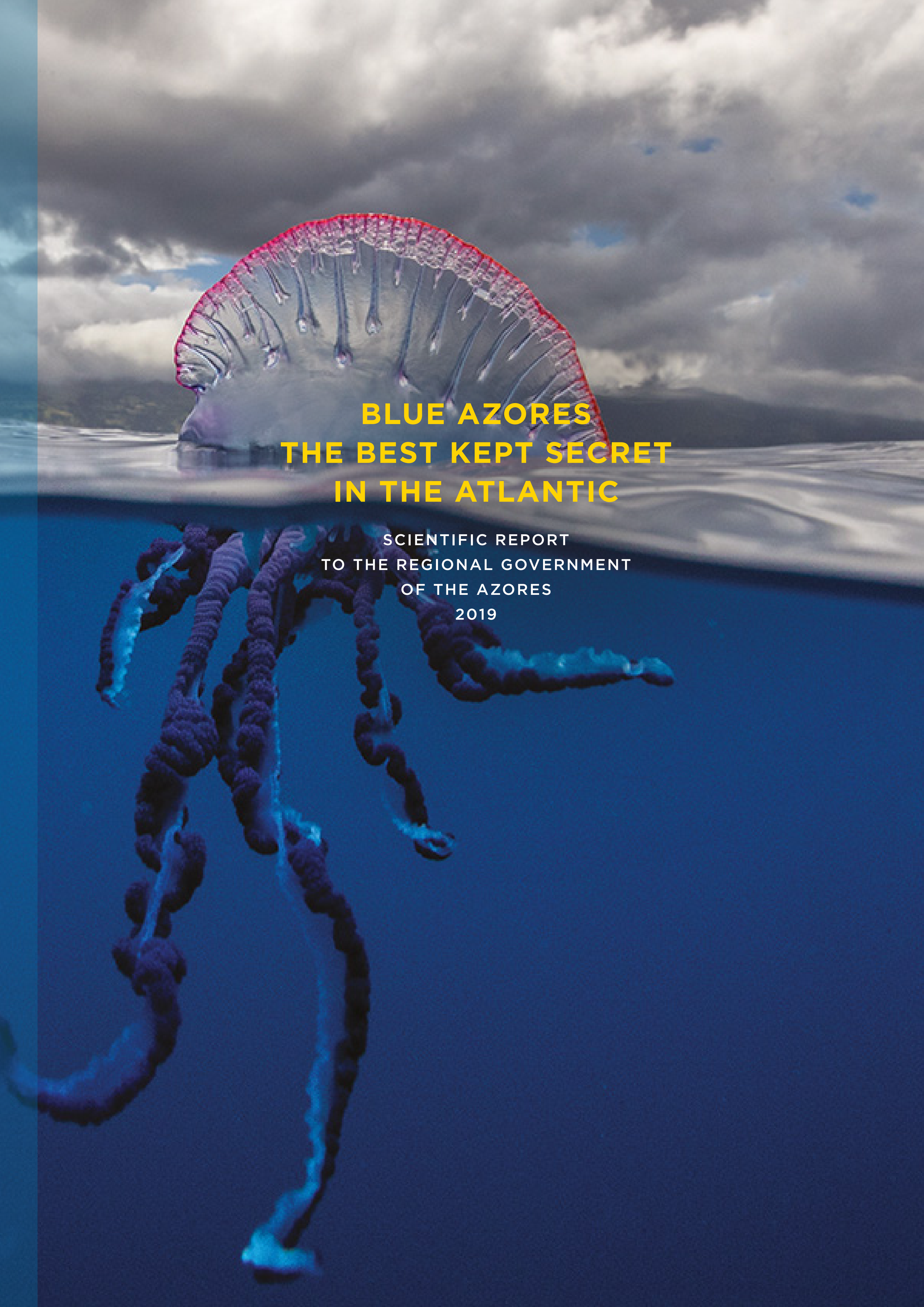

BLUE AZORES
THE BEST KEPT SECRET
IN THE ATLANTIC

SCIENTIFIC REPORT
TO THE REGIONAL GOVERNMENT
OF THE AZORES
2019

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EXECUTIVE **SUMMARY**

The waters around the Azores Archipelago contain some of the most important island, open-water, and deep-sea environments in the Atlantic. Despite its importance, this invaluable, fragile, and irreplaceable blue natural capital is under threat and needs to be protected.

1. Introduction

The Azores is composed of nine volcanic islands in the North Atlantic Ocean about 1300 km west of continental Portugal. The archipelago spans 650 km and is located above an active triple junction between three of the world's largest tectonic plates: American, Eurasian, and African. The average depth is 3000 m, although the islands sit on the Azores Plateau with an average depth of 2000 m. This area is crossed by the Mid-Atlantic Ridge, which is the main underwater geological feature and a part of the largest mountain chain on Earth.

The archipelago is composed of a western group of two islands (Corvo and Flores), a central group of five islands (Faial, Graciosa, Pico, São Jorge, and Terceira), and an eastern group of two islands (Santa Maria and São Miguel), plus the Formigas Seamount, which contains a group of rocky outcroppings.

The Azores has led conservation efforts for several decades in Europe, with 52 areas designated under some type of protection and covering over 100000 km^2 of the EEZ. However, most of these areas still do not have management plans (which are currently being developed), are small, weakly regulated (< 1% of the Azores sea is fully protected), and lack financial and human resources for effective management and proper ecosystem function.

The Azores has also been a leader in developing sustainable fisheries management measures over the years. Nevertheless, there is a common perception among fishers that many stocks and areas are facing serious signs of overexploitation.

The Blue Azores has a vision to facilitate the Azores in becoming a model economy for a blue society where the natural capital is protected, valued, and promoted through sustainable use of marine-associated businesses and civil society sectors, with effective conservation actions across the entire marine environment. For that purpose, the Azores Government has partnered with the Oceano Azul Foundation and the Waitt Foundation to implement this vision. The National Geographic Pristine Seas Project is also a partner, together with the Azores University, the Instituto do Mar (IMAR), the Portuguese Hydrographic Institute, the Task Group for the Extension of the Continental Shelf, and many other researchers and institutions from around the world.

Two expeditions were organized, one in 2016 to the eastern group of islands and another one in 2018 to the central and western groups. The results of these expeditions along with information from ongoing research efforts in the Azores are presented in this report, which shows a vibrant and diverse marine ecosystem, but one that is under great pressure from numerous human threats.

2. Coastal Reefs and Seamounts

2.1. INTERTIDAL

Rock pools are an essential fish habitat for several species of fishes and invertebrates in the Azores, including the IUCN Red Listed dusky grouper *Epinephelus marginatus*, with juveniles of this species common in the rock pools, namely at Formigas Islets. Due to coastal development, these habitats are under increasing pressure and need to be protected. The limpets *Patella candei* (mostly infralitoral) and *P. aspera* (intertidal), are commercially important keystone species that have been intensely exploited in the Azores, where the populations have nearly collapsed. No-take areas, seasonal closures, and bag limits for limpets have been established with the aim of reversing these trends.

2.2. BENTHIC COMMUNITIES

Habitats between 5 and 25 m are dominated by erect algae, although some invertebrates can be abundant above 10 m (e.g. encrusting sponges, the Azorean Barnacle [*Megabalanus azoricus*], and the jewel anemone [*Corynactis viridis*]). Sea urchins are scarce and have little influence on the benthos except for the hatpin urchin (*Centrostephanus longispinus*), which is prevalent in waters > 45 m, particularly at Princess Alice Bank. Algal assemblages at deeper depths (20 m) were dominated by the brown alga *Zonaria tournefortii*. At shallower depths (10 m) the assemblage was more variable, with the dominance changing depending on site. Based on functional groups, Princess Alice Bank was most distinct from the islands.

Faial had a distinct benthic community with sand and turf algae being most abundant. Erect algae were most closely correlated with Corvo, Flores, and Pico. Formigas, and Santa Maria were very similar based on benthic functional groups.

Formigas possesses the sublittoral biotopes with the highest algae biomass recorded in the region, namely dense canopy-forming macroalgae *Cystoseira* and *Sargassum* beds. In deeper waters (45 m) of this seamount, the occurrence of kelp (*Laminaria ochroleuca*) beds have been described. Some invasive algae species, including the genus *Asparagopsis* are abundant throughout the archipelago.

2.3. FISH ASSEMBLAGES

On coastal reefs, the number of fish species varied between islands, with the highest richness observed at Formigas and Faial and the lowest at Flores and Corvo. Fish biomass was also higher at Formigas and Faial and lower at Flores and São Miguel. The highest abundance of individuals was recorded at Formigas and Santa Maria and the lowest levels were found at Corvo and São Miguel. The biomass of coastal fish assemblages was highly variable among islands, with the largest biomass observed at Formigas and inside the Corvo voluntary reserve, which are strongly protected marine areas. Overall values of fish biomass obtained for the Azores are comparable to heavily fished areas in Madeira and the Canary Islands (Friedlander et al. 2017). Very few top predators were present on these coastal assessments.

Pressure on coastal resources seems to be the main cause for these low levels of biomass, with the use of nets widespread on the shelves of several islands. During the 2018 expedition, at Flores Island, an example of how quickly fish populations can be decimated occurred when the media team found only partial bodies (heads and dorsal fins) of several dozen triggerfishes lying on the bottom in the location where, a few hours before, the diving team had observed a large school of several hundred individuals of this species.

The IUCN endangered dusky grouper (*E. marginatus*) is the best-known grouper of the European and North African coasts, but it has been overexploited throughout much of its range and is the focus of conservation efforts throughout the region. To track the movement of dusky groupers around Corvo Island, twelve acoustic receivers were deployed, and seven groupers captured inside the voluntary reserve were acoustically tagged and released. Preliminary results showed that all seven groupers resided inside this small reserve for a 2-month period. The very clear territories demonstrated by these groupers suggest how effective fully protected MPAs for the protection of this species can be.

2.4. NEARSHORE SHARK NURSERIES

Nearshore occurrences of the smooth hammerhead shark (*Sphyrna zygaena*) were documented through acoustic telemetry, baited remote underwater video systems, and interviews with fishers and researchers. Results show that smooth hammerhead sharks are found mostly in the summer months, with small groups of juveniles frequently spotted on the south coast of Flores Island. Larger groups of this species are found at Faial, Graciosa, and Santa Maria (usually on the north shores), with up to 20 individuals of approximately 1–1.5 m in length occurring together. Occasionally large pregnant females have been detected. In comparison, the tope shark (*Galeorhinus galeus*) do not aggregate, although they are frequently sighted in the channel between Flores and Corvo and are often caught at all islands (juveniles and adults). Blue sharks (*Prionace glauca*) are regularly seen in the channel between Flores and Corvo and on seamounts and island slopes around Faial and Pico islands, although the wider Azores region is likely a nursery area for this species as well.

2.5. MESOPHOTIC REEFS

Mesophotic reef ecosystems (30–150 m) have received relatively little attention owing to the difficulty in studying these deeper habitats. We used baited remote underwater video systems (BRUVS) at depths from 13 to 170 m at Faial, Pico, Corvo, and Flores islands, and an unbaited dropcam between 50 and 200 m at Flores and Corvo, to assess these mesophotic communities. We recorded 645 individual bony fishes and rays from 35 species in this unique ecosystem. The most abundant fish species were *Anthias anthias*, *Boops boops*, *Coris julis*, *Serranus atricauda*, *Sphoeroides marmoratus*, *Muraena helena*, *Seriola rivoliana*, *Pagellus bogaraveo*, *Pagrus pagrus* and *Balistes carolinensis*. Most of these species had higher abundances at the 50 m stations, with only *Anthias anthias* and *Pagellus bagaraveo* more abundant at the deeper stations. Sampling of benthic habitats showed previously unknown mesophotic communities hosting fragile habitat-forming species of conservation interest such as hard corals, gorgonians, tall leptothecate hydroids, and large sponges. Surprisingly, no sharks were observed on our BRUVS in these mesophotic reefs, which should be a refuge for these species.

The Azores mesophotic reefs are rich in species and deserve special attention since most of these reefs are not covered by effective conservation measures, and the scarcity of large predatory fishes in the region could be a sign of significant fishing impacts.

3. Open Water Environments

3.1. MID-WATER COMMUNITIES

We sampled the pelagic communities across the western and central groups of the Azores, including Pico/São Jorge, Flores and Corvo islands, Cachalote, and Gigante seamounts and Princess Alice Bank. A total of thirty-one sites were sampled using mid-water BRUVS. We recorded 8814 individual pelagic bony fishes, sharks, rays, and marine mammals representing 15 taxa from 12 families. Overall, the most abundant species were small forage fishes: longspine snipefish (*Macroramphosus scolompax*), boarfish (*Capros aper*) and mackerel (*Trachurus* sp.). Sharks were observed regularly, with blue sharks (*Prionace glauca*) and shortfin mako (*Isurus oxyrhynchos*) observed at 32% and 23% of sites, respectively. Remoras (*Remora remora*) associated with the sharks were observed at 16% of sites, while grey triggerfish (*Balistes capriscus*) and rudderfish (*Centrolophus niger*) were observed at 23% and 13% of sites, respectively.

3.2. DEVIL RAY BEHAVIOUR

The Azores constitutes the northernmost distribution limit for mobulid rays in the Atlantic and globally. Devil rays (family Mobulidae) are iconic, endangered animals and despite their large size, their elusive behaviour has limited our understanding and conservation of these species. Three devil rays were tagged in 2016 at two shallow seamounts, Baixa do Ambrósio (Santa Maria island) and Formigas Seamount, using a new non-invasive harness method, deployed on free swimming animals by a free-diver. We used a tag-package combining one acoustic transmitter, one VHF radio transmitter, and one archival satellite tag.

All tagged rays exhibited no immediate reaction to tagging and remained at shallow depths diving slowly (average descent rate 0.16 m/s) during the post-tagging period. The maximum descent rate registered was 2.72 m/s and the maximum recorded depth of 400 m. Devil rays are known to dive very deep (over 2000 m) and visit the seamounts of the Azores in the summer travelling all the way from the west African coast. It is speculated that they visit the Azores to give birth and likely to mate.

3.3. SEABIRDS AND ASSOCIATED MEGAFAUNA

The Azores is a global hotspot for seabirds. There are 10 known breeding seabird species found here, including: Cory's shearwater (*Calonectris borealis*), Manx shearwater (*Puffinus puffinus*), Macaronesian shearwater (*Puffinus lherminieri*), band-rumped storm-petrel (*Hydrobates castro*), Monteiro's storm petrel (*Hydrobates monteiroi*), Bulwer's petrel (*Bulweria bulwerii*), common tern (*Sterna hirundo*), roseate tern (*Sterna dougallii*), yellow-legged gull (*Larus michahelis atlantis*) and sooty tern (*Onycophrion fuscatus*).

Standard observations of seabirds, marine megafauna, and marine litter were conducted along 54 transects, over 39.5 hrs and covering 822 km of the northern Azores. Nine species of seabirds were observed, of which eight are known to breed in the Azores. Six sperm whales (*Physeter macrocephalus*), two humpback whales (*Megaptera novaeangliae*), a fin whale (*Balaenoptera physalus*), two unidentified baleen whale species, 35 bottlenose dolphins (*Tursiops truncatus*) and 160 common dolphins (*Delphinus delphis*) were registered during these surveys. A single loggerhead turtle *Caretta caretta* (~ 32 cm carapace length) was detected in 20 surveys.

4. Deep-sea

4.1. DEEP-SEA FAUNA ASSEMBLAGES

The seafloor of the Azores EEZ is characterized by complex topography comprising island slopes, seamounts, deep fracture zones, trenches, and abyssal plains exceeding 5000 m depth.

During the 2018 expedition, over 21000 km^2 of seafloor was mapped in detail for the first time. There are 300+ seamounts in the Azores that provide ideal conditions for the occurrence of cold-water corals and sponges, which are listed by FAO as Vulnerable Marine Ecosystems. Most of these seamounts are still unexplored scientifically, but some have been exploited by bottom trawls in the past and are impacted by other benthic fishing gear as well. Many of these deep-water species are slow growing, long-lived, and have low reproductive outputs, making them extremely vulnerable to fishing and other human impacts, with recovery times requiring decades to centuries. Cold-water coral diversity is particularly high in the Azores, with 184 species identified to date.

Some of the vertical walls explored with the remotely operated vehicle (ROV) Luso, both at São Jorge and Pico islands, hosted unique assemblages characterized by the presence of the long-lived oyster cf. *Neopycnodonte zibrowii* (lifespan of several centuries) and the sessile crinoid *Cyathidium foresti*. This assemblage has been described as a ‘living fossil community’. The fragile nature of this habitat and its uniqueness in the North Atlantic justifies its protection. South of Pico, dense aggregations of large glass sponges (*Pheronema carpenteri*) were also observed.

4.2. HYDROTHERMAL VENT FIELD

The Gigante Complex Area is located between the islands of Flores and Faial and sits over the Mid-Atlantic Ridge. One major discovery of the 2018 expedition was a new hydrothermal vent field on the slopes of Gigante at 570 m. This hydrothermal vent field was named “Luso” and occupies an area of about 400 m^2 being composed of at least 26 chimney-like structures of different sizes with orifices of up to about 30 cm in diameter. A total of 28 taxa were identified from the Luso vent field from 8 different phyla. Among these, the most extensive and densest coral garden of the long-lived *Paragorgia* spp. was observed in this area. Preliminary characterization of the Gigante seamount region has identified at least 200 different benthic species with the best represented taxonomic groups being Cnidaria (80 taxa), Porifera (60 taxa), and Actinopterygii (34 taxa).

4.3. DEEP SEA DROPCAMS

National Geographic's Exploration Technology Lab developed the Deep-Ocean Dropcams to explore the deepest depths of the ocean. A total of 39 successful deployments were conducted in the Azores Archipelago in June 2018. Rockfishes (Sebastidae), cutthroat eels (Synaphobranchidae), grenadiers (Macrouridae), and the mora (*Mora moro*) were the most commonly occurring fish taxa observed at these deeper depths. Lanternfishes (Myctophidae) and porgies (Sparidae) were the most abundant families of fishes observed. Individuals from the Class Elasmobranchii (sharks, rays, and skates) occurred on 74% of the deployments and were present on all 10 of the deepest deployments (> 1000 m). The Bluntnose sixgill shark (*Hexanchus griseus*) and the Portuguese dogfish (*Centroscymnus coelolepis*) were seen most frequently at these depths. Other observed taxa included lantern sharks (Etmopteridae), dogfish (Centrophoridae), and finback catsharks (Proscylliidae). The observed fish assemblages of the deepest deployments (1000–1480 m) were characterized by eels (Anguilliformes), cods (Gadiformes), and sharks (Elasmobranchii).

Mobile invertebrates including brachyuran crabs, shrimps, squid, chaetognaths (arrow worms), sea stars, and sea urchins (including *Cidaris cidaris*) were also encountered on the dropcams. Sessile invertebrates included black corals (*Bathypathes* cf. *patula*), octocorals (including *Viminella flagellum* and *Paracalyptrophora josephinae*), stony corals (*Dendrophyllia cornigera*), anemones (including *Cerianthus* sp.) and deep-sea sponges (Porifera).

5. Commercial Fishing Impacts

The Azores has one of the largest no-trawling areas in the world and therefore the main threats are related to longlines, illegal drift nets, nearshore overfishing, and poaching. The current fully protected areas are very small and therefore most ecosystems are impacted by different influences, primarily commercial fishing. Fishing activity within the Azores EEZ is non-uniformly distributed, with hotspots around São Miguel and Santa Maria, and the Princess Alice and Azores banks.

Drifting pelagic longline is the predominant fishing gear used by both Portuguese and Spanish-flagged vessels and accounted for 47.2% of all fishing effort in 2018. This fishing gear mainly targets billfishes and pelagic sharks, such as blue and mako. The second and third most used fishing gears are pole and line and set longlines, representing 34.3% and 15.1% of total fishing effort in 2018, respectively. These are predominantly used by the Portuguese-flagged fleet.

Overall, the footprint of fishing within the Azores' EEZ is large and covers most of the region's waters. This is especially true at the outer 100 nm of the EEZ where nearly 40 Spanish-flagged drifting longliners fish for up to 1000 vessel-days per year. Catches of billfishes and sharks have nearly tripled since the 1950s. Blue sharks comprised 8% of the total longline catch in the 1960s but increased to 70% in the 2000s, whereas the catch of benthopelagic fishes such as the valuable black seabream have declined five-fold since 1950. Porgbeagles (*Lamna nasus*) accounted for 88% of the shark catch in the 1960's but now account for < 1%. These results call for urgent implementation of large-scale fully protected MPAs and more effective fisheries regulations measures throughout the region.

6. Recommendations

There are four main priorities to advance conservation policies in the Azores and allow the region to benefit from the long term and sustainable use of its sea.

The first priority is to significantly increase the proportion of the Azores EEZ under full protection, aiming at including the most valuable species and ecosystems, and species of high commercial value. This should focus on coastal habitats, seamounts, open-water ecosystems, and the deep-sea. With < 1% of the Azores seas under full protection, this is a top priority for the region.

The second priority is to fully implement the existing conservation areas by developing management plans that fully or strongly protect these areas and allocate the necessary financial and human resources to properly manage them. Current scientific studies, including these expeditions' results, show no clear conservation benefits from the existing MPAs except where they are strongly protected.

The third priority is to implement additional measures that promote the sustainable local fisheries and eliminate more unsustainable fishing practices such as the use of pelagic longline fishing, coastal gillnets, and the impacts of set longlines on seamounts and benthic communities.

The fourth priority is to promote education and ocean literacy throughout the archipelago and to the wider Portuguese society in support of the conservation measures proposed in this report. Awareness of the threats facing the Azores seas and of the effectiveness of the solutions to mitigate these threats, will be required to support government action, adoption of conservation and sustainable fishing measures by the different authorities, and compliance by all ocean users.

A number of specific recommendations to achieve these four priorities are included in the conclusions of this report.

7. The Expeditions in Numbers

2016:

- 10 researchers
- 16 participants
- > 350 dives and > 450 hours spent underwater
- > 278 kilometres travelled
- 75 survey sites
- 46 live-feed cameras

2018:

- 38 researchers
- 96 participants
- > 600 dives and > 500 hours spent underwater
- 1203 kilometres travelled
- 21469 km^2 of newly mapped sea floor area
- 60 hours exploring the deep-sea ecosystems with the ROV Luso in 13 dives
- 107 survey sites
- 39 successful deep dropcam deployments (300 to 1500 m)
- 155 open ocean camera deployments
- 76 nearshore cameras
- 48 live-feed cameras
- 737 students enrolled in the Open Explorer Classroom from eight countries

INTRODUCTION

INTRODUCTION

The waters around the Azores Archipelago contain some of the most important island, open-water, and deep-sea environments in the Atlantic. The ocean has long defined the cultural heritage of the people of these islands. Despite its importance, this invaluable and irreplaceable blue natural capital is under threat and needs to be protected, valued, and promoted to sustain environmental, social, and economic goals. By doing so, the Azores can become a model sustainable ocean region for the rest of Europe and the world.

Geography and Geology

The Azores is an autonomous region of Portugal, composed of nine volcanic islands in the North Atlantic. The islands are distributed approximately along a SE-NW axis on an oceanic elevation known as the Azores Plateau, with about 500000 km^2 and an average depth of 2000 m. This region is crossed by the Mid-Atlantic Ridge and is bordered to the south by the Eastern Fracture of the Azores and cut by the Rift of Terceira. The archipelago is located above an active triple junction between three of the world's largest tectonic plates (Machado et al. 2008). It is approximately 1300 km west of mainland Portugal, 1600 km east of North America, and 800 km north-west of Madeira. The Azores subarea EEZ corresponds to nearly 1 million km^2 (55% of the EEZ of Portugal) with an average depth of 3000 m.

The archipelago is composed of a western group of two islands (Corvo and Flores), a central group of five islands (Faial, Graciosa, Pico, São Jorge, and Terceira), and an eastern group of two islands (Santa Maria and São Miguel) plus the Formigas Islets, which comprises only around 0.9 hectares and have a maximum height of just 11 m above sea level. The westernmost islands (Corvo and Flores) are located on the North American Plate, while the remaining islands are located within the boundary that divides the Eurasian and African plates (Figure 0.1). The Mid-Atlantic Ridge is the main geological feature between the American and African-Eurasian plates.

The distance between the most northern and most southern islands, Corvo and Santa Maria, respectively, is over 600 km. More than 300 seamounts have been identified in the region; the main ones are shown in Figure 0.1.1.

FIGURE 0.1.

The Azores Exclusive Economic Zone and geological plates.

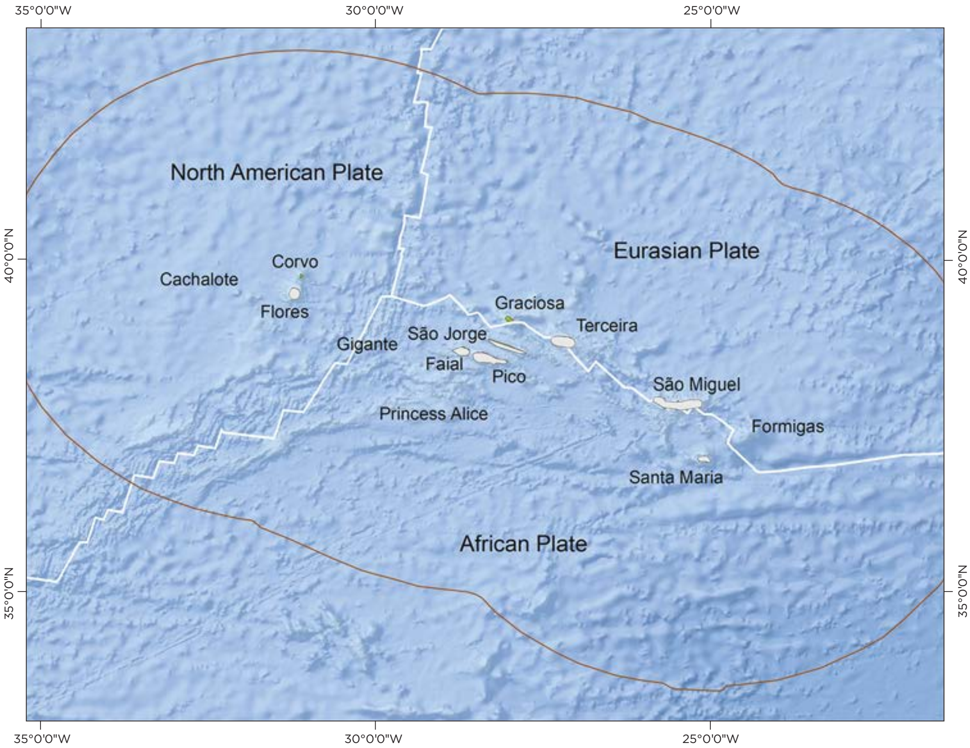
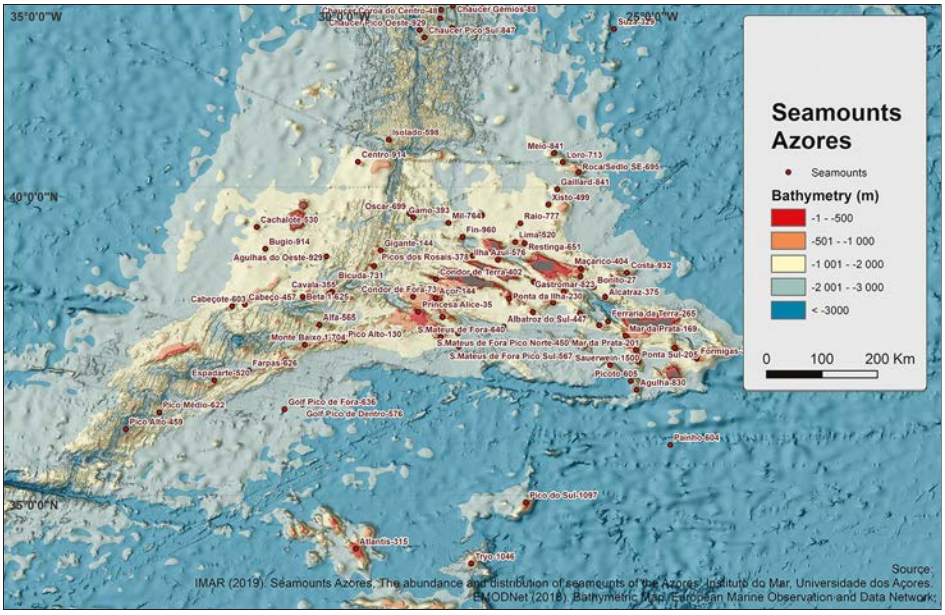


FIGURE 0.1.1.

