

Section 4

Subchapter 5L

Seamounts and pinnacles

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Key points

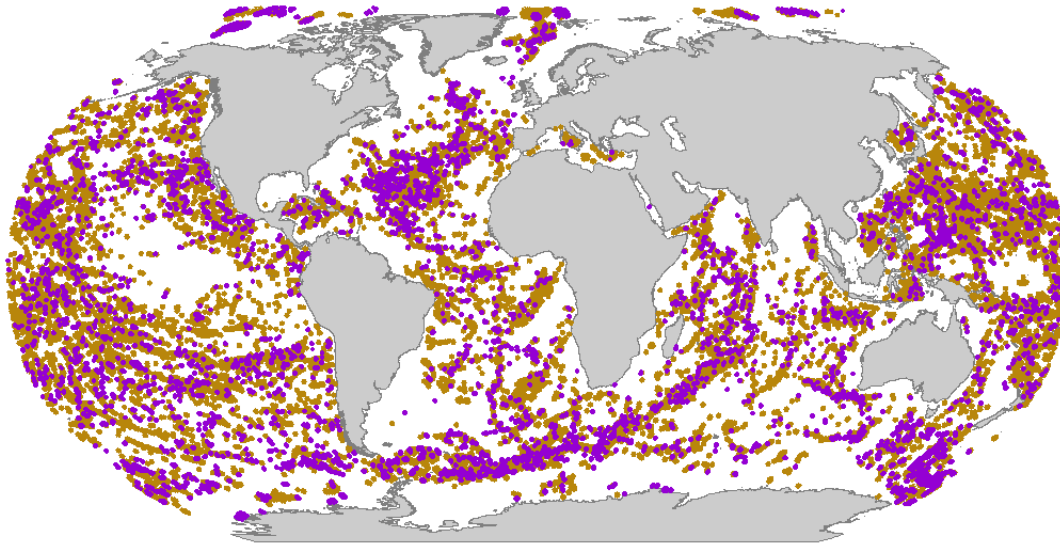
- Increase in:
 - Seamount studies using novel and integrated approaches such as environmental DNA, camera systems, human-occupied or remotely operated vehicles, baited remote underwater videos and machine learning.
 - Seamount pressures and impacts, including fishing, mining interests, ocean acidification and climate change effects.
 - Protection legislation
- While most studies in the global ocean report a seamount effect on the physical oceanographic environment and biological processes, a few found conflicting results when seamounts are studied on a case-by-case basis.
- Despite significant improvements, the understanding of abyssal seamounts, those found within areas beyond national jurisdictions and connectivity of seamount fauna remains limited.

1. Introduction

Seamounts are underwater topographic features that rise at least 1,000 m from the seabed, with small pillar-like features termed pinnacles (Leitner and others, 2021a). The number of predicted seamount locations has increased due to heightened interest and technical advances (see figure I; Yesson and others, 2021; Gevorgian and others, 2023).

Figure I

Seamount predictions



✱ Consistent seamount predictions (32 340) ● New seamounts (5549)

Source: Adapted from Yesson and others, 2021; credit: Pavanee Annasawmy.

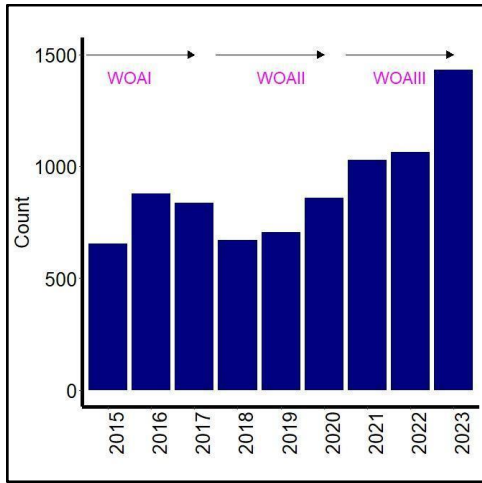
The present subchapter reviews a non-exhaustive list of advancements in understanding seamount distributions, related physical processes, ecological patterns and pressures, highlighting region-specific changes ([supplementary tables 1 through 8 accessible here: <https://doi.org/10.13140/RG.2.2.35490.08647>](#)). The subchapter does not include detailed scientific definitions or explanations.

2. Description of changes in knowledge since the first *World Ocean Assessment*

Since the publication of the first *World Ocean Assessment*, there has been an increase in seamount publications following re-analysis of archived data and recent multi-disciplinary surveys (see figure II), likely driven by increasing interest in exploration, species distribution and ecology for sustainable fisheries and conservation, human impacts and the role of seamounts in the global carbon pump and sink (Tao and others, 2022).

