3.1 Azores ecoregion – Ecosystem overview

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Ecoregion description

For this overview, the Azores ecoregion corresponds to the Azores Exclusive Economic Zone (EEZ) inside ICES Subarea 10 (Figure 1). The ecoregion lies within a much larger open ocean ecosystem, and straddles the Mid-Atlantic Ridge (MAR). The Azores is a Portuguese archipelago composed of nine islands with almost no geological continental shelf, and the Azores Exclusive Economic Zone (EEZ) includes 461 identified seamounts.

The Azores are located on the northern border of the Subtropical Gyre of the North Atlantic, characterized by a high horizontal temperature gradient and the strong influence of the Gulf Stream; this transports hot surface water of equatorial and tropical origin from the west to the ecoregion. The North Atlantic Oscillation (NAO) affects the flow of regional sea currents.

The main water masses in the Azores ecoregion are as follows: the North Atlantic Central Water at depths shallower than 600–700 m above the main thermocline; the North Atlantic Deep Water below 2000 m depths; and the Subarctic Intermediate Water, Labrador Sea Water, and Antarctic Intermediate Water at intermediate depths. The Mediterranean Water can also occur at intermediate depths between approximately 650 m and 1200 m.

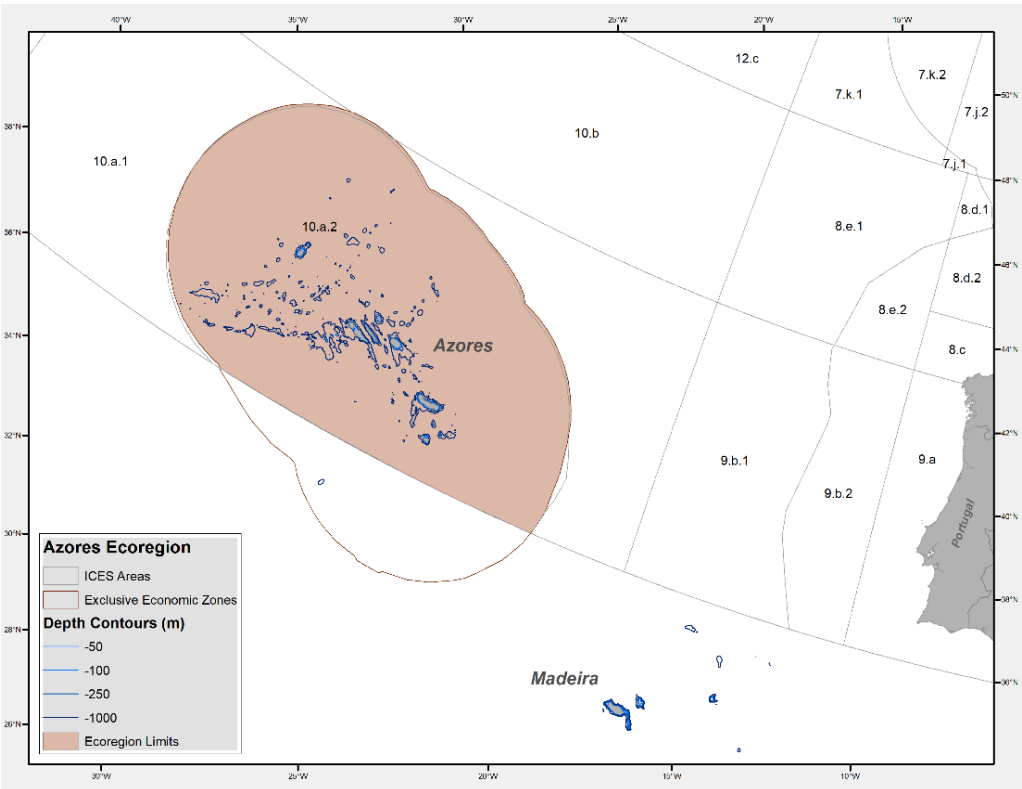


Figure 1 The Azores ecoregion, showing EEZs, ICES statistical areas, and depth contours.

Fisheries in the Azores are managed under the EU Common Fisheries Policy (CFP), with some fisheries managed by the North East Atlantic Fisheries Commission (NEAFC), the International Commission for the Conservation of Atlantic Tunas (ICCAT), and regional government. Fisheries advice is provided by the International Council for the Exploration of the Sea (ICES), the European Commission's Scientific Technical and Economic Committee for Fisheries (STECF), the South West Waters Advisory Council (SWWAC), and the Long Distance Advisory Council (LDAC). For large pelagic fish (tuna and tuna-like species) fisheries advice is provided by ICCAT. Environmental policy is managed by national agencies and OSPAR, with advice being provided by national agencies, OSPAR, the European Environment Agency (EEA), and ICES. International shipping is managed under the International Maritime Organization (IMO) and whaling is managed by the International Whaling Commission (IWC).

Key signals within the environment and the ecosystem

- The Subtropical Gyre primarily influences the ecoregion where surface conditions have recently been warmer than average, particularly in the Gulf Stream region. A northward shift of the subtropical front there may explain the 3°C warming anomaly.
- There is an indication that the size composition of the plankton community is shifting towards smaller taxa.
- The annual rate of discovery of non-indigenous species increased from 1.1 per year between 1950 and 1999, to 2.1 per year between 2000 and 2015.