Distribution of main seamounts in the Azores (depth in meters is shown after the seamount name).



Natural History

From a biogeographical perspective, the Azores are often grouped with Cape Verde, Canary Islands, Salvage Islands, and Madeira in the Macaronesian region. The archipelago lies in the Palearctic ecozone, forming a unique biome that includes the Macaronesian subtropical laurel forest (Figure 0.2), with many endemic species of plants and animals (Triantis et al. 2010).

FIGURE 0.2.

Lush subtropical forest at Poço da Alagoinha, Flores Island.

Maritime Heritage

The Azores were uninhabited until colonized by the Portuguese in the 15th Century. It was one of the most important passages in the North Atlantic navigation routes, marking the first and last port-of-call for many sailing ships leaving or returning to Europe. The island chain was an important stop for New England whaling ships of the 18th and 19th century, as it was a convenient place to refresh supplies, recruit crewmembers, and to hunt for sperm whales, which frequented the deeper waters off the islands.

Threats

Humans have exploited littoral, nearshore, and offshore living resources of the Azores since the earliest colonization. In recent years pressures on littoral and offshore resources have grown with the transition from subsistence or artisanal exploitation to more commercial operations. The Azores have relatively little direct pollution and habitat destruction from industry or large population areas; however, the proliferation of plastics and other man-made debris coming mostly from the North Atlantic Gyre has increased in recent years. Although the majority of the information on the quantities of plastic present in the marine environment comes from the coastline and surface waters, the deep seafloor may act as the major final sink (Woodall et al. 2014, Pham et al. 2013; Pham et al. 2014, Rodríguez and Pham, 2017). The prevalence of microplastics is less studied, especially in marine sediments, and these expeditions contributed samples to address these knowledge gaps.

Some important impacts include coastal development, namely the modification of tide pools to natural swimming pools that are widespread throughout the islands, impacting intertidal species and fish species, such as the endangered dusky grouper, that utilize these tidepools during critical early stages of life. Limpets are also overexploited in the islands and although some protection exist with limpet exclusion zones, poaching and poor management of the resource endanger the recovery of these species. Port development and expansion, including marinas, and sand extraction in a few locations also pose direct impacts to coastal ecosystems. Recently, invasive species have been detected and can be prevalent in some locations. However, the main threats to the marine ecosystems of the Azores come from fishing and climate change. The Azores has one of the largest no-trawl areas in the world, and local fishers still use artisanal and sustainable fishing methods such as pole and line for tuna. Nevertheless, pelagic longlines used by the Spanish fleet and national vessels from the mainland, as well as deep-water longlines used by the regional fleet, are threatening numerous species and habitats, such as sharks, billfishes, deep-water fishes, coral gardens, and sponge aggregations. Lost fishing gear is being detected in most environments in the region. Nearshore use of nets, recreational fishing impacts, and poaching are identified threats that also need to be addressed. The near absence of fully protected marine protected areas (MPAs) severely limits the ability to mitigate these threats. These fully protected MPAs would also help increase resilience to address the overall impacts of climate change, including deep-sea environments. Experimental studies and species habitat suitability modelling have revealed that several species of corals and fishes in the North Atlantic, including the Azores, may be impacted by ocean changes predicted by 2100 (Carreiro-Silva et al. 2014, Morato et al. 2019).

Protection

The marine environment of the Azorean Archipelago and its surrounding Economic Exclusion Zone (EEZ) of nearly 1 million km^2 is of considerable conservation and biological interest because of its isolated position in the middle of the north-eastern Atlantic and the recent geological age of the archipelago. The Azores has led conservation efforts for several decades in Europe with over 100000 km^2 of Azorean coastal habitats, offshore areas, seamounts, hydrothermal vents, and large parcels of mid-ocean ridge in 52 areas designated under some form of protection in the EEZ. However, most of these areas still do not have management plans (which are currently being developed), are small (totalling < 10000 km^2), weakly regulated (< 1% of the Azores sea is fully protected), and lack financial and human resources to allow them to function properly. In addition, there are only a few protected areas located offshore in the EEZ and in the extended continental shelf outside the 200 nautical miles. However, there is a great opportunity to increase the size and levels of protection and implement policies of sustainable use in the region, since the Azores Regional Government is actively pursuing implementation of a sustainable and environmentally friendly model of development.

Blue Azores

The Blue Azores has a vision to facilitate the Azores in becoming a model economy for a blue society where the natural capital is protected, valued, and promoted, through sustainable use of marine-associated businesses and civil society sectors and effective conservation actions across all the marine environment. For that purpose, the Azores Government has partnered with the Oceano Azul Foundation and the Waitt Foundation to implement this vision. The National Geographic Pristine Seas Project is also a partner, together with the Azores University and IMAR – Instituto do Mar, the Portuguese Hydrographic Institute, the Task Group for the Extension of the Continental Shelf, and many other researchers and research institutions from several parts of the world.

The objective of the Blue Azores is to promote marine conservation and sustainable uses of the sea around the Azores through a network of 15% new and fully protected MPAs, developing management plans for the existing ones, implementing sustainable fisheries, increasing literacy about the ocean, and helping to develop a blue economy.

2016 and 2018 Expeditions

Some of the first actions of the Blue Azores were scientific and exploration expeditions to the eastern island groups in September 2016, and to the central and western islands in May–June 2018. The scientific objectives of these expeditions were established with the support of the Regional Government and researchers from the Azores University and IMAR, and aimed to explore the marine environment, especially the poorly studied deep-sea and the open ocean areas in order to quantify the biodiversity of the marine environment.

The 2016 expedition was a partnership with the Waitt Foundation and the Oceano Azul Foundation, with scientific partners (University of the Azores, IMAR – Instituto do Mar, MARE – Marine and Environmental Sciences Centre, CSIC – Spanish National Research Council, CEAB – Blanes Centre for Advanced Studies, CCMAR – Centre of Marine Sciences and CIBIO – Research Centre in Biodiversity and Genetic Resources). The 2016 expedition was carried out on board the Waitt Foundation research vessel Plan-B (Figure 0.3), to quantify the biodiversity of the coastal marine habitats, including the shallow and deep areas around São Miguel and Santa Maria, as well as the Formigas Seamount. The main objective was to assess the health status of the coastal ecosystems (<200 m) of this part of the archipelago. Experimental tagging work on devil rays to test a new non-invasive method was also a goal.

The 2018 expedition was a partnership between the Oceano Azul Foundation, Waitt Foundation, and National Geographic Pristine Seas, with the participation of the University of the Azores and IMAR, the Portuguese Hydrographic Institute, the Portuguese Task Group for the Extension of the Continental Shelf, and other national and international research centres.

The 2018 Oceano Azul Expedition explored Corvo and Flores islands and nearby seamounts (Cachalote and Gigante), the Princess Alice Bank, Pico and São Jorge islands, and the north of Faial. Corvo and Flores are thought to be the most pristine islands in the Azores, and both islands, along with Graciosa, are recognised by UNESCO as Biosphere Reserves: protected areas designed to demonstrate an equilibrium between man and nature. There was some existing data on the coastal habitats around Corvo, but Flores was nearly unexplored prior to the 2018 expedition. The south of Pico Island is a hotspot for whales, dolphins, and other large marine megafauna. The Princess Alice Bank is a shallow water seamount where large fish megafauna aggregate. The Gigante Seamount is a hotspot for tuna and other pelagic and deep-sea predators. The Cachalote Seamount was previously unexplored, and information about the area between Flores and Corvo was also scarce. The scientific objectives of this expedition were to explore the marine environment through:

- Multibeam surveys of the sea bottom at the seamounts, the Mid-Atlantic Ridge, slopes, and plateaus of Corvo and Flores, to produce maps to guide the science efforts;
- In situ surveys of fishes, algae, and other components of the benthic community within two depth strata (10 and 20 m) at Flores, Corvo and Pico;
- Census of marine mammals, sea turtles, sea birds, and marine litter using experienced observers onboard the ships;
- Deployment of deep and shallow water baited/unbaited cameras (BRUVs and dropcams) to assess vulnerable marine ecosystems and the presence of predators (sharks, deep-sea fishes) on the plateaus and slopes of Flores/Corvo islands and nearby seamounts Gigante and Cachalote, and Princess Alice Bank;
- ROV work directed to biodiversity assessments of deep-water fauna and vulnerable marine ecosystems at the Gigante Seamount, Pico, and São Jorge;
- Deployment of open water baited cameras to assess the megafauna and other pelagic components at all sites;
- Tagging dusky groupers at Corvo to understand fish behaviour and effectiveness of the levels of protection of the “Caneiro dos Meros” voluntary reserve.

The 2018 expedition was performed on the vessel Santa Maria Manuela (Figure 0.3), a former cod-fish sailing boat, and the navy ship NPR Almirante Gago Coutinho (Figure 0.3), which conducted multibeam operations and deployed the ROV Luso, owned and operated by the team of EMEPC – Task Group for the Extension of the Continental Shelf.

In this report, we combined the results from these expeditions and previous work conducted throughout the archipelago by research teams at the Azores University and IMAR to describe the marine ecosystems of the Azores, provide policy recommendations, and help inform future conservation and management actions.

FIGURE 0.3.

In 2018 the oceanographic vessel of the Portuguese navy N.R.P Almirante Gago Coutinho (A) and the schooner Santa Maria Manuela (B) conducted surveys of the central and western islands of the archipelago. In 2016 the Waitt Foundation ship Plan B (C) supported the work conducted in the eastern islands.


B


C

MARINE ECOSYSTEMS

MARINE **ECOSYSTEMS**

1. Oceanography and Hydrography

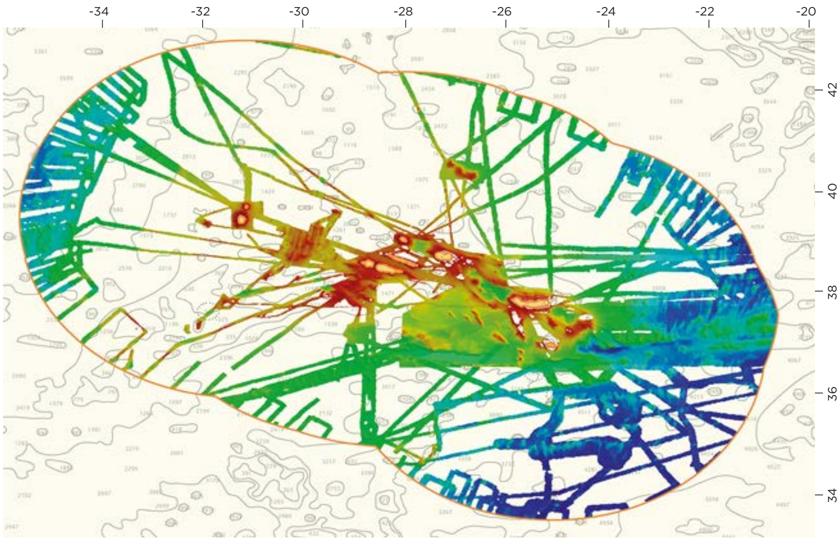
The oceanography of the Azores Archipelago is a complex system of currents (Amorim et al. 2017). Large-scale circulation is dominated by the cold North Atlantic Current in the north and the warm Azores Current in the south, both branches of the Gulf Stream. However, meso and local-scale circulation is strongly shaped by eddies and (re)surface circulations related to topographical features (Santos et al. 1995, Caldeira and Reis 2017). The region's ocean is oligotrophic (Santos et al. 1995) but located at the subtropical/warm temperate ecotone boundary (Afonso et al. 2013), with strong oceanographic seasonal/decadal changes and episodic anomalies (Santos et al. 1995), rendering its marine biodiversity (resident and migratory) unique in the north Atlantic.

Several water masses are present in the Azores region: the North Atlantic Central Water until about 700 m depth; the Northern Sub-Polar Water, the Antarctic Intermediate Water, the Mediterranean Outflow Water at intermediate depths; and the North Atlantic Deep Water below 2000 m depth (Santos et al. 1995; Mann and Lazier, 1996; Johnson and Stevens, 2000). The eastward-flowing Azores current is considered as the northern limit of the North Atlantic Subtropical Gyre (Juliano and Alves, 2007). Average sea surface temperature ranges from 15°C in the winter to 27°C in the summer (Martins et al. 2007). A deep mixed layer is present at around 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).

The Exclusive Economic Zone of Portugal (the 20th largest in the world) has been the focus of recent efforts of detailed mapping using advanced technologies such as multibeam sounders. In the context of the extension of continental shelf submission to the UN, the Hydrographic Institute of Portugal has mapped around 2.6 million square kilometres of ocean floor. However, large parts of the subarea of the Azores EEZ are still unmapped (Figure 1.1).

FIGURE 1.1.

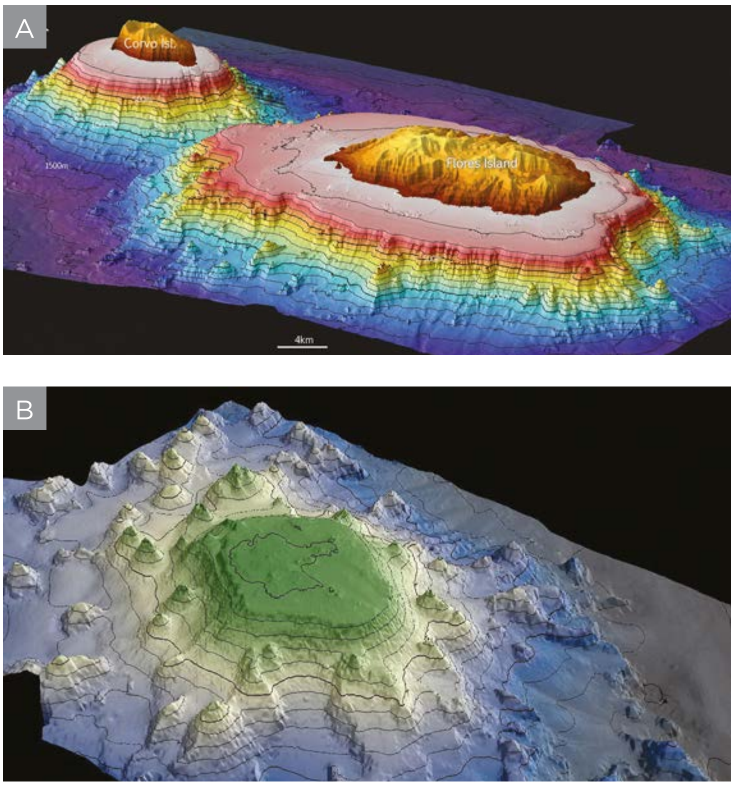
EEZ around the Azores showing the areas already mapped with multibeam sounders. The areas between the central and western group of islands including the Mid-Atlantic Ridge and west of Flores were mapped for the first time during the 2018 expedition (Hydrographic Institute and Task Group for the Extension of the Continental Shelf - EMEPC - multibeam surveys).



During the 2018 expedition, the Hydrographic Institute's ship Gago Coutinho mapped 21469 km^2 of sea floor area around the Mid-Atlantic Ridge, where the Gigante complex is located, as well as the islands of Corvo and Flores and the seamount Cachalote (Figure 1.2). The latter is a subsided island with a typical guyot shape (Lambeck, 1984).

FIGURE 1.2.

Examples of seafloor mapping performed during the 2018 expedition by the Hydrographic Institute's ship Gago Coutinho. (A) the islands of Flores and Corvo; (B) the seamount Cachalote which is a submerged island with the top presently at 440 m.



2. Coastal Reefs and Seamounts

2.1. INTERTIDAL

Rocky littoral communities of the Azores (Figure 2.1) are dominated by macroalgae where turf formations represent the main life form (Wallenstein and Neto 2006). Community structure is mainly shaped by substratum stability—unstable cobble communities are separate from those of more stable boulders and bedrock. Boulders present an intermediate community composition between cobbles and bedrock. Exposure to wave action is a secondary factor influencing community structure and composition and is partly due to the lack of sheltered habitats in the Azores due to the coastal morphology.

FIGURE 2.1.

Intertidal communities at Flores Island.

In the Azores, intertidal communities of rocky shores can be organized in three main zones reflecting their general zonation pattern: the supralittoral fringe, a spray and splash uppermost zone dominated by littorinids; the upper eulittoral dominated by barnacles; and the lower eulittoral dominated by limpets and macroalgae. A general pattern for this zonation is described by Morton et al. (1998) and presented in Table 2.1.

TABLE 2.1.

General pattern of zonation for Azorean bedrock shores (Morton et al. 1998).

Zone	Characterizing Biota	Associated Biota
Maritime	Vascular halophytes (species vary from one shore to another)	Insects, arachnids, lizard (*Lacerta dugesi*), sea birds
Supralittoral fringe	*Melarhaphe neritoides, Littorina striata* and the lichens *Verrucaria maura* and/or *Lichina pygmaea*	*Ligia italica*
Upper eulittoral	*Chthamalus stellatus*	*Littorina striata, Grapsus grapsus*, green algae (*Ulva* sp.)
Lower eulittoral	*Patella candei gomesii* and, occasionally, Patella ulyssiponensis aspera	Certain high-zoned macrophytes (e.g. *Fucus spiralis*), *Stramonita haemastoma, Eriphia verrucosa, Pachygrpsus marmoratus*
Sublittoral fringe and upper sublittoral	Macrophytic algae (various species bound together by *Corallina officinalis*)	Amphipods, sipunculans, gastropods and polychaetes associated with the algal turf; *Paracentrotus lividus*

Natural rock pools are an important habitat feature of the Azorean rocky intertidal zone. They constitute essential fish habitat for several species of fishes (Santos et al. 1994) and invertebrates, including the IUCN Red Listed (Vulnerable) dusky grouper *Epinephelus marginatus*, which utilizes these rock pools as nursery habitat following post-larval settlement (Machado 2010). Juvenile dusky groupers were commonly observed in the rock pools visited at Formigas Islets.

The limpets *Patella candei* (mostly infralitoral) and *P. aspera* (intertidal) are keystone species of the rocky intertidal. They have been subjected to intense exploitation in the Azores in the past few decades, resulting in marked population declines since the 1980s (Martins 2009). To protect these populations and to manage these overexploited stocks, a plan has been established by the Azorean Regional Government declaring various measures, most notably the establishment of limpet protected zones and seasonal fishing closures since 1993 (Santos et al. 1994, Abecasis et al. 2015), but most have been ineffective in protecting these species (Diogo et al. 2016).

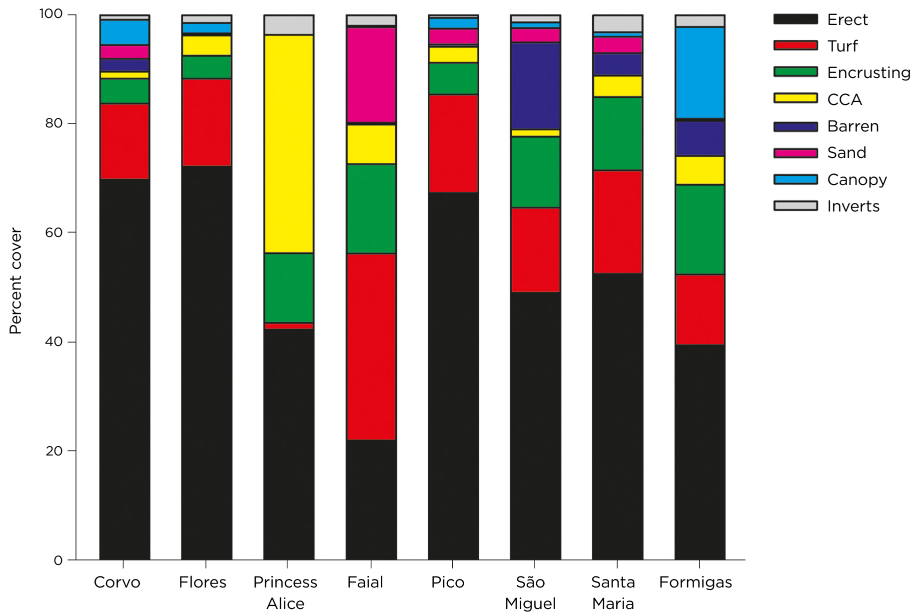
2.2. BENTHIC COMMUNITIES

Characterization of the benthos was conducted along 50 m long transects parallel to the shoreline at each sampling depth strata. For algae and sessile invertebrates, we used a line-point intercept methodology along each transect, recording the species or taxa found every 20 cm on the measuring tape. For mobile invertebrates, we counted individuals in twenty-five 50 x 50 cm quadrats randomly placed along each of the 50 m transects.

Benthic habitats between 5 and 25 m are dominated by erect algae (Figure 2.2.1), although some invertebrates can be abundant above 10 m, such as encrusting sponges, the Azorean barnacle (*Megabalanus azoricus*), and the jewel anemone (*Corynactis viridis*). Sea urchins are scarce and have little influence on the benthos except for the hatpin urchin (*Centrostephanus longispinus*), which is prevalent in waters > 45 m, particularly at Princess Alice Bank.

FIGURE 2.2.1.

Benthic function groups by island. Erect = erect macroalgae, Encrusting = encrusting macroalgae, CCA = crustose coralline algae, Canopy = canopy-forming macroalgae (e.g., *Cystoseira* and *Sargassum*).

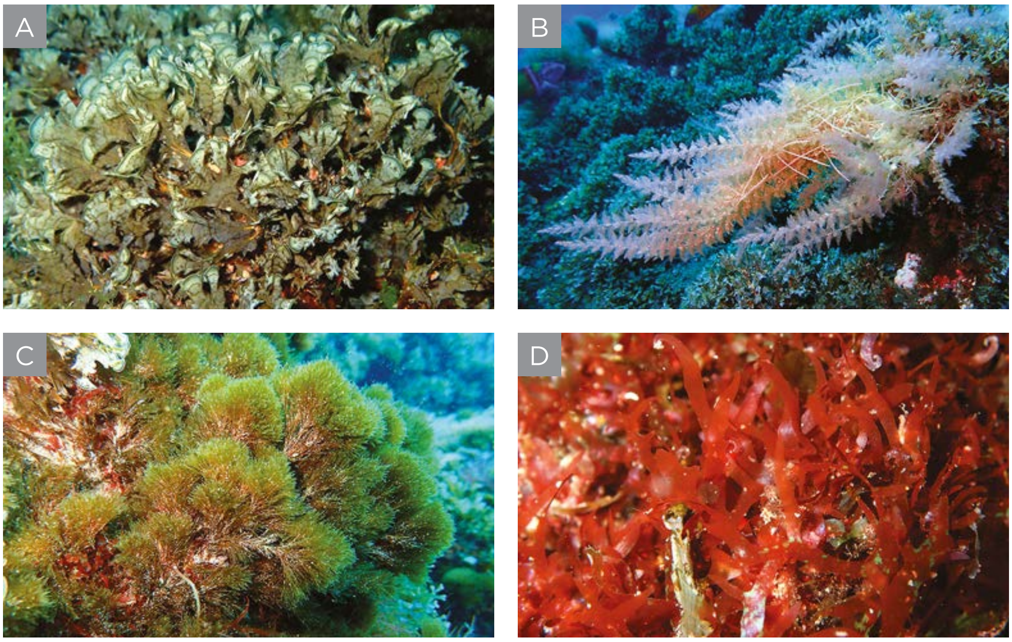


In addition to erect algae, which accounted for 52% of total benthic cover overall, turf algae accounted for an additional 16%, followed by encrusting algae (11%), crustose coralline algae (8%), barren substrate (4%), sand (4%), canopy-forming algae (e.g., *Cystoseira* and *Sargassum*), and invertebrates. Erect macroalgae was highest at Flores (72%), followed by Corvo (70%), and Pico (67%). Faial had the highest percentage of turf algae (34%) and the lowest percentage of erect macroalgae (22%).

Deeper algal assemblages (20 m) were dominated by the brown alga *Zonaria tournefortii* (Figure 2.2.2). At shallower depths (10 m) the assemblage was more variable, with the dominance changing depending on site. Dominant species include: the invasive species *Asparagopsis armata* and *A. taxiformis*, *Z. tournefortii*, turf coralline algae (*Amphiroa*, *Haliptilon*, *Corallina*), *Taonia atomaria*, *Dictyota* spp., *Dictyopteris polypodioides*, *Colpomenia sinuosa*, and *Padina pavonica*.

FIGURE 2.2.2.

Dominant benthic species. (A) *Zonaria tournefortii*, (B) *Asparagopsis armata*, (C) *Halopteris filicina*, (D) *Acrosorium venulosum*.



Large fucoid brown algae such as *Fucus*, which dominate the NE Atlantic continental shores, are general sparser in the Azores. Instead, dense *Cystoseira* beds may develop in rocky tidepools, low intertidal bedrock and shallow infralittoral reefs. Dense forests of *Cystoseira abies marina* (Figure 2.2.3) may still be found throughout the Azores (e.g. Graciosa, São Miguel, Formigas) but have been declining elsewhere in Macaronesia.

FIGURE 2.2.3.

Forest of *Cystoseira abies marina*, with school of chubs, at Formigas.

Erected algae generally become sparser towards deep infralittoral depths (> 40 m depth) due to the low light levels. However, the clarity of the Azores waters permits the transition towards animal-dominated circalittoral communities to occur at nearly 70 m depth, on average (Amorim et al. 2013). Luxuriant deep kelp assemblages may occur at depths of 55 m and persist down to 80 m depth.

Large invertebrates like black corals may occur below 40 m, typically on vertical walls, along with other smaller invertebrates. On sites exposed to strong currents below 10 m, the jewel anemone (*Corynactis viridis*) (Figure 2.2.4) is common. The nudibranch *Felimare picta azorica* (Figure 2.2.5), once considered a subspecies endemic to the Azores, is now considered part of a larger complex (Almada et al. 2016).

FIGURE 2.2.4.

The jewel anemone (*Corynactis viridis*) is a common invertebrate found in both shallow and deeper waters.

FIGURE 2.2.5.

Felimare picta azorica, a nudibranch once considered endemic to the Azores.

Asparagopsis taxiformis (Figure 2.2.6) is a cryptogenic invasive species in the Azores, which covers as much as 20% of the bottom at some locations (e.g. Flores). First reported for São Miguel in 1993 (Neto 1997), it is now present on most islands. Another invasive species is *Clavelina oblonga* (Figure 2.2.7), a sea squirt that was likely introduced from yacht hulls. Its origin is Bermuda and the Caribbean (Wirtz 1995). During the 2016 expedition, particular attention was given to the detection of non-indigenous taxa, with 12 species recorded: three Rhodophyta (*Asparagopsis armata*, *Asparagopsis taxiformis*, *Symphyocladia marchantioides*), six Bryozoa (*Amathia verticillata*, *Bugula neritina*, *Bugulina simplex*, *Schizoporella errata*, *Virididentula dentata*, *Watersipora subtorquata*), two Ascidiacea (*Botryllus schlosseri*, *Distaplia corolla*), and one fish (*Diplodus vulgaris*). Algae were the most representative non-indigenous species group (71 occurrences, 55% of the transects), followed by the common seabream *D. vulgaris* (24%). For the first time in the Atlantic, we detected the invasive red alga *Acrothamnion preissii* (Parente et al. 2018), and also the invasive green alga *Halimeda incrassata* (Santa Maria).

FIGURE 2.2.6.

Asparagopsis taxiformis, is an invasive species in the Azores.

