerable marine ecosystems.




| | |
|---|---|
| Hard Rock Café, Chaucer S, Estrela, Kurchatov N, Isolado, Agulhas Corvo-Graciosa, Gigante N, Gigante Agulhas NW, Sardinha, Sedlo W, Gaillard, Ilha Azul SE, Álvaro Martins, Ferraria Norte, Ferraria Mar, Girard, Pico S Lajes, Faial W Capelinhos, Albatroz do Meio, Princesa Alice Picos S, Sauerwein | Flores NE, Kurchatov SE, Kurchatov S, Kurchatov SW, Voador, Farpas, Espadarte, Graciosa S, São Jorge W Rosais, Dom João de Castro, Condor, Ponta da Ilha N, Ponta da Ilha S, Açor S |
| Corvo NW, Corvo NE, Corvo SE, Corvo SW, Flores E, Flores S, Flores W, Gigante Agulhas NE, Diogo Teive, Cabeçote, Menez Gwen, Alfa E, João Leonardes, Serreta Mar, Graciosa NE, Graciosa SE, Graciosa SW, Perestrelo Bartolomeu, Ilha Azul E, São Jorge NW, São Jorge S Urzelina, São Jorge SW Velas, Terceira NE, Terceira SW Angra, Beirada de Fora, Alcatraz, Faial NW, Faial N, Faial-Pico N, Pico NW, Pico NE, Pico SW Espartel, Faial-Pico S, Faial S, Faial Filhas do Condor, Bourée NE, São Mateus de Fora, Princesa Alice SW, São Miguel NW, São Miguel N, São Miguel NE, São Miguel E, São Miguel SE, São Miguel S, São Miguel SW, São Miguel W, Maria Celeste, **Formigas**, Margrette, Margrette E, Margrette NE, Santa Maria N, Santa Maria E, Santa Maria SW, Santa Maria W, Santa Maria Pico W, Henry Carr | Flores NW, Cachalote, **Óscar**, Gigante, Gigante 127, **Gigante Agulhas S**, Gigante Agulhas SW, Ferradura E, Ferradura, **Cavala**, **Beta**, Buchanan, Lucky Strike E, Picoto, Alfa, Monte Alto, Sarda E, Sarda, Sedlo, Borda, Mar da Fortuna, Graciosa NW, Ilha Azul, São Jorge NE, São Jorge E Topo, João de Melo, Terceira N, Terceira E, Terceira S, Terceira W Serreta, Gastromar, Albatroz do Norte, Baixo de São Mateus, Agulhas 12 Milhas, Condor de Fora, Agulhas 18 Milhas, Açor, De Guerne N, Princesa Alice W, Princesa Alice, Mar da Prata N, Mar da Prata, Mar da Prata S, Grande Norte, São Jorge SE, Maçarico, De Guerne, Bourée E |

**Figure 490** Application of the portfolio categories concept to the Georeferenced database containing information of species and habitats, and the vessel monitoring system data. The different colors represent the four portfolio categories: blue is low VME – low VMS, yellow is low VME – high VMS, green is high VME – low VMS, and red is high VME – high VMS.

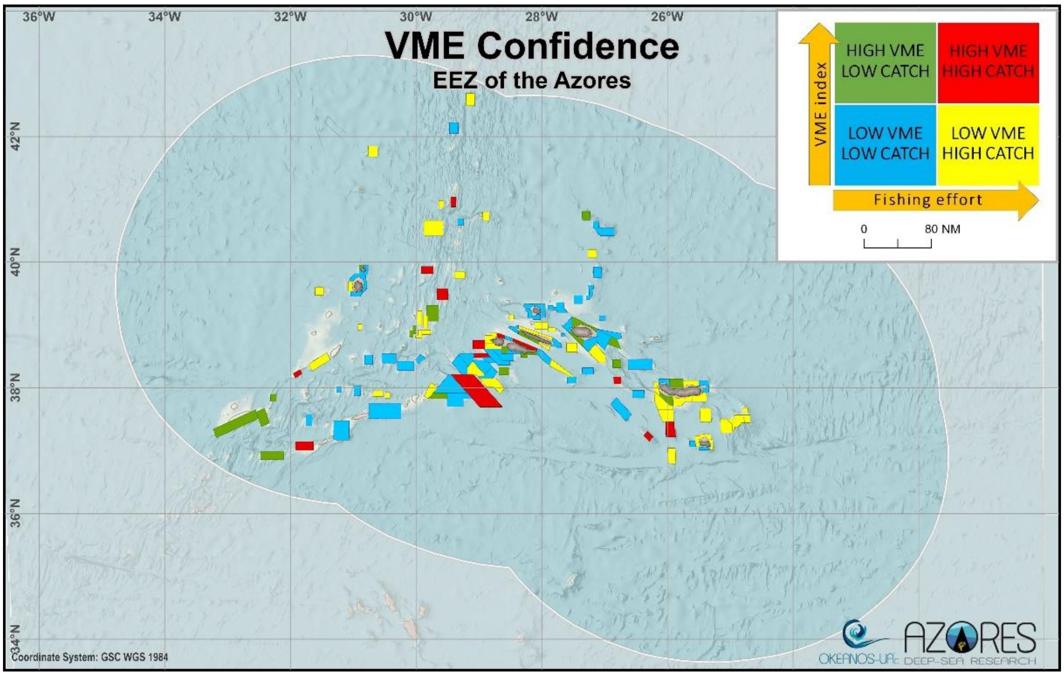



**Figure 491** Application of the portfolio categories concept to each of the 140 geomorphological structures in the Azores. The different colors represent the four portfolio categories: blue is low VME – low VMS, yellow is low VME – high VMS, green is high VME – low VMS, and red is high VME – high VMS.

## *11.3 Evaluating of Descriptor 6 of the Marine Strategy Framework Directive in the deep sea*

The European Commission adopted in 2008 the Marine Strategy Framework Directive (MSFD; Directive 2008/56/EC), which aims to “protect and preserve the marine environment, prevent its deterioration or, where practicable, restore marine ecosystems in areas where they have been adversely affected” throughout the territory of all European Union member states (European Commission, 2008). The MSFD proposes the application of an ecosystem-based approach to manage human activities, with the ultimate goal of achieving or maintaining a Good Environmental Status (GES) in marine ecosystems. Under the MSFD, 11 qualitative Descriptors (D) were formulated to determine the environmental status of specific marine regions or sub-regions. Decision 2017/848/EU defined several primary and secondary criteria to assess each Descriptor uniformly, encouraging Member States to develop regional strategies that reflect the desired holistic framework, while being specific for their territorial waters (European Commission, 2017).

Over the past few years, the Regional Directorate for Maritime Affairs (DRAM) and the Regional Directorate for Maritime Policies (DRPM) of the Regional Government of the Azores have produced several documents to support the implementation of the strategy. In particular, an update to the Initial Marine Strategies Report for the Azores subdivision was written, which included, in Part D, a reassessment of the environmental status and the definition of environmental targets for the 11 qualitative descriptors, including descriptor 6, seabed integrity (D6).

In this context, we evaluated methodologies to analyze the data collected throughout the project to define D6C3 assessment methodologies that concern the “Spatial extent of each type of habitat that is negatively affected by physical disturbances, through the alteration of its biotic and abiotic structure and of its functions", and D6C5 "The extent of the negative effects of anthropogenic pressures on the condition of the habitat type, including alteration of its biotic and abiotic structure and functions, does not exceed a specified proportion of the natural extent of the habitat type in evaluation zone."

### Introduction

The most relevant descriptor of the MSFD to assess the environmental status of deep-sea regions under increasing anthropogenic pressures is D6 (Seafloor integrity). This descriptor aims to guarantee that the seafloor is found "at a level that ensures that the structure and functions of the ecosystems are safeguarded and that benthic ecosystems are not adversely affected" by human activities. D6 is constituted by five different, but complementary criteria: spatial extent and distribution of physical loss of the natural seabed (D6C1), spatial extent and distribution of physical disturbance pressures on the seabed (D6C2), spatial extent of each habitat type which is adversely affected (D6C3), extent of loss of the habitat type (D6C4) and extent of adverse effects from anthropogenic pressures on the condition of the habitat type (D6C5) (European Commission, 2017). Criteria D6C1, D6C2 and D6C3 address specific elements such as physical loss and physical disturbance and their impacts, whereas D6C4 and D6C5 concern overall assessments of D6. Evaluations of D6C4 and D6C5 also take into consideration the assessments performed for D6C1, D6C2 and D6C3.

Despite the existence of criteria and guidelines for monitoring and assessing D6, sensitive indicators and standardized methodologies are still needed to evaluate the status of deep-sea benthic ecosystems. The lack of sensitive indicators is usually further compromised by the lack of comprehensive information on the distribution of biological communities, their ecological status and the pressures they face. Giving the potential effects caused by longlining in the Azores, we tested a new methodology to assess D6 of the MSFD in the Azores by characterizing the health status of CWCs recorded on video images of the seafloor. The proposed methodology contributes to the development of D6C5, providing an objective tool to perform environmental assessments to evaluate the seafloor integrity of deep-sea habitats, responding to the demands of the MSFD.

### Methodologies

*Study area and selection of indicator species*

We used the Gigante seamount complex as the study area to test the methodologies to evaluate D6 in the Azores. Gigante is located on the Mid-Atlantic Ridge and represents an important fishing ground for bottom longline fishing in the Azores region (section 11.2). A set of 5 species of octocorals species known to occur in the Azores and considered foundation species were selected for this study: *Acanthogorgia* sp., *Callogorgia verticillata*, *Candidella imbricata*, *Dentomuricea* aff. *meteor*, and *Viminella flagellum*. Species were classified into different categories of structural complexity and recovery capacity, which was based on life-history traits such as average height, branching pattern, and growth rate. Survival rates, measured in aquaria and during transplantation experiments of coral fragments, were also considered.

*Video surveys and annotations*

A total of 23 underwater video transects recorded by the Azor drift-cam (Dominguez-Carrió et al., 2021) were analysed for this preliminary study. The video system is equipped with parallel lasers 10 cm apart to provide scale to the images and a depth sensor, which was used to improve the positioning of the device when underwater. Overall, more than 10 linear km of seafloor were explored in the Gigante Seamount Complex at depths between 190 and 800 m during. Dives were performed in Gigante and 127 areas and three ridges south-west and north-east of the seamounts. The dives had an average dive length of 435±198 m, and the total amount of video footage recorded added up to more than 18 hours.

Coral colonies of the 5 selected species that appeared inside a 2-meter-wide field of view (determined using the projection of the laser beams) were annotated, and their condition was visually inspected. The physical condition for each colony was determined following an adapted scale developed by Pham et al. (2014), referring to visible physical damage of the colony (e.g., broken, bent or missing branches) and ranging from 1 (no damage/impact) to 5 (maximum damage/impact). The level of epibiosis indicated the relative portion of the colony that was affected by any visible epibiont/parasitic agent (e.g., zoanthids), ranging between 1 (no epibionts reported) to 5 (maximum damage). When the assessment of colony condition was uncertain due to visibility issues, the presence of the coral was annotated but its condition was not considered. The level of bottom longline fishing intensity in the Gigante Seamount Complex was assessed using VMS data (section 11.2). Cumulative data was then gridded in a map of a cell size of 100x100 m (Fig. 4).

Analyses

A total of 11 475 colonies of 5 different species were annotated from the video footage recorded in the Gigante seamount complex. From those, 7 044 coral colonies had their condition assessed, regarding at least one of the selected indicators (Table 2). There were assessed a total of 36 colonies of *Acanthogorgia* sp., 55 of *Callogorgia verticillata*, 82 of *Candidella imbricata*, 61 of *Dentomuricea* aff. *meteor* and with *Viminella flagellum* being by far the most frequent species in the three study areas, with 6810 colonies assessed (97% of total assessments).

Regarding physical condition, *C. verticillata* recorded the highest root mean square (RMS) value of all species (3.61), indicating a higher level of impact. *V. flagellum* scored the second highest RMS for physical damage (3.37), followed by *C. imbricata* (3.20), *D. meteor* (2.74) and *Acanthogorgia* sp. (1.79). As for epibiosis level, the same pattern was registered: *C. verticillata* also scored the highest RMS value (3.44), followed by *V. flagellum* (3.20), *C. imbricata* (2.67), *D. meteor* (2.26) and *Acanthogorgia* sp. (1.43) (Figure 492). Low and medium coral structural complexity groups registered significant differences between both indicators. Low structural complexity scored the highest RMS for physical condition (3.37) followed by high structural complexity (3.19) and medium structural complexity (2.80). Regarding epibiosis level, low structural complexity also registered the highest RMS value (3.20), followed by high structural complexity (2.90) and medium structural complexity (2.33).

Sampling units that solely corresponded to the condition of *V. flagellum* colonies were plotted across the four different fishing intensity groups. No statistical differences were recorded between the RMS values composing the different fishing effort groups, either regarding physical condition or epibiosis level (Fig. 6).

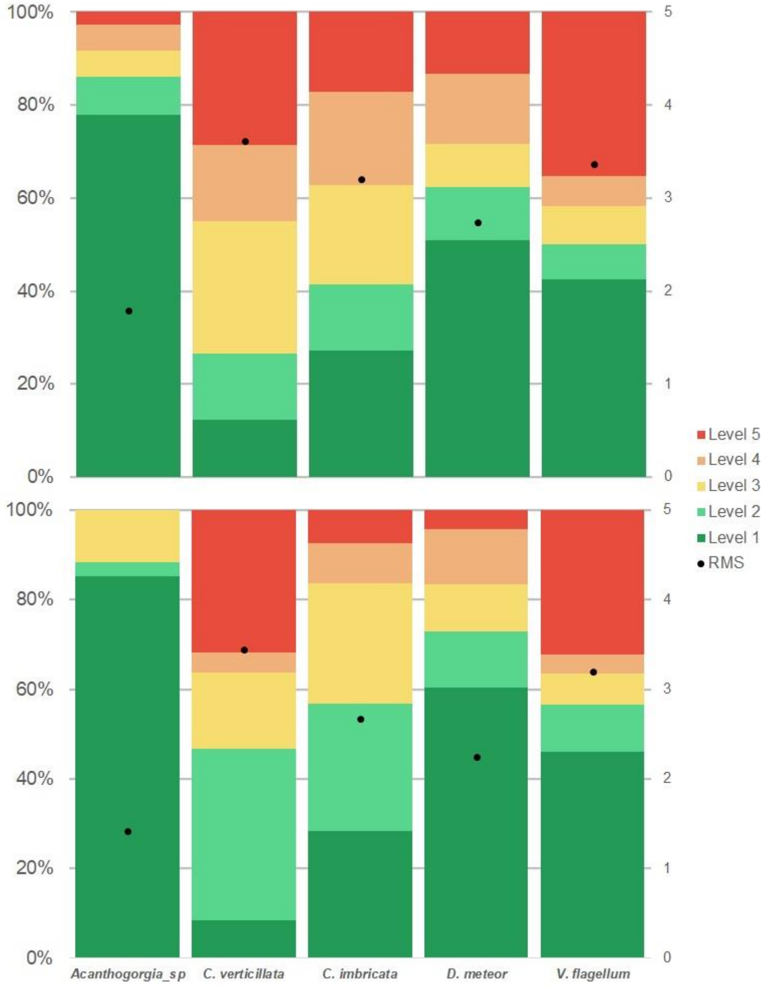



Figure 492 Percentage of colonies that showed different levels of physical condition (top graph) and epibiosis (bottom) per species. Root mean squares are displayed as a black dot.