Pressures

The most important pressures in the Azores ecoregion are the selective extraction of species, marine litter, and the introduction of non-indigenous species. These pressures are mainly linked to the following human activities: fishing, tourism and recreation, and maritime transport (Figure 2). Other pressures, of minor importance in this ecoregion, include underwater noise, abrasion, smoothing, and substrate loss. The main pressures described below are defined in the ICES Technical Guidelines.

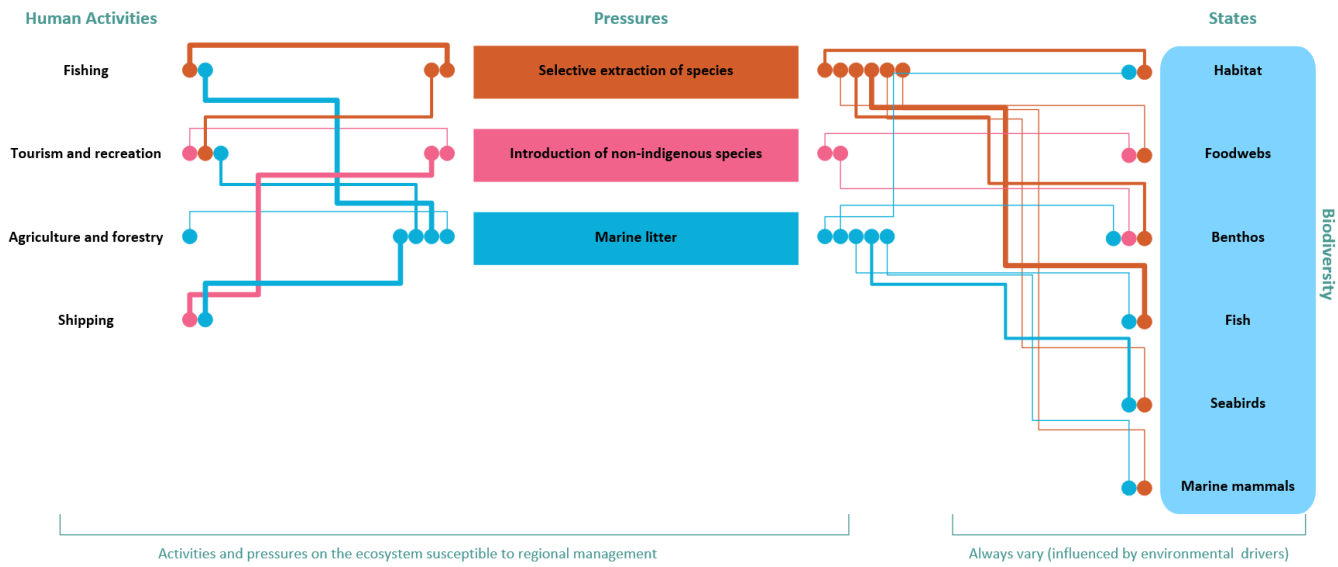


Figure 2 Azores ecoregion overview with the major regional pressures, human activities, and ecosystem state components. The width of lines indicates the relative importance of main individual links (the scaled strength of pressures should be understood as a relevant strength between the human activities listed, and not as an assessment of the actual pressure on the ecosystem). Climate change affects human activities, the intensity of the pressures, and some aspects of state, as well as the links between these.

Selective extraction of species (including non-target species)

Fishing is the main activity contributing to the pressures in the Azores ecoregion. The commercial demersal fisheries that take place in coastal areas use handlines and gillnets, with bottom longlines and handlines being used on the slopes and in

the deep seas. Fisheries for large pelagics use surface longlines as well as pole and line, and fisheries for small pelagics use purse-seines. The bulk of the fisheries, both pelagic and demersal, occur at depths of less than 700 m. Fishing is prohibited below 800 m in the ecoregion. Other fisheries also occur seasonally in some coastal areas, such as the hand harvesting of littoral invertebrates and a trap fishery for benthic crustaceans. Recreational fishing is a relatively important activity because of increasing levels of tourism. Bottom trawling has been banned since 2005.

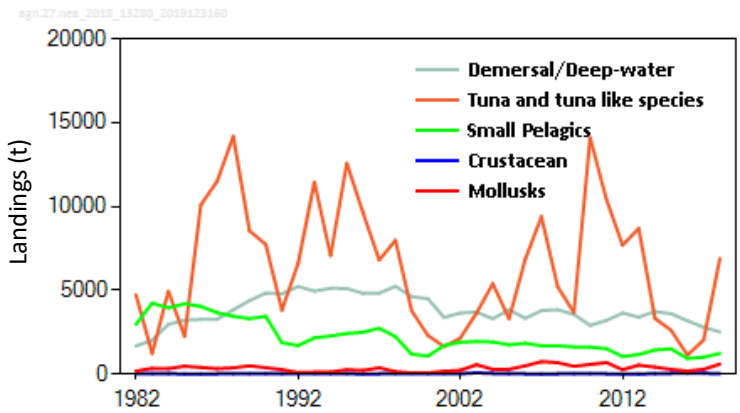
Commercial stocks

The majority of the fisheries in the ecoregion is performed by Azorean vessels, with only a small proportion of the catch taken by vessels from the mainland of Portugal and from Spain (swordfish surface longliners).

Around 90% of the vessels in the Azorean fleet are less than 12 m, and the fleet is licensed to target several species. Demersal and tuna are the most important fisheries (representing on average almost 80% of the total landings in weight). The fishery is flexible, however, with the changing of target according to species abundance and market price.