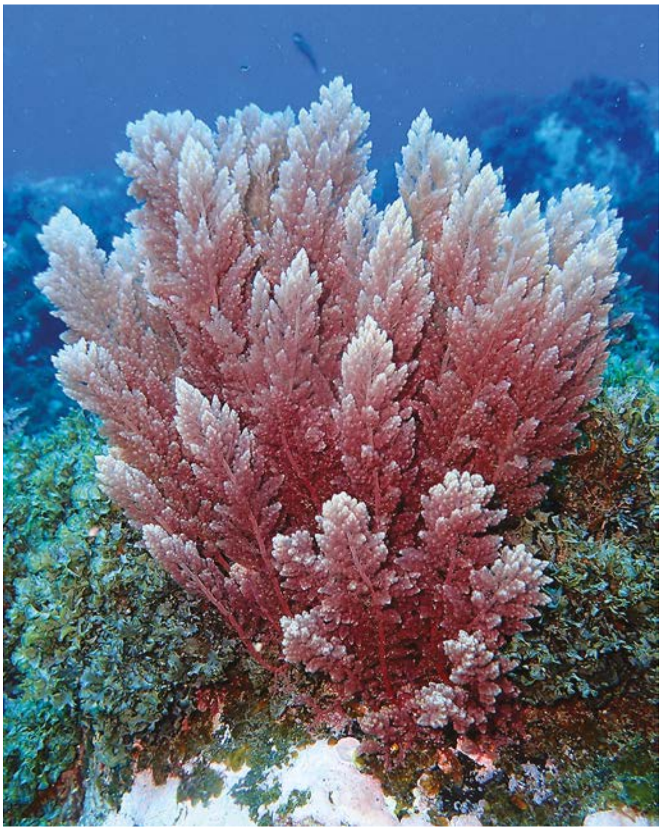


FIGURE 2.2.7.

Clavelina oblonga, an introduced sea squirt.

Island benthic communities showed some separation based on functional groups with Princess Alice Bank being most distinct from the islands. Faial had a distinct benthic community, with sand and turf algae correlating most with this island (Figure 2.2.8, Table 2.2). Erect algae were most closely correlated with Corvo, Flores, and Pico. Formigas, and Santa Maria were highly concordant based on benthic functional groups.

FIGURE 2.2.8.

Principle Coordinates Analysis of benthic functional groups.

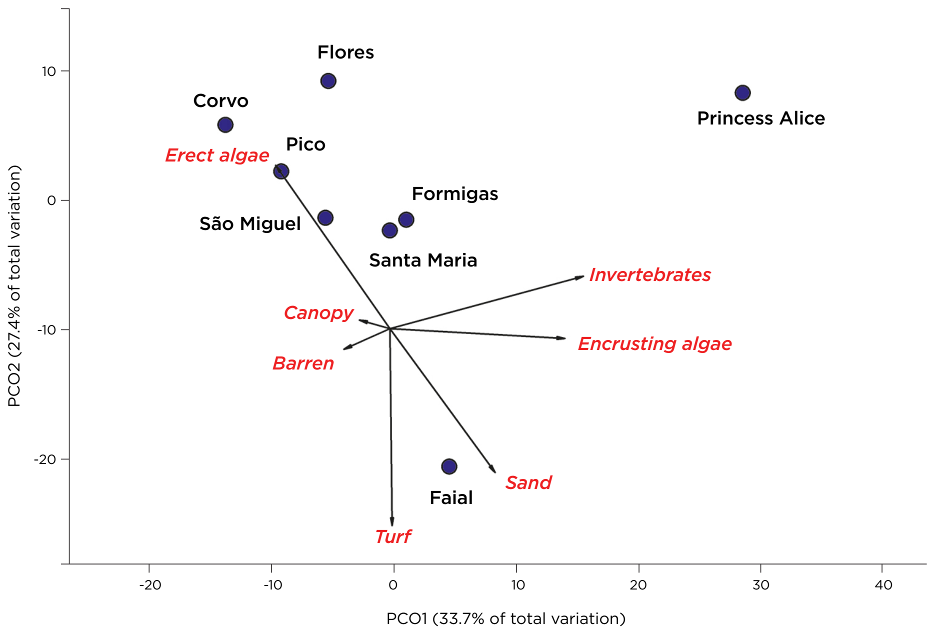


TABLE 2.2.

Functional group cover by island.

Functional	Corvo	Flores	Princess Alice	Faial	Pico	São Miguel	Santa Maria	Formigas
Barren	2.30	0.00	0.00	0.36	0.41	15.94	4.10	6.42
Canopy	4.59	1.92	0.00	0.22	1.97	1.04	0.82	16.85
CCA	1.27	3.74	40.00	7.20	2.99	1.31	3.93	5.29
Encrusting	4.57	4.16	12.80	16.40	5.82	13.02	13.43	16.42
Erect	69.86	72.22	42.40	22.07	67.44	49.10	52.59	39.54
Inverts	0.87	1.41	3.60	1.96	0.47	1.33	3.14	2.15
Sand	2.57	0.38	0.00	17.52	2.90	2.62	3.01	0.38
Turf	13.97	16.16	1.20	34.28	18.00	15.63	18.98	12.95

2.3. FISH ASSEMBLAGES

Fish data obtained during the expeditions was standardised and pooled with previously existing data from the University of the Azores and IMAR team to provide an archipelago-wide assessment of the fish assemblages.

On both expeditions, we used two methods for fish surveys. For the method used by Pristine Seas Expeditions, divers counted and estimated lengths for all fishes encountered within fixed-length (25 m) belt transects at each depth stratum (10 and 20 m depth) within a site. On the initial "swim-out" as the transect line was laid, all fish ≥ 20 cm total length (TL) were tallied within a 4 m wide strip (transect area = 100 m^2). On the return swim back along the laid transect line, all fishes < 20 cm TL were tallied within a 2 m wide strip surveyed (transect area = 50 m^2). Three replicate transects were performed at each depth stratum.

The second method used by the Azores science teams focuses on mobile and larger cryptic fish species, benthic macro-invertebrate, and biotopes (including algae and the presence of non-indigenous species), and is carried out by teams of 3 divers along 50 x5 m transects (fishes, macro-invertebrates) and six regularly spaced 50 x 50 cm photo-quadrats (sessile benthos) along each transect. Each dive included a minimum of two transects to count species (per size class for fishes) and 6 photo-quadrats. Counts were stratified by depth intervals (10–15 m and 20–25 m). Observers noted: 1) the presence of all fishes, classified according to size classes: juvenile, small, medium, large, and very large, according to species-specific sizes for the Azores (Schmiing et al. 2013), and 2) the count of macroinvertebrates above and under the rocks. One observer also estimated the presence of non-indigenous species and the presence of vulnerable marine ecosystems (VMEs; e.g. black coral, kelp).

Fish species richness was significantly different among islands ($F_{7,194} = 5.99$, $p < 0.001$), with the highest richness at Formigas and Faial and the lowest at Flores and Corvo (Figure 2.3.1, 2.3.2). Fish biomass (g m^{-2}) was significantly different among islands ($F_{7,194} = 8.56$, $p < 0.001$), with the highest biomass at Formigas and Faial and the lowest at Flores and São Miguel (Figure 2.3.3). Numerical abundance (individuals m^{-2}) was significantly different among islands ($F_{7,194} = 7.73$, $p < 0.001$), with the highest abundance at Formigas and Santa Maria and the lowest at Corvo and São Miguel.

Thalassoma pavo was the most abundant species accounting for 18% of total fish abundance (Table 2.3.1, Figure 2.3.4). This was followed by schooling fishes such as *Sardina pilchardus*, which was present infrequently but abundant in large schools when found, and *Boops boops*, which accounted for 13% of total fish abundance and was also characteristically observed in large schools. *Coris julis* accounted for 13% of total abundance, followed by *Chromis limbata* (11%). These species had a high frequency of encounter.

TABLE 2.3.1.

Fish numerical abundance (number of individuals m^{-2}) by island.

Species	Corvo	Flores	Faial	Pico	Graciosa	São Miguel	Santa Maria	Formigas	Total
Thalassoma pavo	0.20	0.20	0.36	0.47	0.14	0.14	0.84	1.52	0.42
Sardina pilchardus	0.00	0.00	0.86	1.64	0.13	0.00	0.00	0.00	0.39
Boops boops	0.31	0.25	0.57	0.37	0.69	0.16	0.19	0.02	0.31
Coris julis	0.36	0.42	0.08	0.35	0.45	0.13	0.15	0.14	0.28
Chromis limbata	0.18	0.14	0.33	0.21	0.06	0.09	0.44	0.95	0.26
Atherina presbyter	0.00	0.00	0.00	0.00	0.00	0.00	1.90	0.00	0.21
Sarpa salpa	0.03	0.05	0.18	0.07	0.25	0.13	0.06	0.04	0.10
Abudefduf luridus	0.04	0.04	0.05	0.05	0.01	0.03	0.19	0.27	0.07
Trachurus picturatus	0.45	0.00	0.16	0.00	0.01	0.00	0.00	0.00	0.07
Sparisoma cretense	0.04	0.03	0.04	0.06	0.02	0.01	0.06	0.05	0.04

FIGURE 2.3.1.

Fish assemblage characteristics among islands. Box plots showing median (black line), mean (red line), upper and lower quartiles, and 5th and 95th percentiles. Regions with the same letter are not significantly different (Steel-Dwass unplanned multiple comparisons procedures, α = 0.05).

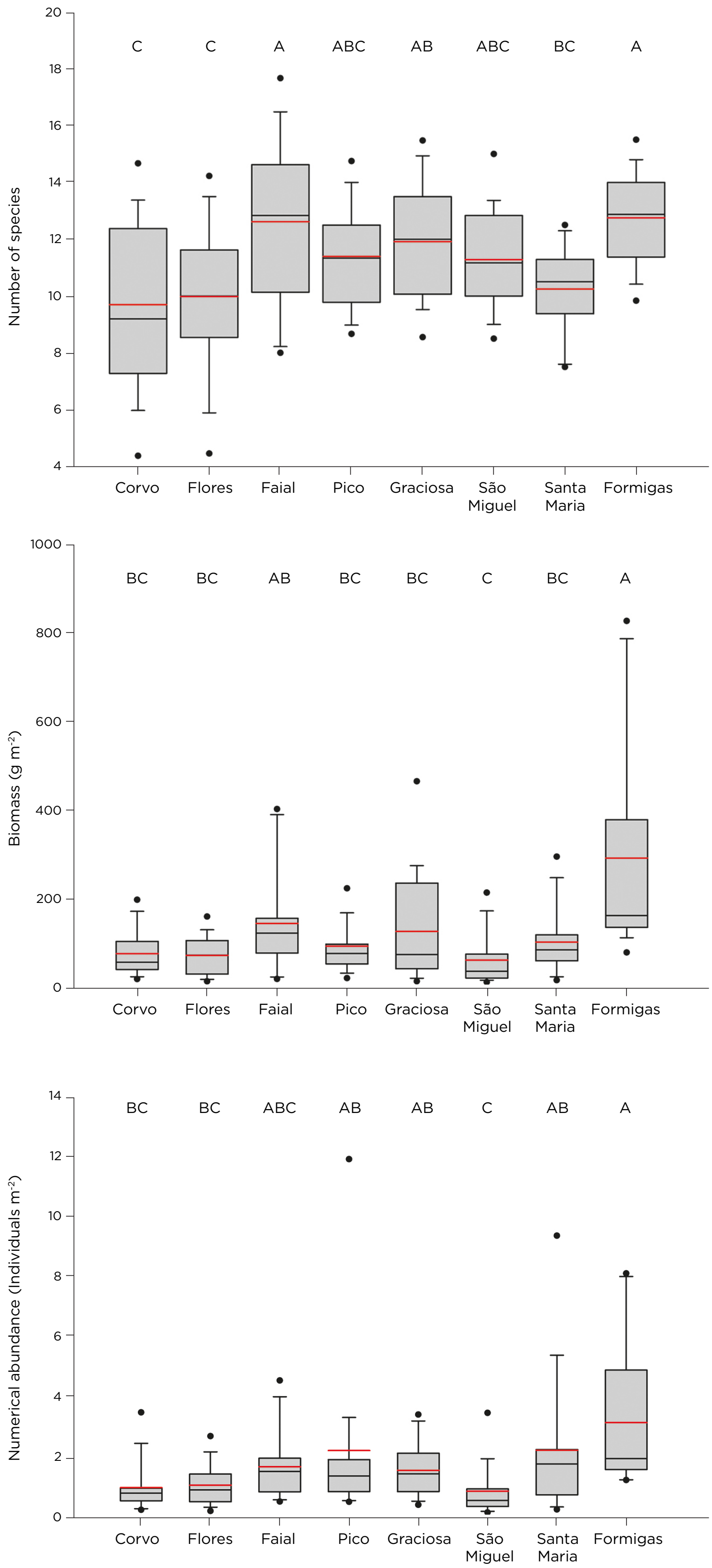


FIGURE 2.3.2.

Fish species richness by sampling location throughout the archipelago. Number of species per transect.

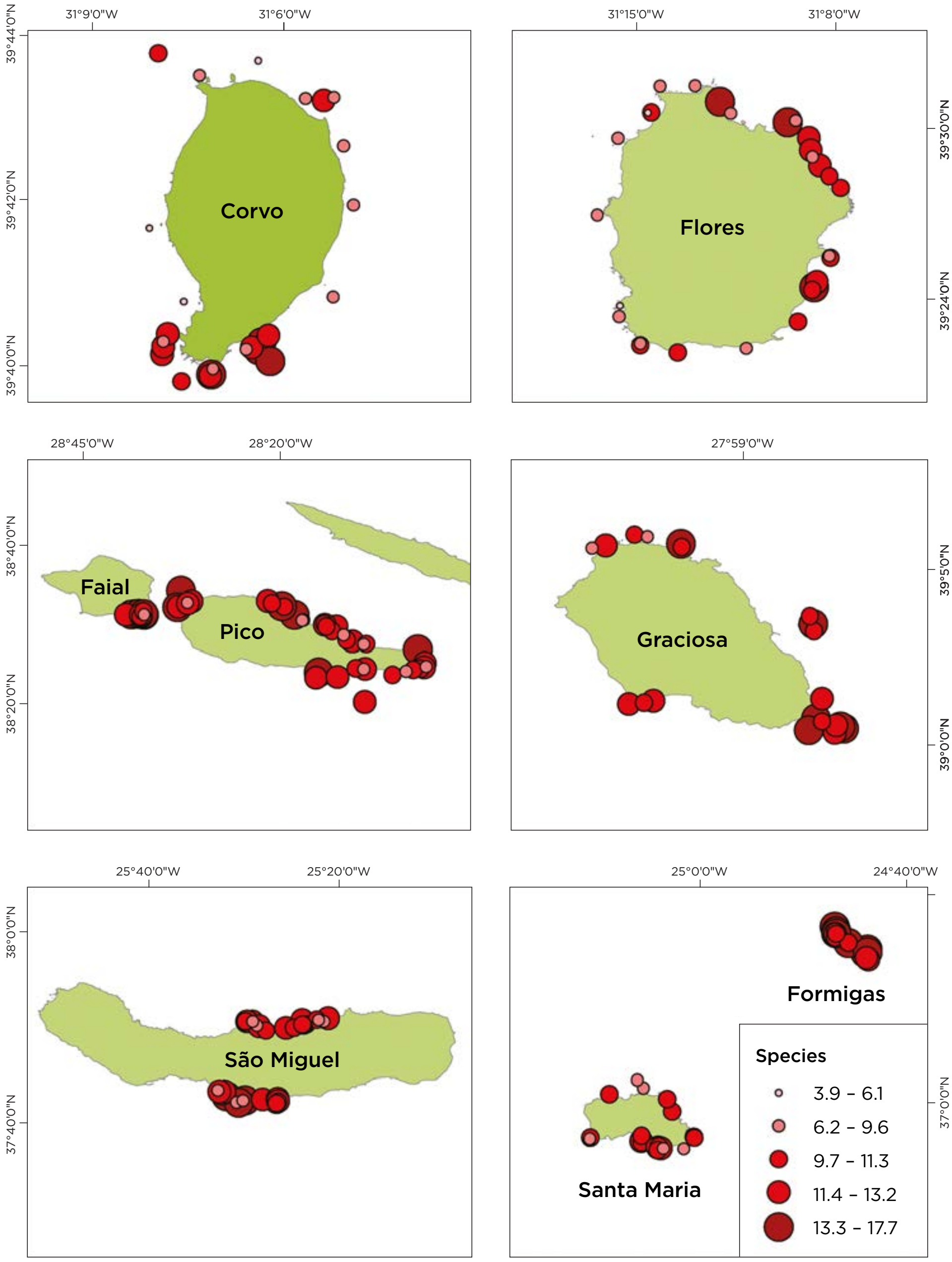


FIGURE 2.3.3.

Fish biomass (g m^{-2}) by sampling location throughout the archipelago.

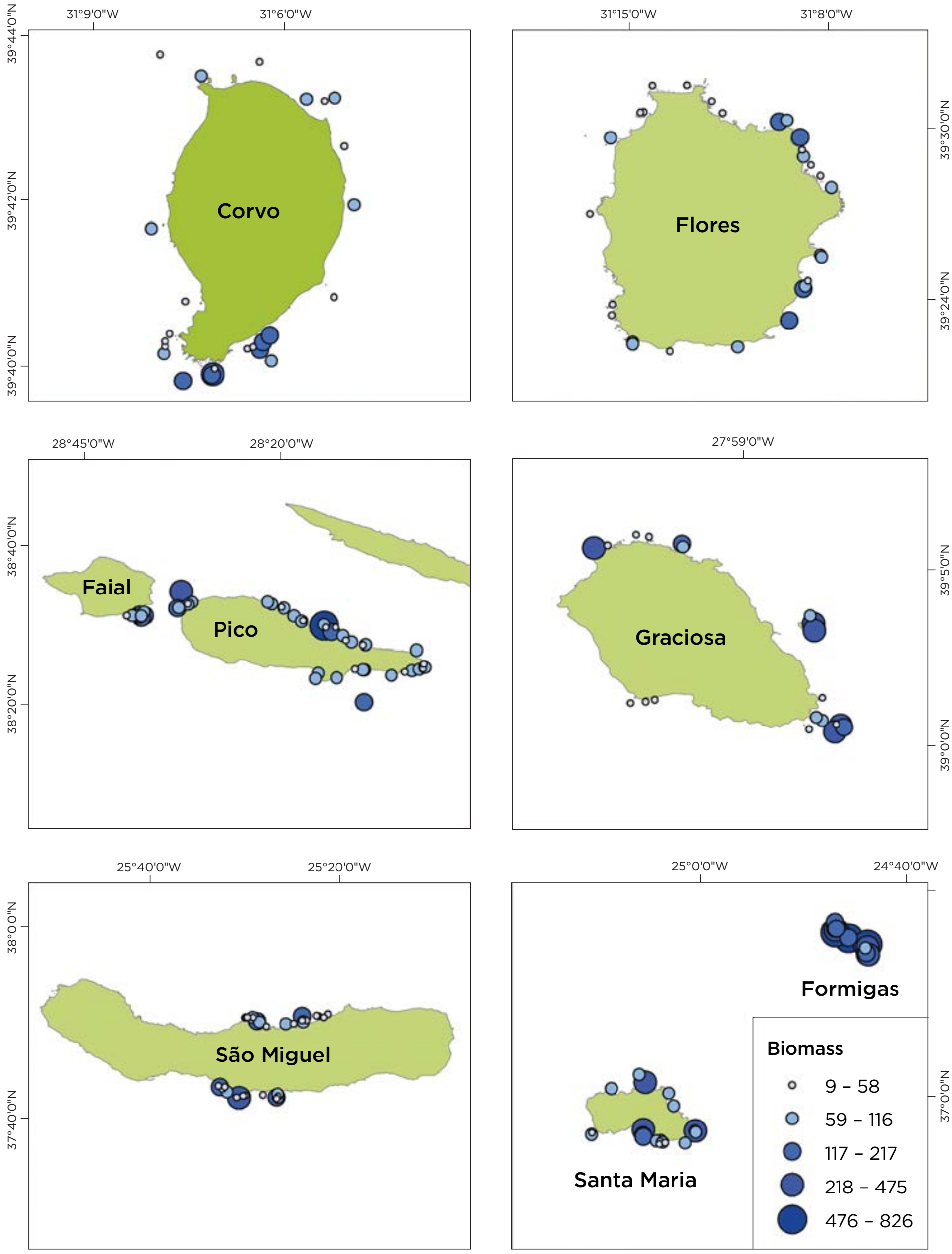


FIGURE 2.3.4.

Thalassoma pavo was the most numerically abundant fish species observed.

Island fish assemblages showed some separation based on biomass (g m^{-2}) with Faial and Pico being most similar, and correlated with the biomass of *Boops boops*, *Sardina pilchardus*, and *Scorpaena* sp. (Figure 2.3.5). Fish assemblages at São Miguel, Flores, Corvo, and Graciosa showed high concordance in ordination space and were distinct from the other island groupings. Formigas and Santa Maria formed a distinct grouping with *Abudefduf luridus*, *Thalassoma pavo*, *Chromis limbata*, and *Kyphosus sectatrix* (Figure 2.3.6) driving much of this separation.

FIGURE 2.3.5.

Principle Coordinates Analysis of fish species by island based on biomass.

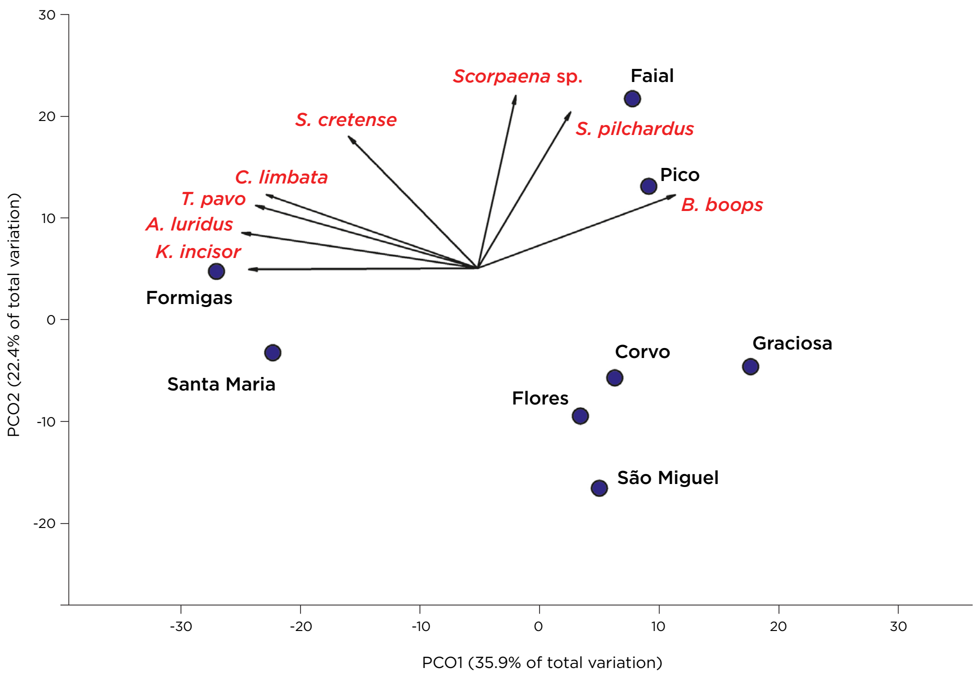


FIGURE 2.3.6.

Kyphosus sectatrix, is an important herbivore in the Azores and is a widely distributed species throughout the Atlantic.

Fish biomass values obtained for the Azores are comparable to heavily fished areas in Madeira and the Canary Islands (Friedlander et al. 2017). Very few top predators were present on these coastal assessments. Pressure on coastal resources seems to be the main cause for these low levels of biomass with the use of nets widespread around several islands. During the 2018 expedition, a large school of several hundred triggerfish was decimated by fishing activity in a matter of hours between the first sighting of this school by divers at Flores Island, to the later arrival of the media team to film the school. Dozens of partial bodies (head and dorsal fins) were found lying on the bottom (Figure 2.3.7).

FIGURE 2.3.7.

School of triggerfish (*Balistes carolinensis*) at Flores island (left) and a few hours later only the remains were found lying on the bottom (right).

2.4. DUSKY GROUPER ACOUSTIC TELEMETRY

The dusky grouper is a species of priority importance for conservation in the region, and a flagship species in the Azores (Figure 2.4.1). Its declining status was the main reason behind the creation, in 1999, of a small voluntary reserve at Corvo Island, when a group of locals and a dive company convinced fishers to stop fishing in the area known as "Caneiro dos Meros" (grouper gully), to support their tourist diving company. This habitat likely hosts the largest density of dusky groupers in the Azores. The dive company closed in 2012, but the fishers continue to protect the area in recognition of its conservation value (Abecasis 2015). This small MPA may also be a source area of larvae of this species for all of Corvo and possibly Flores, as well as serving as a flagship educational program (Figure 2.4.2).

FIGURE 2.4.1.

The dusky grouper, *Epinephelus marginatus*, is listed as Vulnerable by IUCN and is benefiting from protection in a few locations in the Azores.

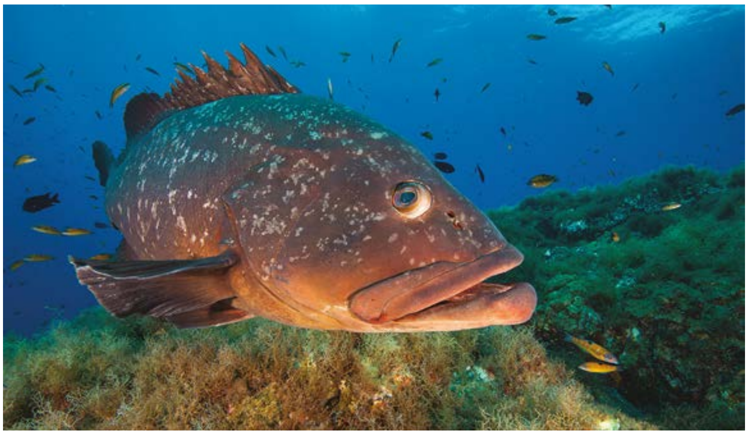


FIGURE 2.4.2.

Acoustic tagging of the dusky grouper at the Boqueirão Harbour with a group of students integrated in the Society for Protection of Birds (SPEA) local environmental education activities (photo F. Ferreira/ PNICorvo).

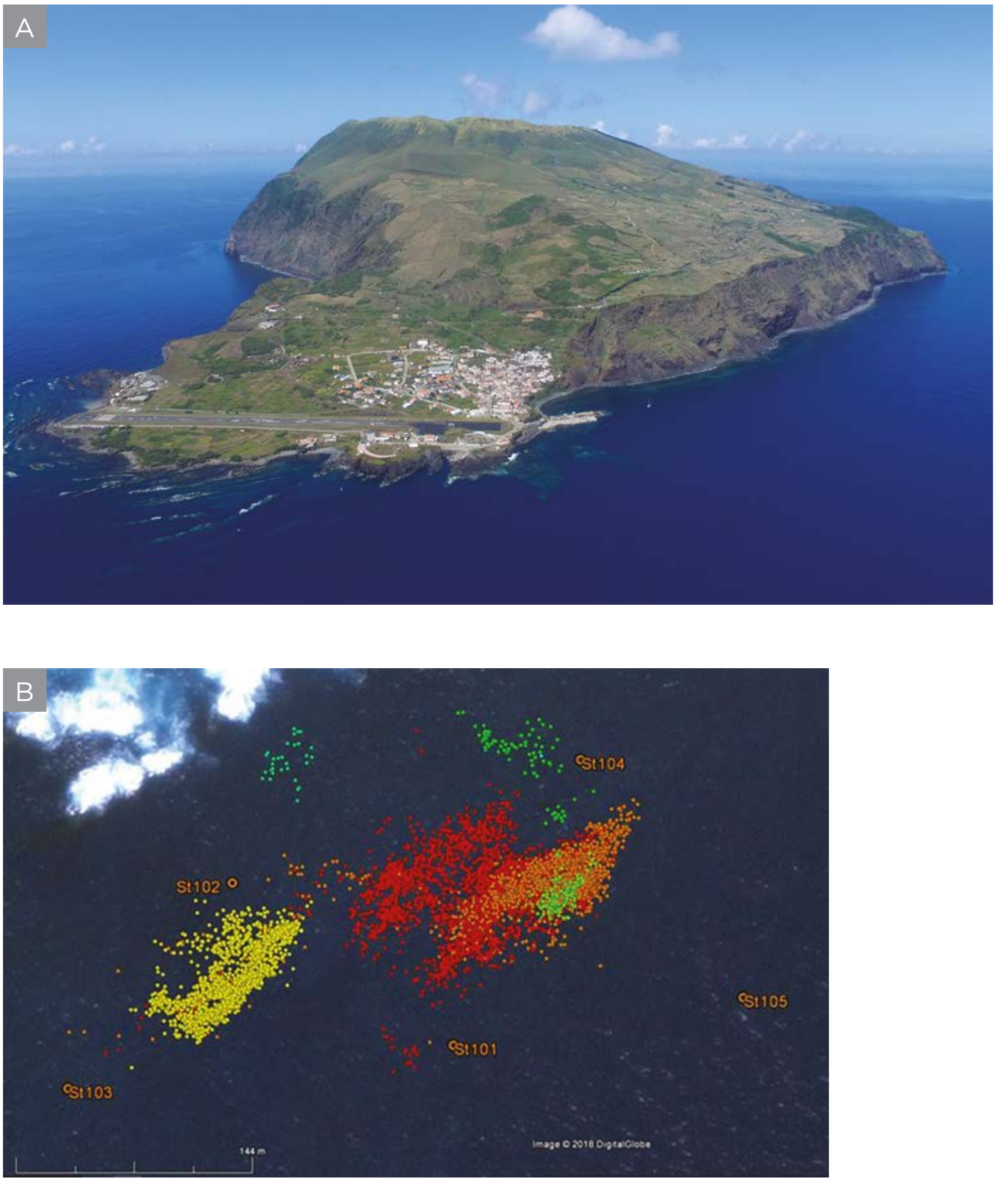
During the 2018 expedition, the team conducted an acoustic telemetry study to assess the potential of this small area to protect dusky grouper territories. Twelve acoustic receivers were moored to the sea bottom in and around the reserve, and in other strategic locations around Corvo Island. Seven groupers were captured while scuba diving, implanted with long-lived acoustic transmitters, and released (Figure 2.4.3). A second batch of 15 fishes was similarly tagged in August 2018, and information from the acoustic receivers of the first seven tagged groupers show that all seven groupers stayed inside the reserve for the 2-month period, as was expected based on previous studies in Faial (Afonso et al. 2013). The groupers' individual territories are also clearly established, and this type of data allows us to better understand the fine-scale habitat use of individual fish relative to one another, showing that fully protected marine reserves can be effective in protecting this species (Figure 2.4.4).