Figure II

Increase in seamount literature since the publication of the first *World Ocean Assessment*



Source: <https://doi.org/10.13140/RG.2.2.32056.00000>; accessed 14 June 2024; credit: Pavanee Annasawmy.

The following key differences are noted between the second and third *World Ocean Assessment* (see table).

Table

Brief advances in seamount knowledge since the second *World Ocean Assessment*

Knowledge baseline (second <i>World Ocean Assessment</i>)	Progress in knowledge (third <i>World Ocean Assessment</i>)
Limited seamount sampling	Enhanced sampling via multidisciplinary cruises, novel approaches, autonomous platforms and improved seamount detection algorithms
Generalized seamount “ecological paradigms”	Paradigms questioned through case-by-case studies
Few region-specific studies noted, especially in the Arctic, Southern and Indian Oceans	Increased research in these regions
Climate change effects limited to oxygen concentration decline	Additional effects on trophic connections and species distributions
Few working groups limited to the global North on seamount conservation and management	Seamount working group established in the Indian Ocean

Limited seamount legislation	Expanding seamount legislation
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Source: Prepared by the writing team.

3. Region-specific changes

Global studies provided high-resolution habitat suitability models for deep-sea reef-forming hard corals, few soft coral species and thorn/black corals (Yesson and others, 2017; Cordes and others, 2023; Tong and others, 2023).

Region-specific changes are summarized below and described in detail in the supplementary tables

Arctic

Similar to the reporting period for the second World Ocean Assessment, recent research on Arctic seamounts (see figure III and supplementary table 1) focused on sediments and sponge communities, yielding the following key findings: sponge-dominated communities on the Schulz Bank vary by depth and the type of substrata (Meyer and others, 2023); the sedimentary cover on Mosby seamount dates from the middle Miocene or younger (Geissler and others, 2019); on Langseth Ridge, sponge life is associated with extinct seep life (von Jackowski and others, 2023) and sponges play a role in pelagic-benthic coupling of microbial communities (Morganti and others, 2022); megafaunal densities and assemblage composition vary between seamounts of the Langseth Ridge (Stratmann and others, 2022).

Figure III

Location of few Arctic seamounts



Source: Pavanee Annasawmy.

3.2 South Atlantic and the wider Caribbean

Vulnerable marine ecosystems are groups of species, communities or habitats that may be vulnerable to impacts from fishing activities (FAO, 2025). Areas hosting certain categories of organisms that may be classified as indicator species, such as seamounts, may be considered vulnerable marine ecosystems with subsequent management measures such as designations of marine protected areas (MPAs) to conserve those ecosystem attributes (Watling and Auster, 2021; Vinha and others, 2024). Deep-sea corals and sponges act as indicator species for vulnerable marine ecosystems (Watling and Auster, 2020).

Seamounts of the Discovery rise were explored by an international effort to map vulnerable marine ecosystems (see figure IV and supplementary table 2). Cold-water coral communities (scleractinians and gorgonians), 36 fish morphotypes (*Laemonema* sp., *Guttigadus* sp.) and 13 cephalopod flank/summit residents, classified in five morphotypes (*Moreteuthopsis ingens*, *Histioteuthis cf. atlantica*, *Opisthoteuthis cf. agassizii*) were uncovered. These records supported the maintenance of fishing closure areas within the South East Atlantic Fisheries Organisation Convention Area (Perez and others, 2022).

Genetic connectivity of seamount populations of Bluenose Warehou (*Hyperoglyphe antarctica*) was reported between 4 seamounts within the Tristan da Cunha exclusive economic zone (EEZ) (Heyworth and others, 2021). Latitude and depth were drivers of benthic assemblage composition, differentiating the 13 tropical and temperate seamounts and oceanic islands of Ascension, Saint Helena and Tristan da Cunha (Bridges and others, 2021). Seamounts were hotspots for fishes living below 200 m depth and