Recreational fishery is also an important component, targeting littoral/coastal resources, demersals, and large pelagics; this trend is increasing because of an increase in tourism.

Fish stocks in the Azores ecoregion are typically part of stocks with a broad distribution, thus the state of stocks is affected by pressures over a wider area than just the ecoregion itself. Most of the demersal/deep-water, small pelagic, and tuna resources are monitored and routinely assessed by ICES or ICCAT. Out of those it is only tunas that have an analytical assessment, with the other fished species managed under the precautionary approach. Tunas, however, have a much broader distribution and the Azores fisheries have only a minor impact on the stock biomass. They will therefore not be considered here (see ICES Oceanic Northeast Atlantic Ecosystem Overview). For the other resources assessed under ICES, the key species that control the dynamics of the demersal/deep-water and small pelagic fisheries are shown below.



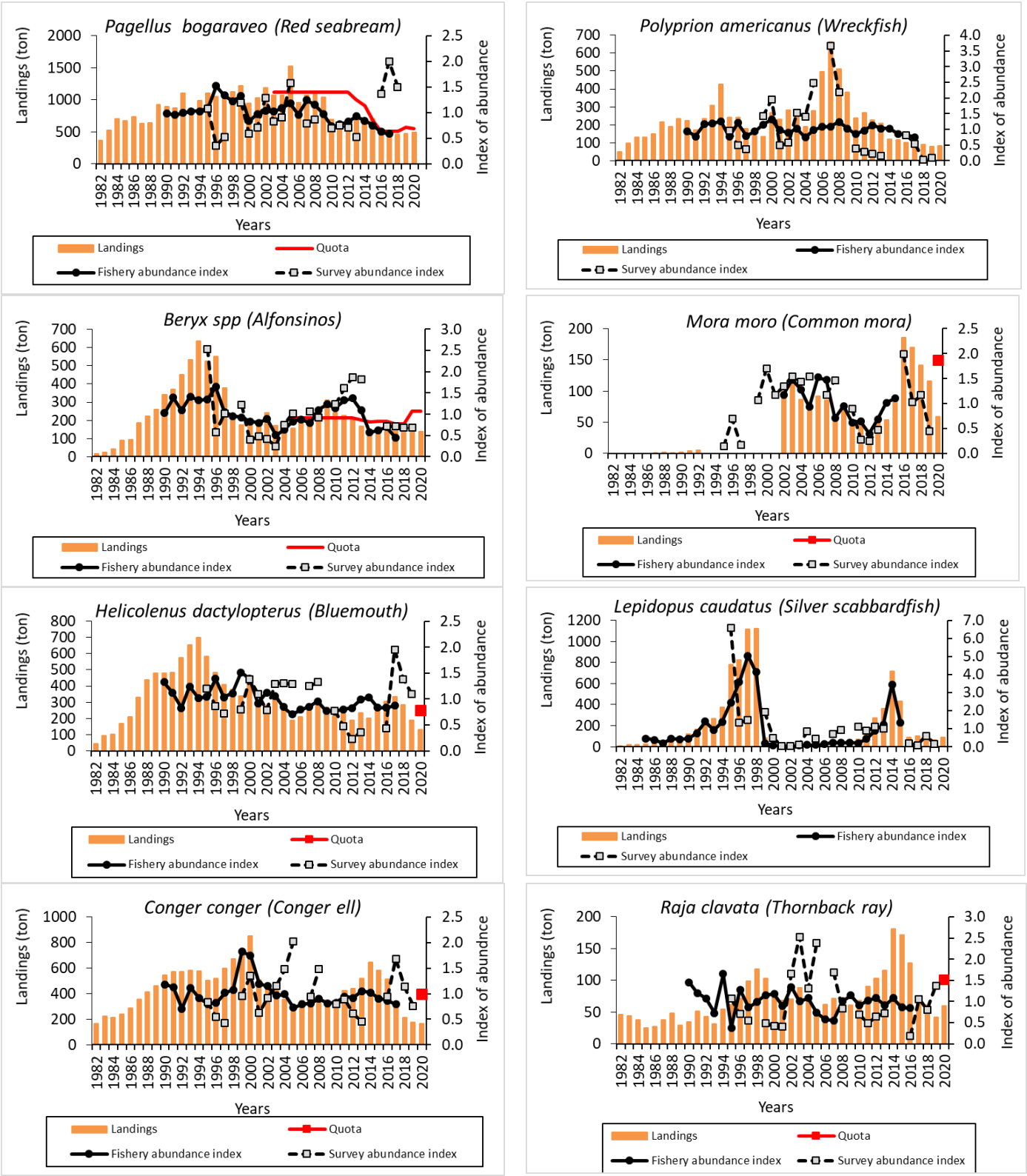


Figure 3 Trends of landings and abundance indices for the main demersal/deep-water fish of the Azores.

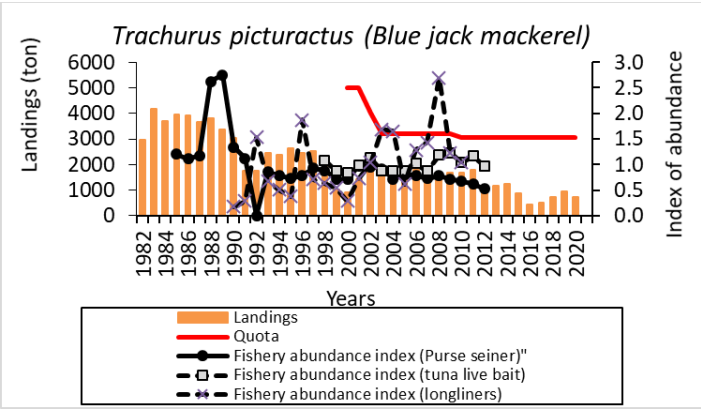


Figure 4 Trends of landings and standardized abundance indices for the main small pelagic resources of the Azores.