FIGURE 2.4.3.

Implanting acoustic transmitter in dusky grouper.

FIGURE 2.4.4.

(A) Corvo island showing the voluntary grouper reserve on the south side of Corvo with an extensive gully system (photo: Marco Silva). (B) Fine-scale positions of seven dusky groupers during a period of two months at the "Caneiro dos Meros" voluntary reserve. Unique colours represent the movement of individual groupers.



2.5. NEARSHORE SHARK NURSERIES

Potential nursery areas for sharks along coastal habitats around the Azores have been known for years, but never quantitatively assessed (Afonso et al. 2014). An undergoing effort (IslandShark Project) is trying to bridge this gap. Part of this work was developed during the 2018 expedition through interviews conducted on the islands of Flores and Corvo, and later on other islands of the central and eastern groups to assess the local ecological knowledge about potential sites and time periods where sharks are abundant.

Interviewees reported that the smooth hammerhead shark (*Sphyrna zygaena*) is relatively rare, not frequently seen, or fished. Most sightings occur during the summer, with sizes typically ranging from 1–4 m but usually < 2 m. No respondents reported having seen aggregations of this species in the western group, but groups of smaller individuals are frequently spotted on the south coast of Flores Island. In contrast, the islands of Faial, Graciosa, and Santa Maria are reported to host larger summer concentrations of these animals, with up to 20 individuals of approximately 1–1.5 m in length (never > 2 m) sometimes spotted together. Normally, these sightings occur on the island's north shores, including Faial's north coast, where other telemetry and video monitoring studies confirmed the occurrence of these nurseries (Figure 2.5.1). Sightings include the summer occurrence of large, pregnant females putatively coming to the island's shores to pup (Afonso et al. 2014, P Afonso unpublished data).

No aggregations were reported for the tope shark (*Galeorhinus galeus*), although they are frequently sighted in the channel between Flores and Corvo (reported to be > 1 m in length), and frequently caught/landed around all islands (juveniles and adults). One respondent reported parturition (birthing) sites for smooth hammerhead and tope sharks in one bay on the north shore of Santa Maria. Experimental fishing off Faial also show smaller individuals of smooth hammerhead and tope sharks caught along the northern coast of the island, between 60–80 m depth (P Afonso, unpublished).

While no respondents reported having seen aggregations of blue shark (*Prionace glauca*), these animals are frequently seen in the channel between Flores and Corvo, and on seamounts and island slopes around Faial and Pico. Most interviewees reported sighting "young" individuals (< 2 m). One fisher reported fishing a single pregnant female. These data agree with previous studies using fisheries and telemetry data, which indicate the broader Azores region is a nursery area for this species (Aires-da-Silva et al. 2008, Vandeperre et al. 2014, 2016).

FIGURE 2.5.1.

Sub-adult smooth hammerhead sharks on Faial's north shore.

2.6. MESOPHOTIC REEFS

Mesophotic ecosystems (30–150 m) are considered extensions of shallow reef communities and may greatly increase the available habitats for reef organisms, yet they have received relatively little attention owing to the difficulty in studying these habitats (Lesser et al. 2009, Puglise et al. 2009; Hinderstein et al. 2010, Rocha et al. 2018).

We sampled fishes using mesophotic baited remote underwater video systems (BRUVS) at depths from 13 to 170 m depth at Faial (N=3), Pico (N=4), Corvo (N=8), and Flores (N=16) islands (Figure 2.6.1). Our stereo-video BRUVS used GoPro Hero 4 cameras with a single light source and were baited with ~ 1 kg of oily fish (mackerel) and deployed for a minimum of 60 minutes. We targeted 3 depth strata: 50 m, 110 m, and 170 m, but also conducted some drops in shallower waters as conditions allowed. Results presented below are for surveys from 50–170 m only (25 drops at Flores and Corvo).

We recorded 645 individual bony fishes and rays on mesophotic BRUVS. Surprisingly, no sharks were observed during the mesophotic surveys. We identified 34 taxa to species, 3 to genus, 2 to family, and 5 remained unidentified. The ten most abundant species were *Anthias anthias*, *Boops boops*, *Coris julis*, *Serranus atricauda*, *Sphoeroides marmoratus*, *Muraena helena*, *Seriola rivoliana*, *Pagellus bogaraveo*, *Pagrus pagrus*, and *Balistes carolinensis* (Figure 2.6.2, 2.6.3). Most of these species had their highest abundance at the 50 m stations with only *Anthias anthias* and *Pagellus bagaraveo* abundant at the 170 m depth.

Fourteen species were observed on both mesophotic BRUVs and deep SCUBA surveys. Of these, the majority were observed only on the 50 m depth BRUVs. However, one species, *Sphoeroides marmoratus*, was observed at 50 m and 110 m while two species, *Serranus atricauda* and *Pagrus pagrus*, were observed at all three BRUV depth strata. The patterns of station occupancy were similar to those of abundance. The 10 most frequently occurring species were: *Sphoeroides marmoratus*, *Serranus atricauda*, *Muraena helena*, *Pagrus pagrus*, *Anthias anthias*, *Coris julis*, *Raja* sp., *Balistes carolinensis*, *Pseudocaranx dentex*, and *Diplodus sargus cadenati*. Of these, only 3 species (*Raja* sp., *P. dentex*, and *D. s. cadenati*) were among the top 10 most frequently occurring but not among the most abundant.

FIGURE 2.6.1.

Locations of mesophotic baited remote underwater video system deployments.

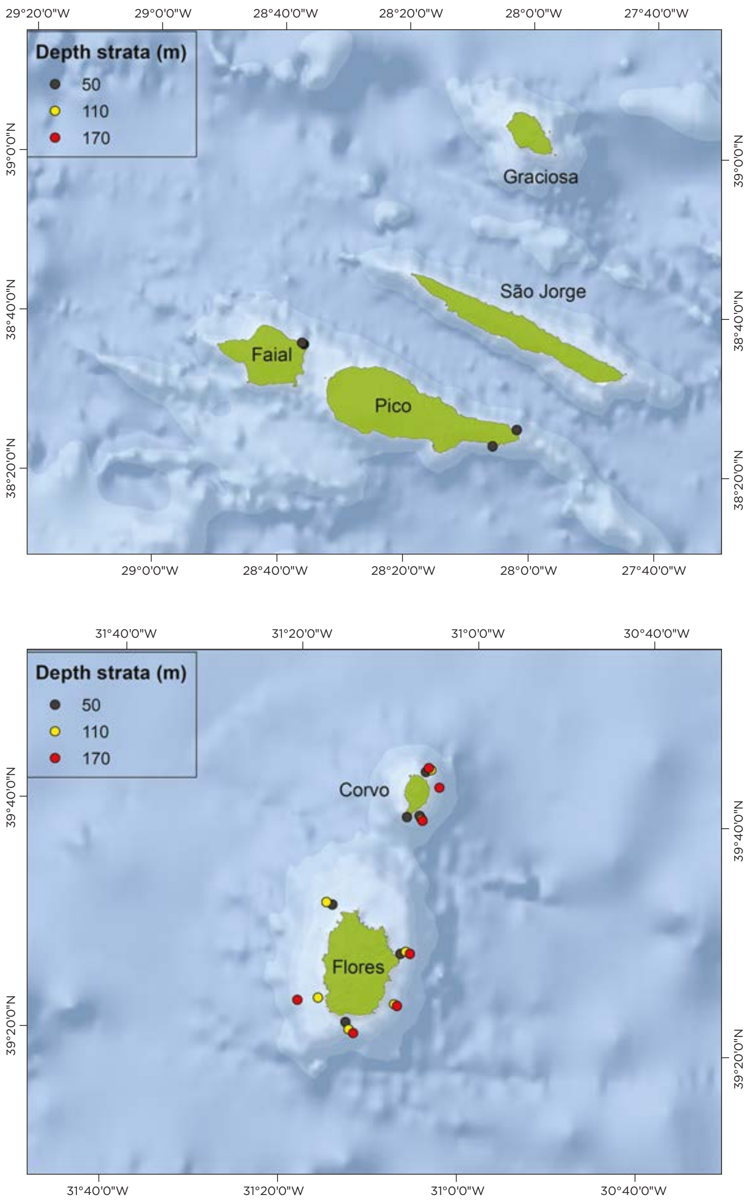


FIGURE 2.6.2.

MaxN and depth distribution of taxa observed on mesophotic BRUVS.

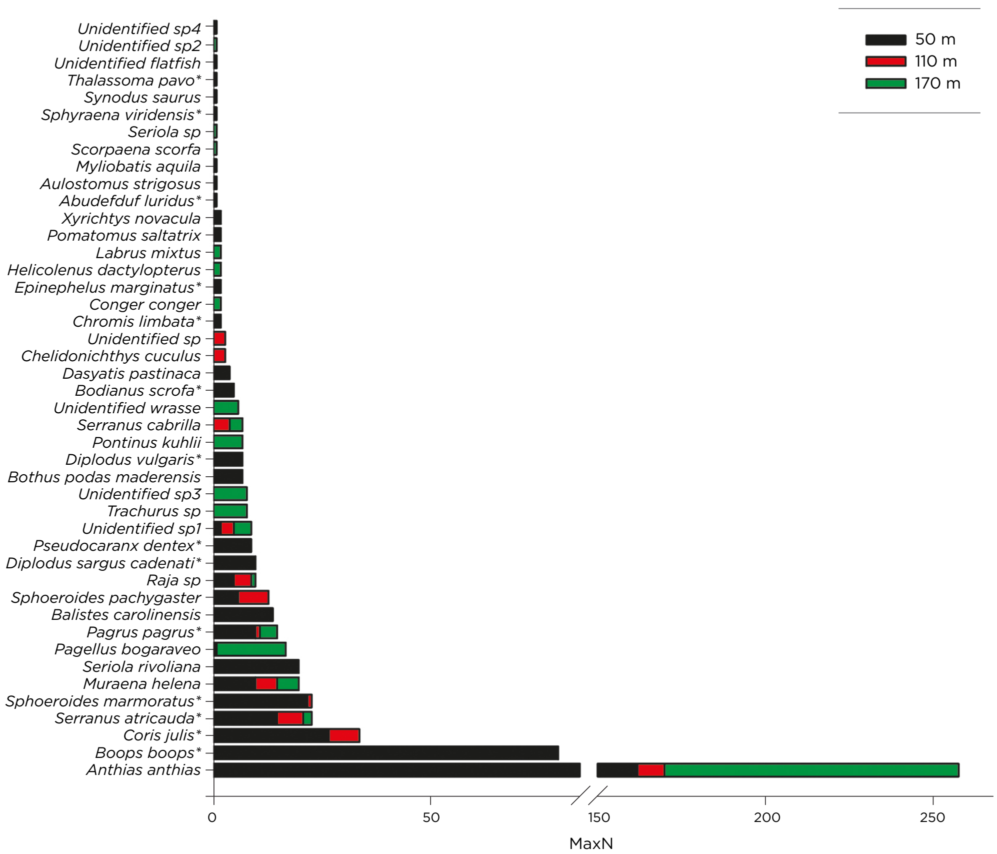
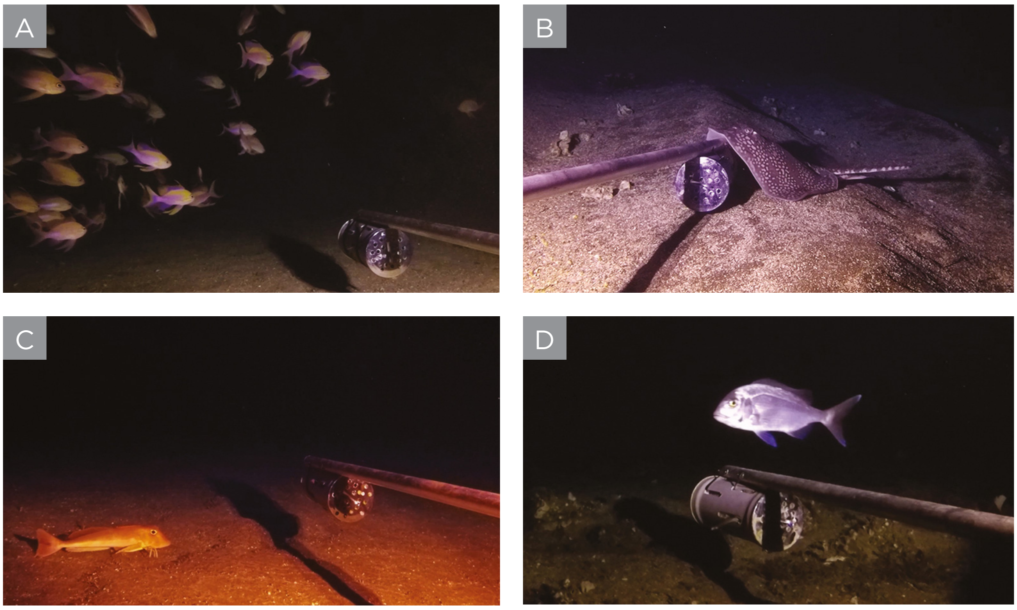


FIGURE 2.6.3.

(A) *Anthias anthias* – 170 m.
(B) *Raja* sp. – 110 m.
(C) *Chelidonichthys cuculus* – 110 m.
(D) *Pagrus pagrus* – 170 m.



Sampling of benthic habitats was also conducted using an unbaited single dropcam with lights, which was used to identify vulnerable marine ecosystems such as maerl beds, deep kelp beds, coral gardens, and sponge aggregations, predominantly on hard bottoms between 50 and 200 m. Stations were at approximately 30 m depth intervals along radial transects perpendicular to the shoreline and covering different wave exposure and seabed geomorphologies. Additional sampling was performed at sites where multibeam surveys indicated potentially interesting seabed features. The distribution of the 49 successful deployments of these dropcams made around Corvo and Flores is shown in Figure 2.6.4.

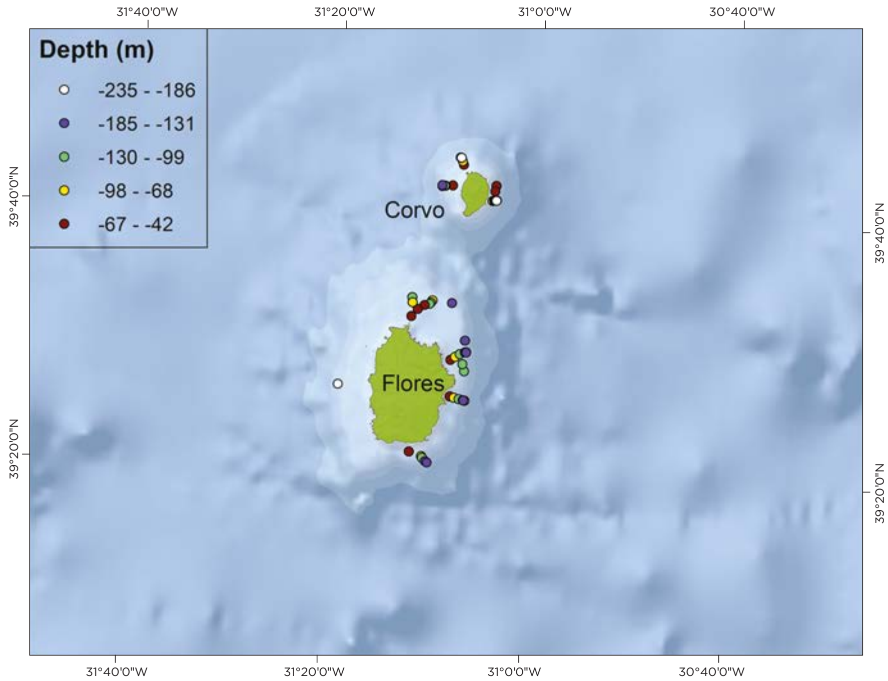


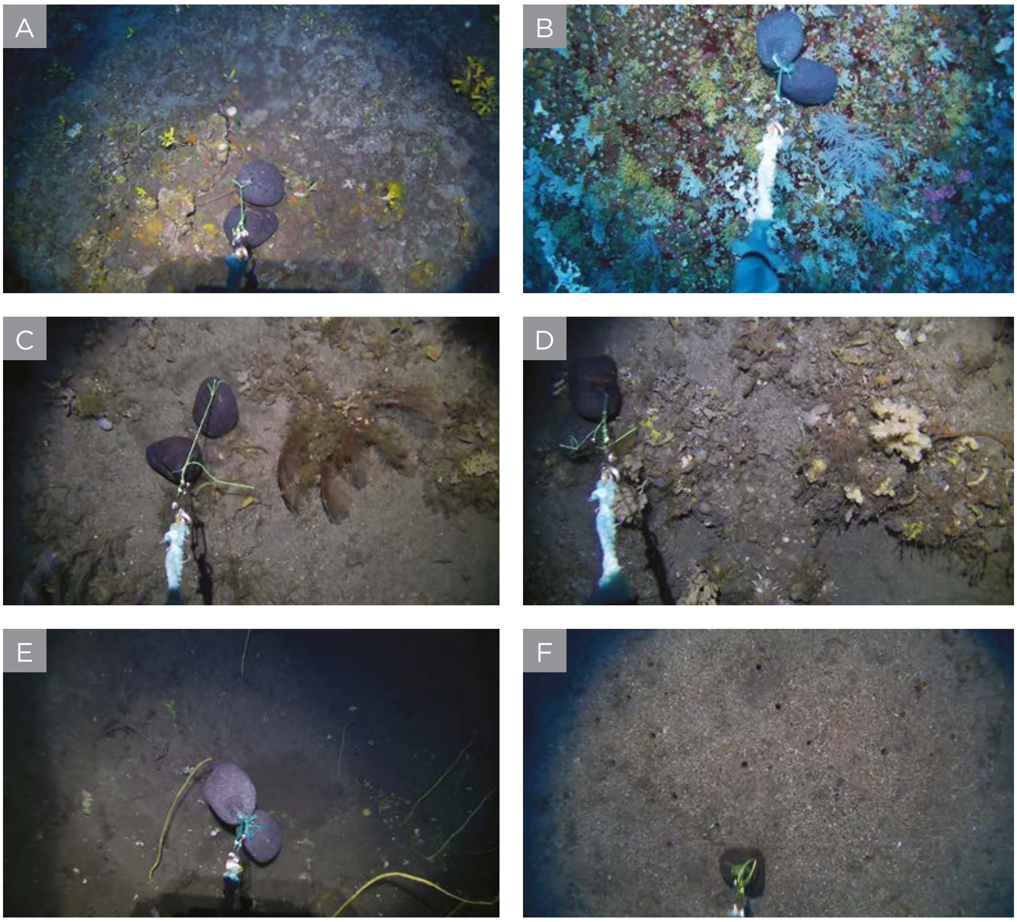
FIGURE 2.6.4.

Location of the successful drop cam deployments made around Corvo and Flores.

Previously unknown circalittoral habitats (see Tempera et al., 2013 for a review) were found, hosting fragile habitat-forming species of conservation interest such as hard corals, gorgonians, tall leptothecate hydroids, and large sponges (Figure 2.6.5 A to E). Sediments between 80 and 110 m exhibited dense infauna beds of yet to determined species, revealed by numerous small circular burrows (Figure 2.6.5. F).

FIGURE 2.6.5.

Circalittoral assemblages recorded around Flores and Corvo islands with the unbaited dropcam. (A) Dendrophylliid coral garden (155 m), (B) dense faunal turf of anemones and gorgonians (92 m), (C–D) mixed aggregations of sponges, corals and tall hydroids (135 m); (E) gorgonian garden (220 m); (F) dense infauna bed (112 m).



No kelp was recorded in this sampling, reinforcing the remarkable isolation of the western island group. These islands are geomorphologically separated from the rest of the archipelago by the Mid-Atlantic Ridge, and are the most upstream location in the archipelago along a pathway of prevailing eastward currents. In this context, the biological communities of Flores and Corvo are particularly vulnerable due to isolation, as they are less likely to receive recruitment from other islands or propagules dispersing from other Macaronesian archipelagos and seamounts or the European shores.

3. Open Water

3.1. MID-WATER COMMUNITIES

Stereo mid-water Baited Remote Underwater Video Stations (BRUVS; Letessier et al. 2015) were used to survey the pelagic fish assemblages and to determine how mid-water communities vary across the archipelago. Each BRUVS rig consisted of a metal bar with two GoPro cameras 80 cm apart with an inward convergent angle of 8°. Five rigs were deployed concurrently at each site in a longline formation, each separated by 200 m of surface line (800 m in total). The longline was deployed perpendicular to the current. Rigs were baited with ~ 800 g of mashed mackerel and deployed with a minimum recording time of two hours. At Cachalote Seamount, the last set ran ~70 mins.

The pelagic communities across the western and central groups of the Azores, including Cachalote Seamount (n=3), Flores Island (n=8), Corvo Island (n=8), Gigante Seamount (n=1), Princess Alice Bank (n=2) and Pico/São Jorge Islands (n=9), were sampled.

The video from each rig was processed and all individual fish observed were identified to the lowest possible taxonomic level, and the maximum number of individuals per frame of video (MaxN) was estimated for each species. MaxN is a relative measure of abundance and avoids double counting of individuals within the same video. Fork lengths were also determined for a subset of individuals by using both the right and left camera vision for each rig. All video analyses were based on methods described in Letessier et al. (2015) and used SeaGis software.

We recorded 8814 individual pelagic fishes, sharks, rays and marine mammals, representing 15 taxa from 12 families, with all taxa except mackerel (*Trachurus* sp., likely *T. picturatus* or *T. trachurus*) identified to species (Table 3.1.1, Figure 3.1.1). Overall, the most abundant species were small forage fishes. Longspine snipefish (*Macroramphosus scolompax*) had the highest mean abundance per deployment, followed by boarfish (*Capros aper*) and mackerel (*Trachurus* sp.). However, in terms of frequency of occurrence, boarfish were the most common, observed at 77% of sites, followed by mackerels at 74% of sites. Longspine snipefish were only found at 48% of sites, but were observed in large schools on some deployments, with > 3000 individuals registered on one set. Sharks were observed regularly, with blue sharks (*Prionace glauca*, Figure 3.1.2) and shortfin mako (*Isurus oxyrhynchos*, Figure 3.1.3) detected at 32% and 23% of sites, respectively. Remoras (*Remora remora*) associated with the sharks were observed at 16% of sites, while grey triggerfish (*Balistes capriscus*) occurred at 23% of sites, and rudderfish (*Centrolophus niger*) were observed at 13% of sites. All other species were observed at < 10% of sites.

Pelagic species richness varied significantly among locations ($F_{5,154} = 4.84$, $p < 0.001$) and was highest at Gigante Seamount, followed by Princess Alice Bank and Flores Island (Figure 3.1.4). Total abundance of individual fishes also varied significantly among locations ($F_{5,154} = 14.04$, $p < 0.001$) with the highest total abundance of fishes at Gigante Seamount, followed by Flores (Figure 3.1.4). These differences are largely driven by the occasional observations of large schools of small forage fishes.

Some species were observed at all sites while others were only associated with coastal waters. Boarfish, longspine snipefish, horse mackerel, and blue sharks were observed at all locations. Shortfin mako sharks and grey triggerfish occurred at each of the island sites as well as Princess Alice Bank; however, none were observed at Cachalote or Gigante seamounts. Rudderfish were observed only at the island locations of Flores, Corvo and Pico/São Jorge. Atlantic spotted dolphins (*Stenella frontalis*) were observed at Flores and Princess Alice Bank. Single observations were made of common stingray (*Dasyatis pastinaca*), blue marlin (*Makaira nigricans*), and longfin yellowtail (*Seriola rivoliana*) at Flores and a single sharptail mola (*Masturus lanceolatus*) was detected at Corvo. Imperial blackfish (*Shedophilus ovalis*) were observed only at Princess Alice Bank. Remoras were observed in association with sharks at Princess Alice Bank, Pico/São Jorge and Corvo. Pilot fish (*Naucrates ductor*) were observed at Princess Alice Bank and Corvo.

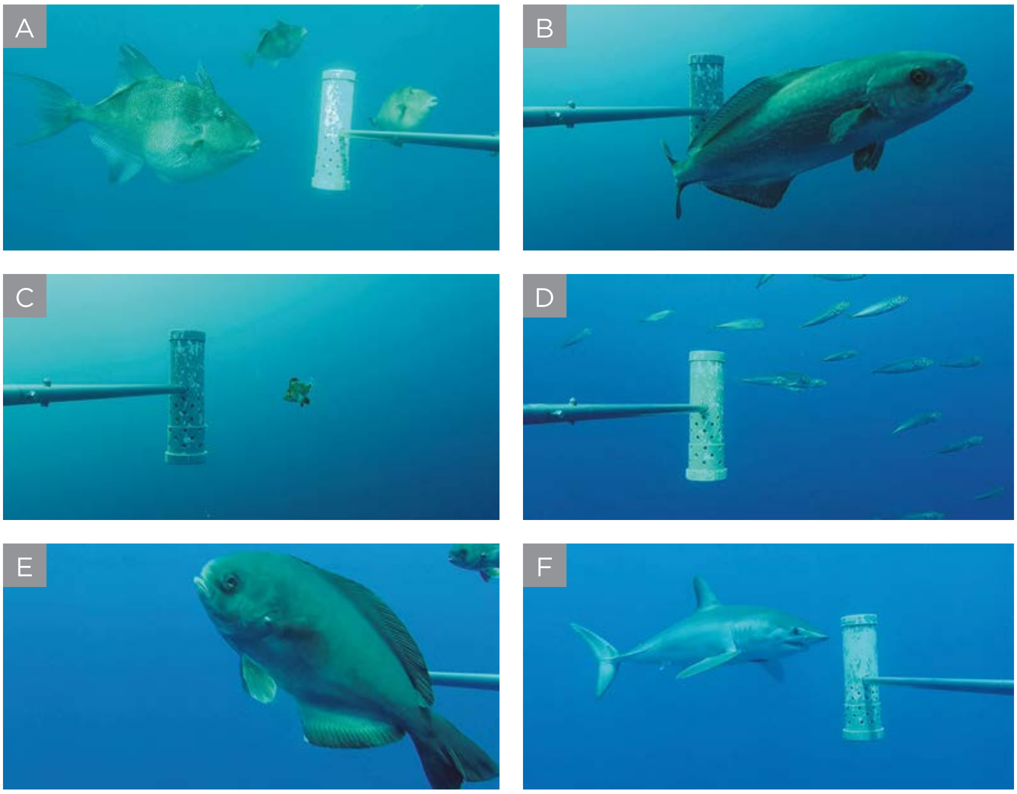


FIGURE 3.1.1.

