Section 4

Subchapter 5O

Ridges, plateaus and trenches

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Key points

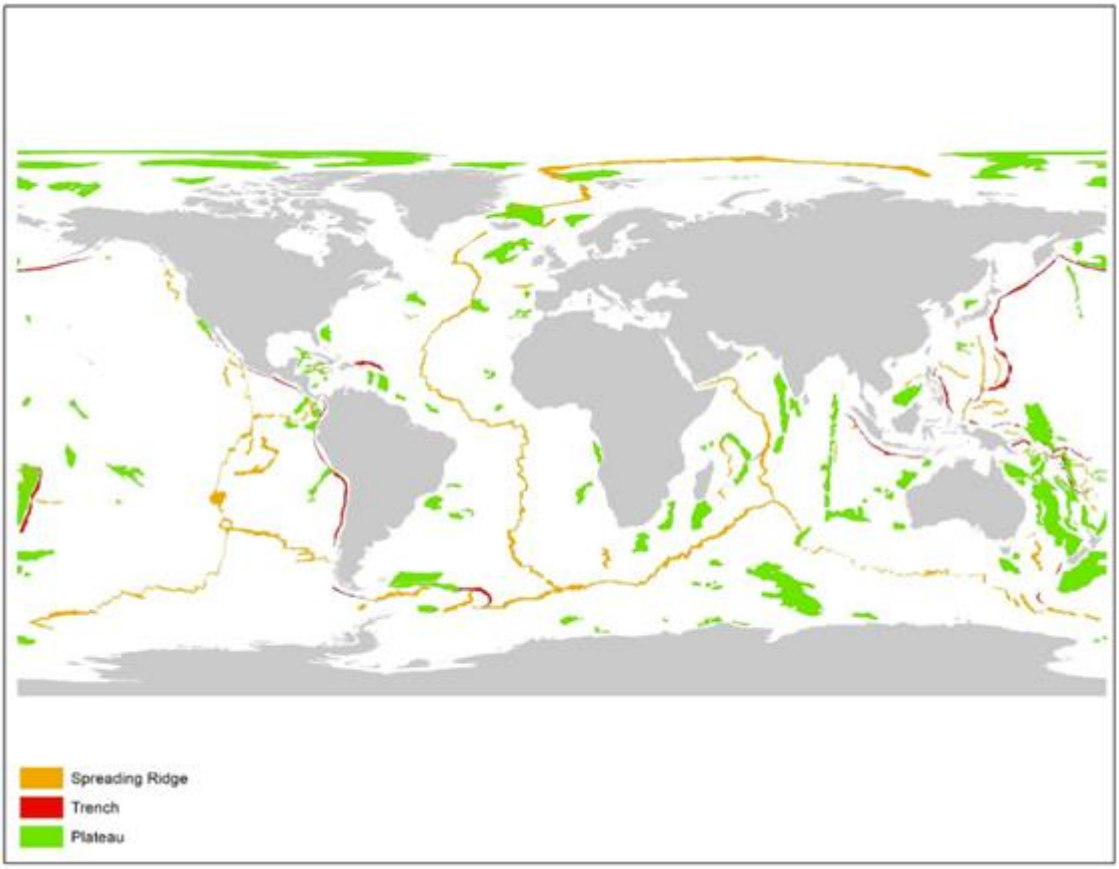
- Greatest advances have been in studies of hadal trench systems facilitated by newly available technologies.
- Progress on exploration of ridge systems has slowed and immense gaps remain despite new discoveries in the Indian Ocean.
- Most plateaus are important fishery areas and are studied in that context.
- Changes owing to human pressures have been observed, leading to protection measures for bottom habitats (applied or are under discussion).