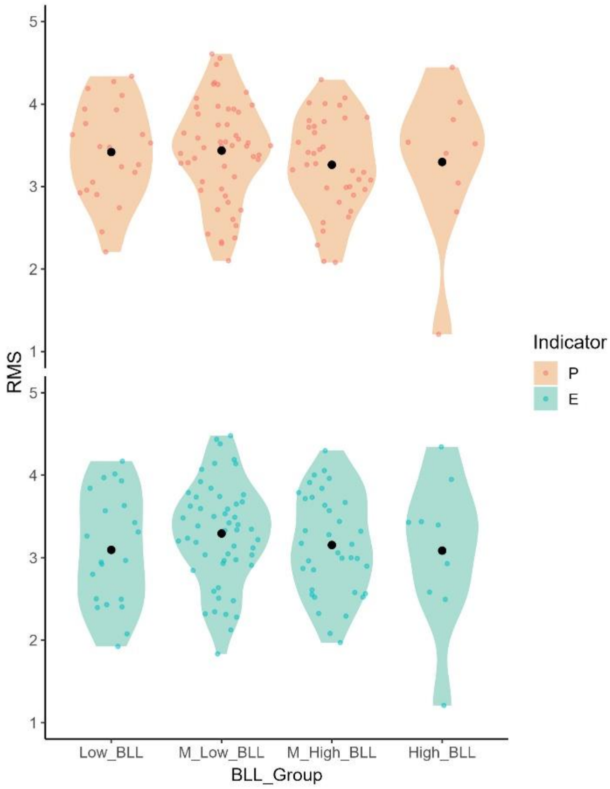



**Figure 493** Values of the RMS regarding physical condition (top graph) and epibiosis level (bottom) calculated in the sampling units of 50 m in length for the species *V. flagellum,* organized accross different levels of fishing intensity. Low_BLL: less than 50h of cumulative fishing; Medium_Low_BLL: 50h - 100h; Medium_High_BLL: 100h - 150h; High_BLL: more than 150h. Means for each fishing effort group are represented in red.

The condition of coral colonies annotated in each of the three areas of the Gigante Seamount complex differ statistically between them regarding their physical condition and epibiosis level assessed. Concerning physical condition, corals annotated in the 127 Seamount scored the highest RMS of the three areas (3.54), followed by the corals present in the Gigante seamount (3.35) and in the Western Ridge (3.06). As for epibiosis level, corals annotated in the 127 Seamount also scored the highest RMS (3.40), followed by corals in the Gigante seamount (3.07) and in the Western Ridge (2.99). Coral condition did not differ significantly between areas with different fishing intensity, with only Low and Medium/Low BLL registering differences regarding both the physical condition and epibiosis level of the corals annotated.

## Insights

The preliminary results indicate that the different CWC species selected show different susceptibilities to disturbances. Some of these were linked with their structural complexities, despite some uncertainty driven by the low number of observations for most species. A precautionary approach to this methodology was always adopted, particularly in the cases where it was difficult to distinguish between physical and epibiosis damage and "natural" conditions. Indeed, most of the higher scores in the species with higher structural complexity (*C. verticillata*, *D. meteor* and even *Acanthogorgia* sp.) were usually attributed to taller, more complex colonies, where damage was more frequent and easily observed and assessed. Nevertheless, in these and most cases, we found epibiosis cover as a suitable indicator which facilitated the annotation process, since its assessment seems to be less susceptible to observer subjectivity than physical condition assessments, where damage assignments are usually based on the idea we have of a "normal" colony structure. Literature also seems to support our suggestion that this indicator is a suitable correlating variable with fishing effort in assessing its impacts to benthic communities (Bo et al., 2014, b; Angiolillo et al., 2015; Ferrigno et al., 2018), upholding the idea that this indicator could be suitable for coral condition assessments and, ultimately, a reliable tool to perform GES assessments of D6 in the deep-sea.

Despite some differences between structural complexities having been detected, the premise that species with higher structural complexity are more susceptible and vulnerable to disturbances was not confirmed. The high proportion of level 5 impacts for *V. flagellum* probably motivated this outcome, which could be related to visibility constraints of the video itself, where in many cases led to inevitably assessing more colonies fully impacted (score of 5) more easily than colonies partially impacted (scores of 2-4), regardless of how precautionary the annotation process was. Moreover, annotations of the numerous dead colonies lying on the seafloor were subject to a high degree of uncertainty, where the distinction between a recently dead specimen and fragments of other colonies was often unclear, which could have also risen the overall RMS values for this structural complexity group. However, the selective impact of fishing towards more complex species, as already proven by Sampaio et al. (2012), could help explain these apparent contradictory results, since these are more frequently captured by bottom longlines. This raises the question of whether the consistent use of bottom-longlines over a long period of time could have actually depleted the seafloor of more structurally complex species, hence rendering their observations much more scarce than simpler ones, such as *V. flagellum*. The recent collection of massive seafloor imagery made it possible to identify that a large part of the benthic communities, including corals and sponges, observed in the main bottom fishing grounds in the Azores are still in good environmental condition and have a high natural and ecological value. However, some long-lived coral colonies with visible impacts from fishing were observed. These on-site observations corroborate the conclusions of previous studies that suggest that well-regulated deep-sea fishing based on hook and line gear (preferably hand line) could contribute to sustainable exploration of the deep sea. Since no differences were detected between the four different fishing intensity classes and the *V. flagellum* conditions and epibiosis, one might speculate that the areas evaluated may still be in good condition and that these values may be used a baseline condition.

The methodology presented here requires some adaptations in order to effectively contribute to posterior GES assessments of D6. These should include a different approach to annotating dead coral colonies, clarifying the level that differentiates a dead colony which is still an observation from one that is already fragmented and part of the sediment. Furthermore, as already mentioned, very small colonies might have often lead to incorrect condition assessments, as it was particularly difficult to recognize and classify physical or epibiosis damage in these cases, which supports a possible colony size limit for future assessments. Moreover, other indicators could also be tested to complement this methodology, such as colony size, coral density and specific composition of CWC communities, for instance. Expanding this methodology to more species and areas with broader fishing pressure values should also enhance this study influence on future seafloor integrity assessments. Continuous efforts are then crucial to constantly provide accurate descriptions of D6 in the deep-sea, performed with relevant, objective and consistent indicators and standardized methodologies.

## 12. Conclusions

The data compiled and obtained during this project contributed to the following main objectives:

- Filling identified knowledge gaps on the characterization of the deep-sea marine biodiversity (<1,000 m depth) until the outer limit of the Azores sub-area of the Portuguese EEZ, in terms of species, communities and habitats present there;
- Contribute to a better definition of deep-sea habitat typologies, including the definition of Vulnerable Marine Ecosystems;
- Mapping the spatial distribution of deep-sea species, communities and habitats until the outer limit of the Azores sub-area of the Portuguese EEZ;
- Identifying areas that fit the definition of VMEs in the Azores;
- Provide decision support information that enables national and international reporting, regarding environmental policies for the marine environment, by the Autonomous Region of the Azores;
- Demonstrate and test applicable low-cost tools to support monitoring the environmental status of the deep sea, up to the outer limit of the Azores sub-area of the Portuguese EEZ.

The data obtained and compiled during this project was sufficient so successful achieve all the main objectives identified in the provision of services. Here we will describe the main conclusions or highlights regarding all the amin objectives.

### *12.1 Filling identified knowledge gaps on the characterization of the deep-sea marine biodiversity*

1. We performed a **detailed compilation of the best existing information** on the biodiversity of the deep sea of the Azores and its spatial distribution down to 1,000 m depth, namely in what regards to 1) VME indicator species; 2) location of known biological communities; 3) inventory and description of habitats identified in the Azores; 4) known spatial distribution of habitats up to the outer limit of the Azores subarea of the Portuguese EEZ. The compilation included data from the Marine Biological Reference Collection (COLETA), video data collected during various research projects, and data from publicly available datasets.
2. We update the Azores Marine Biodiversity Reference Collection (COLETA) database with information collected between 2019 and 2022 and the new data collected during the ARQDAÇO 2023 surveys and with data collected during the provision of services flagship research cruise OceanXplorer 2023. A total of **1 277 new records**, representing a **23% increase** in the pre-existing dataset, were included in the COLETA database. The dataset was expanded to **6 796** reported here and in BD2.

3. We exhausted all other potential sources of information available for the detailed compilation of the best existing information on the deep-sea biodiversity of the Azores. This included a compilation of the information contained in public global databases, such as the ICES Vulnerable Marine Ecosystems data portal, the NOAA Deep Sea Coral Data Portal, and the Ocean Biogeographic Information System (OBIS), were assessed. With the significant increase in the volume of data in the Coleta and in the video annotations datasets, we concluded that the **public datasets did not contain relevant additional information** on the spatial distribution of deep-sea biodiversity, including VME indicator species. Nevertheless, we reported **1 383** records originated from those public datasets for reference and potential use by other users.
4. **Five research cruises** were carried out in the locations identified in the report R1 Report as containing knowledge gaps regarding the deep-sea benthic faunal composition. Altogether, the research cruises lasted approximately **119 days at sea**, corresponding to **551 people at sea**, where a total of **376 dives** were performed, covering about **227 km** of seafloor and producing almost **437 hours** of seafloor video footage.
5. We had the opportunity to build a true partnership with the North American philanthropic entity, Dalio Philanthropies, owner of the **RV OceanXplorer**. This RV was equipped with the best and most advanced ocean exploration technology. This expedition aimed to complement the information that has been collected with the Azor drift-cam, taking advantage of the capabilities from the ship to collect biological samples of deep-sea specimens for taxonomic identification.
6. We **visited all areas** identified in the R1 report, namely 39 unexplored areas in the Azores EEZ. We also visited two areas that were not listed in the R1 report, namely the Gaillard seamount and an area west of Picos S do Princesa Alice. Finally, we also revisited other geomorphological structures that needed complementary sampling efforts.
7. We finally managed to explore the Sedlo seamount with the Azor drift-cam. From 2002 to 2005, Sedlo was the focus of an EU multidisciplinary research project, OASIS (Oceanic Seamounts: An Integrated Study). It is speculated that this seamount hosts one of the most important spawning grounds in the Azores for certain species of fish (e.g., orange roughy and alfonsinos).
8. The Hard Rock Café seamount was finally explored with the Azor drift-cam. The hydrographic Institute have mapped this seamount in 2020 but given its location 210 nautical miles from the natural starting point of the MapGES cruises (Horta) and given its position to the north of the Azores archipelago (normally more affected by adverse weather conditions), the visit to this seamount was being postponed a few years ago. After all conditions were met, the Hard Rock Café was visited. It is a geomorphological structure that, due to its characteristics, was from the first moment on the list of the first options for the expansion of the Azores Marine Park, hence the doubled importance of this visit.
9. It was also the first time that an extensive scientific survey was specifically designed to explore, map, and describe the deep-sea benthic communities that inhabit the banks, ridges, seamounts and slopes located around São Miguel Island
10. We also visited a seamount named Petrov. This area does not yet have high-resolution bathymetry data, so we tried to prospect the area looking for a peak between 300 m and 1,000 m depth. However,

after launching the Azor drift-cam in search of a shallower peak we were unable to reach the bottom. All sonars on board indicated depths between 1,900 m and 2,500 m deep, indicating that this area is much deeper than current nautical charts demonstrate and highlighting, once again, the importance of carrying out multibeam bathymetry surveys in the Azores.

11. The collected footage derives from over 1 155 underwater video transects recorded by ROVs, towed-camera systems, submersible and the Azor drift cam, equalling to a linear distance over the seabed of more than 1 577 kilometres. The existing underwater video transects down to 1,000 m span the whole EEZ, with 69 in Western Group of the Azores, 49 in the Northern Mid-Atlantic Ridge, 103 in the central Mid-Atlantic Ridge, 47 in the Southern Mid-Atlantic Ridge, 295 in the Northern Central Group of the Azores, 392 in the Southern Central Group of the Azores, and 193 in the Eastern Group of the Azores, and 34 outside the EEZ but in areas of interest.
12. To date, 606 underwater dives have been processed at the level 1 and level 2 of annotation, assigning a value of the SACFOR scale to each OTU observed in the segments of 100 m in length. Video footages and annotations were obtained from all the 140 L3 areas. As of 1st November 2023, the database generated from the annotation of the benthic megafauna contains 52,698 records inside of the Azores EEZ. The database contains 855 occurrences of Actinaria, 2 179 of Antipatharia, 971 of Hydrozoa (Order Lepthotheca), 9 776 of Octocorallia, 2 499 of Scleractinia, and 1 037 of hydrozoan family Stylasteridae. In what concerns sponges, from the total of 27 899 records. Additionally, the database contains 458 records of the VME indicator taxa Xenophyophores and 6 989 records of other taxonomic groups.
13. The analysis of the images collected in the deep-sea of the Azores also allowed for the main benthic communities of the invertebrate megafauna to be identified, resulting in a list that includes 39 biological communities including coral gardens (23), cold-water coral reefs (2), sponge aggregations (9), xenophoyphore aggregations (1) and other fauna types (4). Those communities have been identified in the video images and a specific database containing their spatial distribution has been created.
14. Using an integrative taxonomic approach, we have examined 52 specimens across 18 taxa of cold-water corals. This work generated 94 new DNA barcoding consensus sequences (average length 700 bp), and a genome skimming dataset with 9M PE reads per specimen. For the first time a genomic study that combined high-throughput sequencing data from cold-water corals sampled on different sites of the North Atlantic and the Azores was conducted, applying a phylogenomic approach that included 445 taxa. Using this dataset together with diagnosing morphological characters, we have attributed names to seven morphotypes (corals belonging to Paramuriceidae, Keratoisididae, Alcyoniidae), and identified four putative new species (*Alcyonium* sp. nov., *Aquaumbra* sp. nov., and species of the families Aquaumbridae and Cerveridae).
15. The taxonomic examination of Porifera specimens from COLETA greatly increased the knowledge of the sponge diversity of the Azorean Region, which to date represented a poorly studied group. From a total of 52 analised specimens, 36 species were assigned. Four putative new species (*Hertwigia sp*. nov., *Geodia sp*. nov., *Regadrella sp*. nov. and Farreidae gen. to be confirmed sp. nov.) and one genus (Euretidae new. gen. sp. nov) were identified. Three species (*Siphonodictyon viridicens*, *Petrosia (Strongylophora) vansoesti* and *Haliclona (Halichoclona) magna*) and one genus (*Neoschrammeniella*

*sp*.) are new records in the Azores. Additionally, we could resolve identification problems related to species complexes (see *Characella spp*.; *Haliclona spp*.). Furthermore, we had the opportunity to collect and examine fourteen species that were so far mostly know from the literature, or scarcely collected, but are species that may be rare or endemic in the Azores region (to name a few: *Farrea laminaris, Chonelasma ijimae, Raspailia falcifera, Lissodendoryx (Ectyodoryx) foliata, Echynostylinos reticulatus, Xestospongia friabilis)*. We have attributed names to 17 morphotypes names to species, we could also rectify eight OTUS morphotypes that were erroneously attributed based on image (i. e. external morphological characters). For instance, we could recognize that some species share the same external morphologies but are different: the papillate *Characella connectens* vs *Nethea amygdaloides*; the massive *Haliclona magna* vs *Xestospongia friabilis*; the lamellar *Pachastrella monilifera* vs *Poecillastra compressa*; the flabellate *Phakellia spp.* vs *Lissodendoryx (Ectyodoryx) foliata.* Others, presented colour variation but corresponded to the same species, e.g. the *Haliclona implexa* morphotype yellow and white*, Exsuperantia archipelagus* and Porifera digitate yellow. We could also better understand the presence of cryptic species complexes (e.g. *Characella spp., Asconema spp.*), or polyphyletic (e.g. family Chanilinidae), where the taxonomic characters based on spicules are not enough to distinguish between species. Therefore, further work including a genomic approach is necessary to confirm the putative species put forward here.