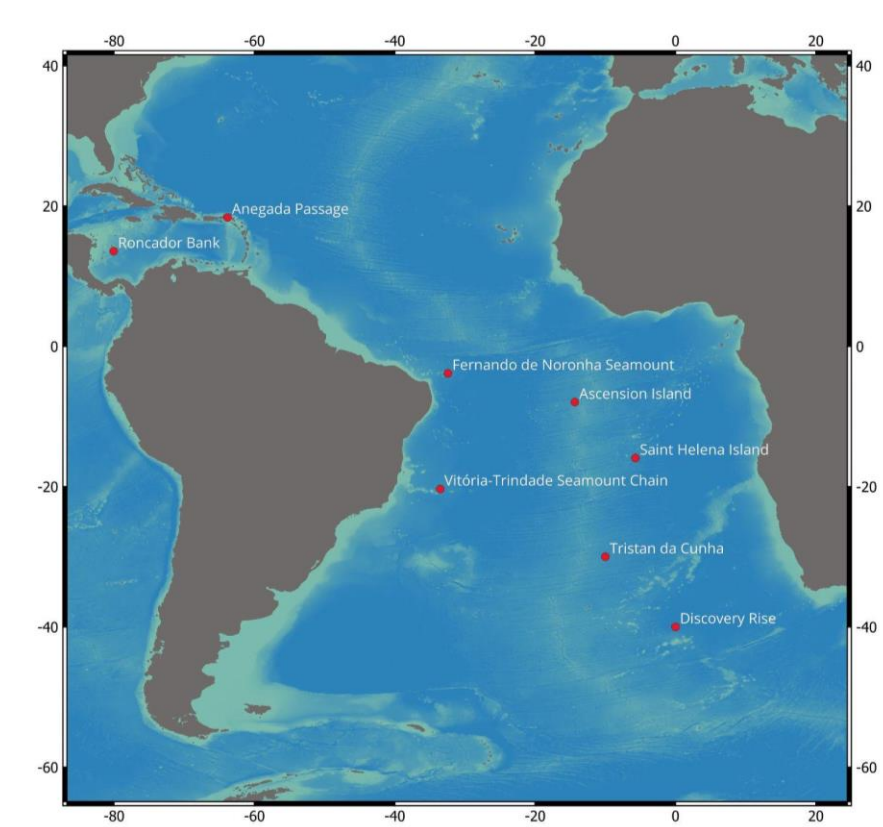
micronekton (crustaceans, fishes and cephalopods of 2 to 20 cm in size) over summits less than 200 m (Campanella and others, 2021). Vulnerable marine ecosystems were described and protected within the boundaries of MPAs established in the Tristan da Cunha EEZ.

The Fernando de Noronha and the Vitória-Trindade seamount chains and underlying currents drive the genetic diversity of *Octopus insularis* (Lima and others, 2022).

Further research showed species connectivity between seamounts of the Fernando de Noronha Ridge (Tosetto and others, 2024), seismic activities at Roncador bank (Idárraga-García and León, 2019) and factors influencing coral assemblage and communities at Anegada passage (Quattrini and others, 2017; Auscavitch and others, 2020).

Figure IV

Location of South Atlantic seamounts, islands and other features



Source: Ariadna Mecho.