Species observed on mid-water baited remote underwater video systems: (A) grey triggerfish (*Balistes capriscus*), (B) rudderfish (*Centrolophus niger*), (C) boarfish (*Capros aper*), (D) horse mackerel (*Trachurus* sp.), (E) imperial blackfish (*Shedophilus ovalis*) and (F) shortfin mako shark (*Isurus oxyrhynchos*).

TABLE 3.1.1.

Species-specific metrics from pelagic BRUVS during the 2018 expedition. Total represents the sum of MaxNs for each species across all individual rig deployments, mean MaxN per deployment is the maximum number of species observed per frame on each individual rig divided by the total number of deployments, percentage of sites observed is the percentage of mid-water BRUVS sample sites at which the species was observed, minimum (Min length), maximum (Max length) and mean lengths for each species are reported in centimetres.

Family	Species	Common name	Total	MaxN (± sd)	% sites observed	Mean length (cm) (± sd)	Min length (cm)	Max length (cm)
Balistidae	*Balistes capriscus*	Grey triggerfish	52	0.33 (0.16)	23	30.79 (0.05)	26.85	36.70
Caproidae	*Capros aper*	Boarfish	1337	8.63 (3.95)	77	3.30 (0.05)	1.34	7.51
Carangidae	*Naucrates ductor*	Pilotfish	9	0.06 (0.05)	6	25.93 (1.02)	23.04	31.43
	Seriola rivoliana	Longfin yellowtail	1	0.01 (0.01)	3	27.72 (-)	27.72	27.72
	Trachurus sp	Horse mackerel	2260	14.58 (3.14)	74	9.08 (0.12)	3.19	25.10
Carcharhinidae	*Prionace glauca*	Blue shark	15	0.10 (0.02)	32	109.85 (23.18)	37.07	246.62
Centriscidae	*Macroramphosus scolopax*	Longspine snipefish	5108	32.96 (23.03)	48	5.15 (0.12)	1.79	19.07
Centrolophidae	*Centrolophus niger*	Rudderfish	4	0.03 (0.01)	13	24.54 (4.55)	16.20	34.43
	Schedophilus ovalis	Imperial blackfish	3	0.02 (0.02)	3	36.21 (1.53)	34.67	39.27
Dasyatidae	*Dasyatis pastinaca*	Common stingray	1	0.01 (0.01)	3	90.52 (-)	90.52	90.52
Delphinidae	*Stenella frontalis*	Atlantic spotted dolphin	9	0.06 (0.05)	6	155.43 (9.24)	108.44	178.75
Echeneidae	*Remora remora*	Remora	6	0.04 (0.02)	16	10.98 (1.33)	6.67	14.56
Istiophoridae	*Makaira nigricans*	Blue marlin	1	0.01 (0.01)	3	-	-	-
Lamnidae	*Isurus oxyrinchus*	Shortfin mako shark	7	0.05 (0.02)	23	168.87 (9.99)	145.74	220.05
Molidae	*Masturus lanceolatus*	Sharptail mola	1	0.01 (0.01)	3	154.35 (-)	154.35	154.35

FIGURE 3.1.2.

Blue sharks (*Prionace glauca*) were observed at 32% of pelagic sampling stations.

FIGURE 3.1.3.

Shortfin mako sharks (*Isurus oxyrinchus*) were observed at 23% of pelagic sampling stations.

FIGURE 3.1.4.

Pelagic species richness (top) and numerical abundance (bottom) for each location from mid-water BRUVS. Box plots showing median (black line), mean (red line), upper and lower quartiles, and 5th and 95th percentiles. One-way ANOVA with Tukey HSD multiple comparison tests. Locations with the same letter are not significantly different. Numerical abundance is ln(x+1) transformed.

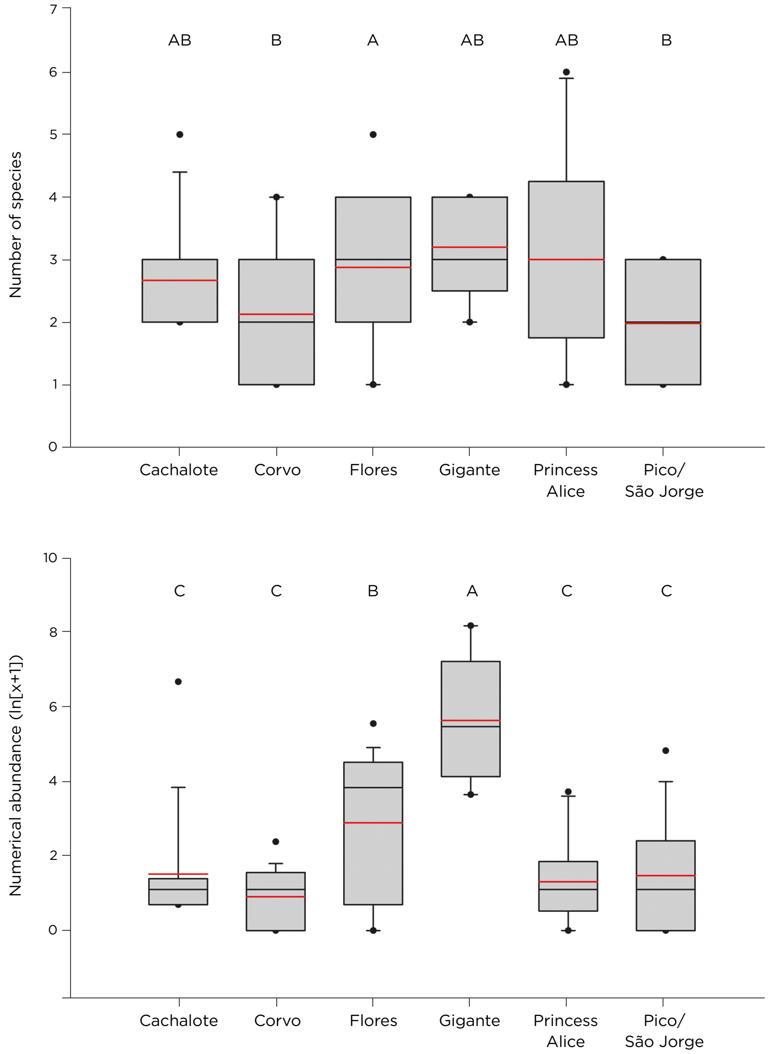
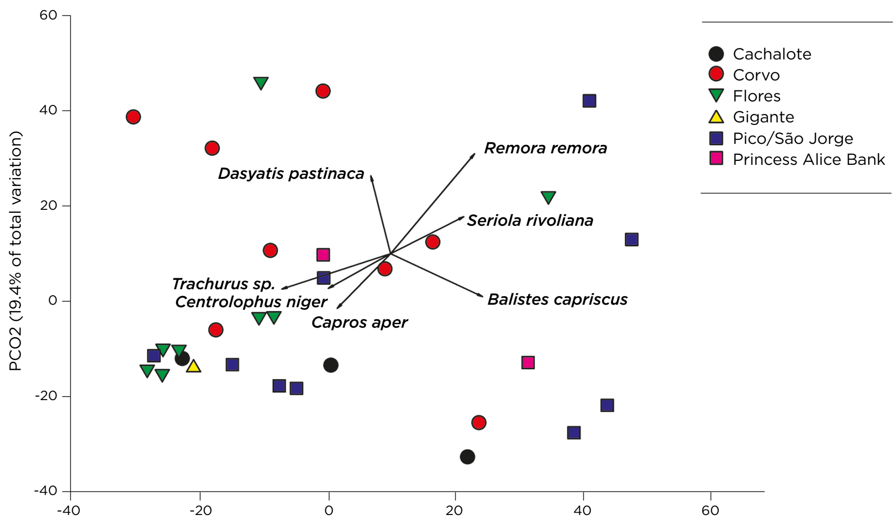


FIGURE 3.1.5.

Principal coordinates analysis displaying variation in species composition among locations based on Bray-Curtis Similarity Index of ln(x+1) transformed numerical abundance data. Overlaid vectors indicate species with a correlation higher than 0.30.



Species composition varied significantly among locations (Pseudo-$F_{5,30}$ = 1.56, p = 0.039, Figure 3.1.5). Seamounts (Gigante, Cachalote, and Princess Alice Bank) clustered together in multivariate space, with *Trachurus* sp., *Centrolophus niger*, and *Capros aper* most closely correlated with these locations. Overall, sites within locations were highly variable with low concordance.

The pelagic realm had rich plankton communities, which provide a crucial source of food to many large aquatic organisms, such as fish, turtles, and whales (Figure 3.1.6, 3.1.7). It also provides habitat for the larvae and juveniles of myriad aquatic organisms.

FIGURE 3.1.6.

The Portuguese man o' war (*Physalia physalis*) is found throughout the world's oceans.

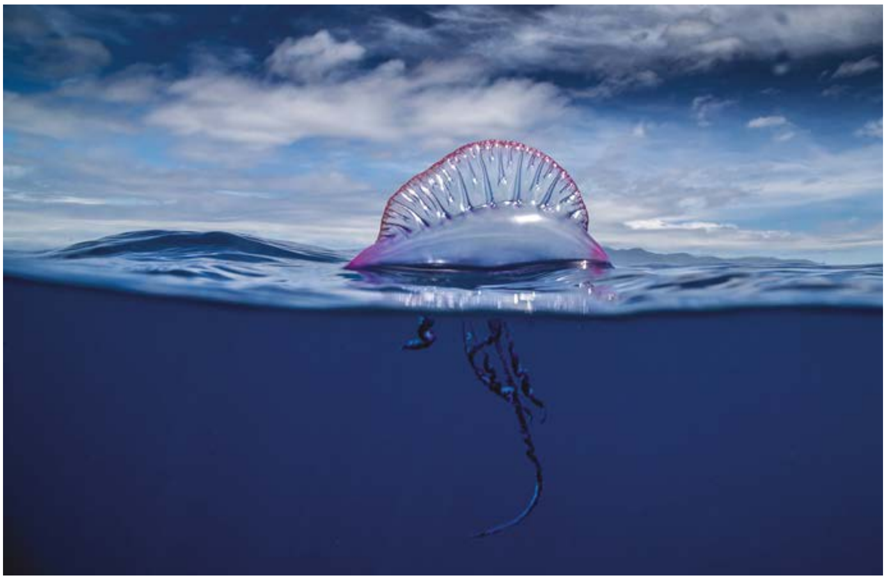


FIGURE 3.1.7.

Glaucus atlanticus is a pelagic sea slug that also has a global distribution. It is able to feed on the Portuguese man o' war due to its immunity to the venomous nematocysts.

3.2. DEVIL RAY BEHAVIOUR

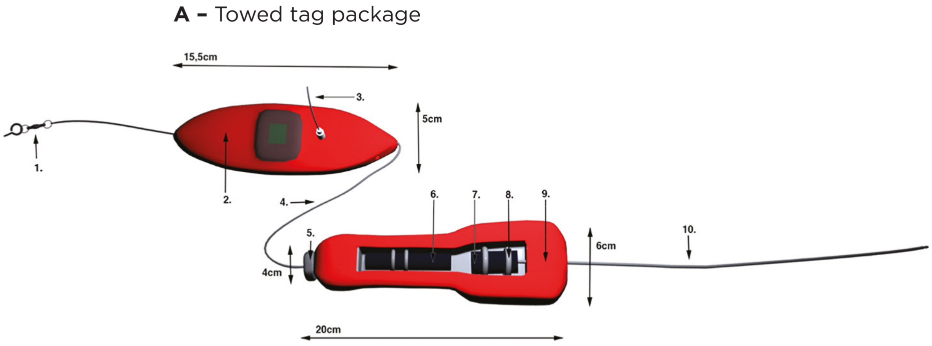
There are at least three species of mobulids occurring in the region, possibly four: giant manta *Manta birostris*; Chilean devil ray *Mobula tarapacana* (Figure 3.2.1); and one or both of the giant devil ray *Mobula mobular*/spinetail devil ray *Mobula japanica* species complex (Sobral and Afonso 2014). Devil rays (family Mobulidae) are iconic, endangered animals, and despite their large size, their elusive behaviour has limited our understanding and conservation of these species. We tagged three Chilean devil rays (*Mobula tarapacana*) at two shallow seamounts, Baixa do Ambrósio and Formigas Seamount, 5 km northwest and 37 km northeast of Santa Maria Island, respectively, using a new non-invasive harness method, deployed on free swimming animals by a free-diver (Figure 3.2.2). We used a tag-package combining one acoustic transmitter (V16-4H Vemco Ltd., Halifax, Nova Scotia), one R1500 VHF radio transmitter (ATS Inc., Isanti, Minnesota, frequency 164.356 kHz) and one archival satellite tag (MK10 or MiniPAT Wildlife Computers Inc., Redmond, Washington). The harness was composed of nylon tether inserted through a 70 cm long section of 5 mm diameter transparent polyethylene tube to prevent abrasion. We used 4hr galvanic timed releases to predetermine the tag and harness release.

FIGURE 3.2.1.

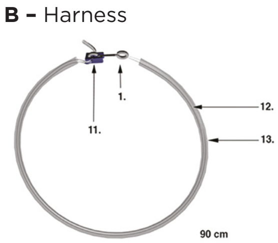
Chilean devil rays (*Mobula tarapacana*) at Formigas Seamount.

FIGURE 3.2.2.

Diagram of (A) the towed tag package and (B) the harness system (adapted from Fontes et al. 2018).



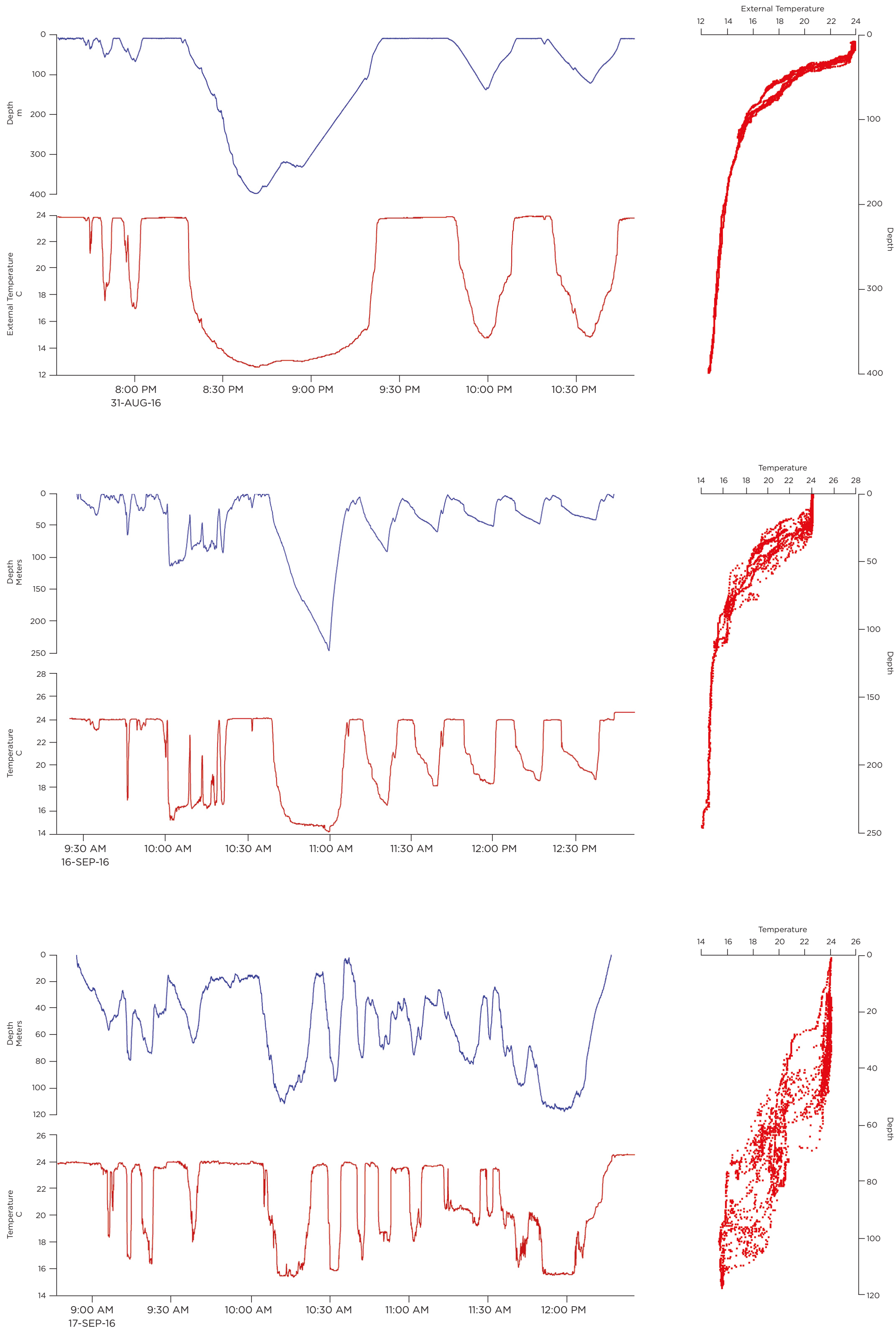
1. GTR Link
2. MK10 Satellite tag
3. MK10 antenna
4. Kevlar Line
5. Lead ballast disk
6. Acoustic tag
7. VHF tag
8. Zip ties
9. Syntactic foam
10. Radio antenna
11. Stopping rubber
12. Nylon monofilament line



To evaluate the spatial and diving behaviour, as well as the behavioural reaction of the devil rays to the harness itself, we combined direct observations right after tagging with an analysis of the diving data collected by the tags. All tagged rays exhibited no immediate reaction to tagging and rays remained at shallow depths (average depth = 16 m) and dove slowly (average descent rate 0.16 m/s, maximum 0.38 m/s) during the post-tagging period. The average descent rate and depth of devil rays during the remainder of the track was higher (51.5 m and 0.25 m/s), with a maximum descent rate of 2.72 m/s and maximum recorded depth of 400 m (Figure 3.2.3).

FIGURE 3.2.3.

Depth and temperature profiles for three devil rays tagged at Formigas seamount (two bottom graphs adapted from Fontes et al. 2018).



3.3. SEABIRDS AND ASSOCIATED MEGAFAUNA

3.3.1. Seabirds

The Azores region is considered a global hotspot for seabirds. There are 10 known breeding seabirds species found in the Azores including: six procellariiformes (Cory's shearwater *Calonectris borealis*, Manx shearwater *Puffinus puffinus*, Macaronesian shearwater *Puffinus lherminieri*, band-rumped storm-petrel *Hydrobates castro*, Monteiro's storm petrel *Hydrobates monteiroi* and Bulwer's petrel *Bulweria bulwerii*) and four charadriiformes (common tern *Sterna hirundo*, roseate tern *Sterna dougallii*, yellow-legged gull *Larus michahelis atlantis*, and sooty tern *Onycophrion fuscatus*) (Monteiro et al. 1996).

Abundant seamounts in the region enhance local productivity and create important feeding opportunities for many seabirds (Morato et al. 2008). Cory's shearwater is the most common seabird in Portuguese waters and the Azores hosts 75% of the world's breeding population of this species. The Azores is also home to more than 63% of the European roseate tern population and the most northern colonies for the Bulwer's petrel and sooty tern (Del Nevo et al. 1993, Bried and Bourgeois 2005). The western-most islands of Corvo and Flores are home to two small colonies of Manx shearwater. The Monteiro's storm-petrel (*Oceanodroma monteiroi*) is one of three endemic seabird species that breeds in Portuguese waters and was recently described as a different species from the band-rumped storm petrel (Bolton et al. 2008). Most of the seabird species occurring in the Azores are listed in Annex I of the EU Birds Directive (Directive 2009/147 /EC), and their feeding and breeding areas should be considered priority areas for conservation as Important Bird Areas (IBAs).

During the 2018 expedition, research on seabirds and associated marine megafauna focused on the western portion of the archipelago. Gigante Seamount, which covers 945 km^2, is located between the islands of Faial and Flores along the Mid-Atlantic ridge (Morato et al. 2008). This area is also important to other marine megafauna such as cetaceans, tunas, swordfish, and sea turtles. Additional work was conducted around the western most islands of Flores and Corvo, which includes the largest marine IBA in the Azores (2104 km^2) and is part of the Azores Marine Park (Regional Legislative Decree n°28/2011/A).

Standard observations of seabirds (European Seabirds at Sea methodology) and marine megafauna and marine litter (Fisheries Observation Program from the Azores – POPA – methodology) were conducted along 54 transects, over 39.5 hrs and covering 822 km (Table 3.3.1, Figure 3.3.1). Nine species of seabirds were observed, of which eight are known to breed in the Azores (Monteiro et al. 1996). Four species of cetaceans were recorded, including: common dolphin (*Delphinus delphis*), bottlenose dolphin (*Tursiops truncates*), fin whale (*Balaenoptera physalus*) and one unidentified baleen whale species (*Balaenoptera* sp.). In total, 25133 seabirds and 60 marine mammals associated with seabirds were recorded (Table 3.3.2).

TABLE 3.3.1.

Transects for marine megafauna in 2018 using the European Seabirds at Sea methodology.

Day	N	Km	Avg. km
12-May	5	65	13.0
13-May	4	101	25.3
14-May	4	70	17.5
15-May	11	59	5.4
16-May	11	105	9.5
17-May	11	183	16.6
18-May	2	87	43.5
19-May	4	111	27.8
20-May	2	42	21.0
Total	54	822	15.2

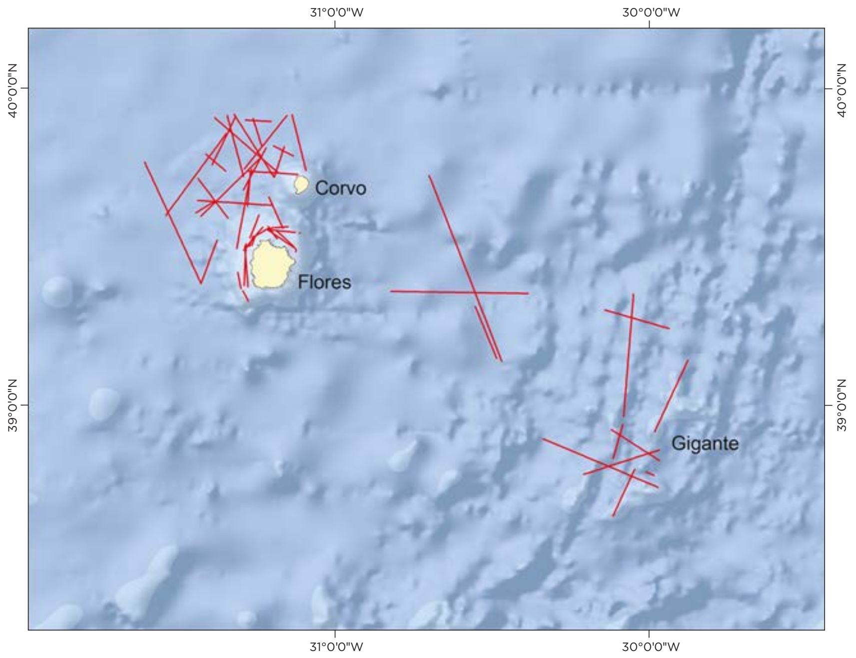


FIGURE 3.3.1.

Transects for marine megafauna in 2018 using the European Seabirds at Sea methodology.

TABLE 3.3.2.

Total observations of the species recorded according to the European Seabirds at Sea methodology (Camphuysen and Garthe 2004). Date = May 2018.

Species/Date	12*	13*	14	15	16	17	18*	19	20	Total
Cory's shearwater	632	1357	663	9783	1651	10082	44	319	118	24649
Manx shearwater	0	0	19	15	15	247	0	14	1	311
Common tern	0	0	2	4	5	7	0	5	2	25
Roseate tern	0	0	0	0	5	2	0	1	0	8
Macaronesian shearwater	0	0	1	2	0	2	0	0	0	5
Bulwer's petrel	0	0	1	0	1	1	0	0	0	3
Yellow-legged gulls	0	0	5	7	16	7	0	12	1	48
Sooty shearwater	0	0	0	0	0	11	0	0	0	11
Storm-petrel	0	1	0	0	0	0	0	0	0	1
Terns	0	0	3	6	23	35	0	7	6	80
Fin whale	0	0	0	0	0	0	1	0	0	1
Baleen whale	0	0	0	0	0	0	1	0	0	1
Common dolphin	0	20	0	0	0	23	1	0	0	44
Bottlenose dolphin	0	14	0	0	0	0	0	0	0	14

*Transect and observations on the Gigante Seamount

Cory's shearwater was the most abundant seabird species recorded, by an order of magnitude (n=24649, Figure 3.3.2). This species forages ~75 km from their colonies on short duration feeding excursions and up to 1800 km on long range migrations (Magalhães et al. 2008).

The Manx shearwater was the second most observed seabird observed (n = 311) and was mostly found off the west coast of Corvo Island, where flocks of 30 or more individuals were observed (Figure 3.3.3). Although this species is not included in Annex I of the Birds Directive, Corvo and Flores are of great importance for Manx shearwater, which was once the most abundant seabird in the Azores (Frutuoso 1978), but the remaining colonies are only found at these two islands with an estimate of 115–235 pairs (Monteiro et al. 1999).

FIGURE 3.3.2.

Cory's shearwater (*Calonectris borealis*) was the most abundant seabird species recorded and is known to forage an average of 75 km from the colonies on short-term trips and up to 1800 km on long-term trips.

FIGURE 3.3.3.

Manx shearwater *Puffinus puffinus*, was the second most observed seabird species during the expedition occurring in rafts off the west coast of Corvo.

Bulwer's petrel was recorded at Gigante Seamount (n=1) and between Flores and Corvo (n=2) (Figure 3.3.4). This species has a pantropical distribution with a population size in the Azores of 70 pairs (Monteiro et al. 1999). Tagged individuals that breed in Selvagens Islands travelled 1700 km north off Corvo Island, thus highlighting the importance of this area for the Azores and Madeira populations (Dias *et al*. 2016). Five Macaronesian shearwaters were observed in the western island group. *Puffinus lherminieri*, the Macaronesia shearwater has a population estimated at 840 to 1530 breeding pairs in the archipelago (Figure 3.3.5, Pita-Groz et al. 2005). One species of unidentified storm-petrel was observed (either the band-rumped storm petrel or Monteiro's storm petrel). Monteiro's storm petrel ('painho-de-Monteiro') *Hydrobates monteiroi*, is an endemic species in the Azores Archipelago known to nest in Graciosa Island, but possibly also in Corvo or Flores islands (Figure 3.3.6).

FIGURE 3.3.4.

Bulweria bulwerii (Bulwer's petrel or 'alma negra') were found at Gigante and on the islands of Corvo and Flores. They are highly migratory with the north of Corvo being identified as an important feeding area for both the Azores and Selvagens populations.

FIGURE 3.3.5.

Puffinus lherminieri Macaronesia shearwater has a population estimated at 840 to 1530 breeding pairs in the archipelago.

FIGURE 3.3.6.

Monteiro's storm petrel ('painho-de-Monteiro') *Hydrobates monteiroi*, an endemic species in the Azores Archipelago known to nest in Graciosa Island, but possibly also in Corvo or Flores islands.

Yellow-legged gulls (n=48) and several species of terns (8 roseate terns, 25 common terns, and 80 identified to genus) were observed in our surveys (Figure 3.3.7). The western island group is important for the roseate tern, with a population of 997 individuals, primarily on Flores Island. The Azores possess 63% of the total breeding population for this species at the European level (Del Nevo et al. 1993).

FIGURE 3.3.7.

Yellow-legged gull (*Larus michahelis*, 'gaivota'). Although present all year round on the Azores, this species is a pelagic feeder and does wander, so may be prone to vagrancy (Moore 1996), even to North America (Wilds & Czaplak 1994).