16. The collaborative work with highly renowned researchers on cold-water coral and sponge taxonomy and phylogenetics, will support continued work on taxonomic revisions that will be useful in reconstructing evolutionary histories. Finally, this will improve our understanding of the biogeographic relationship between the Azorean cold-water corals and sponge communities within the wide Atlantic context.

### *12.2 Better definition of deep-sea habitat typologies, including the definition of Vulnerable Marine Ecosystems*

The systematic review of all the data collected allowed, not only for a compilation of occurrence records, but also to increase the current knowledge regarding the deep-sea biodiversity in the Azores. The compilation and review of the best available data provided the following:

1. The identification of more than 191 species of cold-water corals, comprising species of the anthozoan subclass Octocorallia, orders Antipatharia and Scleractinia and of the hydrozoan family Stylasteridae. Also, the identification of a large diversity of hydrozoans, zoantharians and actinarians summing up to more than 250 species of deep-sea cnidarians in the Azores, with still many species to be described. This list is likely to grow in the future with increasing deep-sea sampling effort from ROV expeditions. The spatial distribution of the known records of Cnidaria, including cold-water corals in the COLETA database and in other publicly available databases spread the whole EEZ. These numbers make the Azores a cold-water coral hotspot in the NE Atlantic.

2. The identification that there is currently limited knowledge on the species diversity of sponges in the Azores. For this reason, sponges observed in images were only classified based on morphological characters and coloration. The opportunity to compare the species visualized in situ by image with the material collected in the scientific missions within the scope of this project, allowed assigning a taxonomic name to many species that were only known by their shape, i.e., like (morpho)species. Nevertheless, diversity of sponges in the Azores is reported to be high (about 458 species), with than 330 species being bathyal and abyssal.
3. The identification of 60 taxa that are listed as ICES VME indicator species, including 9 Scleractinia (stony corals), 27 Octocorallia (gorgonians, soft corals, and sea-pens), 6 Antipatharia (black corals), 3 Stylasteridae (lace corals), 10 Demospongiae (sponges), 3 Hexactinellida (sponges), 1 Foraminifera (Xenophyophore), and 1 Ceriantharia (anemone). Given that the importance of certain VME indicator species may vary geographically, with marked differences in the abundances of some taxa across large spatial extents, their assessment can be driven by local perceptions, which could also differ depending on the background of the experts. Therefore, some VME indicator species originality included for higher latitudes in the North Atlantic, may need to be reassessed according to their specificities in the Azores, that are more biogeographically related to Macaronesia than to boreal regions (Northern Europe, Canada, and Iceland).
4. The identification of 39 benthic communities composed of associations of conspicuous epibenthic species, including 23 coral gardens, 2 cold-water coral reefs, 9 sponge aggregations, 1 xenophoyphore aggregations, and 4 of other fauna types. From these, 25 benthic communities were considered to fit the criteria for VMCommunites based on the presence and density of structurally complex bioengineering species, the uniqueness of their components and/or the intrinsic vulnerability of the community to disturbances as well as their capacity of recovery.

### *12.3 Mapping the spatial distribution of deep-sea species, communities and habitats*

1. Our explorations have added supporting evidence to consider the Sedlo seamount as an essential fish habitat. We found areas that are home to the orange roughy (*Hoplostethus atlanticus*) and discovered that Sedlo, and other neighbouring seamounts, are home to a high number of deep-sea shark species, some of which are rarely seen in the Azores. We also discovered aggregations of the black coral *Leiopathes expansa* on the summit of Sedlo W, with most specimens being relatively small in size. This area appears to be a good candidate to be considered a Vulnerable Marine Ecosystem and should be kept on the list of priority areas for conservation in the Azores.
2. Deep-sea explorations with the Azor drift-cam also added supporting evidence to consider Hard Rock Café and Isolado, Essential Fish Habitats. We found that these areas were both home to the highly endangered deep-sea fish orange roughy (*Hoplostethus atlanticus*) and both exhibited large schools of the wreckfish (Polyprion americanus). These areas also showed a high number of deep-sea shark species, some of which rarely observed in the Azores. Although these areas showed low abundances in terms of benthic megafauna, we detected some frequent colonies of the slow-growing black corals *Antipathes dichotoma* and *Leiopathes expansa*.

3. We also explored the Borda, João Leonardes, and Gaillard seamounts, north of Graciosa Island. Together with Sedlo, these seamounts appear to host unique deep-sea benthic communities when compared to other areas of the Azores EEZ explored so far with the black corals *Leiopathes expansa* and *Parantipathes hirondelle*, the bamboo coral Acanella arbuscula, stylasterids of the genus *Errina*, the sea urchin sea bream *Cidaris cidaris* and lamellated sponges of the genus *Phakellia*, among others.
4. The abundance, diversity, and condition in which the several benthic communities observed were found thriving on the Terceira island's slopes was particularly special. Despite these previously unexplored areas being subjected to considerable degrees of fishing effort, most of the benthic fauna observed was visually healthy and harboured many associated fish species as well. The main highlights of Terceira island's slopes surveys were the sighting of uncommonly large specimens of the coral *Dentomuricea* aff. *meteor* in Terceira N, quite possibly the largest specimens we have recorded so far in the Azores region, the detection of areas with the display of black coral aggregations such as *Leiopathes glaberrima* and *L. expansa*, and the Observation of what we believe are small primnoid corals yet to be identified in at least two different seamounts in Terceira E area.
5. Most seamounts on the way to and around São Miguel Island, such as Albatroz N, Ferraria N, Ferraria Mar, Mar da Prata and Grande Norte host interesting deep-sea benthic communities with the deeper areas demonstrating abundant coral gardens of both *Narella versluysi* and *Narella bellissima,* sometimes, in aggregation with *Callogorgia verticillata, Acanthogorgia* sp. or *Leiopathes expansa*. Shallower areas were mainly characterized by large gardens of *Viminella flagellum,* sometimes associated with *Callogorgia verticillata* and other times with frequent and large *Dentomuricea.*
6. Also noteworthy is the observation, around the island of São Miguel, of some coral aggregations that seem to be particularly rare to observe in the Azores archipelago. These include (i) a vast area completely covered by a reef of the hard coral *Eguchipsammia cornucopia*; (ii) an extraordinarily dense coral garden that includes, among other species, the coral *Paragorgia johnsoni* (a species that does not appear to be very common on the islands' slopes), and particularly high densities of the primnoid species *Narella bellissima* and *N. versluysi*; iii) a vast area dominated by an unidentified species from the Stylasteridae family (i.e. lacy corals); and iv) an area dominated by a rare purplish coral, possibly belonging to the genus Paramuricea.
7. Large colonies of black corals (*Leiopathes* sp.), possibly more than 1,000 years old, which are "hanging" on steep walls of the Princesa Alice bank. It is possible that before demersal fishing exploited this bank, these arborescent black corals, vulnerable to fishing, were much more abundant and larger and older. These corals are very slow growing and can live for thousands of years.
8. One of the largest and densest gorgonian forests *Callogorgia verticillata* found in the Azores. This gorgonian forest, found on the Dom João de Castro seamount, is characterized by fan-shaped colonies whose feathery branches resemble palm leaves.
9. Dense aggregations of the largest species of sponges that inhabit the deep sea of the Azores (e.g., *Characella pachastrelloides*, *Haliclona magna*), on the Princesa Alice bank. Sponges play a structuring role in the deep sea, increasing ecosystem productivity and creating habitat for other species.

10. One of the few (and small) cold-water coral reefs of *Lophelia pertusa* and *Madrepora oculata* known in the Azores, found at around 850 m depth in the Capelinhos area, west of Faial. Hard cold-water coral reefs play an important role in deep-sea biogeochemical cycles but are very vulnerable to ocean acidification. Better understanding of their distribution and susceptibility to climate change are priority lines of research for the future.
11. In one of the areas explored with multibeam, an unknown canyon (or gorge) was found, approximately 15 km long, 340 m wide and with cliffs approximately 100 m high. The canyons of the Azores are quite unknown habitats and where unique ecosystems can be found.
12. The invasive alga *Rugulopteryx okamurae*, which in recent years has had an increasingly frequent presence along the Azorean coast, has been repeatedly observed in large patches up to depths of around 900 m, suggesting that the impact of this species on resident communities may not only limited to coastal areas, but also extends to the deep sea of the Azores. Therefore, in order to fully understand how *Rugulopteryx okamurae* alters the distribution and niche dynamics of native species and the extent of its impacts, there is a need to investigate how it affects low- to high-depth communities.

## *12.4 Identifying areas that fit the definition of VMEs in the Azores and other policy recommendations*

We presented recommendations for the protection of deep-sea ecosystems and obtaining or maintaining their good environmental status, in accordance with the requirements of the Marine Strategy Framework Directive.

1. We evaluated the 140 geomorphological structures of the Azores in relation to each of the five FAO criteria to define what constitutes a VME, based on the information compiled, collected and analysed during this project. The evaluation was based on the species and communities found in each geomorphological structure as well as a measure of their abundance in the BD2 Georeferenced database containing information of species and habitats (see section 6).
2. The assessment of underwater features against the VME criteria identified 41 out of the 140 areas that could fit the criteria that defines a VME: Hard-Rock Café, Flores NE, Chaucer S, Estrela, Kurchatov N, Isolado, Kurchatov SE, Kurchatov S, Kurchatov SW, Agulhas Corvo-Graciosa, Óscar, Gigante N, Gigante, Gigante Agulhas NW, Gigante Agulhas SW, Cavala, Beta, Sardinha, Voador, Farpas, Espadarte, Sedlo W, Gaillard, Graciosa S, Ilha Azul SE, São Jorge W Rosais, Álvaro Martins, Dom João de Castro, Ferraria Norte, Ferraria Mar, Girard, Pico S Lajes, Faial W Capelinhos, Condor, Ponta da Ilha N, Ponta da Ilha S, Albatroz do Meio, Açor S, Princesa Alice Picos S, Sauerwein, and Formigas.
3. To support the assessments of the Descriptor 6 criteria (D6C3 and D6C5), we carried out an assessment of the degree of pressure and threat relating to human activities. We adopted a standard methodology for this purpose which starts from the characterization and mapping of conservation values and pressures arising from activities and potential uses. We also developed matrices of pressures and threats that allow an objective assessment of impacts and contribute to the assessment of D6C3 and D6C5. The application of the VME and fishing effort portfolio categories identified 22 areas classified as VME that fall in the portfolio category high VME – low VMS, 14 falling in the portfolio category high

VME – high VMS, and 3 in the other category. The areas where high fishing effort overlaps with high VME index may be areas of potentially significant adverse impacts in vulnerable marine ecosystems.

4. We evaluated methodologies to analyze the data collected throughout the project to define D6C3 assessment methodologies that concern the "Spatial extent of each type of habitat that is negatively affected by physical disturbances, through the alteration of its biotic and abiotic structure and of its functions", and D6C5 "The extent of the negative effects of anthropogenic pressures on the condition of the habitat type, including alteration of its biotic and abiotic structure and functions, does not exceed a specified proportion of the natural extent of the habitat type in evaluation zone."
5. The recent collection of massive seafloor imagery made it possible to identify that a large part of the benthic communities, including corals and sponges, observed in the main bottom fishing grounds in the Azores are still in good environmental condition and have a high natural and ecological value. However, some long-lived coral colonies with visible impacts from fishing were observed. Since no differences were detected between the four different fishing intensity classes and the V. flagellum conditions and epibiosis, one might speculate that the areas evaluated may still be in good condition and that these values may be used a baseline condition.
6. The research cruises made it possible to identify that a large part of the benthic communities, including corals and sponges, observed in the main demersal fishing grounds of the Azores (such as Princesa Alice, the slopes of Terceira and São Miguel Islands and Banco D João de Castro) are still in good environmental condition and have a high natural and ecological value. However, some long-lived coral colonies with visible impacts from fishing were observed. These in-situ observations corroborate the conclusion of previous studies that suggest that well-regulated deep-sea fishing based on hook and line gear (preferably hand line) could contribute to the sustainable exploration of the deep sea.
7. The Sauerwein ridge, between the islands of São Miguel and Santa Maria, had a surprisingly low biodiversity, highlighting once again the need to better understand the reasons that explain the spatial distribution patterns of benthic communities to better inform management and conservation of these vulnerable ecosystems.
8. Finally, we successfully demonstrated the use of low-cost image collection system called Azor drift-cam for exploration and monitoring of deep-sea ecosystems.

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## 14. References

Aballéa, M., Radford-Knoery, J., Appriou, P., Bougault, H., Charlou, J.L., Donval, J.P., Etoubleau, J., Fouquet, Y., German, C.R. & Miranda, M. (1998). Manganese distribution in the water column near the Azores Triple Junction along the Mid-Atlantic Ridge and in the Azores domain. Deep Sea Research Part II: Topical Studies in Oceanography, 45(8), 1319-1338.