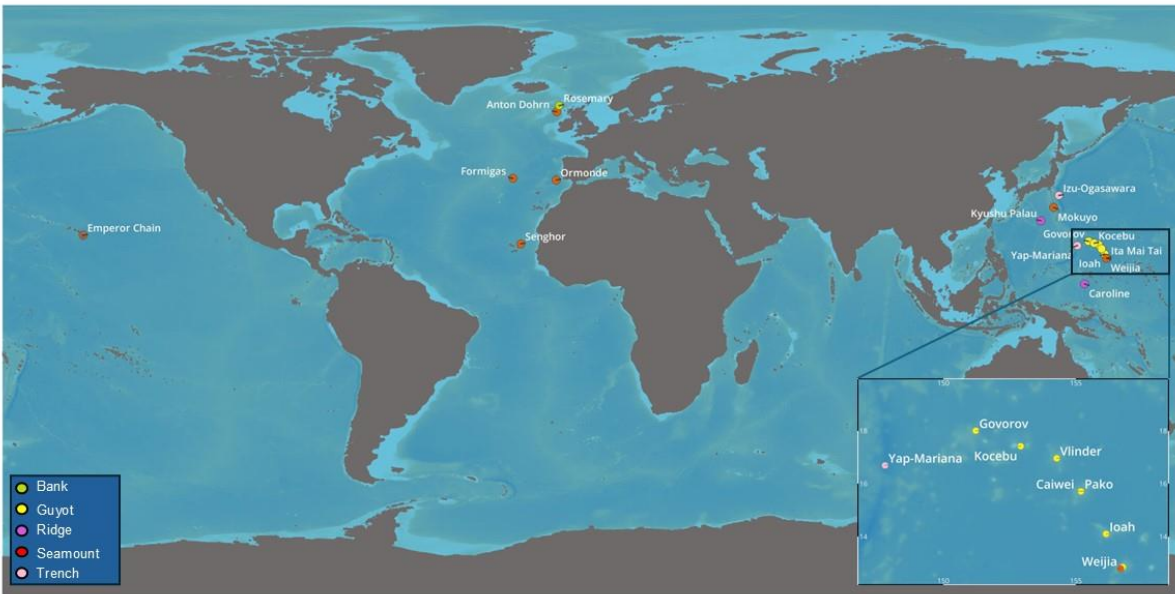
North Atlantic

North Atlantic seamounts (see figure V and supplementary table 3) were investigated during recent expeditions by Germany and the United States of America and. A science-based and participatory process shepherded by the regional government led to the creation of the largest MPA network (Azores Marine Protected Area Network; 287 000 km²) in Europe, 15% designated as fully protected and 15% as highly protected. Positive effects of the Azores MPA archipelago were observed on resident, large-bodied fishes and higher fish abundance in deeper habitats (Afonso and others, 2018). The dynamic interactions

between hydrology and seamount topography support enhanced food supply and presence of vulnerable marine ecosystems taxa at Cabo Verde seamounts (Vinha and others, 2024). Internal waves influenced local hydrology, potentially driving food and nutrient supply and contributing to larval fish aggregations and higher trophic level predators at Senghor seamount (Denda and others, 2017; Mohn and others, 2021), coral larvae dispersal at Rosemary seamount (Stashchuk and Vlasenko, 2021) and supported benthic communities at Ormonde and Formigas seamount (Mosquera Giménez and others, 2019).

Figure V

Location of North Atlantic and Pacific bathymetric features



Source: Ariadna Mecho.

North Pacific

North West, Central and North East Pacific seamounts and pinnacles (see figure V) remain the most studied ones in the world's ocean. Recent studies by Canada, China, the Russian Federation and the United States of America and the use of autonomous and mobile technologies (useful for providing longer time series, allowing the mapping of seafloor habitats, greater sampling collection and refined observations through real-time video footage), as well as machine learning (enhancing data processing and analyses), have enhanced the understanding of the formation and evolution, biodiversity and taxonomy, biogeochemistry, seamount effect on the physical oceanographic environment (e.g presence of anticyclonic caps, Taylor columns, internal waves) impacting all trophic levels, from microbes to megafauna and ecosystem research and management of these seamounts (Baco and others, 2017; 2023b, Domokos, 2022; Mejia-Mercado and Baco, 2022, 2023; Leitner and others, 2021a, 2021b, 2021c; Shu and others, 2022; Wang and others, 2024; supplementary table 4). Time-series of the Mokuyo, Izu-Ogasawara Arc have shown shifts in vent communities (Chen and others, 2024).

Ecologically or biologically significant marine areas are areas that hold special importance in terms of their ecological and biological characteristics (e.g. by providing essential habitats, food sources or

breeding grounds for particular species). Seamounts of the northwest Pacific in areas beyond national jurisdictions qualify as ecologically or biologically significant marine areas amid existing or anticipated pressures linked to potential seabed mining and climate change (Du Preez and others, 2023).

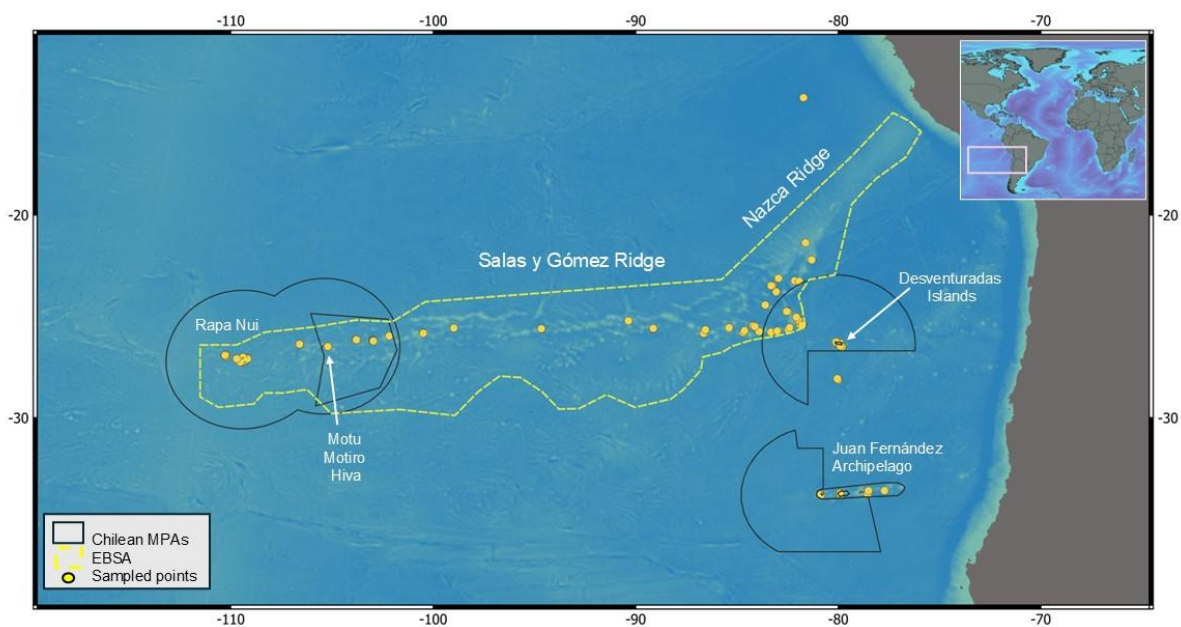
The 2024 Seamount Science Summit – Ecological Insights Workshop gathered 26 experts who provided key recommendations for managing seamounts as vulnerable marine ecosystems under United Nations General Assembly resolution 59/25. To date, only the Northwest Atlantic Fisheries Organization has fully implemented these recommendations, designating all seamounts within its regulatory area as vulnerable marine ecosystems and prohibiting bottom-contact fishing (NPFC, 2024).