1. Introduction and context

Ridges, plateaus and hadal trenches are distinctive offshore habitats, identified in the first *World Ocean Assessment* (2017) as potentially threatened by human disturbances such as fisheries, pollution and mining. In the second *World Ocean Assessment* (2021) it was reported that despite this vulnerability and added climate change pressures, they remained poorly known. The present subchapter assesses the extensive slopes of mid-ocean spreading ridges that divide ocean basins (see figure I); ; hadal trenches at depths greater than 6000 m (see figure I); plateaus, either continent-derived fragments or other origins (see figure I); seamounts and ridge-associated hydrothermal vents (Beaulieu and others, 2013) are considered in sect. 4, subchaps. 5L and 5P, respectively)

Figure I

World map, hadal trenches in red; mid ocean spreading ridges in orange and plateaus in green



Source: adapted from Harris and others, 2014.

2. Description of environmental changes between 2020 and 2024

New knowledge acquired since 2020 and how it can be used to evaluate changes

Ridges

The bathyal (200 to 3,000 m depth) slopes of the mid-ocean ridge system, dominated by soft sediments interspersed with rocky outcrops at summits and fracture zones remain poorly surveyed. The Mid-Atlantic Ridge provides about half the living space for bathyal species in the North Atlantic. North of the Azores, surface productivity is high, supporting diverse demersal fish (Priede and others, 2022) and benthic invertebrates (Alt and others, 2019) with overlying waters exploited by migratory seabirds (Davies and others, 2021). Predicted seafloor biomass is lower between the Azores and the Equator and the benthic fauna is almost unknown even in proposed deep-sea mining contract areas (26– 32°N), (Radziejewska and others, 2022).

The Arctic Mid-Ocean Ridge hosts many geological features and habitat types. Although some research was done on impacts of fishing (e.g. Morrison and others, 2020), biodiversity (e.g. Ramirez-Llodra and others, 2020), mineral resources (e.g. Juliani and Ellefmo, 2018) and bioprospecting (e.g. Royseth and

others, 2023), additional studies are needed on the "typical" soft sedimentary slopes (Ramirez-Llodra and others, 2024). On the Central Indian Ridge and the Southwest Indian Ridge, new species or range extensions for polychaetes, corals sponges and crustaceans were discovered (Periasamy and Ingole, 2022: Periasamy and others, 2022, 2023a, 2023b, 2023c 2023d). The Southeast Indian Ridge remains one of the least studied regions on the Indian Ocean.

No new information was published on the Pacific Oceanic Ridges.

The mid-ocean ridge system extends over 65,000 km around the globe but only in small areas around islands, sea-mount summits and sites of special interest such as hydrothermal vents is anything known about species, abundance, biomass and ecosystems. The Mid-Atlantic Ridge between Iceland and the Azores has been explored (Priede and others, 2022), but this represents only 5% of the global ridge system; the South Atlantic and other ocean ridges remain largely unknown.

Hadal trenches

Globally, all major hadal trenches have been surveyed with new technologies revealing a rich diversity of habitats (Weston and Jamieson, 2022; Jamieson and others, 2022). Abyssal taxa have extended into hadal depths (Jamieson and Vecchione, 2022) and new trench-endemic species and ecological relationships revealed (Lörz and others, 2018; Kniesz and others, 2018; Riehl and others, 2018, Peoples and others, 2024) with a rich hadal microbial flora including viruses (Zhou and others, 2022), bacteria (Rastelli and others, 2019) and fungi (Peng and others, 2021) that contribute to biochemical processes.

In the Indian Ocean, various habitats were observed, including soft and hard substrates in Sunda Trench (Jamieson and others, 2022). In the South Pacific, the Kermadec Trench was revisited in 2022 (Peng and others, 2022) revealing, habitats driven by flow and substrate characteristics. Across the Pacific Trenches, seafloor biological oxygen consumption varies greatly but is always greater than on adjacent abyssal plains, reflecting increased fertilization from the rain of particles funnelled into the trenches (Glud and others, 2021).