Adkins JF, McIntyre K Schrag DP (2002), The salinity, temperature, and δ18O of the glacial deep ocean. Science, 298: 1769–1773

Alvarez, B.; Hooper, J.N.A. (2002). Family Axinellidae Carter, 1875. Pp. 724-747. *In:* Hooper, J.N.A. & Van Soest, R.W.M. (ed.) Systema Porifera. A guide to the classification of sponges. Kluwer Academic/ Plenum, NY. 1708 + xlviii.

Alves, M.L.G.R. & de Verdière, A.C. (1999). Instability Dynamics of a subtropical jet and applications to the Azores front current system: Eddy- Driven Mean Flow. Journal of Physical Oceanography 29, 837–864. doi: 10.1175/1520- 0485.

Amorim, P., Perán, A.D., Pham, C.K., Juliano, M., Cardigos, F., Tempera, F. & Morato, T. (2017). Overview of the Ocean Climatology and Its Variability in the Azores Region of the North Atlantic Including Environmental Characteristics at the Seabed. Frontiers in Marine Science, 4, 56. doi: 10.3389/fmars.2017.00056.

Andrews, A. H., Stone, R. P., Lundstrom, C. C. & DeVogelaere, A. P. (2009). Growth rate and age determination of bamboo corals from the northeastern Pacific Ocean using refined 210Pb dating. Marine Ecology Progress Series 397, 173-185.

Angiolillo, M., di Lorenzo, B., Farcomeni, A., Bo, M., Bavestrello, G., Santangelo, G., et al. (2015). Distribution and assessment of marine debris in the deep Tyrrhenian Sea (NW Mediterranean Sea, Italy). Marine pollution bulletin, 92(1-2), 149-159. doi: 10.1016/j.marpolbul.2014.12.044

Auster, P. J., Lindholm, J., & Valentine, P. C. (2003). Variation in habitat use by juvenile Acadian redfish, Sebastes fasciatus. Environmental Biology of Fishes, 68, 381-389

Auster, P.J., Gjerde, K., Heupel, E., Watling, L., Grehan, A., & Rogers, A.D. (2011). Definition and detection of vulnerable marine ecosystems on the high seas: problems with the "move-on" rule. ICES Journal of Marine Science, 68, 254-264. https://doi.org/10.1093/icesjms/fsq074.

Baillon, S., Hamel, J. F., Wareham, V. E., & Mercier, A. (2012). Deep cold-water corals as nurseries for fish larvae. Frontiers in Ecology and the Environment, 10(7), 351-356.

Baker, E.T., Edmonds, H.N., Michael, P.J., Bach, W., Dick, H.J., Snow, J.E., Walker, S.L., Banerjee, N.R. & Langmuir, C.H. (2004). Hydrothermal venting in magma deserts: The ultraslow-spreading Gakkel and Southwest Indian Ridges. Geochemistry, Geophysics, Geosystems, 5(8).

Baker, E.T., Resing, J.A., Haymon, R.M., Tunnicliffe, V., Lavelle, J.W., Martinez, F., Ferrini, V., Walker, S.L. & Nakamura, K. (2016). How many vent fields? New estimates of vent field populations on ocean ridges from precise mapping of hydrothermal discharge locations. Earth and Planetary Science Letters, 449, 186-196.

Bashmachnikov, I., Lafon, V. & Martins, A. (2004). SST stationary anomalies in the Azores region. Procceedings SPIE 5569, 148–155.

Bashmachnikov, I., Mohn, C., Pelegri, J.L., Martins. A., Jose, F., Machín F. & White, M. (2009). Interaction of Mediterranean water eddies with Sedlo and Seine Seamounts, Subtropical Northeast Atlantic. Deep-Sea Research Part II, 56(25): 2,593–2,605.

Bayer, F. M., Grasshoff, M., & Verseveldt, J. (Eds.). (1983). Illustrated trilingual glossary of morphological and anatomical terms applied to Octocorallia. Brill Archive.

Beaulieu, S.E., Szafranski, K. (2019) InterRidge Global Database of Active Submarine Hydrothermal Vent Fields, Version 3.4. World Wide Web electronic publication available from http://vents-data.interridge.org.

Bergquist, P.R.; Fromont, P.J. (1988). The Marine Fauna of New Zealand: Porifera, Demospongiae, Part 4 Poecilosclerida. New Zealand Oceanographic Institute Memoir. 96: 1-197.

Bettencourt, R., Barros, I., Martins, E., Martins, I., Cerqueira, T., Colaço, A., ... & Stefanni, S. (2017). An insightful model to study innate immunity and stress response in deep-sea vent animals: Profiling the mussel Bathymodiolus azoricus. Organismal and Molecular Malacology, 161.

Beuck, L. et al. (2016) Biotope characterisation and compiled geographical distribution of the deep-water oyster Neopycnodonte zibrowii in the Atlantic Ocean and Mediterranean Sea. Rapp. Comm. int. Mer Médit. 41, 462.

Bo, M., Bava, S., Canese, S., Angiolillo, M., Cattaneo-Vietti, R., and Bavestrello, G. (2014). Fishing impact on deep Mediterranean rocky habitats as revealed by ROV investigation. Biological Conservation, 171, 167-176. doi: 10.1016/j.biocon.2014.01.011.

Bo, M., Bavestrello, G., Angiolillo, M., Calcagnile, L., Canese, S., Cannas, R., ... & Cau, A. (2015). Persistence of pristine deep-sea coral gardens in the Mediterranean Sea (SW Sardinia). PLoS One, 10(3), e0119393.https://doi.org/10.1371/journal.pone.0119393.

Bolger AM, Lohse M, Usadel B (2014) Trimmomatic: A flexible trimmer for Illumina sequence data. Bioinformatics (Oxford, England) 30(15): 2114–2120. https://doi.org/10.1093/bioinformatics/btu170

Boury-Esnault, N. & Rützler, K. (Eds.) (1997) Thesaurus of Sponge Morphology. Smithsonian Contributions to Zoology, 596, 1–55. doi: 10.5479/si.00810282.596.

Boury-Esnault, N.; Pansini, M.; Uriz, M.J. (1994). Spongiaires bathyaux de la mer d'Alboran et du golfe ibéro-marocain. Mémoires du Muséum national d'Histoire naturelle. 160: 1-174.

Bower, A.S., Le Cann, L., Rossby, T., Zenk, W., Gould, J., Speer, K., Richardson, P.L., Prater, M.D. & Zhang H-M. (2002). directly measured mid-depth circulation in the North Atlantic Ocean, Nature, 419, 603–607.

Braga-Henriques, A., Porteiro, F. M., Ribeiro, P. A., Matos, V. D., Sampaio, Í., Ocaña, O., & Santos, R. S. (2013). Diversity, distribution and spatial structure of the cold-water coral fauna of the Azores (NE Atlantic). Biogeosciences, 10(6), 4009-4036.

Brito A, Ocaña O (2004) Corales de las Islas Canarias. Antozoos com esqueleto de los fondos liotrales y profundos. Francisco Lemus, La Laguna.

Buhl-Mortensen, L., Vanreusel, A., Gooday, A. J., Levin, L. A., Priede, I. G., Buhl-Mortensen, P., ... & Raes, M. (2010). Biological structures as a source of habitat heterogeneity and biodiversity on the deep ocean margins. Marine Ecology, 31(1), 21-50.

Burton, M. (1928). Hexactinellida. Danish Ingolf Expedition. 6 (4): 1-18.

Burton, M. (1930). Norwegian Sponges from the Norman Collection. Proceedings of the Zoological Society of London. 1930 (2): 487-546, pls I-II. Cairns, S.D. (1991) A generic revision of the Stylasteridae (Coelenterata: Hydrozoa). Part 3. Keys to the genera, B. Mar. Sci., 49, 538–545.

Cairns SD, Taylor ML (2019) An illustrated key to the species of the genus Narella (Cnidaria, Octocorallia, Primnoidae). ZooKeys 822: 1–15. https://doi.org/10.3897/zookeys.822.29922

Cairns, S. (2000). A revision of the shallow-water azooxanthellate Scleractinia of the Western Atlantic. Studies on the natural history of the Caribbean region, 75(1), 1-192.

Cairns, S. D. (2011). Global diversity of the stylasteridae (Cnidaria: Hydrozoa: Athecatae). PloS one, 6(7), e21670. https://doi.org/10.1371/journal.pone.0021670.

Cairns, S. D., & Bayer, F. M. (2009). A generic revision and phylogenetic analysis of the Primnoidae (Cnidaria: Octocorallia).

Cairns, S.D., Bayer, F.M. (2003) Studies on western Atlantic Octocorallia (Coelenterata: Anthozoa). Part 3: The genus Narella Gray, 1870. Proceedings of the Biological Society of Washington, 116, 617–648.

Caldeira, R. & Reis, J.C. (2017). The Azores confluence zone. Frontiers in Marine Science 4, 37. doi: 10.3389/fmars.2017.00037.

Cárdenas, P. (2010). Phylogeny, Taxonomy and Evolution of the Astrophorida (Porifera, Demospongiae). Department of Biological Sciences, University of Bergen, PhD thesis.

Cárdenas, P. and Rapp, H.T. (2012) A review of Norwegian streptaster-bearing Astrophorida (Porifera: Demospongiae: Tetractinellida), new records and a new species. Zootaxa 3253, 1–52.

Cárdenas, P., & Rapp, H. T. (2015). Demosponges from the Northern Mid-Atlantic Ridge shed more light on the diversity and biogeography of North Atlantic deep-sea sponges. Journal of the Marine Biological Association of the United Kingdom, 95(7), 1475-1516.

Cárdenas, P.; Moore, J.A. (2019). First records of Geodia demosponges from the New England seamounts, an opportunity to test the use of DNA mini-barcodes on museum specimens. Marine Biodiversity. 49 (1): 163-174.

Cárdenas, P.; Rapp, H.T.: Klitgaard, A.B.; Best, M.; Thollesson, M.; Tendal, O.S. (2013). Taxonomy, biogeography and DNA barcodes of Geodia species (Porifera, Demospongiae, Tetractinellida) in the Atlantic boreo-arctic region. Zoological Journal of the Linnean Society. 169, 251-311.

Carpine, C. & M. Grasshoff 1985. Catalogue critique des Octocoralliaires des collections du Musée océanographique de Monaco I. Gorgonaires et Pennatulaires. Bulletin de l´Institut Océanographique 73, nº 1435: 1-72.

Carreiro-Silva, M., Andrews, A.H., Braga-Henriques, A., Porteiro,. F.M., Matos. V. & Santos R.S. (2013). Variability in growth rates of long-lived black coral Leiopathes sp. from the Azores (NE Atlantic). Marine Ecology Progress Series 473, 189–199 doi: 10.3354/meps10052.

Carreiro-Silva, M., Braga-Henriques, A., Sampaio, I., Matos, V., Porteiro, F. & Ocaña, O. (2011). Isozoanthus primnoidus, a new zoanthid species (Anthozoa: Hexacorallia) associated with the gorgonian Callogorgia verticillata (Anthozoa: Octocorallia) in the Azores. ICES Journal of Marine Science, 68(2), 408-415 doi:10.1093/icesjms/fsq066.

Carreiro-Silva, M., Dominguez-Carrió, C., & Morato, T.. (2021). DeepWalls: Report on summer 2020 survey with submersible LULA1000. Zenodo. https://doi.org/10.5281/zenodo.5506765

Carreiro-Silva, M., Dominguez-Carrió, Carlos, Morato, Telmo, & Le Bris, Nadine. (2019a). "LUSO" Hydrothermal vent field Expedition; 4th August 2018 (RV L'Atalante - IFREMER). Zenodo. https://doi.org/10.5281/zenodo.6557934

Carreiro-Silva, M., Fox, A., Carlsson, J. & Arnaud-Haound, S. (2019b). Reproduction, dispersal and genetic connectivity in benthos and fishes.. Deliverable 4.4. ATLAS project.

Carreiro-Silva, M., Ocaña, O. V., Stanković, D., Sampaio, I., Porteiro, F., Fabri M-C., & Stefanni, S. (2017). Zoanthids associated with cold-water corals in the Azores Region: hidden diversity in the deep-sea in the deep-sea. Frontiers in Marine Science, 4, 88.

Carreiro-Silva, M., Ramos, M., & Morato, T.. (2019c). Greenpeace Pole-to-Pole expedition – Azores 2019. Zenodo. https://doi.org/10.5281/zenodo.6557865

Carter, H.J. (1876). Descriptions and Figures of Deep-Sea Sponges and their Spicules, from the Atlantic Ocean, dredged up on board H.M.S.'Porcupine', chiefly in 1869 (concluded). Annals and Magazine of Natural History. (4) 18(105): 226-240; (106): 307-324; (107): 388-410;(108): 458-479, pls XII-XVI.

Carvalho, F. C.; Cárdenas, P.; Ríos, P.; Cristobo, J.; Rapp, H. T.; Xavier, J. R. (2020). Rock sponges (lithistid Demospongiae) of the Northeast Atlantic seamounts, with description of ten new species. *PeerJ.* 8: e8703.

Carvalho, F.C.; Pomponi, S.A.; Xavier, J.R. (2015). Lithistid sponges of the upper bathyal of Madeira, Selvagens and Canary Islands, with description of a new species of *Isabella*. Journal of the Marine Biological Association of the United Kingdom. 95 (7), 1287-1296.

Carvalho, M. de S.; Lopes, D.A.; Cosme, B.; Hajdu, E. (2016). Seven new species of sponges (Porifera) from deep-sea coral mounds at Campos Basin (SW Atlantic). Helgoland Marine Research. 70 (10): 1-33.

Cascao, I., Domokos, R., Lammers, M. O., Marques, V., Dominguez, R., Santos, R. S., & Silva, M. A. (2017). Persistent enhancement of micronekton backscatter at the summits of seamounts in the Azores. Frontiers in Marine Science, 4, 25. doi: 10.3389/fmars.2017.00025

Castello-Branco C, Collins AG, Hajdu E. 2020. A collection of hexactinellids (Porifera) from the deep South Atlantic and North Pacific: new genus, new species and new records. PeerJ 8:e9431 DOI 10.7717/peerj.9431.

Cathalot, C. C., Van Oevelen, D., Cox, T. J. S., Kutti, T., Lavaleye, M. S. S., Duineveld, G. C. A., et al., (2015). Cold-water coral reefs and adjacent sponge grounds: hotspots of benthic respiration and organic carbon cycling in the deep sea. Frontiers in Marine Science 2, 1–12. doi:10.3389/fmars.2015.00037.