3.3.2. Marine Megafauna

Observations of cetaceans, sea turtles, and marine litter were conducted using the Fisheries Observation Program from the Azores (POPA). A total of 15 surveys performed in June 2018 (10 at Gigante Seamount), registered six sperm whales (*Physeter macrocephalus*), two humpback whales (*Megaptera novaeangliae*), a fin whale (*Balaenoptera physalus*), two unidentified baleen whale species, 35 bottled-nose dolphins (*Tursiops truncatus*) and 160 common dolphins (*Delphinus delphis*) (Figure 3.3.8). A single loggerhead turtle *Caretta caretta* (~ 32 cm carapace length) was sighted in 20 surveys (Figure 3.3.9). Marine litter was detected in 16% of the surveys (n = 44), with general plastics in the range of 5–60 cm. Fishing gear was also commonly observed (30–60 cm).

FIGURE 3.3.8.

Marine mammals. (A–B) Sperm whale (*Physeter macrocephalus*) is the largest predator on the planet and an abundant species off most Azores islands. (C) Risso's dolphin (*Grampus griseus*). (D) Short-beaked common dolphin (*Delphinus delphis*).

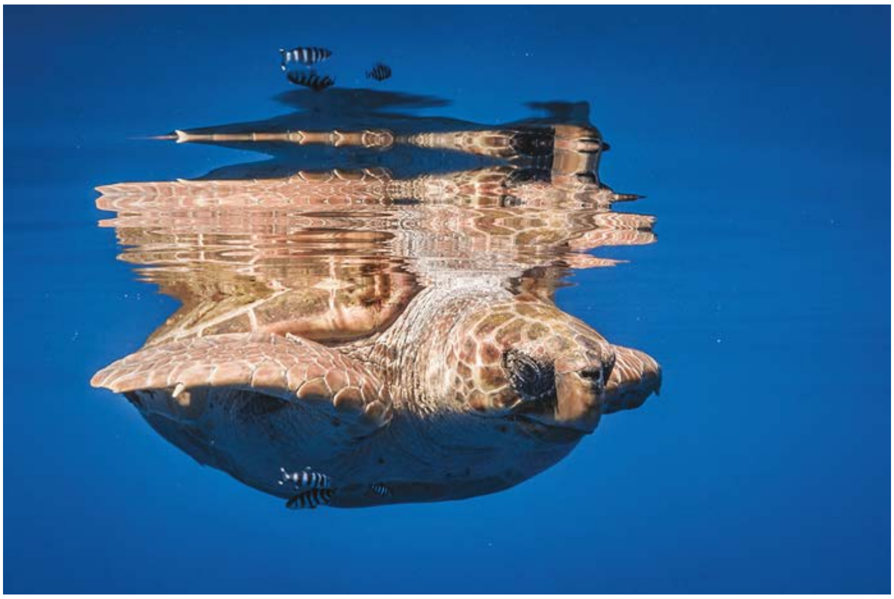


FIGURE 3.3.9.

A loggerhead turtle (*Caretta caretta*) off Formigas. Juveniles and subadults of this species occur frequently in the Azores which is an important feeding place during the life cycle migration of this species which associates particularly with seamounts (Santos et al. 2007).

4. Deep Sea

4.1. DEEP SEA FAUNA ASSEMBLAGES

The seafloor of the Azores EEZ is characterized by complex topography comprising island slopes, seamounts, deep fracture zones, trenches, and abyssal plains exceeding 5000 m depth (Tempera et al. 2012). The enhanced local productivity of seamounts and island slopes, together with accelerated currents and availability of hard substrates, provides ideal conditions for the colonization of deep-sea suspension-feeding fauna such as cold-water corals and sponges. Cold-water coral diversity is particularly high in the Azores, with 184 species identified to date (Braga-Henriques et al. 2013, Sampaio et al. 2019). Octocorals together with Antipatharia (black corals) and Stylasteridae (hydrocorals) form tri-dimensional complex habitats, referred to as coral gardens (OSPAR 2010), that are used by a large number of associated sessile (e.g. zoantharians, anemones, hydroids) and vagile (e.g. polychaetes, echinoderms, crustaceans, fish) species (Buhl-Mortensen et al. 2010). Many of these species are slow growing, long-lived, and have low reproductive outputs, making them extremely vulnerable to fisheries or other human impacts, with recovery times of individual coral colonies and communities requiring decades to centuries. These characteristics have resulted in many coral gardens being listed as Vulnerable Marine Ecosystems (VME) (UNGA 2007, OSPAR 2010).

After the first expeditions to the deep sea in the late 19th century, extensive scientific research based in the Azores has opened a window to the functioning of deep-sea and seamount ecosystems and illuminated the impacts of human activities in such ecosystems. However, these places are still poorly known, and many of the 300+ seamounts in the Azores are still scientifically unexplored yet being used as important grounds for bottom-contact gear fisheries. Therefore, it is of paramount importance to conduct deep-sea exploration in the seamounts of the Azores, in order to inform the sustainable management of marine resources while promoting the conservation of VMEs.

4.2. OVERVIEW OF THE DEEP-SEA CAMPAIGN

As part of the 2018 expedition, unexplored areas of the deep Azores were visited by the Portuguese remotely operated underwater vehicle (ROV) “Luso” on-board the “NRP Almirante Gago Coutinho” from June 3–24, 2018. The aims of this campaign were to: (i) map benthic communities inhabiting unexplored seamounts in the Central (Gigante complex) and Western (Cachalote complex) part of the Azores Region, (ii) identify new areas that fit the FAO vulnerable marine ecosystems definition, and (iii) address patterns of distribution of deep-sea benthic biodiversity in the Azores. This cruise also provided valuable information on the framework of assessing Good Environmental Status within the context of the Marine Strategy Framework Directive, Marine Spatial Planning, and sustainable management of deep-sea ecosystems in the Azores.

A total of 11 ROV transects were conducted with the ROV Luso on the island slopes of Pico and São Jorge and the flanks and summits of three seamounts in the Gigante Complex Area (Gigante, Seamount 127 and the western ridge, Figure 4.2.1), covering a depth range between 250 and 1100 m (Table 4.2.1). The 11 video transects covered about 11 linear km of seafloor.

FIGURE 4.2.1.

Location of the dives performed with the ROV Luso on the Gigante Seamount Complex (left) and on the flanks of São Jorge and Pico islands (right).

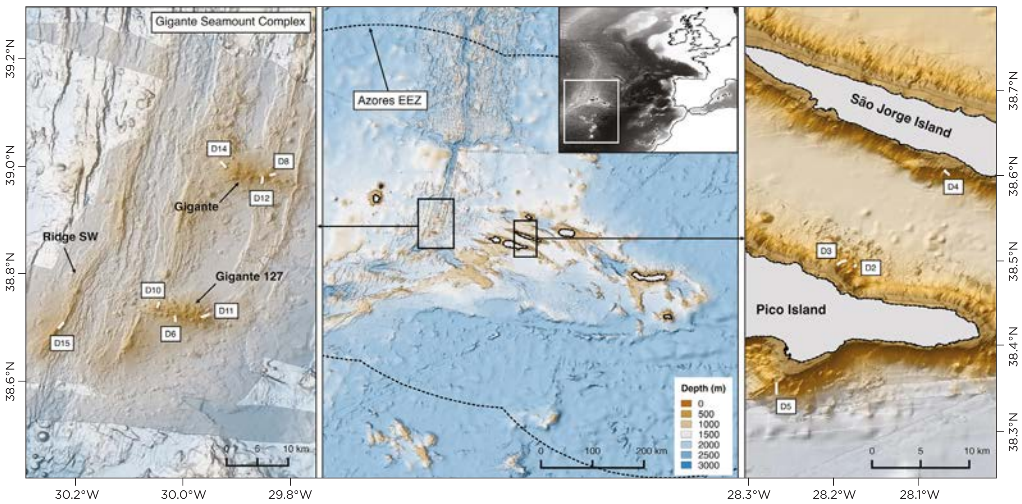


TABLE 4.2.1.

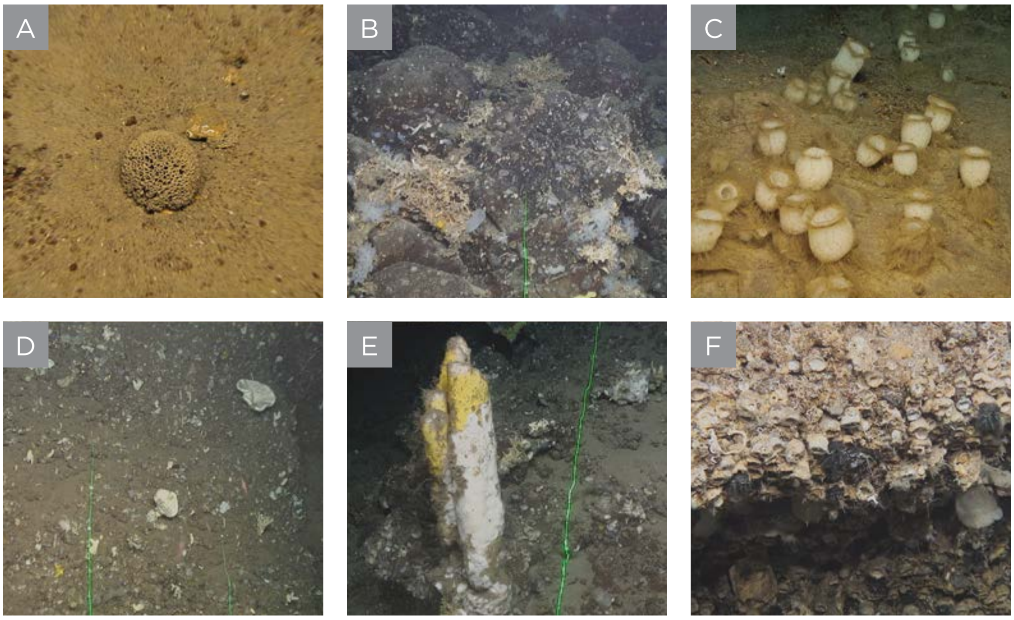
ROV Luso dives performed on the flanks of São Jorge and Pico Islands and the Gigante Complex Area during the Blue Azores 2018 expedition. Latitudes and longitudes refer to the location where the ROV reached the seabed.

Dive	Location	Longitude	Latitude	Depth range (m)
D02	North Pico	38.4964	-28.1733	725–870
D03	North Pico	38.8372	-28.3167	475–870
D04	South São Jorge	38.4964	-28.1947	270–655
D05	South Pico	38.3456	-28.2794	500–1100
D06	Gigante 127	38.8194	-30.0139	310–610
D08	Gigante	38.9859	-29.8374	560–730
D10	Gigante 127	38.7484	-30.0452	330–680
D11	Gigante 127	38.7383	-30.0476	380–770
D12	Gigante	38.9694	-29.8535	235–740
D14	Gigante	39.0412	-29.9292	400–760
D15	Ridge SW	38.7089	-30.1898	440–590

4.3. DEEP-SEA EPIBENTHIC FAUNAL ASSEMBLAGES

The slopes of São Jorge and Pico islands are characterized by a mix of gentle slopes and sharp vertical walls, generating a wide variety of deep-sea habitats that are colonized by numerous sessile invertebrate species. The soft-bottom habitats of the deepest areas explored on the northern side of Pico Island, between 700 and 1000 m depth, were characterized by the presence of xenophyophores (Figure 4.3.1). These organisms are sessile agglutinating protozoans of the Phylum Foraminifera, that can attain sizes of 25 cm and build complex test structures that can form aggregations of up to 7–10 ind·m^{-2} (Levin 1991). The observed foraminifera, most likely belonging to the species *Syringammina fragilissima*, were accompanied by the long-spine sea urchin *Cidaris cidaris*, the solitary stony coral *Deltocyathus* cf. *moseleyi* and the large anemone *Bolocera* cf. *tuediae*, as well as some other burrowing invertebrates. Xenophyophore fields are considered as biodiversity hotspots on sedimentary seafloor areas because of their role in providing food, habitat, and refuge for marine invertebrates, and by playing key roles in carbon cycling (Levin and Gooday 1992). Because of their fragile and easily damaged tests, their structural complexity and functional significance, xenophyophores fields have been recognized as VMEs (FAO 2016). These may represent important habitats in the Azores but that have been little documented so far. It should be noted however, that xenophyophores fields are unlikely to be impacted by the current bottom hook-and-line fishing gears, and that bottom trawling, which could significantly damage this ecosystem, is banned in the Azores region.

FIGURE 4.3.1.



Some images of the invertebrate assemblages identified on the slopes of São Jorge and Pico Islands. (A) The xenophyophore *Syringammina fragilissima* on soft sediments at 1000 m depth. (B) Rocky outcrops with living and dead colonies of the cold-water coral *Lophelia pertusa*, together with hexactinellid sponges. (C) Aggregation of the glass sponge *Pheronema carpenteri*. (D) Example of the wide variety of sponge species that can be found on the slopes of Pico and São Jorge islands. (E) Large specimen of the sponge *Characella pachastrelloides*. (F) The black crinoid *Cyathidium foresti* observed on a vertical cliff south of São Jorge.

The deepest soft-bottom areas explored on the slopes south of Pico, at around 1000 m, were characterized by accumulations of dead coral framework, most likely of the species *Lophelia pertusa*, with the presence of a few living colonies growing on top of the coral rubble, rocks and boulders. Interestingly, the observation of living *L. pertusa* reefs is rare in the Azores, as opposed to other areas of the North Atlantic. Instead, extensive coral rubble accumulations are conspicuous, suggesting the demise of such coral reefs during the last deglaciation, when environmental conditions (increased temperature and decreased productivity) became unsuitable for *L. pertusa* reef survival (Marina Carreiro-Silva and Norbert Frank, unpublished data).

Another important benthic community observed in the south of Pico at depths around 800 m, were dense aggregations of the large glass sponge *Pheronema carpenteri* colonising both hard and soft substrates. This species forms extensive communities in the Azores and studies are now being conducted to determine the ecosystem services they generate and their role as habitat providers. Sponge aggregations of a wide variety of shapes and sizes were also the most common benthic communities found between 400 and 800 m depth. A large portion of the deep-sea sponges occurring in the Azores belong to unknown species, some of which may even be new to science. Among the species identified, a great number of lithistid sponges were notable (e.g. large *Petrosia* sp., *Leiodermatium* cf. *pfeifferae*, cf. *Neophrissospongia nolitangere* and cf. *Macandrewia azorica*), together with many different encrusting sponges.

These species were observed in higher densities on rocky outcrops, producing a very patchy distribution dependent on the type of substrate available. In some areas, giant sponges of the species cf. *Characella pachastrelloides* provided habitat for many species (e.g. shrimps) and substrate to other sponges. Despite the scarce knowledge on the taxonomy and functioning of sponge aggregations, they are increasingly recognized as providing structurally complex biogenic habitats that locally increase biodiversity, providing important ecosystem services, such as nutrient recycling and carbon sequestration (e.g. Kutti et al. 2013). The fragility and slow growth of sponges makes them particularly vulnerable to human activities such as bottom trawling (e.g. Pusccedu et al. 2014), which does not occur in the Azores. However, sponges are often accidently taken as by-catch during bottom long-line fishing in the Azores, which may cause significant impact to these habitats. As such, many deep-sea sponge grounds fulfil the FAO definition of VME and have also been included in the OSPAR list of threatened and/or declining species and habitats in the northeast Atlantic (OSPAR 2008).

Some of the vertical walls explored with the ROV Luso, both in São Jorge and Pico islands, host a unique assemblage characterized by the presence of the long-lived oyster cf. *Neopycnodonte zibrowii* (lifespan of several centuries) and the sessile crinoid *Cyathidium foresti*. 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). To our knowledge, the presence of this assemblage was only described for the island slopes of Faial and was unknown for the other slopes until this expedition. The nature of this habitat and singularity in the North Atlantic calls for conservation measures to protect it from human pressures.

4.4. DEEP-SEA EPIBENTHIC FAUNAL ASSEMBLAGES ON THE GIGANTE COMPLEX AREA

The Gigante Complex Area (GCA) is located between the islands of Flores and Faial (Figure 4.2.1). It sits over the Mid-Atlantic Ridge, close to the triple junction of the African, European and North American plates. Gigante is a ridge-like seamount (~ 10 x 6 km) that rises 800 m from the seafloor to water depths of about ~150 m. It follows the main trend of the Azores volcanic emplacement direction (110–120°) and is crossed by lineaments parallel to the Mid-Atlantic Ridge (MAR) (Lourenço et al. 1998). This area has been poorly studied in the past, but it is an important fishing ground for both bottom and pelagic fishing. It is also known as an important ground for visiting pelagic species and an area of enhanced micronekton abundance but very little is known about its local benthic communities.

The preliminary characterization of its predominant benthic fauna was based on seven video transects carried out at depths between 250 and 800 m, on the flanks and summits of three peaks of the GCA: Gigante Seamount 127 and Western Ridge (Figure 4.4.1). At least 200 different benthic species have been identified so far in the video footages. The best represented taxonomic groups were Cnidaria (80 taxa), Porifera (60 taxa), and Actinopterygii (34 taxa), with fewer representatives for the remaining phyla. Preliminary analysis suggests that besides properties of water masses, substrate type, sediment deposition, and bathymetric changes shape the composition of local communities.

Soft bottoms were the common substrate on the deeper part of the flanks (500–800 m) and were mostly colonized by low densities of several species of solitary corals of the genera *Flabellum* and *Deltocyathus*, found half-buried on the sediment in many occasions. On the deep flanks of 127 seamount (NW flank), a dense aggregation of the Berycidae fish *Hoplostethus mediterraneus* was observed, with hundreds of individuals over the seabed in a static position. At these depths, glass sponge *Pheronema carpenteri* aggregations were also identified, mostly on Gigante seamount (SE flank). Densities reported were not as high as those observed on the flanks of Pico island, and patches were composed of only a few large specimens. Small Porifera were the predominant group on high deposition sites, occasionally in association with small colonies of Octocorallia (mostly Acanthogorgiidae, Paramuriceidae and Plexauridae) and Antipatharia (mostly Aphanipathidae).

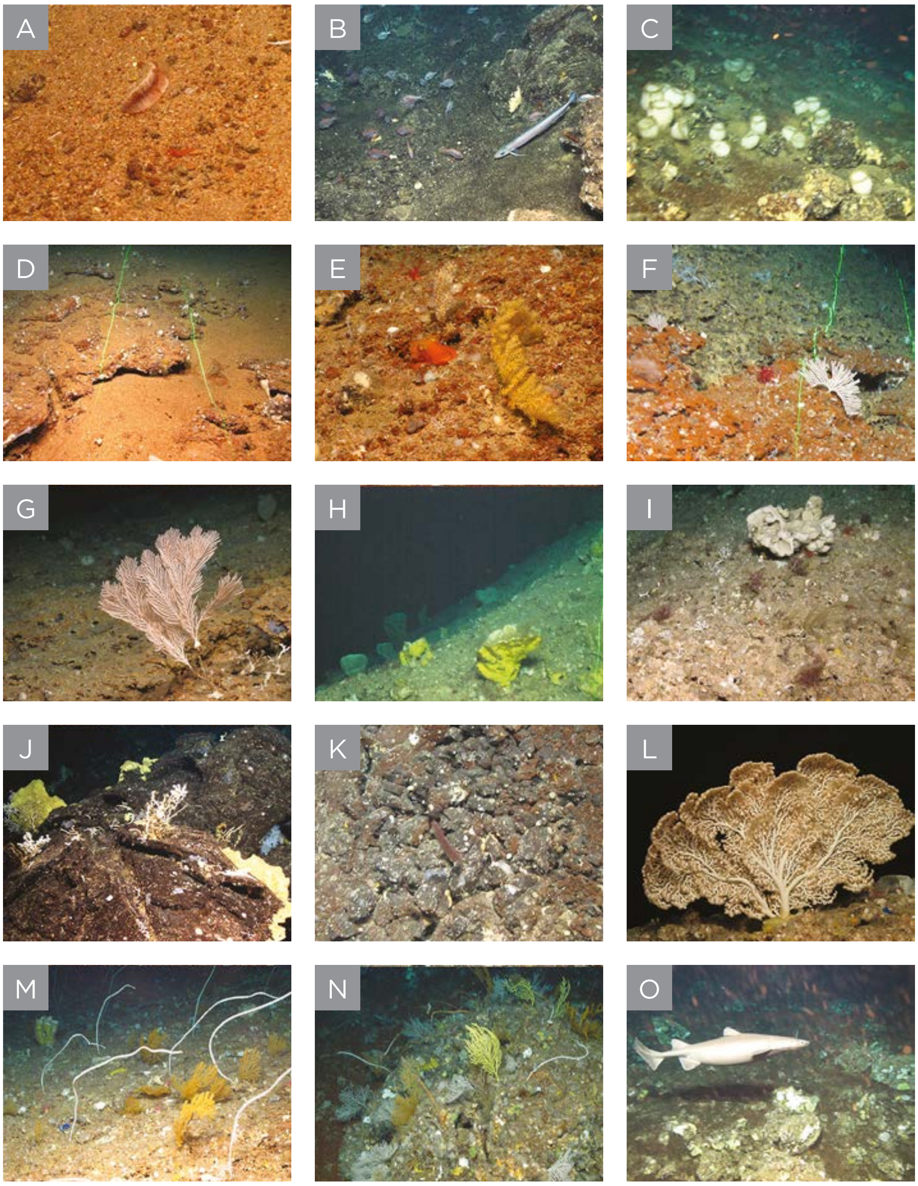
At similar depth intervals, areas characterised by the presence of hard substrates, especially lithic rocks, hosted a wider variety of organisms which formed different assemblages. This was the case of the gorgonian *Narella* cf. *bellissima*, which was observed in association with the mushroom soft coral of the genus *Anthomastus*. Other species characteristic of lithic rocks were the large gorgonian *Callogorgia verticillata*, massive and tubular sponges, and the gorgonian *Anthothela*. Areas of intact basaltic lava balloons hosted two main assemblages. One dominated by the flabellate sponge cf. *Poecillastra compressa* and the coralliid *Pleurocorallium* cf. *johnsoni*, often in association with colonies of *Anthomastus*, smaller sponges and several unidentified octocorals species. Crumbled lava balloons generally exhibited a lower species diversity and abundance, limited to small sponges and black corals (*Parantipathes hirondelle* and *Stichopathes gravieri*). The high density of cold-water corals and sponges at some of these sites conform with the definition of cold-water coral gardens and sponge aggregations and may be classified as VMEs. However, some of these areas have been strongly affected by bottom fishing gears.

On the NW flank of Gigante the shallowest hydrothermal vent field on the Mid-Atlantic Ridge was discovered at 570 m depth. Interestingly, areas adjacent to the vent field hosted dense populations of the gorgonian species *Paragorgia arborea* and *Paragorgia johnsoni*, together with smaller octocorals such as *Pleurocorallium* cf. *johnsoni* and *Anthomastus* cf. *agaricus*. Similar assemblages were also observed on the western ridge, with much larger and denser populations of *Paragorgia* specimens and other accompanying species, such as the solitary coral *Leptopsammia formosa* and the sponge *Poecillastra compresa*, among many others. Gorgonian colonies formed impressively dense coral gardens on basaltic and lithic rocks, so far, the most extensive and densest *Paragorgia* spp. coral garden identified in the Azores region. *Paragorgia* colonies could be observed on both sides of the ridge, placing their fan-shape structure towards the direction of the upwelling currents, likely to maximize the surface area exposed to the dominant bottom current and hence maximize food capture. Some coral colonies reached over 1 m in height and 1.5 m in diameter and could be over one century in age. Many of the *Paragorgia* colonies in the shallowest portion of the ridge showed broken branches, which may indicate impacts from bottom fishing. It should be noticed, however, that footages from Cavala seamount obtained before fishing impacts also showed similarly broken colonies making it difficult to distinguish natural from fishing impacts. The density, size, uniqueness, and fragility of the *Paragorgia* populations observed on the western ridge makes this area a good candidate for a VME, and thus may need management measures for their protection and long-term conservation.

In the summit area of the three areas explored (approx. 500–300 m depth), cold-water coral hotspots could be observed colonizing patches of hard substrate, with dense *Viminella flagellum* populations found in association with several species, mainly large sponges (e.g., *Leiodermatium lynceus*, cf. *Characella pachastrelloides*, cf. *Neophrissospongia nolitangere*) and at least four families of gorgonians (Plexauridae, Primnoidae, Ellisellidae and Acanthogorgiidae) including, among others, the species *Callogorgia verticillata*, *Candidella* cf. *imbricata*; *Dentomuricea* cf. *meteor*, *Muriceides* spp. and *Acanthogorgia* cf. *hirsuta*. Some of these octocoral hotspots fit the VME definition due to their structural complexity, vulnerability and associated benthic diversity. In addition, multiple sightings of likely pregnant kitefin sharks (*Dalathias licha*), generally in association with little valleys on the seamounts' flanks, suggest that summit areas of those seamounts might be important aggregation spots for deep-sea sharks.

FIGURE 4.4.1.

Some of the benthic assemblages of the Gigante Complex Area. (A) The solitary stony coral *Flabellum* cf. *chuni*. (B) An aggregation of the fish *Hoplostethus mediterraneus* with the presence of *Molva macrophthalma.* (C) The glass sponge *Pheronema carpenteri*. (D) Encrusting and small globular sponges on rocky outcrops in high sedimentation areas. (E) The gorgonian *Acanthogorgia armata*, another species of *Acanthogorgia* and the cephalopod *Pteroctopus tetracirrhus*. (F) The gorgonian *Narella* cf. *bellissima*. (G) The gorgonian *Callogorgia verticillata*. (H) An aggregation of the tubular sponges cf. *Characella pachastrelloides*. (I) The gorgonian *Anthothela* dominated facies with the sponge cf. *Neophrissospongia nolitangere*, Coralliidae and Plumulariidae species. (J) The sponges cf. *Poecillastra compressa* and *Pleurocorallium* cf. *johnsoni*. (K) The black coral *Parantipathes hirondelle* on crumbled basaltic rock. (L) The gorgonian *Paragorgia johnsoni*, dead cirripeds, Alcyoniidae and a stony coral of the Dendrophylliidae family. (M) The gorgonians *Viminella flagellum*, *Acanthogorgia* cf. *hirsuta* and the sponges cf. *Characella pachastrelloides* and cf. *Hemicorallium* sp. (N) The gorgonians *V. flagellum*, *Candidella* cf. *imbricata*; *Dentomuricea* cf. *meteor* and several species of encrusting sponges. (O) The deep-water shark *Dalathias licha*.



4.5. A NEW HYDROTHERMAL VENT FIELD DISCOVERED ON THE SLOPES OF GIGANTE SEAMOUNT

A new hydrothermal vent field was discovered on the slopes of Gigante at 570 m depth (Figure 4.5.1). The hydrothermal vent field was named "Luso" as this is the first deep hydrothermal vent field discovered on a Portuguese expedition, led by Portuguese scientific teams, on a Portuguese vessel, and using a Portuguese ROV and ROV team. Following this discovery, and taking advantage of an ongoing collaboration between IMAR-UAz and Nadine Le Bris from the Sorbonne Université, the Luso vent field was revisited on the 4th of August 2018 with the ROV VICTOR6000 onboard the RV L'Atalante to perform additional observations and sampling to initiate the multidisciplinary characterization of the discovered vent field.

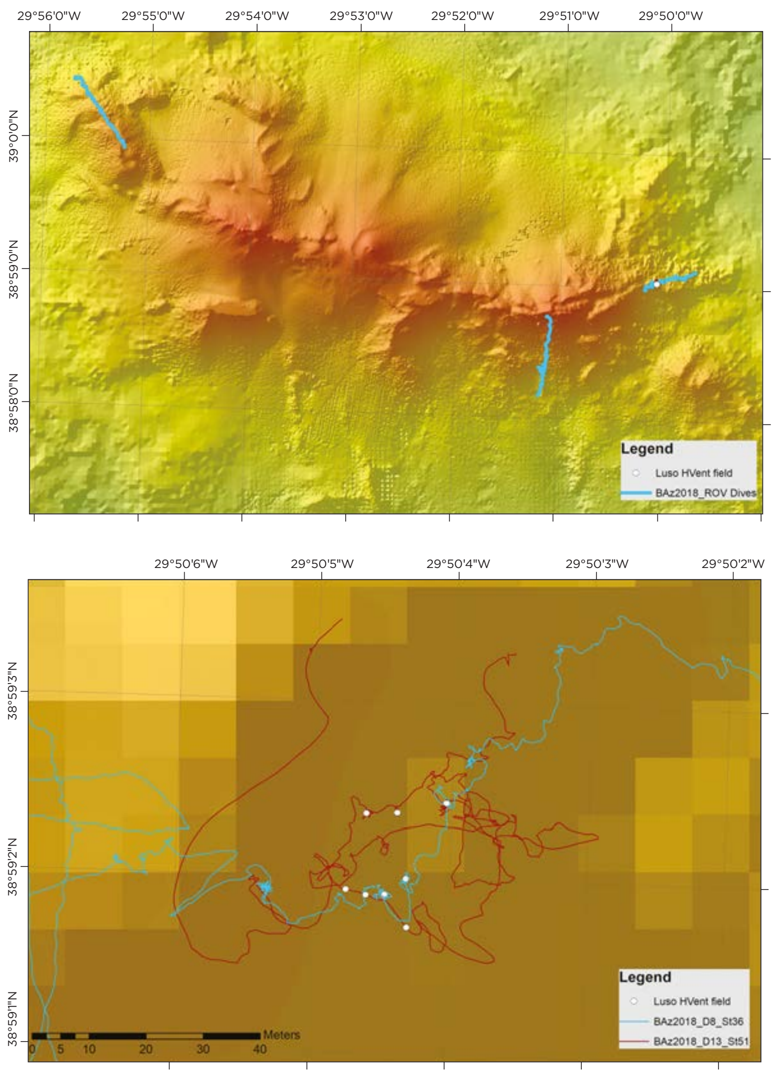


FIGURE 4.5.1.