South East and West Pacific

Underexplored seamounts in the South-East Pacific basin (see figure VI) are concentrated along three major ridges: the Salas y Gómez, Nazca and Juan Fernández, hosting more than 144 seamounts, 51 of which lie within the EEZ of Chile, with summits ranging from 0 to 2000 m deep.

Figure VI

South-East Pacific basin



Source: Ariadna Mecho.

Recent expeditions by the Schmidt Ocean Institute (SOI, USA), the Japan Agency for Marine-Earth Science and Technology and the Center for Ecology and Sustainable Management of Oceanic Islands (ESMOI, Chile) surveyed 32 seamounts and discovered more than 34 uncharted ones. Southeast Pacific seamounts are recognized as biodiversity hotspots, featuring 150 new species from the SOI 2024 cruises, including habitat-forming, endemic species and pristine ecosystems, earning recognition as ecologically or biologically significant marine areas. High ecological connectivity prevails in the region, supporting the resilience of marine populations across the Pacific.

Chile has established large-scale MPAs, covering the Rapa Nui and Desventuradas ecoregions. Peru has

created a MPA located in the eastern Nazca Ridge. Over 73% of the ridges and associated seamounts still lie in areas beyond national jurisdictions, vulnerable to human activities (i.e. fishing, potential deep-sea mining, floating plastic debris and microplastics). International stakeholders are working to establish the first “blue corridor” to protect and ensure the long-term health of biodiversity (Wagner and others, 2021; Delgado and others, 2022; Boteler and others, 2022; Chavez-Molina and others, 2023; Gaymer and others, 2025).

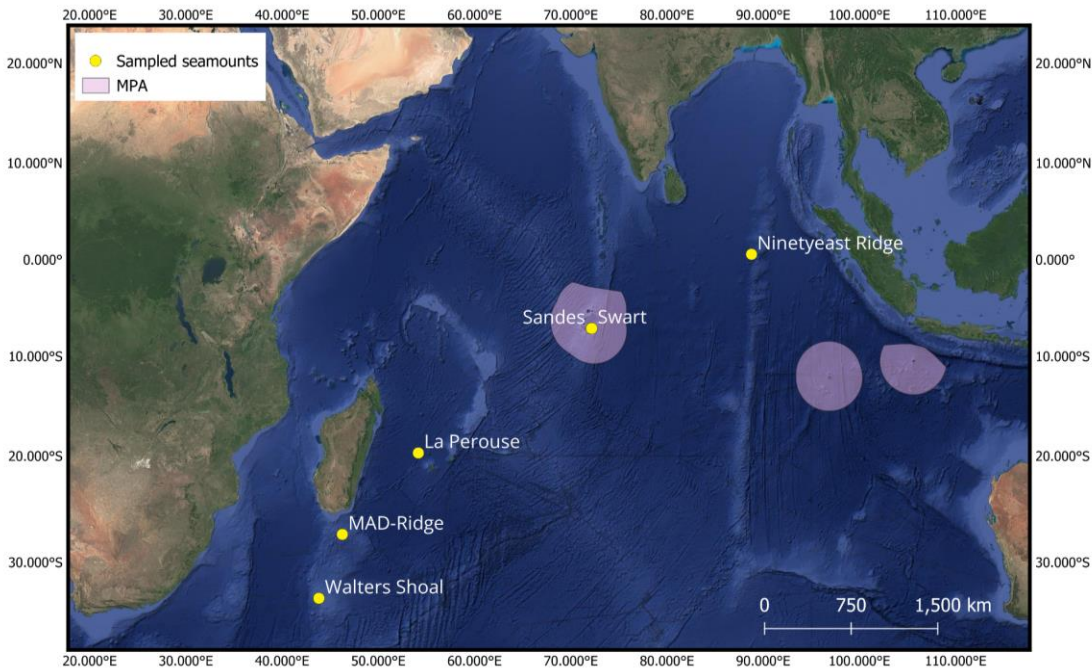
In the South-West Pacific Ocean, recent research efforts shed light on benthic communities, megafauna and biophysical coupling on seamounts off New Caledonia (supplementary table 5). In New Zealand, an updated database now includes nearly 3000 features.