Chin, C.S., Klinkhammer, G.P. and Wilson, C. (1998). Detection of hydrothermal plumes on the northern Mid-Atlantic Ridge: results from optical measurements. Earth and planetary science letters, 162(1), 1-13.

Clark, M. R., Althaus, F., Schlacher, T. A., Williams, A., Bowden, D. A., & Rowden, A. A. (2016b). The impacts of deep-sea fisheries on benthic communities: a review. ICES Journal of Marine Science, 73(suppl_1), i51-i69.

Clark, M. R., Bowden, D. A., Rowden, A. A., & Stewart, R. (2019). Little evidence of benthic community resilience to bottom trawling on seamounts after 15 years. Frontiers in Marine Science, 6, 63.

Clark, M. R., Consalvey, M., & Rowden, A. A. (Eds.). (2016a). Biological sampling in the deep sea. John Wiley & Sons.

Connor, D.W., & Hiscock, K. 1996. Data collection methods (with Appendices 5 - 10). In: Marine Nature Conservation Review: rationale and methods, ed. by K. Hiscock, 51-65, 126-158. Peterborough, Joint Nature Conservation Committee. (Coasts and seas of the United Kingdom. MNCR series.)

Costello, M. J., & Chaudhary, C. (2017). Marine biodiversity, biogeography, deep-sea gradients, and conservation. Current Biology, 27(11), R511-R527.

Cruz, T. (2002). Esponjas marinas de Canarias. Consejería de Política Territorial y Medio Ambiente del Gobierno de Canarias. S/C Tenerife. 260 pp.

de Matos, V.; Braga-Henriques, A.; Santos, R. S.; Ribeiro, P. A. (2014a). New species of *Heteropathes* (Anthozoa: Antipatharia) expands genus distribution to the NE Atlantic. *Zootaxa*. 3827(2), 293-300.

de Matos, V.; Braga-Henriques, A.; Santos, R. S.; Ribeiro, P. A. (2014). New species of Heteropathes (Anthozoa: Antipatharia) expands genus distribution to the NE Atlantic. Zootaxa. 3827(2), 293.

De Weerdt WH (1989) Phylogeny and vicariance biogeography of North Atlantic Chalinidae (Haplosclerida, Demospongiae). Beaufortia 39 (3):55–95

De Weerdt, W.H.; van Soest, R.W.M. (1986). Marine shallow-water Haplosclerida (Porifera) from the south-eastern part of the North Atlantic Ocean. Zoologische Verhandelingen. 225: 1-49.

Di Camillo, C. G., Bavestrello, G., Cerrano, C., Gravili, C., Piraino, S., Puce, S., & Boero, F. (2017). Hydroids (Cnidaria, Hydrozoa): a neglected component of animal forests. Marine animal forests, 397.

Dias, A.; Santos, G. G.; Pinheiro, U. (2019). A new species of Characella Sollas, 1886 (Tetractinellida; Demospongiae; Porifera) from deeper waters off the coast of Brazil. Zootaxa. 4559(1): 196-200.

Díaz, J.A.; Ramírez-Amaro, S.; Ordines, F. (2021). Sponges of Western Mediterranean seamounts: new genera, new species and new records. PeerJ. 9: e11879.

Díaz, J.A.; Ramírez-Amaro, S.; Ordines, F.; Cárdenas, P.; Ferriol, P.; Terrasa, B.; Massutí, E. (2020). Poorly known sponges in the Mediterranean with the detection of some taxonomic inconsistencies. Journal of the Marine Biological Association of the United Kingdom. 100 (8): 1247-1260.

Diogo, H., Pereira, J. G., Higgins, R. M., Canha, Â., & Reis, D. (2015). History, effort distribution and landings in an artisanal bottom longline fishery: An empirical study from the North Atlantic Ocean. Marine Policy, 51, 75-85.

Domingos, C.; Pilar, R.; Xavier, C., Xavier, J.R. 2023. The phoenix project – disentangling a species complex in the deep Atlantic. Communication in 5th International Workshop on taxonomy of Atlanto-Mediterranean Deep-Sea and Cave Sponges. 11th-16th September 2023. Rapallo (Genoa, Italy).

Dominguez-Carrió, C., Fontes, J., & Morato, T. (2021a). A cost-effective video system for a rapid appraisal of deep-sea benthic habitats: The Azor drift-cam. Methods in Ecology and Evolution, 12(8), 1379-1388.

Dominguez-Carrió, C., Gollner, S., & Morato, T. (2019a). RV Pelagia cruise 64PE454: Rainbow hydrothermal vent and southern MAR 2019 - Hopper tow-cam video footage -. Zenodo. https://doi.org/10.5281/zenodo.6593981

Dominguez-Carrió, C., Gollner, S., Visser, F., & Morato, T. (2019b). Cruise Report - NICO Cruise Leg 12, Hopper dives on board of R/V Pelagia. Zenodo. https://doi.org/10.5281/zenodo.3416992

Dominguez-Carrió, C., Gomes, S., & Morato, T.. (2021b). Cruise report - 64PE479 onboard of R/V Pelagia Terceira Island 2020 - Hopper tow-cam video footage. Zenodo. https://doi.org/10.5281/zenodo.7429503

Duchassaing, de Fonbressin P. & Michelotti, J. (1860) Mémoire sur les Coralliaires des Antilles. Mémoires de l' Acadmie des Sciences de Turin, Series 2, 19, 279–365.

Duineveld, G. (2017). Cruise Report - REPORT PELAGIA CRUISE 64PE412 TREASURE (Towards Responsible ExtrAction of SUbmarine REsources) Horta - Horta 25 June – 13 July 2016. Zenodo. https://doi.org/10.5281/zenodo.556556Xx

Duplessis, K.; Reiswig, H.M. (2004). Three new species and a new genus of Farreidae (Porifera: Hexasterophora: Hexactinosida). Proceedings of the Biological Society of Washington. 117 (2): 199-212.

Duncan, E. M., Vieira, N., González-Irusta, J. M., Dominguez-Carrió, C., Morato, T., Carreiro-Silva, M., ... & Pham, C. K. (2023). Predicting the distribution and abundance of abandoned, lost or discarded fishing gear (ALDFG) in the deep sea of the Azores (North Atlantic). Science of The Total Environment, 900, 166579.

Durden, J. M., Bett, B. J., Jones, D. O., Huvenne, V. A., & Ruhl, H. A. (2015). Abyssal hills–hidden source of increased habitat heterogeneity, benthic megafaunal biomass and diversity in the deep sea. Progress in Oceanography, 137, 209-218.

Eleftheriou, A. (2013) Methods for the Study of Marine Benthos, 4th edition (Ed. A Eleftheriou). John Wiley & Sons, Oxford, UK. 467p.

EMEPC. (n.d.) Campanhas. https://www.emepc.pt/campanhas

Erickson, K. L., Pentico, A., Quattrini, A. M., & McFadden, C. S. (2021). New approaches to species delimitation and population structure of anthozoans: Two case studies of octocorals using ultraconserved elements and exons. Molecular ecology resources, 21(1), 78–92

Faircloth BC (2016) PHYLUCE is a software package for the analysis of conserved genomic loci. Bioinformatics (Oxford, England) 32(5): 786–788. https://doi.org/10.1093/bioinformatics/btv646

Fallon, S.J., James, K., Norman, R., Kelly, M. & Ellwood, M.J. (2010). A simple radiocarbon dating method for determining the age and growth rate of deep-sea sponges. Nuclear Instruments and Methods in Physics Research, Section B: Beam Interactions with Materials and Atoms. 268(7–8), 1241–1243.

FAO, (2009). Report of the Technical Consultation on International Guidelines for the Management of Deep-sea Fisheries in the High Seas, Rome. 4–8 February and 25–29 August 2008, FAO Fisheries and Aquaculture Report, 881. 86 pp. http://agris.fao.org/agris-search/search.do?recordID=XF2015010283

FAO. (2016). Vulnerable marine ecosystems. Processes and practices in the high seas. Food and Agriculture Organization of the United Nations Fisheries and aquaculture Technical Paper 595, 185 pp.

Feraud, G., Kaneoka, I. & Allegre, C.J. (1980). K/Ar ages and stress pattern in the Azores: dynamic implications. Earth and Planetary Science Letters, 46, 275-286.

Ferrigno, F., Appolloni, L., Russo, G. F., & Sandulli, R. (2018). Impact of fishing activities on different coralligenous assemblages of Gulf of Naples (Italy). Journal of the Marine Biological Association of the United Kingdom, 98(1), 41-50.

France, S.C., 2007. Genetic analysis of bamboo corals (Cnidaria: Octocorallia: Isididae): Does lack of colony branching distinguish Lepidisis from Keratoisis? Bull. Mar. Sci. 81, 323–333.

Fristedt, K. (1887). Sponges from the Atlantic and Arctic Oceans and the Behring Sea. Vega-Expeditionens Vetenskap. Iakttagelser (Nordenskiöld) 4. 401-471, pls 22-31.

German, C.R., Parson, L.M., Bougault, H., Coller, D., Critchley, M., Dapoigny, A., Day, C., Eardley, D., Fearn, A., Flewellen, C. and Kirk, R. (1996). Hydrothermal exploration near the Azores Triple Junction: tectonic control of venting at slow-spreading ridges?. Earth and Planetary Science Letters, 138(1), 93-104.

Gerovasileiou, V.; Voultsiadou, E. (2012). Marine Caves of the Mediterranean Sea: A Sponge Biodiversity Reservoir within a Biodiversity Hotspot. PLoS ONE. 7(7): e39873.

Gili JM, Alvà V, Coma R, Orejas C, Pagès F, Ribes M, et al. The impact of small benthic passive suspension feeders in shallow marine ecosystems: the hydroids as an example. Zoologische verhandelingen. 1998;323:99–105.

Gomes-Pereira, J. N., & Tempera, F. (2016). Hydroid gardens of Nemertesia ramosa (Lamarck, 1816) in the central North Atlantic. Marine Biodiversity, 46, 85-94.

Gomes-Pereira, J. N., Carmo, V., Catarino, D., Jakobsen, J., Alvarez, H., Aguilar, R., ... & Porteiro, F. (2017). Cold-water corals and large hydrozoans provide essential fish habitat for Lappanella fasciata and Benthocometes robustus. Deep Sea Research Part II: Topical Studies in Oceanography, 145, 33-48.

Grasshoff, M. (1977) Die Gorgonarien des östlichen Nordatlantik und des Mittelmeeres: III. Die Familie Paramuriceidae (Cnidaria: Anthozoa). "Meteor - Forschungs - Ergebnisse, D27, 5–76.

Grasshoff, M. (1979) Neubeschreibung der Oktokoralle Paragorgia johnsoni Gray 1962 (Cnidaria: Anthozoa: Scleraxonia). Senckenbergiana Biologica, 60, 427–435.

Grasshoff, M. (1986) Die Gorgonaria der expeditionen von "Travailleur 1880–1882 und "Talisman 1883 (Cnidaria, Anthozoa). Bulletin du Muséum National d'Histoire Naturelle Paris, 4 (8), A 1, 9–38.

Grasshoff, Manfred (1972) Die Gorgonaria des östlichen Nordatlantik und des Mittelmeeres, I. Die Familie Ellisellidae (Cnidaria: Anthozoa) : Auswertung der "Atlantischen Kuppenfahrten 1967" von F.S. "Meteor". Meteor Forschungsergebnisse: Reihe D, Biologie, 10 . pp. 73-87.

Hawkes, N., Korabik, M., Beazley, L., Rapp, H. T., Xavier, J. R., & Kenchington, E. (2019). Glass sponge grounds on the Scotian Shelf and their associated biodiversity. Marine Ecology Progress Series, 614, 91-109. doi: 10.3354/meps12903.

Hoang DT, Chernomor O, von Haeseler A, Minh BQ, Vinh LS (2018) UFBoot2: Improving the Ultrafast Bootstrap Approximation. Molecular Biology and Evolution 35(2): 518–522. https://doi.org/10.1093/molbev/msx281

Hooper J.N.A. and van Soest R.W.M. (Ed.) (2002) Systema Porifera: a guide to the classification of sponges Kluwer Academic/Plenum Publishers, New York.

Horowitz J, Opresko D, Molodtsova TN, Beaman RJ, Cowman PF, Bridge TCL (2022) Five new species of black coral (Anthozoa; Antipatharia) from the Great Barrier Reef and Coral Sea, Australia. Zootaxa 5213(1): 1–35. https://doi.org/10.11646/zootaxa.5213.1.1

Horowitz J, Opresko DM, González-García MP, Quattrini AM (2023) Description of a new species of black coral in the family Aphanipathidae (Anthozoa, Antipatharia) from Puerto Rico. ZooKeys 1173: 97-110. https://doi.org/10.3897/zookeys.1173.104141

Hughes, R. G. (1986). Differences in the growth, form and life history of Plumularia setacea (Ellis and Solander)(Hydrozoa: Plumulariidae) in two contrasting habitats. Proceedings of the Royal society of London. Series B. Biological sciences, 228(1251), 113-125.

Hydes, D. J., Statham, P. J. and Burton, J. D. (1986). A vertical profile of dissolved trace metals (Al, Cd, Cu, Mn, Ni) over the median valley of the Mid Atlantic Ridge, 43 N: implications for hydrothermal activity. Science of the Total Environment, 49, 133-145.

ICES (2013). Assessment of the list of VME Indicator species and elements. Advice 2013, Book 1. Advice 1.5.5.3. June 2013.

ICES (2016). Report of the Joint ICES/NAFO Working Group on Deep-water Ecology (WGDEC), 15–19 February 2016, Copenhagen, Denmark. ICES CM 2016/ACOM:28. 82 pp.

ICES (2017). Report of the Working Group on the Biology and Assessment of Deep-sea Fisheries Resources (WGDEEP) (ICES CM 2017/ACOM:14; p. 702 pp.). ICES.

ICES (2019a). ICES/NAFO Joint Working Group on Deep-water Ecology (WGDEC). ICES Scientific Reports. 1:56. 119 pp. http://doi.org/10.17895/ices.pub.5567.