Map of the Gigante seamount (left) with the "Luso" hydrothermal vent field (white dot). Known chimney-like structures are also shown (white dots in the right panel). Blue and red lines show ROV dives conducted during the 2018 Expedition. See Figure 4.2.1 for location of Gigante seamount complex within the Azores.

The Luso hydrothermal vent field occupies about 400 m^2 and is composed of at least 26 chimney-like structures of different sizes; with orifices up to about 30 cm in diameter (Figure 4.5.2). Active and inactive vent chimneys are distributed preferentially along the ENE-WSW fractures. Chimneys were composed by loose and fragile material, displaying a concentric composition reflected in different colours and textures. In general, three compositional zones can be recognized: I) the innermost zone, which is in contact with the hydrothermal fluid, composed of white, loose and low-density precipitates, with rare green clays, with a mineralogical composition characterized by a dominance of amorphous Si (Opal A); II) the middle zone shows brownish to yellowish precipitates, intermixed with olive-green clays scattered locally, with a mineralogical composition characterized by an intermixed clay composition with amorphous Si and oxyhydroxides; III) the outermost zone is composed by brownish ochre material, dominated by Fe-Mn oxyhydroxides. Inactive chimneys do not present a clear zonation and are dominated by a darker material, showing an enrichment in Fe-oxyhydroxides crosscut by fine and dark glassy veinlets with a deep purple tint (identified as amorphous silica) and an unclear zone I, well-defined in the active chimneys.

Hydrothermal fluids are transparent but well noticeable from a distance. They are moderately warm reaching a stable maximum temperature of 62°C when measured *ca*. 10 cm inside the outer rim of the main chimney conduit. Fluids are moderately acidic, iron-rich, CO2 rich, hydrogen rich, with moderate methane contents, but contain no sulphides.

FIGURE 4.5.2.

Examples of chimney like structures in the Luso hydrothermal vent field.

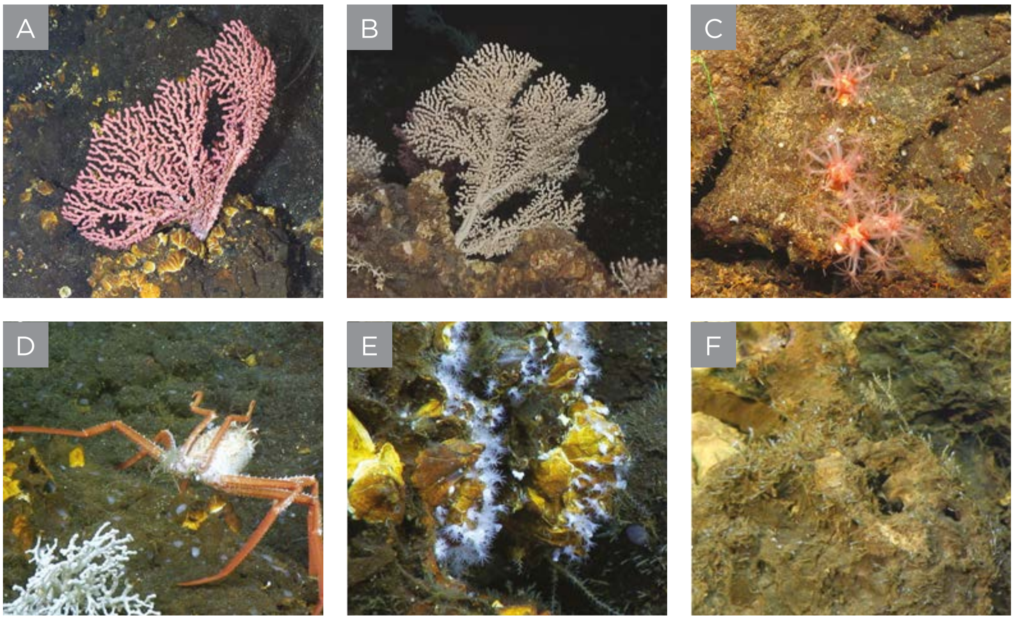


FIGURE 4.5.3.

Examples of the benthic macrofauna found on Luso hydrothermal vent field. (A) gorgonian *Paragorgia arborea*. (B) gorgonian *Paragorgia johnsoni*. (C) soft coral *Anthomastus* c.f. *agaricus*. (D) crab *Paromola cuvieri*. (E) balonomorph barnacle likely of the genus *Pachylasma* with signs of iron precipitation on its exoskeleton and in association with the zoanthid c.f. *Parazoanthus aliceae*. (F) tubiculous amphipods of the Family Ischyroceridae.

Biological observations on the vents showed no typical hydrothermal vent macrofaunal, as opposed to other hydrothermal vent fields along the MAR. However, a total of 28 taxa were identified from the Luso vent field, corresponding to 8 phyla (Figure 4.5.3). None of the observed taxa are considered vent-specific. Crustacea was the largest group collected, both in terms of numerical abundance and species richness. For many taxa, the identification of specimens could only be made to family level, with the number of species potentially increasing after revision by specialized taxonomists.

This system thus differs considerably from other hydrothermal fields along the MAR, characterized by fluids of high temperature, high concentrations of methane, sulphur and metals, supporting high biomass of specialized chemosynthetic fauna (Van Dover 2000). The geological and physical-chemical nature (low temperature, high CO2) of this vent system resembles the low-temperature hydrothermal vents (Pele's vents) at Loihi Seamount in Hawai'i (Karl et al. 1988), and elsewhere in the Pacific (e.g., Kennedy et al. 2003) dominated by extensive deposits of Fe oxides of microbial origin.

4.6. DEEP-OCEAN DROPCAMS

National Geographic's Exploration Technology Lab developed Deep-Ocean Dropcams to observe deep-sea life in situ by capturing high quality imagery of the sea floor (Turchik et al. 2015, Figure 4.6.1). Dropcams have an onboard VHF transmitter that allows for recovery using locating antennae with backup location achieved via communication with the ARGOS satellite system. Dropcams house a Sony Handycam FDR-AX33 4K Ultra-High Definition video with a 20.6 megapixel still image capability.

This is encased in a 33-cm diameter borosilicate glass sphere and rated to 7000 m depth. Viewing area per frame is between 2–6 m^2, depending on the steepness of the slope where the Dropcam lands.

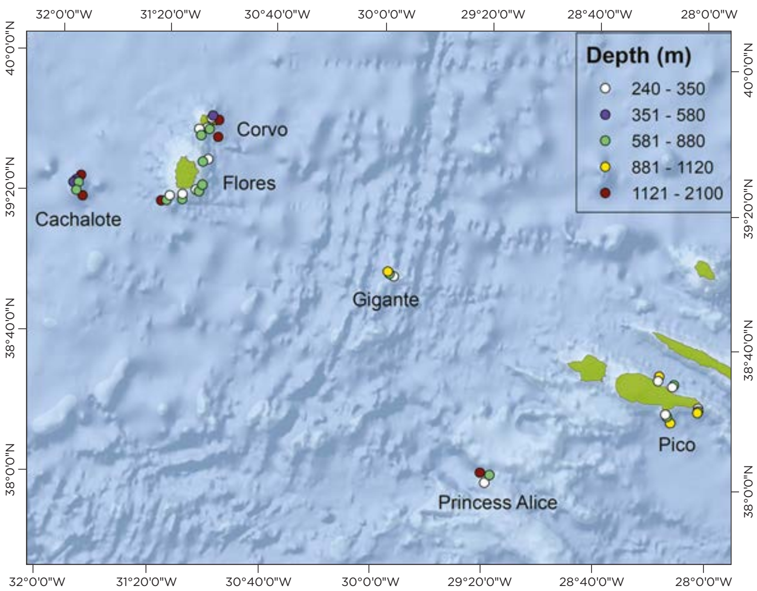
A total of 39 successful deployments of the Deep-Ocean Dropcam were conducted in the Azores in June 2018 (Figure 4.6.2). Cameras were baited with ~ 1 kg of frozen fish and deployed for 6 to 9 hrs. Lights and camera were programmed to periodically turn off. Between one and three total hours of video footage was recorded for each drop. Deployment depths ranged from 240 to 1480 m (mean = 748 m). Video footage was annotated for taxa present (identified to lowest possible taxon) and maximum number of individuals of a given taxon per video frame (MaxN). Frequency of occurrence (Freq. occ. %) for each taxon observed was calculated as the percent of incidence over 39 successful deployments. The substrata for each deployment were classified into standard geological categories following Tissot et al. (2007). These were: mud (M), sand (S), pebble (P), cobble (C), boulder (B), continuous flat rock (F), diagonal rock ridge (R), and vertical rock-pinnacle top (T).

FIGURE 4.6.1.

National Geographic's Deep-Ocean Dropcams.

FIGURE 4.6.2.

Deep-Ocean Dropcam deployments in the Azores Archipelago.



Deep Sea Dropcam Fish Assemblages

Rockfishes (Sebastidae), cutthroat eels (Synaphobranchidae) (Figure 4.6.3), and grenadiers (Macrouridae) were the most commonly occurring fish families on dropcam deployments in the Azores, occurring on 50%, 47%, and 47% of the deployments, respectively. Rockfishes occurred in hard-bottom habitats, in mixes of boulder, rock-ridge, and pebble habitats. Cutthroat eels commonly occurred in sand habitats, but also in mixes of pebble, cobbles, and flat rock habitats. Grenadiers also occurred in sand habitats, as well as areas of flat rock. The common mora (*Mora moro*, Family Moridae) was also frequently observed, occurring on 41% of the deployments (Table 4.6.1).

Lanternfishes (Myctophidae) and porgies (Sparidae) were the most abundant families, with MaxN values up to 35 and 30 individuals per frame, respectively. Both occurred on ~25% of the deployments. Porgies occurred in boulder and flat rock habitats, and occasionally in sand habitats. Lanternfishes occurred in sand and sometimes boulder habitats. Other taxa that occurred in abundance were boarfishes (Caproidae), *Anthias* spp. (Serranidae), and cutthroat eels, each with MaxN of 11–14 individuals per frame. Most other fish taxa had MaxN values of 1–3 per frame.

FIGURE 4.6.3.

Cutthroat eels (Synaphobranchidae) at 820 m at Princess Alice Bank.

TABLE 4.6.1.

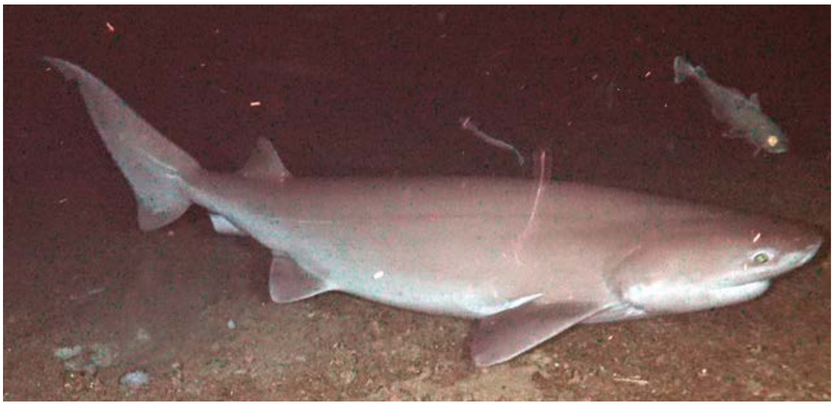
MaxN and frequency of occurrence (%) of fish taxa observed in deep-ocean dropcam deployments.

Class	Order	Family	MaxN	Freq. occ (%)
Actinopterygii	Anguilliformes	Synaphobranchidae	11	47
		Congridae	1	21
		Muraenidae	1	3
	Beryciformes	Berycidae	1	3
		(unidentified)	1	6
	Gadiformes	Macrouridae	3	47
		Moridae	6	41
	Lophiiformes	Chaunacidae	1	3
	Myctophiformes	Myctophidae	35	24
	Perciformes	Sparidae	30	26
		Epigonidae	1	18
		Polyprionidae	1	12
		Serranidae	14	9
		Caproidae	12	6
		Melamphaidae	1	6
		Carangidae	2	3
		Labridae	1	3
		Trichiuridae	1	3
	Scorpaeniformes	Sebastidae	3	50
		Scorpaenidae	2	12
		(unidentified)	2	3
Chondrichthyes	Chimaeriformes	Chimaeridae	1	3
Elasmobranchii	Carcharhiniformes	Proscylliidae	1	3
	Hexanchiformes	Hexanchidae	1	24
	Squaliformes	Somniosidae	1	24
		Etmopteridae	2	21
		Centrophoridae	2	12
	(unidentified)	(unidentified)	2	18

Individuals from the Class Elasmobranchii (sharks, rays, skates) occurred on 74% of the deployments, and occurred on each of the 10 deepest deployments (all > 1000 m depth). The Bluntnose sixgill shark (*Hexanchus griseus*; Family Hexanchidae, Figure 4.6.4) and the Portuguese dogfish (*Centroscymnus coelolepis*; Family Somniosidae) were seen most frequently, both appearing on ~25% of the deployments. Bluntnose sixgill sharks were seen on a mixture of sand, boulder, and flat rock habitat, from 320–1467 m. Portuguese dogfish were seen on a mixture of sand, boulder, flat rock, and rock-ridge habitat, from 680–1400 m. Other observed taxa include lantern sharks (Etmopteridae), dogfish (Centrophoridae), and finback catsharks (Proscylliidae).

FIGURE 4.6.4.

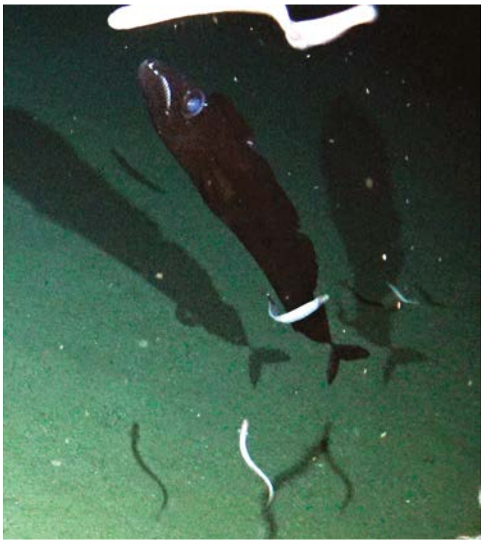
Bluntnose sixgill shark (*Hexanchus griseus*), and the common mora (*Mora moro*), observed at 880 m at Cachalote Seamount.



Rare sightings included a chimaera (Chimaeridae), a sea toad (Chaunacidae), and a black scabbardfish (Trichiuridae, Figure 4.6.5), seen at 790, 700, and 1340 m depth, respectively. The latter two were observed over sand habitat or pebble, while the chimaera was observed on flat rock. Two amberjacks (*Seriola* sp., Family Carangidae) were seen on one occasion, at 305 m depth.

FIGURE 4.6.5.

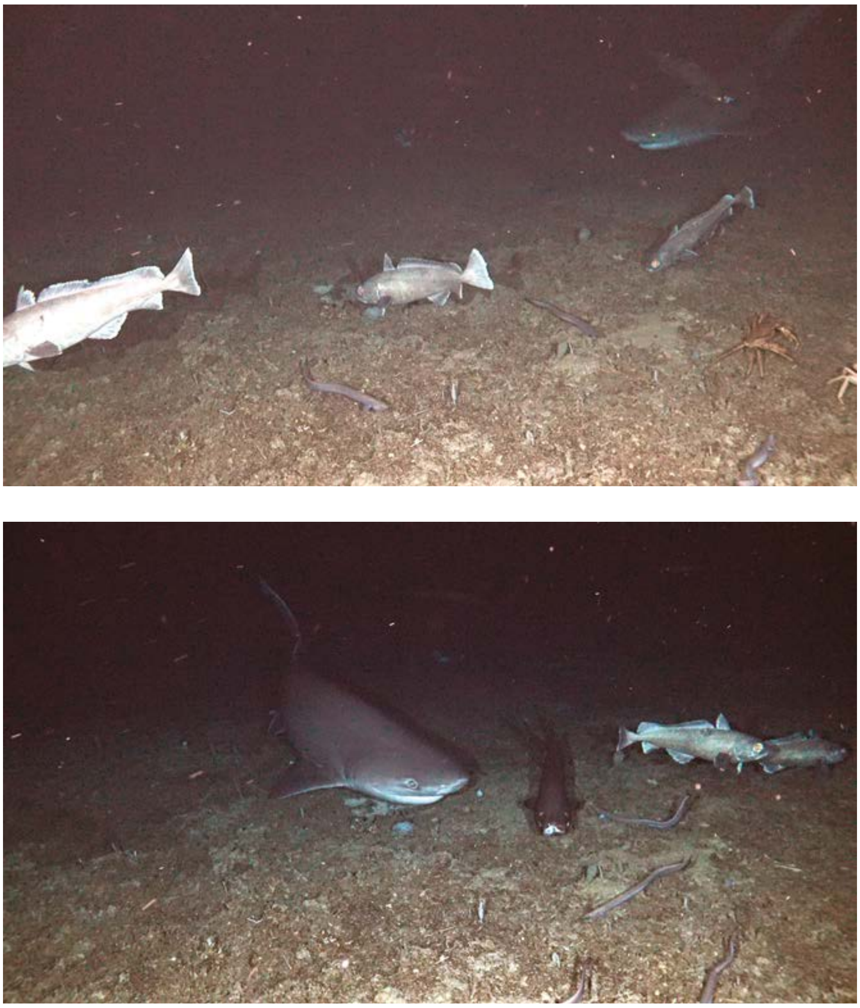
Black scabbardfish (*Aphanopus* sp.) at 1340 m off the southwest shore of Flores island.



The observed fish assemblages of the deepest deployments (1000–1480 m) were characterized by eels (Order Anguilliformes; including cutthroat eels), cods (Order: Gadiformes; including grenadiers), and cartilaginous fishes (Class Elasmobranchii; including sixgill sharks and dogfish sharks). Deployments at Cachalote Seamount were characterized by a diverse assemblage with a high abundance of sharks and morids (Figure 4.6.6).

FIGURE 4.6.6.

Fishes from the family Moridae and sharks at Cachalote Seamount.



Deep-Ocean Dropcam Invertebrates

Mobile invertebrates, including Brachyuran crabs, shrimps, squid, chaetognaths (arrow worms), sea stars (Asteroidea), and sea urchins (Echinoidea, including *Cidaris cidaris*), were encountered in the deep-ocean video footage (Figure 4.6.7). Arrow worms (Phylum: Chaetognatha) were observed on 53% of the deployments. In most cases, MaxN of arrow worms was only 1 or 2, but in some cases, they were abundant, with the highest observed MaxN at 15 individuals in a frame. Brachyuran crabs (Order Decapoda) were also frequently encountered (occurrence on 50% of deployments). The deep-sea red crab, *Chaceon affinis*, was the most common, as well as the toothed rock crab (*Cancer bellianus*). Krill and shrimp were common, observed on 83% of deployments. Squid (Family Ommastrephidae) were observed on three occasions.

Sessile invertebrates observed included black corals (*Bathypathes* cf. *patula*), octocorals (including *Viminella flagellum* and *Paracalyptrophora josephinae*), stony cup corals (*Dendrophyllia cornigera*), anemones (Anthozoa, including *Cerianthus* sp.) and deep-sea sponges (Porifera).

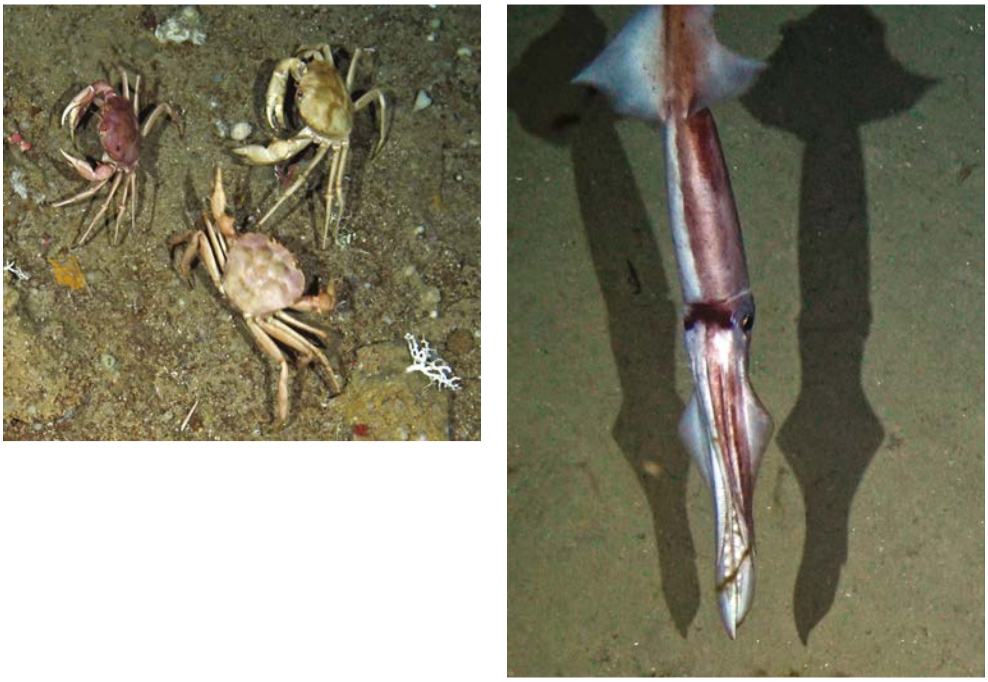


FIGURE 4.6.7.

Deep-sea red crabs (*Chaceon affinis*) were frequently observed across the depth range at most sites. Squid (Ommastrephidae) were observed on three occasions (680–750 m) at Flores and Corvo.

5. Commercial Fishing Impacts

The Azores Islands have one of the largest no-trawl areas in the world and therefore the main threats are related to longlines, illegal drift nets, nearshore overfishing, and poaching. The current fully protected areas are however very small and therefore most ecosystems are currently disturbed by different types of impacts, namely those of commercial fisheries.

We examined the magnitude and spatial distribution of fishing effort inside and around the Azores EEZ in 2017 and 2018 using data from Global Fishing Watch (GFW - http://globalfishingwatch.org/). Fishing activity within the Azores EEZ is non-uniformly distributed, with hotspots around São Miguel and Santa Maria, and the Princess Alice and Azores banks. Higher fishing effort was also detected in pelagic waters to the northeast of the EEZ, past 100 nm (Figure 5.1). These patterns result from the detection of 132 distinct vessels fishing within the EEZ between 2017 and 2018, using AIS data from Global Fishing Watch. Collectively, these vessels fished for 4085 and 3937 vessel-days in 2017 and 2018, respectively. Total fishing hours around the Azores rank on the high end of global fishing intensity (Kroodsma et al. 2018).

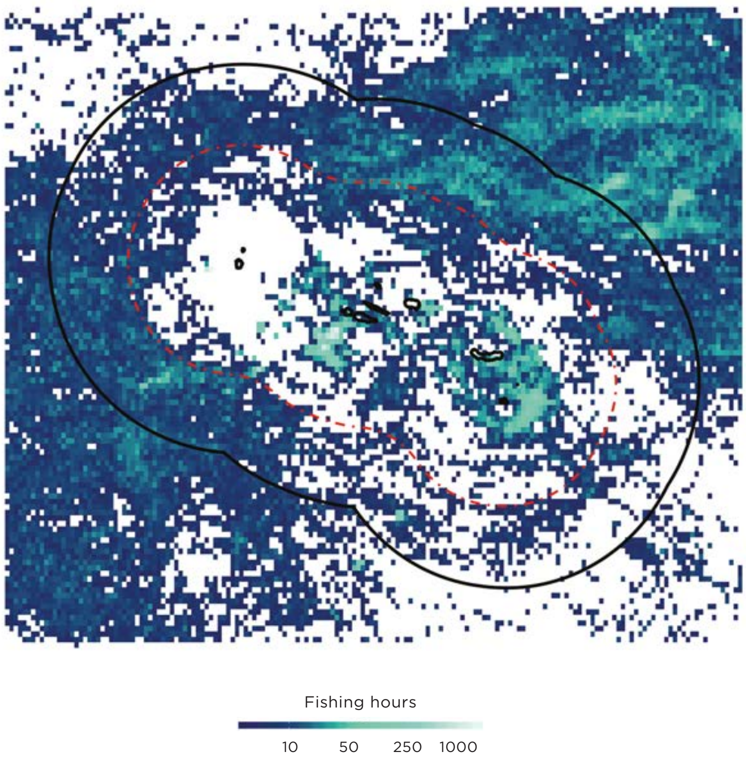


FIGURE 5.1.

Total fishing effort inside and outside Azores' EEZ (2017-2018). Black line indicates EEZ limits, red dashed line indicates the 100 nm limit.

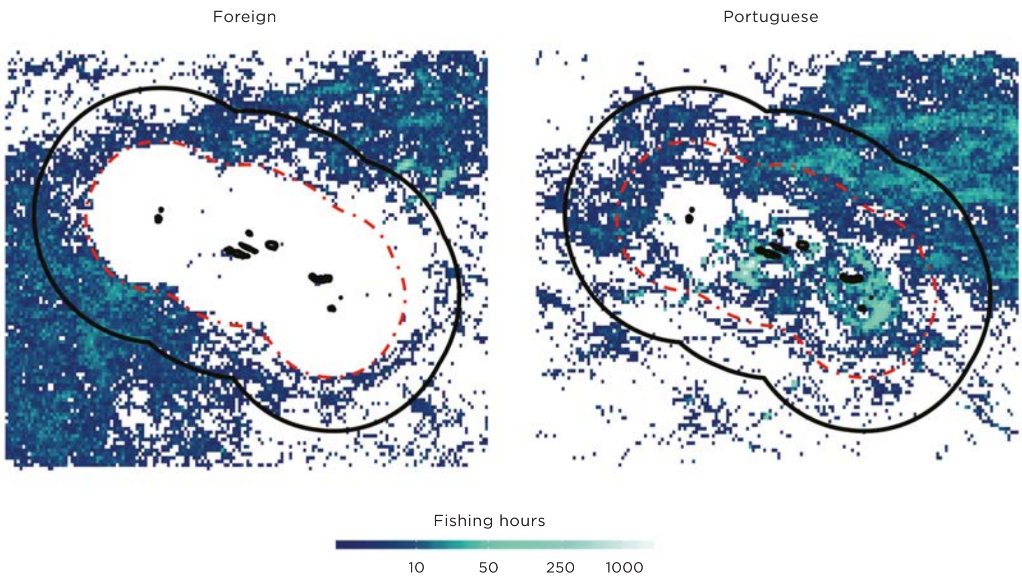
In 2018, most of the fishing effort within the Azores EEZ was done by Portuguese-flagged vessels that constitute a fleet of 71 boats using pole and line, drifting longlines, and set longlines. The remaining fishing effort is predominantly from Spanish-flagged longliners (Table 5.1). These foreign vessels fish exclusively outside the first 100 nm of the EEZ (Azores territorial waters), whereas the Portuguese-flagged fleet operates throughout the EEZ, especially close to the islands and to the northeast of the EEZ, extending all the way to outside the 200 nm boundary (Figure 5.2).