Human impacts include accumulation of pollutants such as plastics (Abel and others, 2021), mercury (Sanei and others, 2021), halogenated organics (Cui and others, 2020) and black carbon (Zhang and others, 2022). Trench habitats are vulnerable to disturbances with estimated recovery times of over 100 years (Jamieson and others, 2022). Renewed proposals for permanent sequestration of captured liquid CO_2 into hadal trenches, that would eliminate all resident biota are a matter for concern (Goldthorpe, 2017; Luo and others, 2023).

Plateaus

The two largest plateaus in the North Atlantic (Harris and others, 2014) are the Hatton-Rockall and Azores plateaus, both highly biodiverse and important fishery areas. The Azores plateau has interconnected assemblages of cold-water corals that differ according to the temperature and properties of surrounding waters and regional productivity (Taranto and others, 2023). It is a hotspot for large migratory marine mammals, turtles, sharks and tunas (Afonso and others, 2020), but knowledge gaps remain (Vecchione and Bergstad, 2022).

In the Southeast Atlantic, mapping of vulnerable marine ecosystems of the Walvis Ridge/plateau (Bridges and others, 2023; Bergstad and others, 2019a, 2019b) shows patchy cold-water coral communities among

relict coral rubble on flat-topped seamounts. In the Southwest Atlantic, exploration of the summit of the Rio Grande Rise (Kitazato and others, 2017) indicated distinctive communities of corals and sponges associated with ferromanganese cobalt crusts, depth and slope (Corrêa and others, 2022; Perez and others, 2018), along with hexactinellid "sponge gardens" of *Sarostegia oculata*, (Hajdu and others, 2017).

The São Paulo Plateau extends southeast from the Brazilian Continental Margin (2000 to 4500 m depths) encompassing over 80% of Brazilian oil and gas production (Perez and others, 2020a). In the north, asphalt seeps harbour mainly hexactinellid sponges and typical deep-sea isidid octocorals, brisingid starfishes and galatheid crabs (Fujikura and others, 2017). Along the escarpment to the south, Perez and others (2020b) described benthic habitats and communities at 4,219 to 2,644 m depths associated with topography and deep-water mass distribution.

High productivity over the plateau surrounding the Falkland Islands (Malvinas)[1] is driven by an influx of sub-Antarctic waters. Deep benthic biomass is dominated by *Stylasteridae* (lace corals), sponges, *Pennatulacea* (sea pens) and cup corals (Pearman and others, 2022).

In the southern Indian Ocean, the Kerguelen Plateau (45-65°S) traverses the Polar Front (e.g. Bestley and others, 2020), resulting in major differences in phytoplankton, zooplankton and mesopelagic fish productivity (Matsuno and others, 2020, Hunt and Swadling 2021, Cotte and others, 2022) with different trophic dynamics between the western and eastern parts of the Plateau (Hunt and others, 2021, Constable and Swadling, 2020)

In the western Indian Ocean, the Mascarene Plateau supports the largest seagrass beds in the world that, along with rhodolith beds, provide key shallow-water biogenic habitats for various taxa, including new species. Dominant mega-epifauna taxa were cnidarians, fish, echinoids and shrimps/prawns (Bhagooli, 2021).

Around New Zealand, benthic species distributions of the Chatham Rise and Campbell plateau have been studied in support of habitat suitability modelling to enhance effectiveness in data-poor areas (Stephenson and others, 2021),

Unique faunal assemblages have been found on Arctic Ocean plateaus that are vulnerable to both fisheries and global warming (Jørgensen and others, 2022). In the Pacific-Arctic region, epifaunal communities of the Chukchi plateau are proposed as long-term observatories of responses to climate changes (Zhulay and others, 2019)