ICES (2019b). Working Group on the Biology and Assessment of Deep-sea Fisheries Resources (WGDEEP). (ICES Scientific Reports 1:21; p. 988 pp.). ICES. http://doi.org/10.17895/ices.pub.5262

ICES (2020a). ICES/NAFO Joint Working Group on Deep-water Ecology (WGDEC). ICES Scientific Reports. 2:62. 188 pp. https://doi.org/10.17895/ices.pub.7503

ICES (2020b). Workshop on EU regulatory area options for VME protection (WKEUVME). ICES Scientific Reports. 2:114. 237 pp. https://doi.org/10.17895/ices.pub.7618

ICES (2021). Working Group on Deep-water Ecology (WGDEC). ICES Scientific Reports. 3:89. 162 pp. http://doi.org/10.17895/ices.pub.8289

ICES (2022a). ICES/NAFO Joint Working Group on Deep-water Ecology (WGDEC). ICES Scientific Reports. 4:75. 68 pp. http://doi.org/ 10.17895/ices.pub.21196066

ICES (2022b). Benchmark Workshop on the occurrence and protection of VMEs (vulnerable marine ecosystems) (WKVMEBM). ICES Scientific Reports. 4:55. 99 pp. http://doi.org/10.17895/ices.pub.2010163

IPCC, 2023: Sections. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 35-115, doi: 10.59327/IPCC/AR6-9789291691647

Johnson, J., & Stevens, I. (2000). A fine resolution model of the eastern North Atlantic between the Azores, the Canary Islands and the Gibraltar Strait. Deep Sea Research Part I: Oceanographic Research Papers, 47, 875–899. doi: 10.1016/S0967-0637(99)00073-4.

Juliano, M. F., & Alves, M. L. G. R. (2007). The Subtropical front/current systems of Azores and St. Helena. Journal Physical Oceanography 37, 2573–2598. doi: 10.1175/2007JPO3150.1.

Katoh K, Standley DM (2013) MAFFT Multiple Sequence Alignment Software Version 7: Improvements in Performance and Usability. Molecular Biology and Evolution 30(4): 772–780. https://doi.org/10.1093/molbev/mst010

Kelly, M.; Erpenbeck, D.; Morrow, C.; Van Soest, R.W.M. (2015). First record of a living species of the genus Janulum (Class Demospongiae) in the Southern Hemisphere. Zootaxa. 3980 (2): 255-266.

Kraft, N. J., Cornwell, W. K., Webb, C. O., & Ackerly, D. D. (2007). Trait evolution, community assembly, and the phylogenetic structure of ecological communities. The American Naturalist, 170(2), 271-283.

Krautter, M., Conway, K. W., Barrie, J. V., & Neuweiler, M. (2001). Discovery of a "living dinosaur": globally unique modern hexactinellid sponge reefs off British Columbia, Canada. Facies, 44(1), 265-282.

Kükenthal, W. G. (1915). Pennatularia. (No Title).

Lafon, V.M., Martins, A.M., Bashmachnikov, I.L., Jose, F, Melo-Rodrigues, M., Figueiredo, M.P., et al., (2004). "SST variability in the Azores region using AVHRR imagery: regional to local scale study," in Proceedings SPIE 5569, Remote Sensing of the Ocean and Sea Ice 2004, 130, eds C. R. Bostater and R. Santoleri, 130–139.

Lapointe, A., Watling, L., 2022. Towards a revision of the bamboo corals (Octocorallia): Part 5, new genera and species of Keratoisididae from the Tasmanian deep sea. Zootaxa 5168, 137–157.

Lévi, C.; Vacelet, J. (1958). Éponges récoltées dans l'Atlantique oriental par le 'Président Théodore-Tissier' (1955-1956). Revue des Travaux de l'Institut des Pêches maritimes 22 (2). 225-246.

Levin, L. A. (1991). Interactions between metazoans and large, agglutinating protozoans: implications for the community structure of deep-sea benthos. American Zoologist, 31(6), 886-900.

Levin, L. A., & Gooday, A. J. (1992). Possible roles for xenophyophores in deep-sea carbon cycling. Deep-sea food chains and the global carbon cycle, 93-104.

Leys, S. P., & Lauzon, N. R. (1998). Hexactinellid sponge ecology: growth rates and seasonality in deep water sponges. Journal of Experimental Marine Biology and Ecology, 230(1), 111-129.

Lopes, D.A., Hajdu, E. & Reiswig, H.M. (2011) Taxonomy of Farrea (Porifera, Hexactinellida, Hexactinosida) from the southwestern Atlantic, with description of a new species and a discussion on the recognition of subspecies in Porifera. Canadian Journal of Zoology, 89, 169–189. doi: 10.1139/Z10-105

López-González PJ, Gili JM (2008) A new species of *Nidalia* Gray, 1835 from Mid-Atlantic seamounts (Octocorallia, Alcyonacea, Nidaliidae). Helgol Mar Res 62:389–392.

Lourenço, N., J.M. Miranda, J.F. Luís, A. Ribeiro, L.A.J. Mendes-Victor, J. Madeira, and H.D. Needham (1998). Morpho-tectonic analysis of the Azores Volcanic Plateau from a new bathymetric compilation of the area. Marine Geophysical Researches, 20(3), 141-156.

Łukowiak, M., Van Soest, R., Klautau, M., Pérez, T., Pisera, A., & Tabachnick, K. (2022). The terminology of sponge spicules. *Journal of Morphology*, 283, 1517– 1545. Doi: 10.1002/jmor.21520

Maillard, C. (1986). Atlas Hydrologique de l'Atlantique Nord-Est. Brest: IFREMER.

Maldonado, M. (1996). On the presence of anatriaenes in Pachastrellidae (Porifera: Demospongiae): evidence for a new phylogenetic family concept. Journal of Natural History. 30 (4): 389-405.

Maldonado, M. (2002). Family Pachastrellidae Carter, 1875. Pp.141-162. In: Hooper, J.N.A., van Soest,R.W.M. (eds) Systema Porifera. A Guide to the Classification of Sponges (2 volumes). Kluwer Academic/Plenum Publ., New York. 1708+XVLIII.

Maldonado, M., López-Acosta, M., Sitjà, C., García-Puig, M., Galobart, C., Ercilla, G., & Leynaert, A. (2019). Sponge skeletons as an important sink of silicon in the global oceans. Nature Geoscience, 12(10), 815-822. doi: 10.1038/s41561-019-0430-7.

Marriott, P., Tracey, D. M., Bostock, H., Hitt, N., & Fallon, S. J. (2020). Ageing deep-sea black coral Bathypathes patula. Frontiers in Marine Science, 479. doi: 10.3389/fmars.2020.00479.

Martins, A., Bashmachnikov, I. & Mendonça, A. (2008). Multi-sensor (SeaWiFS/MODIS/AVHRR) Surface Signature of the Azores Current. Geophysical Research Abstracts, Vol. 10. Available online at: http://meetings. copernicus.org/www.cosis.net/abstracts/EGU2008/11379/EGU2008-A-11379.pdf.

Martins, E., Figueras, A., Novoa, B., Santos, R. S., Moreira, R., & Bettencourt, R. (2014). Comparative study of immune responses in the deep-sea hydrothermal vent mussel Bathymodiolus azoricus and the shallow-water mussel Mytilus galloprovincialis challenged with Vibrio bacteria. Fish & shellfish immunology, 40(2), 485-499.

McFadden CS, Sánchez JA, France SC (2010) Molecular phylogenetic insights into the evolution of Octocorallia: a review. Integrative and Comparative Biology 50: 389–410.

McFadden CS, van Ofwegen LP (2013) Molecular phylogenetic evidence supports a new family of octocorals and a new genus of Alcyoniidae (Octocorallia, Alcyonacea). ZooKeys 346: 59–83. doi: 10.3897/zookeys.346.6270

McFadden, C. S., van Ofwegen, L. P., & Quattrini, A. M. (2022). Revisionary systematics of Octocorallia (Cnidaria: Anthozoa) guided by phylogenomics. Bulletin of the Society of Systematic Biologists, 1(3). Doi:10.18061/bssb.v1i3.8735

Molodtsova, T. N. (2011). A new species of Leiopathes (Anthozoa: Antipatharia) from the Great Meteor seamount (North Atlantic). Zootaxa, 3138(1), 51.

Molodtsova, T.N. (2013) Deep-sea mushroom soft corals (Octocorallia: Alcyonacea: Alcyoniidae) of the Northern Mid-Atlantic Ridge. Marine Biology Resources, 9, 488–515. doi: 10.1080/17451000.2012.750427

Morato, T., & Taranto, G. H. (2019). Cruise report - 64PE456 onboard of R/V Pelagia Terceira Island 2019 - Hopper tow-cam video footage. Zenodo. https://doi.org/10.5281/zenodo.6592501

Morato, T., Bulman, C., & Pitcher, T. J. (2009). Modelled effects of primary and secondary production enhancement by seamounts on local fish stocks. Deep Sea Research Part II: Topical Studies in Oceanography, 56(25), 2713-2719.

Morato, T., Carreiro-Silva, M., Dominguez-Carrió, C., Taranto, G. H., Rodrigues, L., Brito, J., & Gomes, S. (2019a). Cruise Report - MapGES / ATLAS Project: August 2018 Cruise on board of R/V Arquipélago. Zenodo. https://doi.org/10.5281/zenodo.3417022

Morato, T., Carreiro-Silva, M., Taranto, G. H., Dominguez-Carrió, C., Ramos, M., Ríos, N., ... & Bettencourt, Renato. (2019b). Cruise Report - BLUE AZORES PROGRAM EXPEDITION 2018 ON BOARD THE NRP GAGO COUTINHO. Zenodo. https://doi.org/10.5281/zenodo.3416898

Morato, T., Dominguez-Carrió, C., Evans, S., Taranto, G. H., Neves de Sousa, L., Mohn, C., & Carreiro-Silva, M. (2021a). iMAR: Integrated assessment of the distribution of Vulnerable Marine Ecosystem along the Mid-Atlantic Ridge in the Azores region. Zenodo. https://doi.org/10.5281/zenodo.6556837

Morato, T., Dominguez-Carrió, C., Gomes, S., Rodrigues, L., Gonçalves, G., Carneiro, I., Ramos, M., & Carreiro-Silva, M. (2022). MapGES 2022 Cruise Report: Exploration and mapping of deep-sea biodiversity in the Azores, summer 2022. Zenodo. https://doi.org/10.5281/zenodo.7075749

Morato, T., Dominguez-Carrió, C., Gomes, S., Taranto, G. H., Blasco, J., Ramos, M., Fauconnet, L., Zárate, C. G., & Carreiro-Silva, M. (2020a). MapGES 2019: Summer 2019 cruise on board of N/I Arquipélago. Zenodo. https://doi.org/10.5281/zenodo.3727570

Morato, T., Dominguez-Carrió, C., Gomes, S., Taranto, G. H., Ramos, M., Fauconnet, L., Rodrigues, L., & Carreiro-Silva, M. (2020b). MapGES 2020 Cruise Report: Exploration of Azores deep-sea habitats, summer 2020. Zenodo. https://doi.org/10.5281/zenodo.5503634

Morato, T., Dominguez-Carrió, C., Gonzalez-Irusta, J., Carreiro-Silva, M. & Sweetman, A. (2019c) Chapter 10. Habitat Suitability Model utility, In Deep-ocean climate change impacts on habitat, fish and fisheries, In Lisa Levin, Maria Baker, and Anthony Thompson (eds). FAO Fisheries and Aquaculture Technical Paper No. 638. Rome, FAO. 186 pp. Licence: CC BY-NC-SA 3.0 IGO.

Morato, T., Dominguez-Carrió, C., Mohn, C., Ocaña Vicente, O., Ramos, M., Rodrigues, L., ... & Carreiro-Silva, M. (2021b). Dense cold-water coral garden of Paragorgia johnsoni suggests the importance of the Mid-Atlantic Ridge for deep-sea biodiversity. Ecology and Evolution, 11(23), 16426-16433. https://doi.org/10.1002/ece3.8319

Morato, T., González-Irusta, J.M., Dominguez-Carrió. C., … & Carreiro-Silva, M. (2019d) Biodiversity, biogeography and GOODS classification system under current climate conditions and future IPCC scenarios. Deliverable 3.3., ATLAS project.

Morato, T., Kvile, K. Ø., Taranto, G. H., Tempera, F., Narayanaswamy, B. E., Hebbeln, D., … & Pitcher, T. J. (2013). Seamount physiography and biology in the north-east Atlantic and Mediterranean Sea. Biogeosciences 10, 3039–3054. doi:10.5194/bg-10-3039-2013.

Morato, T., Machete, M., Kitchingman, A., Tempera, F., Lai, S., Menezes, G., Pitcher, T., & Santos, R. (2008). Abundance and distribution of seamounts in the Azores. Marine Ecology Progress Series, 357, 17–21. https://doi.org/10.3354/meps07268

Morato, T., Pham, C. K., Fauconnet, L., Taranto, G. H., Chimienti, G., Cordes, E., ... & Carreiro-Silva, M. (2021c). North atlantic basin-scale multi-criteria assessment database to inform effective management and protection of vulnerable marine ecosystems. Frontiers in Marine Science, 255.

Morato, T., Pham, C. K., Pinto, C., Golding, N., Ardron, J. A., Muñoz, P. D., & Neat, F. (2018). A multi criteria assessment method for identifying Vulnerable Marine Ecosystems in the North-East Atlantic. Frontiers in Marine Science, 5, 460. doi: 10.3389/fmars.2018.00460

Morrissey, D., Gordon, J. D., Saso, E., Bilewitch, J. P., Taylor, M. L., Hayes, V., ... & Allcock, A. L. (2023). Bamboozled! Resolving deep evolutionary nodes within the phylogeny of bamboo corals (Octocorallia: Scleralcyonacea: Keratoisididae). Molecular Phylogenetics and Evolution, 188, 107910. https://doi.org/10.1016/j.ympev.2023.107910

Morrissey, D., Untiedt, C. B., Croke, K., Robinson, A., Turley, E., & Allcock, A. L. (2022). The Biodiversity of Calcaxonian Octocorals from the Irish Continental Slope Inferred from Multilocus Mitochondrial Barcoding. Diversity, 14(7), 576.

Mortensen, P.B., Buhl-Mortensen, L., Gebruk, A.V. & Krylova, E.M. (2007) Occurrence of deep-water corals on the Mid-Atlantic Ridge based on MAR-ECO data. Deep-Sea Resources Pt. II, 55, 142–152. https://doi.org/10.1016/j.dsr2.2007.09.018

Murillo, F. J., MacDonald, B. W., Kenchington, E., Campana, S. E., Sainte-Marie, B., & Sacau, M. (2018). Morphometry and growth of sea pen species from dense habitats in the Gulf of St. Lawrence, eastern Canada. Marine Biology Research, 14(4), 366-382. https://doi.org/10.1080/17451000.2017.1417604

Nele, A. N, Hooper JNA, Rützler K, de Voogd NJ, Alvarez de Glasby B, Hajdu E, Pisera AB, Manconi R, Schönberg CHL, Janussen D, Tabachnick KR, Klautau M, Picton B, Kelly M, Vacelet J, Dohrmann M, Díaz M--C, Cárdenas P (2015) World Porifera Database. Accessed at http://www. marinespecies. org/porifera on 2023-01-20. doi:10.14284/359.