Indian Ocean

The pelagic diversity, taxonomy, distribution, migration, ecotoxicology, trophic and biophysical interactions, connectivity and observations of physical phenomena along the South-West Indian Ridge, Sandes, La Pérouse, MAD-Ridge and Walters Shoal seamounts have been investigated since 2016 with French, German, British and Norwegian research efforts (see figures VII and VIII; Laptikhovsky and others, 2017; Letessier and others, 2017; Read and Pollard, 2017; Rogers, 2018; Annasawmy and others, 2019; Annasawmy, 2019; Hosegood and others, 2019; Letessier and others, 2019; Annasawmy and others, 2020a, 2020b, 2024; Cherel and others, 2020; Harris and others, 2020; Marsac and others, 2020; Noyon and others, 2020; Roberts and TERNON, 2020; Rocke and others, 2020; Yesson and others, 2021; Diaz and others, 2023; Diaz, 2023; Swanborn and others, 2023; Yutsis and others, 2023; Eager, 2024; O’Hara, 2024; Robinson and others, 2024) (supplementary table 6).

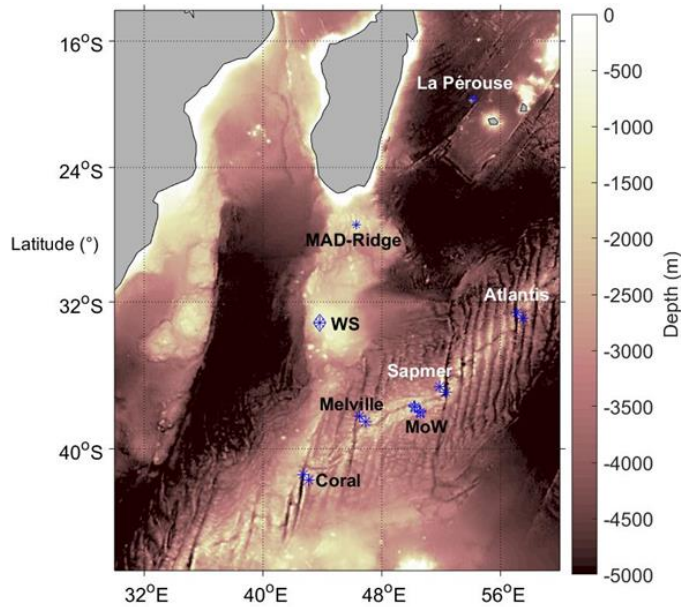
Figure VII

Indian Ocean seamounts and marine protected areas



Source: Dannielle Eager.

Figure VIII South-West Indian Ocean seamounts



Source: Annasawmy, 2019.

Several seamount paradigms were questioned:

(a) The seamount oasis effect was observed on some South-West Indian Ridge seamounts and for specific taxa but was not widespread across Indian Ocean seamounts.

(b) Lack of Taylor cap formation (trapped/enclosed circulations over seamount summits) under intense mesoscale eddies (rotating cyclonic or anticyclonic water masses) and over shallow seamounts.

(c) Seamounts are not hotspots of micronekton diversity and densities (Annasawmy and others, 2019, 2020a; Marsac and others, 2020).

The lanternfish *Diaphus suborbitalis*, which is a key trophic link between plankton and top predators and which contributes to the biological carbon pump by transporting carbon from the surface to deeper waters through diel vertical migration, has been observed exclusively at seamounts to date and not in open ocean waters (Annasawmy and others, 2019; 2024; 2025; Cherel and others, 2020). Seamounts are distinct topographic barriers in the ocean, affecting the trophic connections between micronekton, which feed on zooplankton and which migrate from deeper waters to the top 200 m at night and those which do not migrate (Annasawmy and others, 2024).