Molluscs (*Patella* spp. and *Megabalanus azoricus*) have been heavily exploited commercially in the Azores ecoregion, and are now on the OSPAR list of threatened and declining species.

Seabirds and marine mammals

Observer programmes in Azorean fisheries have found few or no seabirds as bycatches. However, data on the incidental catch of seabirds are lacking for fisheries that use pole and line. There are negligible effects on marine mammals from Azorean fisheries, although interactions have been reported.

Non-indigenous species

The ecoregion has a total known number of 105 non-indigenous and cryptogenic (obscure or of unknown origin) species. The majority (57 species) arrived between 1950 and 1999. Since 2000, a total of 33 new species have been recorded in the Azores. The annual rate of discovery of non-indigenous species increased from 1.1 per year between 1950 and 1999, to 2.1 per year between 2000 and 2015 (see Figure 5). The dominating taxonomic groups are mollusca, rhodophyta, and chordata.

Shipping, particularly through ballast water and the biofouling of hulls, is the main species introduction vector, followed by water currents (natural spread from neighbouring areas).

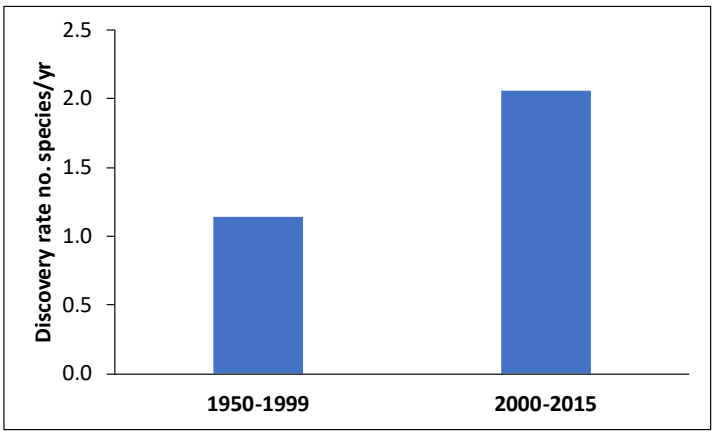


Figure 5 Average annual rate of new non-indigenous and cryptogenic species discoveries in the Azores ecoregion between 1950 and 1999, then between 2000 and 2015. (Source: AquaNIS, 2018).

Marine litter

Marine litter derives from land, discarding at sea, or brought from outside the ecoregion by oceanic currents. The accidental ingestion of debris has been recorded in birds, turtles, and some fish in the Azores ecoregion; this may cause an

obstruction in the digestive tract leading to death. There is no record of macroplastics being found in stranded marine mammals in the Azores. Birds and turtles may become entangled in lost fishing gear.

Plastic fragments were found in 93% of the stomachs of Cory's shearwater fledglings found dead, but there is no evidence that the fragments themselves caused death. The effect of microplastics across the marine foodweb of the Azorean ecosystem is uncertain.

Other pressures in the ecoregion

- **Abrasion** pressure principally affects the seabed habitats, but the rate is low in the Azores because bottom trawling is banned. The bottom longline fishery can damage deep-sea coral habitats.
- **Smothering and selective extraction of non-living resources** from the seabed is caused by the extraction of aggregates and by navigational dredging in inshore waters.
- **Substrate loss** is caused by coastal development, including land reclamation for coastal defences, residential development and agriculture, ports, marinas, shipping channels, and aggregate extraction.
- **Underwater noise** is caused by activities such as shipping, as well as tourism and recreation, which may affect marine mammals, fish, and other organisms using sound or pressure senses.
- **Introduction of contaminating compounds** is primarily a result of coastal discharges and shipping. This pressure can affect all ecosystem components but may accumulate in the foodweb, leading to particular consequences for the higher trophic levels (mammals and birds). Some of these compounds may be very stable and remain in the ecosystem for many decades after their introduction.
- Input of **nutrient and organic enrichment** is relatively important in coastal areas where intensive agriculture is practised or where certain industries are prevalent. Shipping and atmospheric nitrogen contamination also contribute to this pressure.

Land-based pressures may affect populations of seabirds in this ecoregion. These pressures include the introduction of predatory mammals (e.g. rats and cats) to islands as well as the attraction to artificial light of juvenile seabirds, particularly the Procellariformes (petrels, shearwaters, and storm-petrels).

Climate change impacts

At the global level, current greenhouse gas emissions correspond most closely to the IPCC Regional Concentration Pathway (RCP) 8.5. Within the Azores ecoregion, this scenario projects a 2.5°C warming above mean conditions for the years 2050–2099. There is little spatial variability in projected warming across this relatively small ICES ecoregion (see Figure 6).

Human-induced climate change and ocean acidification may be expected to have a significant influence on the ecoregion in the future. There is, however, little or no information at present on existing or predicted future changes in the biology of the ecoregion as a consequence of climate change.

This ecoregion is a hotspot for cold-water corals, and laboratory studies have demonstrated that cold-water corals are vulnerable to ocean acidification.