TABLE 5.1.

Fishing vessels and fishing days within the Azores EEZ by flag state (2017–2018).

Flag state	Vessels (2017)	Fishing days (2017)	Vessels (2018)	Fishing days (2018)
Portugal	61	2,989	71	3,167
Spain	45	1,094	43	763
Estonia	1	2	2	4
France	0	0	1	3

FIGURE 5.2.



Fishing effort by Portuguese and foreign-flagged fishing vessels (2017–2018). Black line indicates EEZ limits, red dashed line indicates the 100 nm limit.

Drifting pelagic longlining is the dominant fishing gear used by both Portuguese and Spanish-flagged vessels and accounts for 47.2% of all fishing effort in 2018. This fishing gear targets mainly billfishes and pelagic sharks such as blue and mako. A recent paper presenting a global analysis on the impact of this type of fishing on sharks showed that, on average, 25% of the space occupied by pelagic sharks overlaps with fishing effort, reaching 37% in the North Atlantic (Queiroz et al. 2019). This calls for immediate and concrete conservation actions directed to protect these species.

The second and third most used fishing gears are pole and line and set bottom longlines representing 34.3% and 15.1% of total fishing effort in 2018, respectively (Table 5.2). These two gear types are predominantly used by the Portuguese-flagged fleet. The remaining fishing effort in 2018 is from unidentified fishing gear and a handful of vessels classified as trollers and trawlers.

TABLE 5.2.

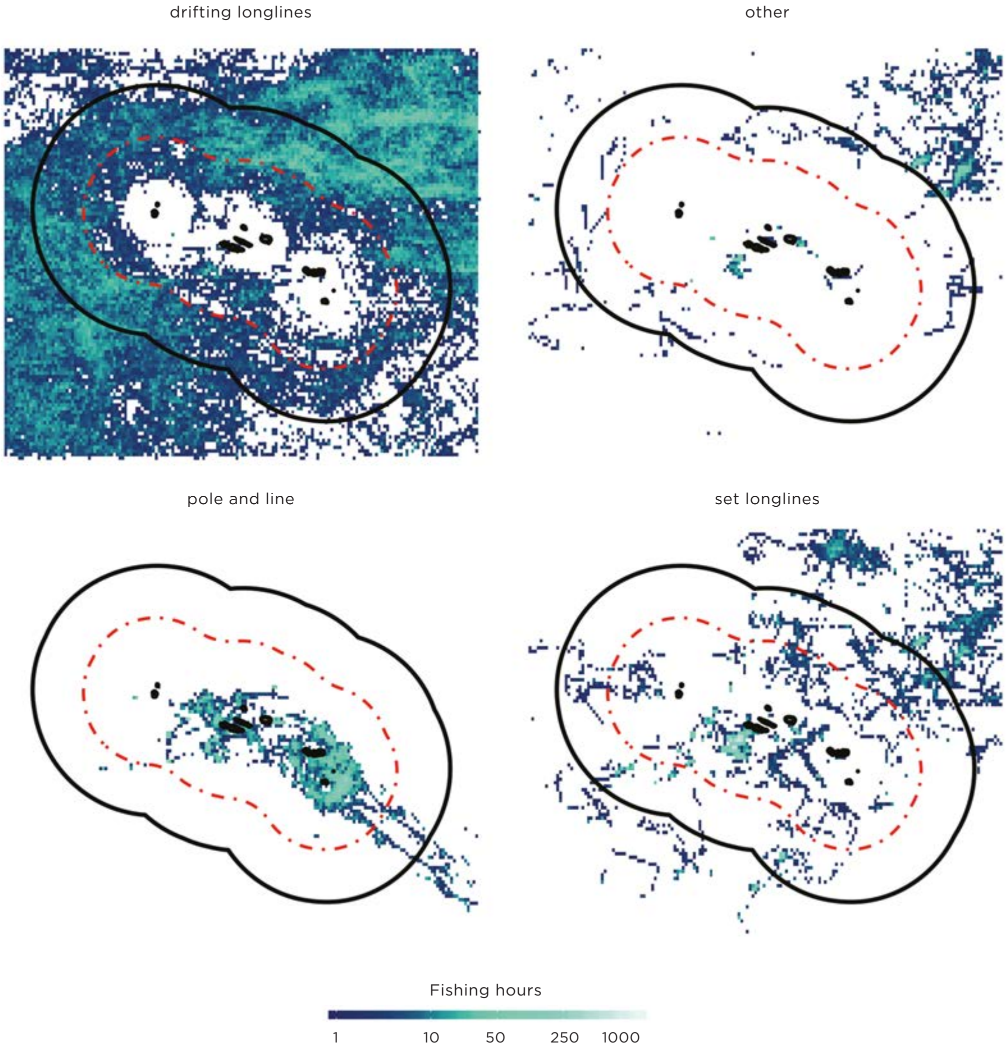
Fishing vessels and fishing days within the Azores' EEZ by gear type (2017–2018).

	2017		2018	
Gear type	**Vessels**	**Fishing days**	**Vessels**	**Fishing days**
Drifting longlines	64	2,298	59	1,857
Pole and line	26	937	31	1,350
Set longlines	12	767	13	595
Other	5	83	14	135

The footprint of drifting longlines is the most extensive between all gear types and covers most of the Azores EEZ (Figure 5.3). Only small coastal areas appear unfished by longliners, although it is possible that smaller fishing vessels—for which Global Fishing Watch data is scarce—operate here. In contrast, the pole and line fleet is much more concentrated within territorial waters (100 nmi), which is expected since it is comprised mainly of Azorean vessels. Vessels using set longlines are also active inside the territorial waters but present a more scattered footprint that extends towards the northeast.

FIGURE 5.3.

Fishing effort by gear type (2017-2018). Black line indicates EEZ limits, red dashed line indicates the 100 nm limit.



Overall, the footprint of fishing within the Azores EEZ is large and likely covers most of the region's waters. This is specially the case in the outer 100 nm of the EEZ, where close to 40 Spanish-flagged drifting longliners fish for up to 1000 vessel-days a year (Table 5.3). Within the EU common fisheries policy exclusive waters (< 100 nm), virtually all fishing effort is by Portuguese vessels using longlines (both set and drifting) and pole and line methods. Given that Global Fishing Watch lacks data on small-scale vessels, it is likely that the more artisanal and local fleet is missing from this analysis. As such, the coastal areas are not properly captured by this analysis, which therefore provides an underestimation of fishing effort.

TABLE 5.3.

Fishing vessels and fishing days within the Azores' EEZ by flag state and gear type (2017-2018).

		2017		2018	
Flag	**Gear type**	**Vessels**	**Fishing days**	**Vessels**	**Fishing days**
Portugal	pole and line	26	937	31	1,350
Portugal	drifting longlines	25	1,259	26	1,153
Spain	drifting longlines	39	1,039	33	704
Portugal	set longlines	8	752	8	568
Portugal	other	2	41	6	96
Spain	other	2	40	5	32
Spain	set longlines	4	15	5	27
Estonia	other	1	2	2	4
France	other	0	0	1	3

TOTAL MARINE FISHERY CATCHES (1950–2014)

Official fishery statistics often fail to report what has been truly extracted from the marine environment. Estimated total catch, including illegal, unreported, and unregulated (IUU) catch in the Azores was reconstructed by Pham et al. (2013a) and amended by the Sea Around Us Project at the University of British Columbia (www.seaaroundus.org/).

Large pelagics (≥ 90 cm) accounted for 44% of the total catch overall and consisted primarily of tunas and billfishes (Table 5.4, Figures 5.4, 5.5). The catch of this functional group has nearly tripled since the 1950s. Medium benthopelagics (30–89 cm) were the next most important group, accounting for 20% of the total and consisted mainly of blue jack mackerel *Trachurus picturatus* (67%) and blackspot seabream *Pagellus bogaraveo* (16%). Catch of this group has declined by nearly five-fold since the 1950s. Medium demersal fishes (30–89 cm) accounted for 15% of the total catch and their contribution has not changed substantially except for large catches in the 1973 (22721 tonnes) and 1974 (20919 tonnes) of unidentified fishes by the former Soviet Union. Large sharks (≥ 90 cm) accounted for 8% of the total catch and consisted of blue sharks *Prionace glauca* (42%), porbeagle *Lamna nasus* (27%), and unidentified Elasmobrachii (22%). Porbeagles accounted for 88% and 59% of the shark catch in the 1960s and 1970s, respectively. They have comprised < 1% of the catch since the 1980s. In contrast, the contribution of blue sharks to the total shark catch has increased from 8% in the 1960s to 70% in the 2000s.

Bigeye tuna (*Thunnus obesus*) comprised much of the catch of large pelagics in the early years but have been supplanted by skipjack tuna (*Katsuwonus pelamis*) in more recent years. Swordfish catches increased in the 1980s and early 1990s but are currently at low levels. Blue jack mackerel (*Trachurus picturatus*) comprised most of the medium benthopelagic catch until recent years, where blackspot seabream (*Pagellus bogaraveo*) contributed more to the catch of this group. Catch of porbeagle shark (*Lamna nasus*) showed a large peak in the mid-1960s but declined precipitously by the early 1970s. Blue sharks (*Prionace glauca*) have comprised much of the shark catch in recent years. Pilchard (*Sardina pilchardus*) catch was extremely sporadic with large catches in 1966 and 1979 and little catch otherwise. Large demersals were comprised primarily of conger eels (*Conger conger*) with modestly consistent catch over time except for smaller catches in the 1970s and early 1980s.

TABLE 5.4.

Total reconstructed catch from the Azores by fish functional grouping. Data from the Seas Around Us Project (www.seaaroundus.org).

Year	Total	1950	1960	1970	1980	1990	2000	2010
Large pelagics (≥ 90 cm)	44.38	19.36	46.37	34.11	57.40	45.17	40.44	57.77
Medium benthopelagic (30–89 cm)	19.58	50.59	21.67	17.14	20.50	16.58	17.84	10.25
Medium demersal (30–89 cm)	15.42	10.93	6.69	36.28	10.76	10.95	12.37	9.24
Large sharks (≥ 90 cm)	8.00	0.24	12.91	0.63	1.78	12.05	17.10	10.29
Others	7.67	5.31	3.27	6.68	7.03	11.75	8.58	10.17
Small pelagic (< 30 cm)	2.52	6.80	6.42	4.06	1.02	0.32	0.73	0.24
Large demersal (≥ 90 cm)	2.43	6.78	2.67	1.10	1.50	3.18	2.94	2.03

FIGURE 5.4.

Total catch (reported and unreported) for the Azores from 1950 to 2014. Data from the Seas Around Us Project (www.seaaroundus.org).

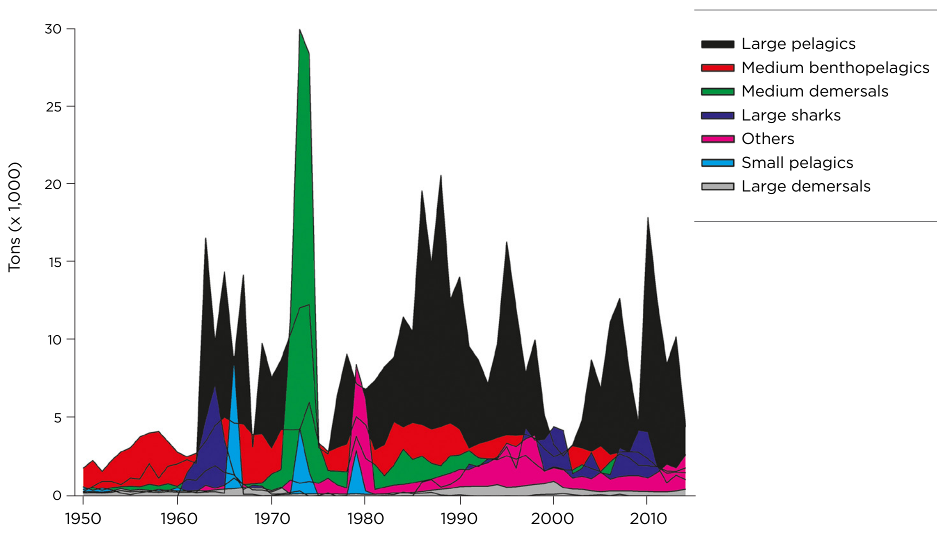
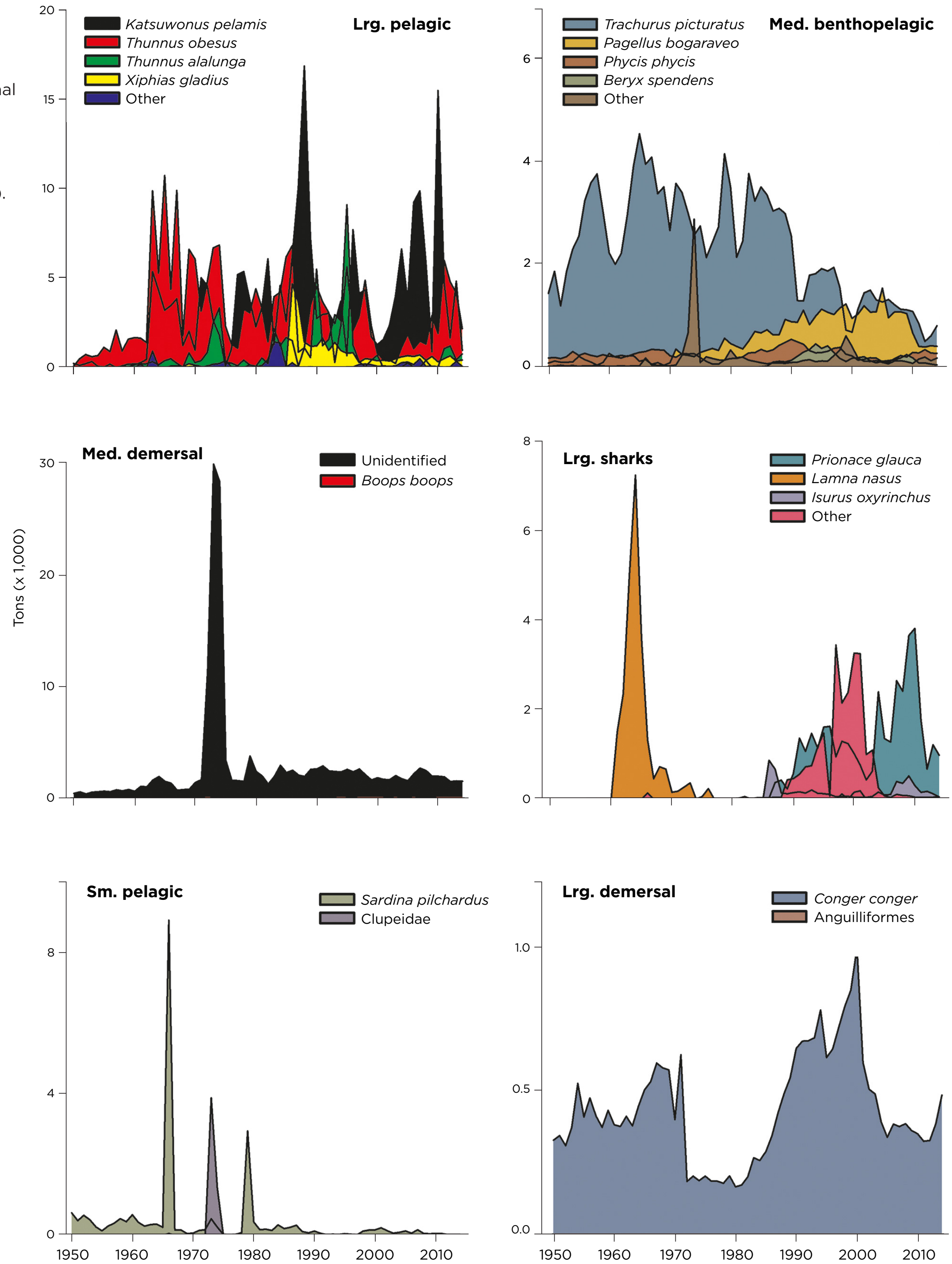


FIGURE 5.5.

Time series of catch by functional group. Data from the Seas Around Us Project (www.seaaroundus.org).



CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS AND **RECOMMENDATIONS**

The waters around the Azores Archipelago contain some of the most important island, open-water, and deep-sea environments in the Atlantic. The ocean has long defined the cultural heritage of the Azoreans. Despite its importance, this invaluable, fragile, and irreplaceable blue natural capital is under threat due to numerous stressors, and needs to be protected, valued, and promoted to sustain environmental, social, and economic goals. By doing so, the Azores can become a model sustainable ocean region for the rest of Europe and the world.

The Azores has led conservation efforts for several decades in Europe with 52 areas designated under some type of protection. However, most of these areas still do not have management plans (which are currently being developed), are small, weakly regulated (< 1% of the Azores sea is fully protected), and lack financial and human resources to allow them to function properly. The Azores has also been a leader in developing sustainable fisheries management measures with, for example: the prohibitions of deep-sea bottom trawling and purse seining for tuna species in a large portion of the EEZ; the exclusion of bottom longlines within 3 nm and its restriction from 3 to 6 nm from shore; the delineation of a 100 nm zone around the islands, which limits pelagic fishing to local vessels only; the closure of important fishing grounds such as the Condor Seamount; and the implementation of multiple technical measures over the years, such as minimum landing sizes or weights, minimum mesh and hook sizes, banning the use of wire leaders on pelagic longlines, limitation of licenses for some specific gears, as well as area and temporal closures. Nevertheless, there is a common perception among fishers that many stocks and areas are facing serious signs of overexploitation.

The magnitude and spatial distribution of fishing effort inside and around the Azores EEZ shows that the footprint of drifting longlines is the most extensive among all gear types, and accounted for 47% of all fishing effort in 2018, covering nearly the entire Azores' EEZ. The overall fishing footprint in the Azores is large by global standards and lost fishing gear was detected in several deep-sea locations. Reconstruction of fishing effort since the 1950s shows sharp declines for some species and strong fishing pressure for others, highlighting the urgent need for additional conservation and fisheries measures to be adopted. One of the most effective ways to address the overexploitation of fisheries resources and the damage associated with fishing gear is by fully or strongly protecting a significant portion of the Azores waters. Marine plastic pollution was observed across a wide range of habitats and the misuse of plastics worldwide needs to be addressed at the global scale, combined with a program of best practices and techniques targeting fishermen and other local residents.

There are four main priorities to advance marine conservation policies in the Azores and allow the region to benefit from the long term and sustainable use of its sea.

The first is to significantly increase the number of areas and the proportion of the Azores EEZ under full protection. Only through fully or strongly protected marine protected areas (MPAs) can the functional and structural integrity of marine ecosystems be preserved. With less than 1% of the Azores seas under full protection, a top priority for the region is to establish fully protected, ecologically representative, well-designed, and properly managed and enforced MPAs. Science shows that only by strongly protecting at least 30% of the ocean will we be able to address the extinction crisis and contribute to recovering fish stocks, protecting habitats and species, allowing ecosystems to recover and maintaining vital ecosystem services.

The second priority is to fully implement the existing conservation areas (MPAs, Natura 2000 sites, species management areas) by developing management plans that effectively protect these areas and allocate the necessary financial and human resources to properly manage them. A great effort has been made in the last three decades by the Azores to designate important conservation areas. However, these areas have not provided their expected benefits owing to poor design and management, lack of enforcement and compliance, and limited financial and human resources for effective management. Our results and those from previous studies show no clear ecological conservation benefits from the existing MPAs except where they are strongly protected (e.g. Formigas and Condor seamounts and Corvo voluntary reserve). Even though 11 marine Important Bird Areas (IBAs) have been identified in the Azores, few of these areas benefit from effective protection status. It is therefore necessary to include these IBAs in efficient fully or strongly protected MPAs, which are properly monitored and managed.

While acknowledging that the Azores has pioneered the implementation of some sustainable fishing practices, the third priority is to implement additional measures that promote sustainable local fisheries and eliminate more unsustainable fishing practices, such as the use of pelagic longline fishing, coastal gillnets, and reduce the impacts of set longlines on seamounts and benthic communities.

The fourth priority is to promote education and ocean literacy throughout the archipelago and to the wider Portuguese society in support of the conservation measures proposed in this report. Awareness of the threats facing the Azores seas and of the effectiveness of the solutions to mitigate these threats, will be required to support government action, adoption of conservation and sustainable fishing measures by the different authorities, and compliance by all ocean users.

A number of recommendations for action have been identified as a result of these two expeditions, analyses of existing data, and through the inputs of researchers and local practitioners. A non-exhaustive list follows, which assumes that these recommendations, if implemented, will be supported by the necessary financial and human resources to help ensure their effectiveness.

Coastal Reefs and Shallow-Water Seamounts:

- Protect natural rockpools throughout the archipelago, preventing their artificialization. These habitats are critical for many fish and invertebrate species, namely the juveniles of the dusky grouper, which is listed as vulnerable by IUCN.
- Fully implement the limpet exclusion zones and management measures: while there are signs of some recovery in certain areas, the populations are still well below historical levels.
- The Azores mesophotic reefs are rich in species and deserve special attention since many of these reefs are not covered by effective conservation measures and are not included in a network of coastal MPAs. The scarcity of large predatory fishes in the region's mesophotic reefs could be a sign of significant fishing impacts. Modern studies of marine ecosystems began long after enormous changes in these systems had occurred and the 'shifting baseline syndrome' makes it difficult to determine what constitutes a natural ecosystem and how to manage these ecosystems.
- Accordingly, greatly increase the area of fully or strongly protected nearshore MPAs throughout the archipelago to rebuild coastal ecosystems and populations of target fish and invertebrate species, which can help alter the current trends of declines. An effective network of MPAs could restore high levels of reproductive biomass of more vulnerable species such as dusky groupers, island groupers, and hogfish, to mention a few. Include in these areas representative elements of all coastal habitats and mesophotic reefs that have high levels of biodiversity. Each sub-region of the archipelago should strive for protecting at least 30% of these nearshore ecosystems.
- Ban or greatly limit the use of coastal gillnets around the islands. Nets are impacting nearshore ecosystems, which are devoid of large, numerous predators except in a few protected places. Additionally, set longlines and the weights of bottom handlines impact fragile and important habitats such as mesophotic reefs (30-150 m). Fish biomass levels obtained throughout the archipelago are comparable to heavily fished areas in nearby Madeira and the Canary Islands (Friedlander et al. 2017), and these communities need to be rebuilt.

- Reinforce the conservation measures at Corvo Island, extending protection to nearshore habitats. MPAs at Corvo and Formigas have the highest densities of dusky groupers found in the archipelago and the success of these MPAs serve as examples of what can be accomplished elsewhere in the archipelago.
- Develop specific and more precautionary conservation and fisheries management plans for Corvo and Flores islands due to their vulnerability as a result of extreme geographic isolation. Owing to their upstream location, these islands are less likely to receive recruitment from other islands or propagules dispersing from other Macaronesian archipelagos and seamounts or from continental Europe.
- Include shark nurseries (e.g. tope shark and smooth hammerhead shark), and areas where these species are known to consistently occur (e.g. the north shore of Faial) in a network of coastal MPAs.
- Fully protect Formigas Seamount, Baixa do Ambrósio (Santa Maria Island), and Princess Alice Bank summit. Formigas has the highest biomass of fish species and hosts unique benthic communities. The summit of Princess Alice Bank is also biological distinct from the nearby islands and is a magnet for megafauna and an important area for the development of sustainable tourism activities. Sharks and rays aggregate on the summits of these seamounts and coastal reefs for putative mating, pupping, and feeding activities and therefore these areas should be included in the coastal network of MPAs.
- Monitor the occurrence and abundance of non-native species, implement effective measures to prevent new invasions (including ‘clean hull’ policies for incoming sailing boats), and build rapid intervention methods to eliminate the early appearance of species with potential to become invasive.

Open Water Environments:

- Protect essential habitat hotspots for pelagic shark populations of conservation interest or that are known to use the Azores as a nursery habitat, including blue, mako, smooth hammerhead, and thresher sharks. Since the Azores fishing fleet targeting pelagic species is mainly composed of sustainable pole and line gears, eliminating pelagic longlines from the Azores EEZ will have the greatest benefit to the local fisheries. This has the added advantage of eliminating bycatch of other species of conservation interest such as sharks, sea turtles, sea birds, etc, without a heavy cost to the Azorean fisheries sector.
- Protect areas of conservation importance for marine mammals, namely breeding, feeding, and aggregation sites, and set some of these areas off limits to tourism operations.

Deep Sea:

A great effort was put forth during the Blue Azores 2018 Expedition to map deep-sea benthic habitats and survey previously unexplored seamounts, which led to the discovery of a new hydrothermal vent field, new species of cold-water corals, and new areas that may fit the FAO vulnerable marine ecosystems (VME) definition. These exciting discoveries, close to the shores of the Azores islands, highlight once again how little we know about the deep-sea of the Azores EEZ. The European Union, and nations like Portugal in particular, are taking great strides to develop trans-Atlantic collaborations to map the deep sea. It would be a costly mistake to neglect what needs to be protected in the deep-ocean waters close to our shores, much of which remains to be discovered. The Blue Azores 2018 Expedition generated scientific data that supports the following specific recommendations:

- Create a long-term strategy for increasing scientific knowledge of the Azores deep sea and provide adequate technological means for the implementation of such a strategy for increasing scientific knowledge to support sustainable management and conservation.
- Continue ongoing efforts to map and identify areas in the deep sea of the Azores that fit the FAO definition of VME.
- Fully protect a representative network of seamounts and island slopes where VMEs (e.g. significant cold-water coral gardens and sponge aggregations) occur. Include representative examples of the “living fossil deep sea community” characterized by the presence of the long-lived oyster cf. *Neopycnodonte zibrowii* (lifespan of several centuries) and the sessile crinoid *Cyathidium foresti*. The fragile nature of this habitat and its singularity in the North Atlantic justifies its protection. Seamounts such as Cachalote, where deployments of deep-sea dropcams showed a highly diverse assemblage with a high abundance of deep-water sharks, should also be considered for such a network.
- Fully protect the newly identified VME area on the SW ridge of the Gigante Seamount complex, composed by the most extensive and densest *Paragorgia* spp. coral garden identified so far on basaltic and lithic rocks in the Azores region. Some coral colonies reaching over 1-meter in height and 1.5 m in diameter with an estimated age of over one century were still pristine while others showed signs of significant impacts by bottom longlines.
- Fully protect the newly discovered Luso hydrothermal vent field.
- Throughout the region, promote the change from set longlines to vertical longlines, which are much more compatible with the conservation of these deep-sea habitats, namely VMEs.

Species and Habitats:

- Approve legislation to fully protect species and habitats of conservation priority such as the dusky grouper, island grouper, hogfish, slipper lobster, sharks, devil rays, deep water coral gardens, and sponge aggregations.
- Develop management plans for all Natura 2000 sites (Special Protection Areas and Special Areas of Conservation) making them fully or highly protected.

The Blue Azores Program, of which these expeditions are a first step, has a vision to facilitate the Azores in becoming a model economy for a blue society where the natural capital is protected, valued and promoted, through sustainable use of marine-associated businesses and civil society sectors, with effective conservation actions across the entire marine environment. It aspires to improving and expanding public education and environmental education programs and initiatives, leading to the conservation of the marine environment, an increase in ocean literacy, and encouraging the development of a thriving conservation-oriented blue economy.

Implementing the measures contained in the recommendations above, together with the supportive actions envisioned in the Blue Azores Program, would bring significant progress towards a more sustainable marine management in the region, making it a model, regionally and globally.

ACKNOWLEDGEMENTS

Under the existing legislation by the Regional Government, swimming with whales or other non-dolphin cetaceans is forbidden in the Azores. Filming and photographing whales underwater are strictly regulated and requires a special permit. All research and filming with whales from both the 2016 and 2018 expeditions were performed under special permits by the Regional Government of the Azores: Permit 19-ORAC-2016 of 14-09-2016 and 11-ORAC-2018 of 12-06-2018. When filming, the approach to whales was done by professionals only, taken all the necessary steps not to disturb the animals.

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APPENDIX

Appendix I.

Expeditions' Participants List

CHIEF SCIENTISTS:	
Alan M Friedlander	National Geographic and University of Hawaii
Emanuel J Gonçalves	Oceano Azul Foundation and MARE-ISPA

EXPEDITION LEADERS:	
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