The habitat preferences of key marine organisms at seamounts of the Indian Ocean are significant in the context of ecosystem health and potential conservation measures in the face of anthropogenic threats such as fishing and plastic pollution (Annasawmy, 2019). In 2022, the Western Indian Ocean National or International Seamounts, banks, submarine structures network was launched, gathering regional researchers, students, policy makers and institutions interested in marine ecosystems' functioning, their exploitation, conservation and governance associated with seamounts and shallow topographic structures in national waters, continental shelves as well as in the high seas of the Western Indian Ocean.

Southern Ocean

A number of seamounts and ridges of the Southern Ocean have been sampled in recent years (supplementary table 7). The interaction of the Antarctic Circumpolar Current (ocean current flowing from west to east around Antarctica) with seamounts generates upward movements, facilitating iron injection, hence fuelling productivity which attracts megafauna (Sergi and others, 2020). Significant research has been made on sedimentary cover at Jiawang seamount, contributing to understanding the formation process of seafloor deposits (Cui and others, 2023). The first observation of thermophilic and hyperthermophilic microorganisms, important for biogeochemical processes such as iron oxide deposition (Emerson and Moyer, 2002), were made at Orca seamount (Rodrigo and others, 2018). Seamounts and ridges of the Ross Sea have also been surveyed.

4. Pressures

Seamounts of the global ocean are under intensive fishing pressures (Baco and others, 2019, 2020, 2023a; Morgan and Baco, 2020), plastic contamination affecting marine life and ocean acidification (see supplementary table 8 for seamount locations). Mining exploration contracts are increasingly being issued in the global ocean which coincides with vulnerable marine ecosystems and conservation priority areas (Rogers, 2019).

Potential mining of cobalt-rich crusts represents an important pressure facing seamounts in the coming years. Habitat removal and sediment plume effects are the top risk sources likely to affect community structure, biodiversity, reproductive capacity, trophic ecology, behaviour and population connectivity of seamount benthic, benthopelagic and pelagic communities. Seamount communities are highly vulnerable with possible impacts across ecological scales, from species to the entire community. Recovery times are estimated to be over 100 years and the scale of impact is estimated between 1 km² and 10,000 km² (Washburn and others, 2019). The one existing study to date of impacts from a seamount mining test has found significant, sustained decreases in the density of mobile epifauna and highly mobile swimmers that persisted both one month and one year after the disturbance in addition to dead and damaged sessile benthic megafauna that were crushed or removed by the excavator (Washburn and others, 2023).

The first comprehensive study of Indian Ocean seamounts has demonstrated the effects of a warmer ocean causing lower productivity levels, lower trophic values of pelagic organisms and potential shifts in food web structure (Annasawmy and others, 2024). A decrease of 28% to 100% in suitable habitats, including seamounts, for cold-water coral species of the North Atlantic has been forecasted due to climate change (Morato and others, 2020).

Time series surveys off New Zealand and Tasmania highlighted the role of untrawled patches and unfished seamounts in post-fishing recruitment, with observations on Graveyard Knoll indicating the first signs of stony coral recovery 15 to 20 years after fishing ceased (Williams and others, 2020; Clark and others, 2021, 2022a). A 2022 survey by the National Institute of Water and Atmospheric Research following the Hunga Tonga-Hunga Ha'apai volcanic eruption in Tonga revealed benthic devastation from pyroclastic flows, except where the seamount features provided shelter for communities which were unaffected (Seabrook and others, 2023).

5. Key remaining knowledge and capacity gaps and new gaps

Despite significant progress, key knowledge and geographical gaps remain about seamount ecology, bathyal ecosystems, seamount functioning, recruitment and connectivity within and between seamount communities, anthropogenic pressures (linked to pollution, fishing, ocean warming, expansion of oxygen minimum zones) and management in areas beyond national jurisdiction and seamounts of the Arctic, Southern and Indian Oceans. Lack of global time series data introduces uncertainties in seamount observations, assumptions and conclusions. The knowledge gaps on seamount crusts are substantial and the lack of experimental data makes assessing the environmental risks of potential deep-sea mining of seamounts challenging. The effect of multiple stressors on seamount disturbance and effectiveness of management actions still remain to be assessed. Although data and observations are increasingly findable, accessible, interoperable and reusable, several years of embargo are generally placed on collected data, thereby reducing scientific progress and collaborations. Local, traditional and Indigenous knowledge is still not taken into account in seamount research from many regions of the world's ocean.