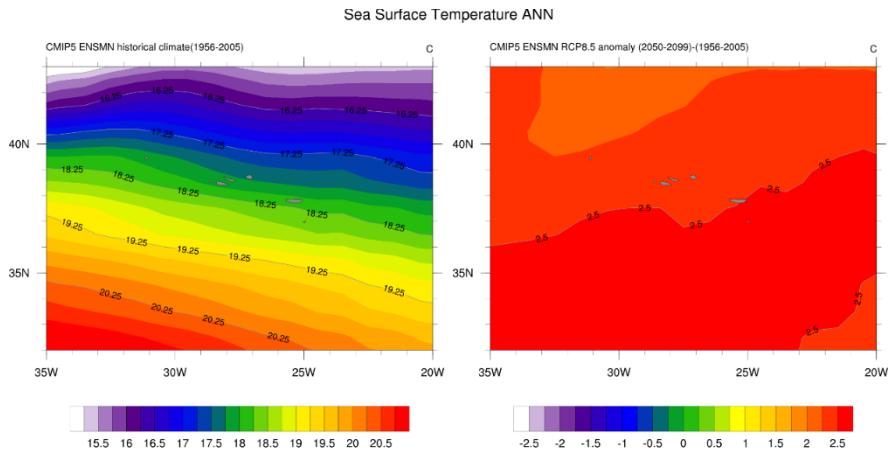


Figure 6 Ensemble mean sea surface temperature (SST) from the 5th Coupled Model Intercomparison Project (CMIP5), interpolated on a 1° × 1° grid for the entire year in the Azores ecoregion. Left panel: Historical SST for 1956–2005. Right panel: Difference in the mean climate in the future time period (RCP8.5: 2050–2099), compared to the historical reference period.

State of the ecosystem components

Substrate

Continental shelves around the Azorean islands are quite narrow and represent an area of just 1500 km^2, half of which is composed of rocks and one third of mixed sediment. Hard substrate is found in each deep-sea biological zone (see Howell, 2010 for classification), but most extensively in the abyssal (> 2700 m). Mixed sediments are also present at each depth level, but the largest area is in the mid-bathyal (1100–1800 m). The most extensive substrate types in the Azores ecoregion are muddy sediment (Figure 7).

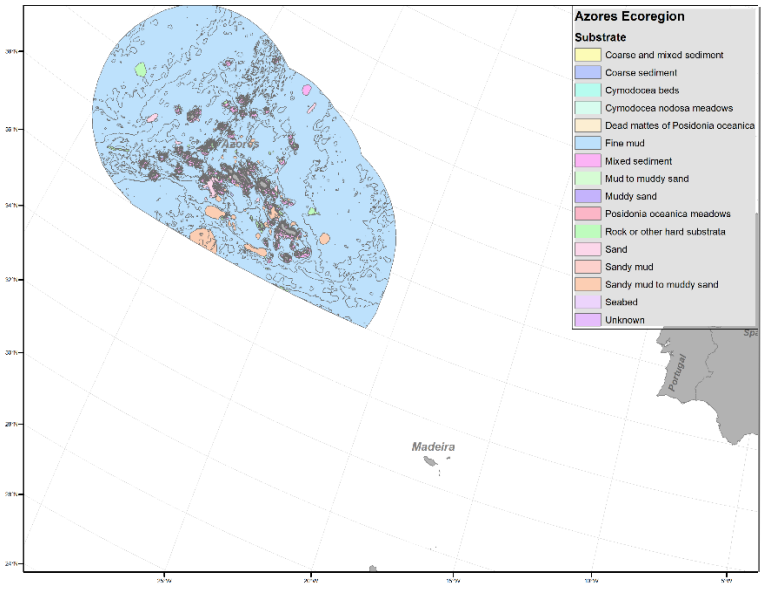


Figure 7 Broadscale substrate map of the Azores ecoregion, as compiled by EMODnet seabed habitats (www.emodnet-seabedhabitats.eu).

Foodwebs

The Azores ecoregion foodweb is characterized by strong links between the deep-sea and the pelagic environment. Toothed whales are the top predators in the ecosystem. Other predators include the deep-water sharks, large-size pelagic fish, large-size bathydemersal fish, large-sized demersal fish, pelagic sharks, rays and other sharks, seabirds, and tunas. The remaining fish groups are the small-sized pelagic fish, bathypelagic fish, and cephalopods. Benthic filter feeders and shrimps are at the lower trophic groups. Pelagic sharks, toothed whales, and cephalopods were identified as potential keystone species, highlighting their importance in the ecosystem structure.

Productivity (PP)

There is seasonality in the primary productivity of the ecoregion, which is linked to changes in SST (Figure 8). In springtime primary productivity varies, with high peaks of chlorophyll concentration in some years (Figure 9).