Nguyen, L. T., Schmidt, H. A., Von Haeseler, A., & Minh, B. Q. (2015). IQ-TREE: a fast and effective stochastic algorithm for estimating maximum-likelihood phylogenies. Molecular biology and evolution, 32(1), 268–274.

NOAA Ocean Exploration. (n.d.) Voyage to the Ridge 2022. https://oceanexplorer.noaa.gov/okeanos/explorations/22voyage-to-the-ridge/dives/dives-ex2206.html

Olenin, S., & Ducrotoy, J. P. (2006). The concept of biotope in marine ecology and coastal management. Marine Pollution Bulletin, 53(1-4), 20-29.

Opresko, D. M. (1998) Three new species of *Leiopathes* (Cnidaria: Anthozoa: Antipatharia) from Southern Australia. Records of the South Australian Museum, v. 31, n. 1, p. 99-111.

Opresko, D. M. (2006) Revision of the Antipatharia (Cnidaria: Anthozoa). Part V. Establishment of a new family, Stylopathidae, Zool. Med. Leiden, 80–4, 109–138 page(s): 13

Opresko, D.M. (2002). Revision of the Antipatharia (Cnidaria: Anthozoa). Part II. Schizopathidae. Zoologische Mededelingen, v. 76, p. 411-442.

Orejas, Covadonga, Addamo, Anna, Alvarez, Marta, Aparicio, Alberto, Alcoverro, Daniel, Arnaud-Haond, Sophie, Bilan, Meri, Boavida, Joana, Cainzos, Veronica, Calderon, Ruben, Cambeiro, Peregrino, Castano, Monica, Fox, Alan, Gallardo, Marina, Gori, Andrea, Guitierrez, Christina, Henry, Lea-Anne, Hermida, Miriam, Jimenez, Juan Antonio, … Zein, Martha. (2017). Cruise Summary Report - MEDWAVES survey (MEDiterranean out flow WAter and Vulnerable EcosystemS). Zenodo. https://doi.org/10.5281/zenodo.556516

Péran, A.D., Pham, C.K., Amorim, P., Cardigos, F., Tempera, F. & Morato, T. (2016). Seafloor Characteristics in the Azores Region (North Atlantic). Frontiers Marine Science 3, 204. doi: 10.3389/fmars.2016.00204.

Pereira, R.S.M. (2013). Caracterização das megaesponjas do batial superior dos Açores. Tese de mestrado, Universidade dos Açores.

Perrin, J., Vielzeuf, D., Ricolleau, A., Dallaporta, H., Valton, S., & Floquet, N. (2015). Block-by-block and layer-by-layer growth modes in coral skeletons. American Mineralogist, 100(4), 681-695.

Pham, C. K., Vandeperre, F., Menezes, G., Porteiro, F., Isidro, E., & Morato, T. (2015). The importance of deep-sea vulnerable marine ecosystems for demersal fish in the Azores. Deep Sea Research Part I: Oceanographic Research Papers, 96, 80-88. doi:10.1016/j.dsr.2014.11.004.

Pisera, A.; Lévi, C. (2002a). Family Azoricidae Sollas, 1888. Pp. 352-355. *In Hooper, J. N. A. & Van Soest, R. W. M. (2002 [2004]) Systema Porifera. A guide to the classification of sponges. 1 (Kluwer Academic/ Plenum Publishers) NY.* 1708 + xlviii.

Pisera, A.; Lévi, C. (2002b). Family Corallistidae Sollas, 1888. Pp. 312-320. *In: Hooper, J.N.A. & Van Soest, R.W.M. (2002 [2004]). Systema Porifera. A guide to the classification of sponges. 1 (Kluwer Academic/ Plenum Publishers) NY.* 1708 + XLVIII.

Pisera, A.; Lévi, C. (2002c). Family Macandrewiidae Schrammen, 1924. Pp. 377-379. *In Hooper, J. N. A. & Van Soest, R. W. M. (2002[2004]) Systema Porifera. A guide to the classification of sponges. 1 (Kluwer Academic/ Plenum Publishers) NY.* 1708+xvliii.

Porteiro, F. M. (2009). A importância das campanhas oceanográficas do Príncipe Albert I do Mónaco para o conhecimento do Mar dos Açores. Boletim do Núcleo Cultural da Horta, 18, 189-219.

Porteiro, F. M., Gomes-Pereira, J. N., Pham, C. K., Tempera, F., & Santos, R. S. (2013). Distribution and habitat association of benthic fish on the Condor seamount (NE Atlantic, Azores) from in situ observations. Deep Sea Research Part II: Topical Studies in Oceanography, 98, 114-128.

Prjibelski A, Antipov D, Meleshko D, Lapidus A, Korobeynikov A (2020) Using SPAdes De Novo Assembler. Current Protocols in Bioinformatics 70(1): e102. https://doi.org/10.1002/cpbi.102

Prouty NG, Roark EB, Andrews AH, Robinson LF, Hill T, Sherwood O, Williams B, Guilderson T, Fallon S (2017) Age, Growth Rates, and Paleoclimate Studies in Deep-Sea Corals of the United States. In: Hourigan TF, Etnoyer, PJ, Cairns, SD (eds.).

Quattrini, A. M., Faircloth, B. C., Dueñas, L. F., Bridge, T. C., Brugler, M. R., Calixto-Botía, I. F., ... & McFadden, C. S. (2018). Universal target-enrichment baits for anthozoan (Cnidaria) phylogenomics: New approaches to long-standing problems. Molecular ecology resources, 18(2), 281–295.

Quattrini, A. M., McCartin, L. J., Easton, E. E., Horowitz, J., Wirshing, H. H., Bowers, H., ... & Herrera, S. (2023). Skimming genomes for systematics and DNA barcodes of corals. bioRxiv, 2023-10. https://doi.org/10.1101/2023.10.17.562770

Quattrini, A. M., Rodríguez, E., Faircloth, B. C., Cowman, P. F., Brugler, M. R., Farfan, G. A., ... & McFadden, C. S. (2020). Palaeoclimate ocean conditions shaped the evolution of corals and their skeletons through deep time. Nature Ecology & Evolution, 4(11), 1531–1538.

Rakka M, Godinho A, Orejas C, Carreiro-Silva M. (2021). Embryo and larval biology of the deep-sea octocoral Dentomuricea aff. meteor under different temperature regimes. PeerJ 9:e11604 https://doi.org/10.7717/peerj.11604

Rakka M., Sampaio I., Colaço A., Carreiro-Silva M (2021). Reproductive biology of two deep-sea octocorals in the Azores Archipelago, Deep Sea Research Part I, 175, 103587, https://doi.org/10.1016/j.dsr.2021.103587.

Ramos, M., Dominguez-Carrió, C., & Morato, T. (2021). Cruise report for 64PE488 onboard R/V Pelagia Terceira Island 2021 - Towed camera video footage. Zenodo. https://doi.org/10.5281/zenodo.6592634

Reid, R. E. H. (1958). A monograph of the Upper Cretaceous Hexactinellida of Great Britain and Northern Ireland. Paleontographical Society. 112: xlvii-xlviii, 1-26, pls I-IV.

Reiswig, H.M. (2014). Six new species of glass sponges (Porifera: Hexactinellida) from the north-eastern Pacific Ocean. Journal of the Marine Biological Association of the United Kingdom. 94 (02): 267-284.

Reiswig, H.M. (2018). Four new species of Hexactinellida (Porifera) and a name replacement from the NE Pacific. in: Deep Sea and Cave Sponges, Klautau, M., Pérez, T., Cárdenas, P. & de Voogd, N. (eds). Zootaxa. 4466 (1): 124-151.

Reiswig, H.M.; Kelly, M. (2011). The Marine Fauna of New Zealand: Hexasterophoran Glass Sponges of New Zealand (Porifera: Hexactinellida: Hexasterophora): Orders Hexactinosida, Aulocalycoida and Lychniscosida. NIWA Biodiversity Memoir. 124: 1-176.

Reiswig, H.M.; Mehl, D. (1994). Reevaluation of Chonelasma (Euretidae) and Leptophragmella (Craticulariidae) (Hexactinellida). pp 151-165 In: Van Soest RWM, van Kempen TMG, Braekman JC (eds) Sponges in Time and Space. Biology, Chemistry, Paleontology. Balkema, Rotterdam.

Reiswig, H.M.; Wheeler, B. (2002). Family Euretidae Zittel, 1877. pp 1301-1331. *In*: Hooper, J.N.A. & van Soest, R.W.M. (2002 [2004]). Systema Porifera. A guide to the classification of sponges (2 volumes). Kluwer Academic/Plenum, NY. 1708 + XLVIII.

Reverdin G, Niiler P P, Valdimarsson H (2003) North Atlantic Ocean surface currents, Journal Geophysical Research, 108, 3002–3023.

Roark, E. B., Guilderson, T. P., Dunbar, R. B., Fallon, S. J., & Mucciarone, D. A. (2009). Extreme longevity in proteinaceous deep-sea corals. Proceedings of the National Academy of Sciences, 106(13), 5204-5208.

Rooks, C., Fang, J. K. H., Mørkved, P. T., Zhao, R., Rapp, H. T., Xavier, J. R., & Hoffmann, F. (2020). Deep-sea sponge grounds as nutrient sinks: denitrification is common in boreo-Arctic sponges. Biogeosciences, 17(5), 1231-1245. doi: 10.5194/bg-17- 1231-2020.

Rossi S, Bramanti L, Broglio E, Gili JM. Trophic impact of long-lived species indicated by population dynamics in the short-lived hydrozoan Eudendrium racemosum. Mar Ecol Prog Ser. 2012;467:97–111.

Ruiz-Pico, S., Serrano, A., Punzón, A., Altuna, Á., Fernández-Zapico, O., & Velasco, F. (2017). Sea pen (Pennatulacea) aggregations on the northern Spanish shelf: distribution and faunal assemblages. Scientia Marina, 81(3), 413-423. doi: http://dx.doi.org/10.3989/scimar.04359.06A

Sampaio, Í. (2020) Identification of Octocoral of the Azores. iAtlantic Project report 39pp.

Sampaio Í, Carreiro-Silva M, Freiwald A, Menezes G, Grasshoff M (2019a) Natural history collections as a basis for sound biodiversity assessments: Plexauridae (Octocorallia, Holaxonia) of the Naturalis CANCAP and Tyro Mauritania II expeditions. ZooKeys 870: 1–32. https://doi.org/10.3897/zookeys.870.35285

Sampaio, Í., Freiwald, A., Porteiro, F. M., Menezes, G., & Carreiro-Silva, M. (2019b). Census of Octocorallia (Cnidaria: Anthozoa) of the Azores (NE Atlantic): a nomenclature update. Zootaxa, 4550 (4), 451–498. http://dx.doi.org/10.11646/zootaxa.4550.4.1.

Sampaio, Í., Morato, T., Porteiro, F., Gutiérrez-Zárate, C., Taranto, G., Pham, C., Gonçalves, J. & Carreiro-Silva, M. (2019c) The Value of a Deep-Sea Collection of the Azores (NE Atlantic Ocean): Marine invertebrate biodiversity in an era of global environmental change. Biodiversity Information Science and Standards 3: e37209. https://doi.org/10.3897/biss.3.37209

Sánchez, J. A. (2005). Systematics of the bubblegum corals (Cnidaria: Octocorallia: Paragorgiidae) with description of new species from New Zealand and the Eastern Pacific. Zootaxa, 1014(1), 1-72. https://doi.org/10.5281/zenodo.5668474

Santín, A.; Uriz, M.-J.; Cristobo, J.; Xavier, J.R.; Ríos, P. (2021). Unique spicules may confound species differentiation: taxonomy and biogeography of Melonanchora Carter, 1874 and two new related genera (Myxillidae: Poecilosclerida) from the Okhotsk Sea. PeerJ. 9: e12515.

Santos, M., Moita, M. T., Bashmachnikov, I., Menezes, G. M., Carmo, V., Loureiro, C. M., ... & Martins, A. (2013). Phytoplankton variability and oceanographic conditions at Condor seamount, Azores (NE Atlantic). Deep Sea Research Part II: Topical Studies in Oceanography, 98, 52-62.

Santos, R. S., Hawkins, S., Monteiro, L. R., Alves, M., & Isidro, E. J. (1995). Marine research, resources and conservation in the Azores. Aquatic Conservation: Marine and Freshwater Ecosystems, 5(4), 311-354.

Santos, R.S., Afonso, P, Colaço, A., Morato, T., Silva, M., & Tempera, F. (2009). A investigação científica e a conservação do ambiente marinho nos Açores: dos primórdios a actualidade. Boletim do Núcleo Cultural da Horta, 18, 29-60.

Saucier, E. H., France, S. C., & Watling, L. (2021). Toward a revision of the bamboo corals: Part 3, deconstructing the Family Isididae. Zootaxa, 5047(3), 247-272.

Searle, R. (1980). Tectonic pattern of the Azores spreading centre and triple junction. Earth and Planetary Science Letters, 51, 415-434.

Sherwood, O. A., & Edinger, E. N. (2009). Ages and growth rates of some deep-sea gorgonian and antipatharian corals of Newfoundland and Labrador. Canadian Journal of Fisheries and Aquatic Sciences, 66(1), 142-152.

Silva, A. (2015). Taxonomia do género Haliclona Grant, 1835 (Demospongiae: Haplosclerida: Chalinidae) do Brasil. Disseratção. Maceio, (2015). 158 pp.

Sim-Smith, C; Kelly, M. (2015). The Marine Fauna of New Zealand: Sponges in the family Geodiidae (Demospongiae; Astrophorina). NIWA Biodiversity Memoir. 188: 102 pp.

Snelgrove, P. V., Thrush, S. F., Wall, D. H., & Norkko, A. (2014). Real world biodiversity–ecosystem functioning: a seafloor perspective. Trends in ecology & evolution, 29(7), 398-405.

Sollas, W.J. (1888). Report on the Tetractinellida collected by H.M.S. Challenger, during the years 1873-1876. Report on the Scientific Results of the Voyage of H.M.S. Challenger during the years 1873–76. Zoology. 25 (part 63): 1-458, pl. 1-44, 1 map.

Somoza, L., Medialdea, T., González, F. J., Calado, A., Afonso, A., Albuquerque, M., ... & Madureira, P. (2020). Multidisciplinary Scientific cruise to the northern Mid-Atlantic ridge and Azores archipelago. Frontiers in Marine Science, 7, 568035. https://doi.org/10.3389/fmars.2020.568035

Stroud, J. T., Bush, M. R., Ladd, M. C., Nowicki, R. J., Shantz, A. A., & Sweatman, J. (2015). Is a community still a community? Reviewing definitions of key terms in community ecology. Ecology and evolution, 5(21), 4757-4765.