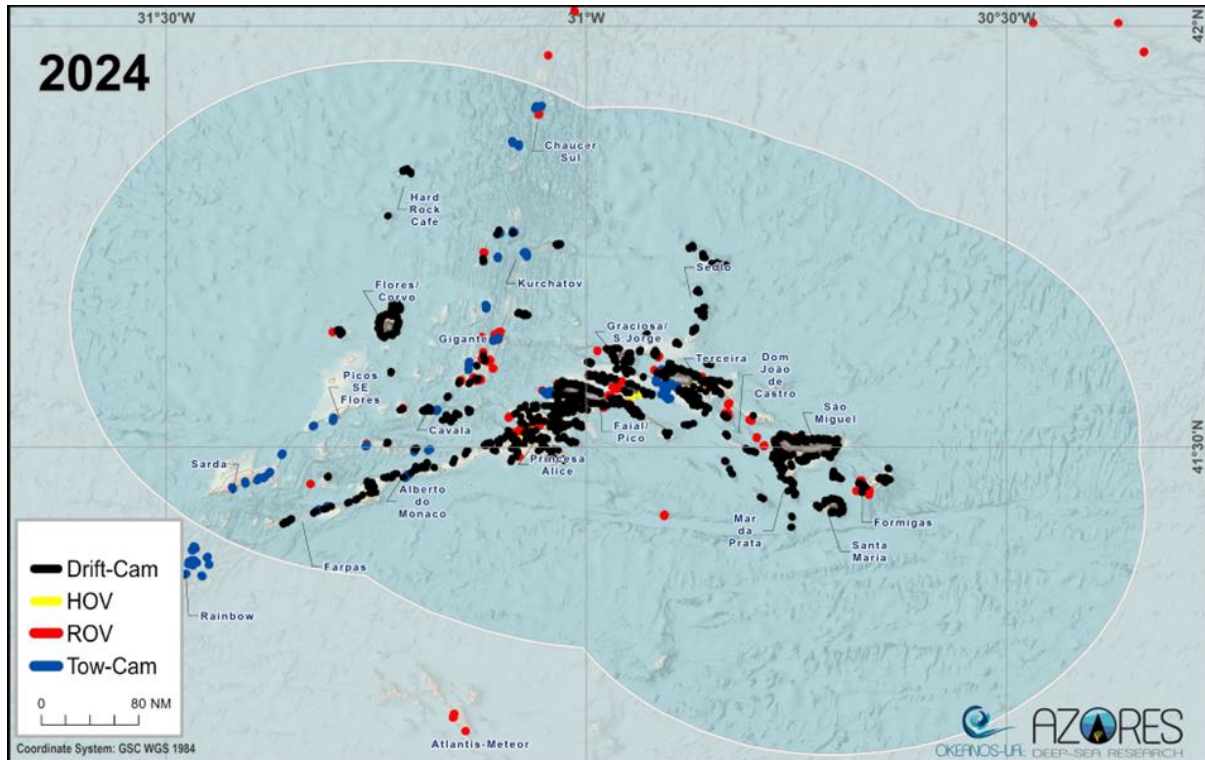
6. Outlook

Individual seamounts exhibit unique characteristics that influence biophysical processes and seamounts are interconnected to each other. Seamounts are facing significant and increasing anthropogenic pressures, making further study of these complex ecosystems a high priority. Integrating artificial intelligence into advanced technologies that monitor deep-sea seamount ecosystems on longer time scales is crucial, as limited research on seamount fauna hinders understanding their biogeography. Further exploration and data collection are needed for seamount detection, assessment and protection. Initiatives such as the scientist ashore programme implemented during the 2024 NA161-169 expeditions of North Pacific seamounts by the National Oceanic and Atmospheric Administration ocean exploration via the Ocean Exploration Cooperative Institute with more than 800 ship-to-shore participants, over 55,000 live stream views, over 1 million social medial views, with full data access,¹ facilitate global collaboration and will significantly build scientific and management capacity. While it is premature to fully assess the impacts of such initiatives, they are expected to enhance seamount research by accelerating discoveries, refining habitat models, increasing public engagement and providing insights into seamount ecosystems that may inform future management strategies. Cost-effective deep-sea research enhances large spatial-scale biodiversity data observation at seamounts (see figure IX; Annasawmy and others, 2025). A more holistic view of seamount ecosystems, local, traditional and Indigenous knowledge must be taken into account.

¹ <https://nautiluslive.org/expeditions/2024>.

Figure IX

Seamount observations in the Azores (North Atlantic) using cost-effective technologies (drift-cameras and tow-cameras, human-operated vehicles, remotely-operated vehicles)



Source: Telmo Morato.

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