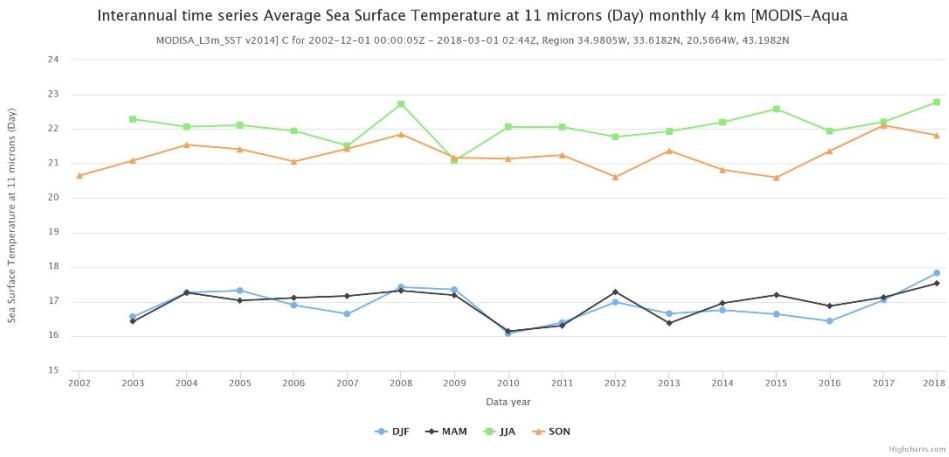


Figure 8 Surface temperature for the Azores ecoregion, by year and by season (DJF: December to February; MAM: March to May; JJA: June to August; SON: September to November) for the period 2002–2018. Source: Giovanni – NASA (http://giovanni.gsfc.nasa.gov/giovanni/).

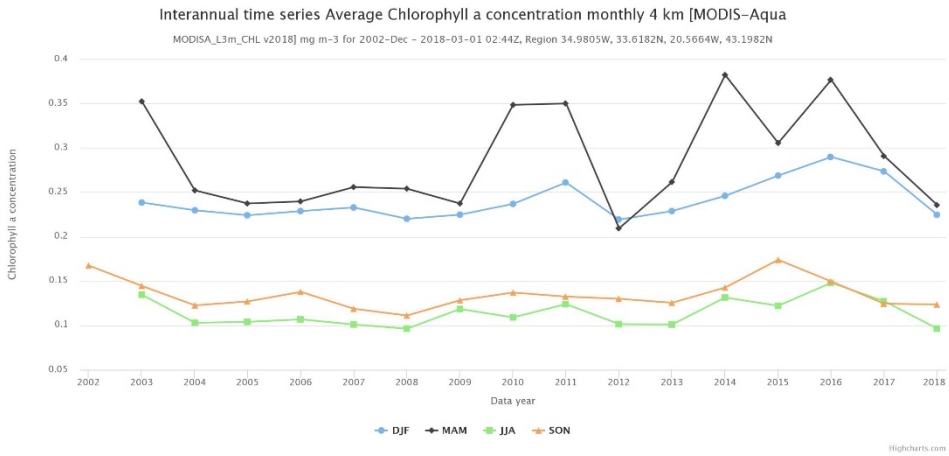


Figure 9 Concentration of chlorophyll *a* for the Azores ecoregion, by year and by season (DJF: December to February; MAM: March to May; JJA: June to August; SON: September to November) for the period 2002–2018. Source: Giovanni – NASA (http://giovanni.gsfc.nasa.gov/giovanni/).

Plankton

Long-term data are derived from the Continuous Plankton Recorder (CPR) survey that has been towed in oceanic waters in the northern part of the ecoregion. Data was first collected at a monthly resolution by the CPR survey in the 1960s to the early 1980s. After a decadal gap the route went into operation again around the Azores ecoregion from 1997 onwards (see Figure 10). Long-term trends suggest that at the decadal scale zooplankton populations are mainly influenced by large-

scale natural climate variations, such as the Atlantic Multidecadal Oscillation and the North Atlantic Oscillation. Phytoplankton trends for this region show a general increase in smaller phytoplankton, and a decrease in larger phytoplankton (e.g. large diatoms and dinoflagellates). For zooplankton, the abundance of Euphausids and Chaetognaths have generally declined over the decadal period whereas the abundance of copepods has remained relatively stable. Of the main zooplankton community, the Appendicularians (larvaceans) have shown the largest increase in abundance over the last 50 years; this may mirror the change in size structure seen in the phytoplankton.

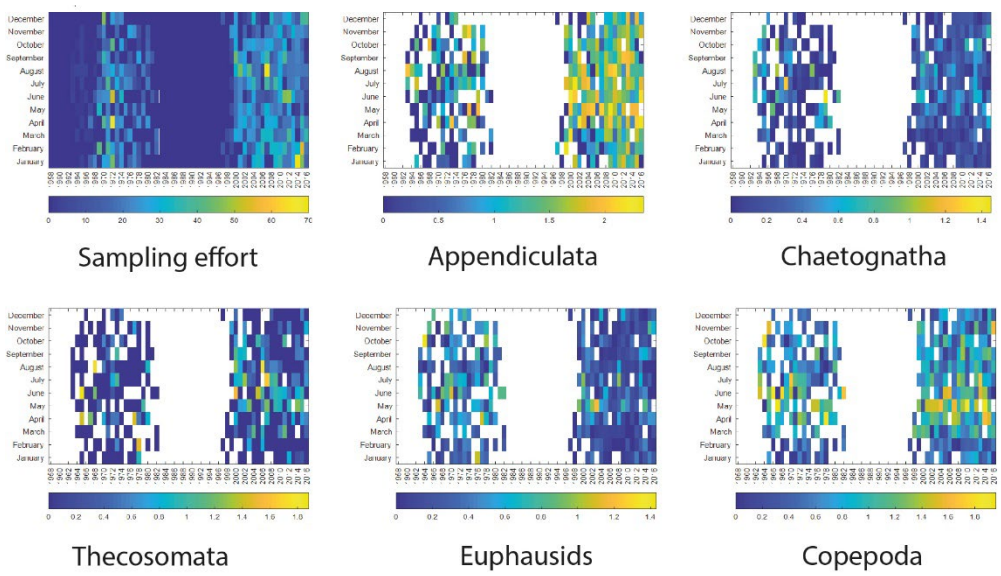


Figure 10 Sampling effort and long-term monthly zooplankton data from the Continuous Plankton Recorder (SAHFOS) survey north of the Azores Islands (standard CPR regions F7/F6).