Studer, T. (1901). Alcyonaires provenant des campagnes de l'Hirondelle (1886–88), Résultats des Campagnes Scientifiques du Prince Albert Ier de Monaco, 20, 1–64.

Tabachnick, K.R. (2002a). Family Euplectellidae Gray, 1867. pp. 1388-1434. In: Hooper, J.N.A.; Van Soest, R.W.M. (2002). Systema Porifera - A Guide to the Classification of Sponges (2 volumes). Kluwer Academic/Plenum, NY, 1708 + XLVIII.

Tabachnick, K.R. (2002b). Family Rossellidae Schulze, 1885. pp. 1441-1505. In: Hooper, J. N. A. & Van Soest, R. W. M. (2002) Systema Porifera - A guide to the classification of sponges. (2 volumes) (Kluwer Academic/ Plenum Publishers: New York, Boston, Dordrecht, London, Moscow). 1708 + xvliii.

Tabachnick, K.R.; Collins, A.G. (2008). Glass sponges (Porifera, Hexactinellida) of the northern Mid-Atlantic Ridge. Marine Biology Research. 4: 25-47.

Tabachnick, K.R.; Menshenina, L.L. (2002). Family Pheronematidae Gray, 1870. pp. 1267-1280. In: Hooper, J. N. A. & Van Soest, R. W. M. (2002) Systema Porifera - A guide to the classification of sponges. (2 volumes). (Kluwer Academic/ Plenum Publishers: New York, Boston, Dordrecht, London, Moscow), 1708 + xvliii.

Tabachnick, K.R.; Menshenina, L.L. (2007). Revision of the genus *Asconema* (Porifera: Hexactinellida: Rossellidae). Journal of the Marine Biological Association of the United Kingdom. 87 (6): 1403-1429.

Tabachnick, K.R.; Menshenina, L.L. (2013). New data on glass sponges (Porifera, Hexactinellida) of the northern Mid-Atlantic Ridge. Part 2. Aphrocallistidae, Euretidae, Euplectellidae and Rossellidae (with descriptions of two new species of Sympagella). Marine Biology Research. 9: 469-487.

Takai, K. & Nakamura, K. (2011). Archaeal diversity and community development in deep-sea hydrothermal vents. Current opinion in microbiology, 14(3), 282-291.

Tempera, F, Atchoi E, Amorim P, Gomes-Pereira J & Gonçalves J (2013). Atlantic Area Marine Habitats. Adding new Macaronesian habitat types from the Azores to the EUNIS Habitat Classification. Technical Report No. 4/2013 - MeshAtlantic, IMAR/DOP-UAç, Horta, 126pp.

Tempera, F., Carreiro-Silva, M., Jakobsen, K., Porteiro, F. M., Braga-Henriques, A., & Jakobsen, J. (2015). An Eguchipsammia (Dendrophylliidae) topping on the cone. Marine Biodiversity, 45(1), 3-4.

Tempera, F., Porteiro, F., Carreiro-Silva, M., Braga-Henriques, A., Giacomello, E., Branco, A., Ferreira, P., Morato, T., & Santos, R. S. (2011). Relatório de Cruzeiro CORALFISH Condor, Voador e Banco Açores 2010 a bordo do NRP Almirante Gago Coutinho. Zenodo. https://doi.org/10.5281/zenodo.7476546

Tendal, O.S. (1972). A monograph of the Xenophyophoria (Rhizopoda, Protozoa). Galathea Report, 12: 7–99.

The State of Deep-Sea Coral and Sponge Ecosystems of the United States. NOAA Technical Memorandum NMFS-OHC-4, Silver Spring, MD. 22 p. Available online: http://deepseacoraldata.noaa.gov/library.

Thomson, J. A. (1927). Alcyonaires provenant des campagnes scientifiques du prince Albert Ier de Monaco, Résultats des Campagnes Scientifiques du Prince Albert Ier de Monaco, 73, 1–77.

Thresher, R. E. (2009). Environmental and compositional correlates of growth rate in deep-water bamboo corals (Gorgonacea; Isididae). Marine Ecology Progress Series, 397, 187-196.

Tixier-Durivault, A., & d’Hondt, M. J. (1974). Les octocoralliaires de la campagne Biaçores. Bulletin du Muséum National dHistoire Naturelle, Paris, 1361-1433.

Tompkins, G.; Baker, E.; Anstey, L.; Walkusz, W.; Siferd, T.; Kenchington, E. (2017). Sponges from the 2010-2014 Paamiut Multispecies Trawl Surveys, Eastern Arctic and Subarctic: Class Demospongiae, Subclass Heteroscleromorpha, Order Poecilosclerida, Family Coelosphaeridae, Genera Forcepia and Lissodendoryx. Canadian Technical Report of Fisheries and Aquatic Sciences. 3224: v + 129.

Topsent, E. (1892). Contribution à l'étude des Spongiaires de l'Atlantique Nord (Golfe de Gascogne, Terre-Neuve, Açores). Résultats des campagnes scientifiques accomplies par le Prince Albert I. Monaco. 2: 1-165, pls I-XI.

Topsent, E. (1898). Éponges nouvelles des Açores. (Première serie). Mémoires de la Société zoologique de France. 11, 225–255.

Topsent, E. (1904). Spongiaires des Açores. Résultats des campagnes scientifiques accomplies par le Prince Albert I. Monaco. 25: 1-280, pls 1-18..

Topsent, E. (1911). Sur une magnifique Geodia megastrella. Archives du Musée de la Rochelle (Bulletin de la Société des Sciences Naturelles de la Rochelle). 1-7, pl. 1.

Topsent, E. (1913). Spongiaires provenant des campagnes scientifiques de la ‘Princesse Alice’ dans les Mers du Nord (1898-1899 - 1906-1907). Résultats des campagnes scientifiques accomplies par le Prince Albert I Monaco. 45, 1-67.

Topsent, E. (1928). Spongiaires de l'Atlantique et de la Méditerranée provenant des croisières du Prince Albert ler de Monaco. Résultats des campagnes scientifiques accomplies par le Prince Albert I. Monaco. 74:1-376, pls I-XI.

Tracey, D., Bostock, H., Shaffer, M. (2018). Ageing methods for protected deep-sea corals: A review and recommendation for an ageing study. DOC Contract 4527 GMC - Age & Growth of coral (POP2017-07). NIWA Client Report No. 2018035WN 40 p.

Uriz, M.J. (2002). Family Geodiidae Gray, 1867. Pp. 134-140. In: Hooper, J.N.A., van Soest, R.W.M. (eds) Systema Porifera. A Guide to the Classification of Sponges (2 volumes). Kluwer Academic/Plenum Publ., New York. 1708+XVLIII.

Vacelet, J.; Boury-Esnault, N. (1987). Taxonomy of Porifera from the N.E. Atlantic and Mediterranean Sea. NATO ASI Series G: Ecological sciences, 13. Springer: Berlin. ISBN 3-540-16091-4. VIII, 332 pp.

Van Soest, R. W., Boury-Esnault, N., Vacelet, J., Dohrmann, M., Erpenbeck, D., De Voogd, N. J., ... & Hooper, J. N. (2012). Global diversity of sponges (Porifera). PLoS one, 7(4), e35105. doi: 10.1371/journal.pone.0035105.

Van Soest, R.W.M.; Meesters, E.H.; Becking, L.E. (2014). Deep-water sponges (Porifera) from Bonaire and Klein Curaçao, Southern Caribbean. Zootaxa. 3878(5): 401-443.

Vogt, P.R. & W.Y. Jung (2004). The Terceira Rift as hyperslow, hotspot dominated oblique spreading axis: a comparison with other slow spreading plate boundaries. Earth and Planetary Science Letters, 218, 77-90.

Watling, L., & Auster, P. J. (2017). Seamounts on the high seas should be managed as vulnerable marine ecosystems. Frontiers in Marine Science, 4, 14.

Watling, L., & Auster, P. J. (2021). Vulnerable marine ecosystems, communities, and indicator species: Confusing concepts for conservation of seamounts. Frontiers in Marine Science, 8, 622586. doi: 10.3389/fmars.2021.622586

Watling, L., & France, S. C. (2021). Toward a revision of the bamboo corals: Part 2, untangling the genus Lepidisis (Octocorallia: Isididae). Bulletin of the Peabody Museum of Natural History, 62(2), 97-110.

Watling, L., France, S. C., Pante, E., & Simpson, A. (2011). Biology of deep-water octocorals. Advances in marine biology, 60, 41-122.

Watling, L., Saucier, E. H., & France, S. C. (2022). Towards a revision of the bamboo corals (Octocorallia): Part 4, delineating the family Keratoisididae. Zootaxa, 5093(3), 337-375.

Wisshak,M., Neumann, C., Jakobsen, J., Freiwald, A.(2009c).The 'living- fossil community' of the cyrtocrinid Cyathidium foresti and the deep-sea oyster Neopycnodonte zibrowii (Azores Archipelago). Palaeontology, Palaeoclimatology, Palaeoecology, doi:10.1016/j.palaeo.2008.09.015.

Wisshak, M.; López Correa, M.; Gofas, S.; Salas, C.; Taviani, M.; Jakobsen, J.; Freiwald, A. (2009b). Shell architecture, element composition, and stable isotope signature of the giant deep-sea oyster Neopycnodonte zibrowii sp. n. from the NE Atlantic. Deep Sea Res. Part I 56, 374–407.

Wisshak, M., Correa, M. L., Zibrowius, H., Jakobsen, J. & Freiwald, A. (2009a). Skeletal reorganisation affects geochemical signals, exemplified in the stylasterid hydrocoral Errina dabneyi (Azores Archipelago). Marine Ecology Progress Series, 397, 197-208.

Wisshak, M., Neumann, C., Jakobsen, J. & Freiwald, A. (2009b) The 'living-fossil community'of the cyrtocrinid *Cyathidium foresti* and the deep-sea oyster *Neopycnodonte zibrowii* (Azores Archipelago). *Palaeogeography, Palaeoclimatology, Palaeoecology, 271(1-2),* 77-83.

Xavier, J. R., Rees, D. J., Pereira, R., Colaço, A., Pham, C. K., & Carvalho, F. C. (2021). Diversity, Distribution and Phylogenetic Relationships of Deep-Sea Lithistids (Porifera, Heteroscleromorpha) of the Azores Archipelago. Frontiers in Marine Science, 8, 600087.

Zeppilli, D., Pusceddu, A., Trincardi, F., & Danovaro, R. (2016). Seafloor heterogeneity influences the biodiversity–ecosystem functioning relationships in the deep sea. Scientific reports, 6, 26352.

Zibrowius, H. (1980). Les Scléractiniaires de la Méditerranée et de l'Atlantique nord-oriental. Mémoires de l'Institut océanographique, Monaco. 11:1–284.

Zibrowius, H. and Cairns, S. D.: Revision of the northeast Atlantic and Mediterranean (1992) Stylasteridae (Cnidaria: Hydrozoa), Memoir. Mus. Natl. Hist. (Serie A, Zoologie), 153, 1–136.

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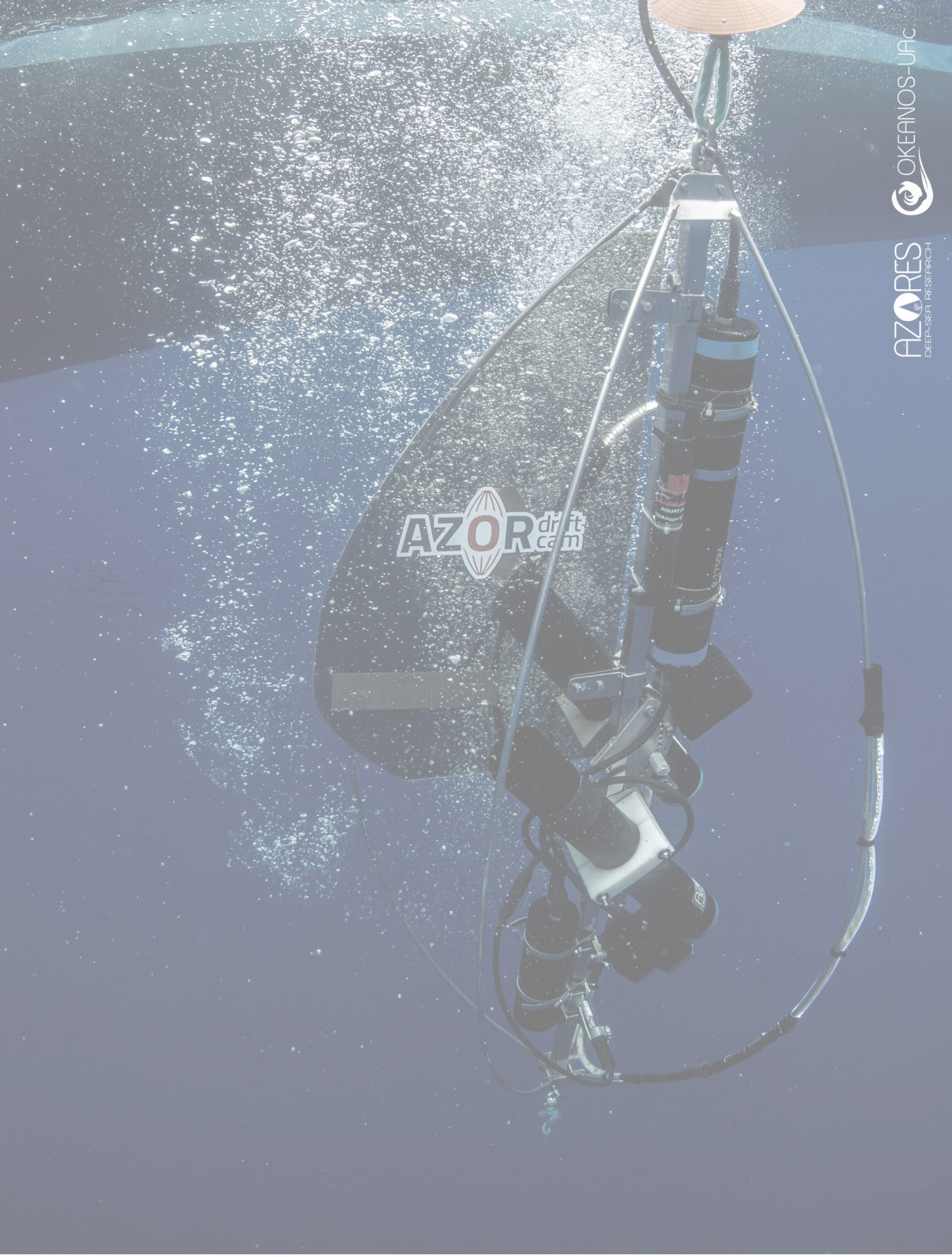


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