Benthos

The Azorean barnacle (*Megabalanus azoricus*), black sea urchin (*Arbacia lixula*), stony sea urchin (*Paracentrotus lividus*), bearded fireworm (*Hermodice carunculata*), Azorean limpet (*Patella aspera*), limpet (*Patella candei*), slipper lobster (*Scyllarides latus)*, and lobster (*Palinuros elephas)* are the most abundant species in the intertidal as well as in the first few meters of the subtidal. The barnacle, limpets, and lobsters have been heavily exploited in the ecoregion; since 2006 two species are on the OSPAR list of threatened species.

Other dominant species in the littoral are the cnidarians (*Caryophyllia* spp.) and sponges (*Clathrina coriacea*, *Haliclona fistulosa,* and *Sycon* sp), the violet sea urchin (*Sphaerechinus granularis)*, and the bivalve *Pinna rudis*. Around 368 macroalgae species have been recorded on the Azorean rocky-shore.

The toothed rock crab (*Cancer bellianus)* dominates the coastal crab community, with the deep-sea red crab (*Chaceon affinis)* replacing it in deeper water. Diverse assemblages of crabs and Pandalid shrimps, stratified by depth, are found throughout the ecoregion. These communities of invertebrates have not been commercially exploited.

The ecoregion is considered a cold-water coral hotspot in the Northeast Atlantic, with more than 164 species and 20 different types of coral assemblage reported. Most coral species found in the region are broadly distributed worldwide, with only a few apparently restricted to a single geographic origin. Coral habitats support a rich associated fauna, supplying many vital ecosystem services. Deep-sea sponge aggregations are also common in the region and cover extensive areas, particularly below 500 m (Rebikoff-Niggeler Foundation's deep-sea video archives; and EU SponGES).

Fish

About 460 fish species, belonging to 142 families, have been recorded in the Azores ecoregion. Major small pelagic species from the Azores are *Trachurus picturatus*, *Scomber japonicus*, *Sardina pilchardus,* and *Boops boops*. Large pelagic species are mainly represented by tunas and tuna-like species such as bigeye tuna (*Thunnus obesus*), skipjack tuna (*Katsuwonus*

pelamis), yellowfin tuna (*Thunnus albacares*), bluefin tuna (*Thunnus thynnus*), and albacore (*Thunnus alalunga*). Other species include the pelagic oceanic sharks and rays; shortfin mako (*Isurus oxyrinchus*), blue shark (*Prionace glauca*), bigeye thresher (*Alopias superciliosus*), smooth hammerhead (*Sphyrna zygaena*), giant manta (*Mobula birostris*), and sicklefin devil ray (*Mobula tarapacana*).

The demersal fish community from the Azores is diverse and is mainly structured by depth zones:

- Shallow-shelf/shelf-break at depths < 200 m: typified by red porgy (*Pagrus pagrus*), tope (*Galeorhinus galeus*), thornback ray (*Raja clavata*), and forkbeard (*Phycis phycis*).
- Upper-slope at 200–600 m: characterized by blackspot seabream (*Pagellus bogaraveo*), European conger (*Conger conger*), offshore rockfish (*Pontinus kuhlii*), alfonsinos (*Beryx splendens* and *B. decadactylus*), bluemouth rockfish (*Helicolenus dactylopterus*), and velvet belly (*Etmopterus spinax*).
- Mid-slope at 600–800 m: typified by smooth lanternshark (*Etmopterus pusillus*) and arrowhead dogfish (*Deania profundorum*).
- Deep mid-slope at 800–1200 m: characterized by common mora (*Mora moro*), leafscale gulper shark (*Centrophorus squamosus*), birdbeak dogfish (*Deania calcea*), and gulper shark (*Centrophorus granulosus*).

Trends in fishing pressure and stock size are presented in the “Selective extraction of species” section of the document. The state of fish stocks in the ecoregion is generally unknown, owing to the lack of analytical assessments. Stocks have broader distributions than just the ecoregion itself and are thus affected by pressures over a wider area.

A range of deep-sea species and some small pelagics are fished in this ecoregion (Figures 3 and 4), but ICES cannot provide quantitative estimates of stock status for those. There are many species of deep-water sharks in the ecoregion, some of which (e.g. Portuguese dogfish and leaf-scale gulper shark) are considered severely depleted. Spawning-stock biomasses of bluefin tuna and swordfish have increased in recent years, and neither are considered to be overfished. Amongst the pelagic shark species occurring in the ecoregion, three are considered more significant and vulnerable to fishing: blue shark (*Prionace glauca*), shortfin mako (*Isurus oxyrinchus*), and porbeagle (*Lamna nasus*). Porbeagle is considered to be severely depleted. Blue shark and mako are considered fully exploited or overfished.

Seabirds

Six Procellariformes and four Charadriiformes breed in the ecoregion. These include: Monteiro’s storm-petrel (*Hydrobates monteiroi*), which breeds endemically and is classified globally as "Vulnerable”; over 75% of Cory’s shearwater world nesting populations (*Calonectris borealis*); and about 50% of the European population of the roseate tern (*Sterna dougallii*).

There is some indication that the Cory´s shearwater population has declined between 1996 and 2001, but no census has been conducted since after this period. The tern populations have been monitored since 1989 and have remained relatively stable, although they show a slightly downward trend. The breeding numbers of both species of storm-petrel have increased ~8–12% since 2000, as a result of improved habitat management.

Marine mammals

Twenty-eight species of cetacean have been recorded from the ecoregion. Most of these are wide-ranging oceanic species. There are two resident groups of bottlenose dolphins (*Tursiops truncatus)* near the islands. Population trends for most cetacean species are not known, although it appears that the number of sperm whales (*Physeter macrocephalus*) using the ecoregion in summer (ca. 300 individuals) is stable.

The Mediterranean monk seal (*Monarchus monarchus)* was present in previous centuries, but nowadays only vagrant individuals occur.

Threatened and declining species in the Azorean ecoregion

Impacts on threatened and declining fish species

Several fish species that have been adversely affected by fishing in the Atlantic are now on the OSPAR list of threatened and declining species (see full list in Table 1). These include the spurdog (*Squallus acanthias)*, the common skate complex (*Dipturus* spp.), porbeagle (*Lamna nasus*), and some deep-water sharks. Although there are either zero TACs for these species, or they are listed as prohibited, several of them remain vulnerable to existing fisheries.

Table 1 OSPAR-listed threatened and declining species and habitats that occur in the Azores ecoregion.

SCIENTIFIC NAME	COMMON NAME
INVERTEBRATES	
Megabalanus azoricus	Azorean barnacle
Patella ulyssiponensis aspera	Azorean limpet
Birds	
Puffinus assimilis baroli (auct.incert.)	Little shearwater
Sterna dougallii	Roseate tern
Rissa tridactyla	Black-legged kittiwake
Puffinus mauretanicus	Balearic shearwater
FISH	
Centroscymnus coelolepis	Portuguese dogfish
Centrophorus granulosus	Gulper shark
Centrophorus squamosus	Leafscale gulper shark
Cetorhinus maximus	Basking shark
Dipturus batis (synonym: *Raja batis*)	Common skate
Hippocampus guttulatus (synonym: *Hippocampus ramulosus*)	Long-snouted seahorse
Hippocampus hippocampus	Short-snouted seahorse
Hoplostethus atlanticus	Orange roughy
Lamna nasus	Porbeagle
Squalus acanthias	[Northeast Atlantic] spurdog
Thunnus thynnus	Bluefin tuna
REPTILES	
Caretta caretta	Loggerhead turtle
Dermochelys coriacea	Leatherback turtle
MAMMALS	
Balaenoptera musculus	Blue whale
Eubalaena glacialis	Northern right whale

Threatened and declining habitats in the Azorean ecoregion

Table 2 Threatened and declining habitats in the Azores ecoregion according to OSPAR.

HABITATS
Coral gardens
Deep-sea sponge aggregations
Lophelia pertusa reefs
Oceanic ridges with hydrothermal vents/fields
Seamounts

Sources and acknowledgements

The content for the ICES regional ecosystem overviews is based on information and knowledge generated by the following ICES processes: Workshop on Benchmarking Integrated Ecosystem Assessment (WKBEMIA) 2012; ACOM/SCICOM Workshop on Ecosystem Overviews (WKECOVER) 2013; Workshop to draft advice on Ecosystem Overviews (WKDECOVER) 2013; and Advice drafting group to finalize draft Ecosystem Overviews (ADGECO) 2015–2019, which provided the theoretical framework and final layout of the documents.
The ICES Workshop for the production of the Azores Ecoregion Ecosystem Overview (WKAZOREco) contributed to the main sections of this overview, together with researchers from the Department of Oceanography and Fisheries of the Azores University (DOP). The following working groups contributed in drafting the subsections on the state of the ecosystem components: ICES working groups on Zooplankton Ecology (WGZE) and Marine Mammal Ecology (WGMME), and the MISTIC SEAS II project [Saavedra *et al.,* 2019]), and ICES Working Group on Introductions and Transfers of Marine Organisms (WGITMO). References have been removed from the text for clarity and can be found below.

The maps and GIS products have been produced by the ICES Secretariat using data from:

1. Exclusive Economic Zones. Marineregions.org (VLIZ)
2. Depth Contours. General Bathymetric Chart of the Oceans (GEBCO)
3. Natura 2000. European Commission
4. Ecoregions. International Council for the Exploration of the Sea (ICES)
5. Ports. Global Shipping Lanes and Harbours (ESRI)
6. Cities. World Cities (ESRI)
7. ICES Areas. International Council for the Exploration of the Sea (ICES)
8. Catchment Area. European Environment Agency (EEA). European Topic Centre on Inland, Coastal and Marine waters (ETC/ICM).
9. Substrate maps. EU EMODNET seabed habitats; www.emodnet-seabedhabitats.eu
10. Surface temperature and concentration of chlorophyll a on the Azores: Giovanni – NASA (http://giovanni.gsfc.nasa.gov/giovanni/).
11. Non-indigenous species. AquaNIS; http://www.corpi.ku.lt/databases/index.php/aquanis

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AquaNIS. 2018. Information system on aquatic non-indigenous and cryptogenic species. http://www.corpi.ku.lt/databases/aquanis. Accessed 9 November 2018.

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