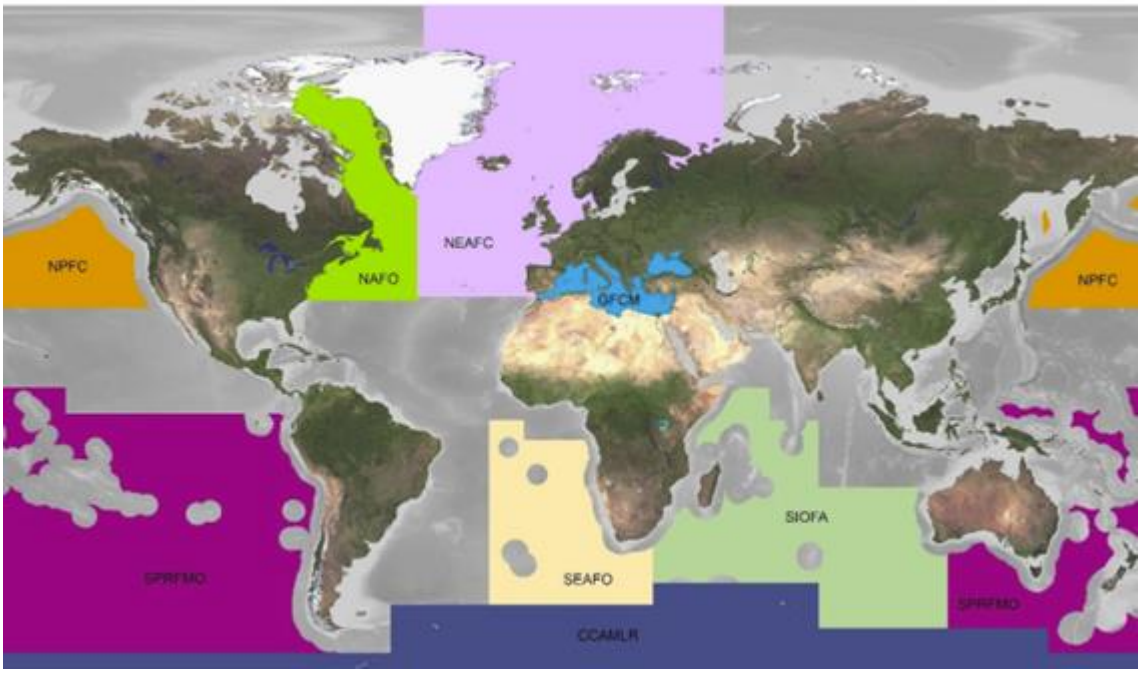
3. Description of economic and social changes between 2020 and 2024 and the relevant governance

Fisheries (subsect. 5A, subchap. 1A)

Deep-sea fisheries extend across slopes, seamounts, ridges and plateaus in all the world's oceans. United Nations resolutions require States to safeguard these environments either through national measures or through regional fisheries management organizations (RFMOs) (Kaikkonen and others, 2024) (see figure II). Fisheries stocks and vulnerable marine ecosystems are increasingly being protected by multiple regulations and spatial protection measures, including closed areas.

Figure II

Map of regional fisheries management organizations



Source: FAO.

Note: NEAFC- North-East Atlantic Fisheries Commission; NAFO- Northwest Atlantic Fisheries Organization;[1] NPFC- North Pacific Fisheries Commission; GFCM- General Fisheries Commission for the Mediterranean;[2] SPRFMO -South Pacific Regional Fisheries Management Organization; SEAFO- South East Atlantic Fisheries Organization; SIOFA- Southern Indian Ocean Fisheries Agreement; CCAMLR-Commission for the Conservation of Antarctic Marine Living Resources.

In the North Atlantic, Hatton-Rockall plateau extends across exclusive economic zones (EEZ) and areas beyond national jurisdiction and presents spatial management challenges in the face of international bottom trawling fleets (Johnson and others, 2019) whereas the Azores plateau is mainly exploited by locally based vessels managed by national measures (Morato and others, 2020). In the southwest Pacific, bottom trawl fisheries on the Challenger Plateau are managed by New Zealand within the EEZ and by the South Pacific Regional Fisheries Management Organization in the area beyond national jurisdiction further offshore. Fisheries for hoki, ling and blue whiting on the Campbell Plateau are within the EEZ (Fisheries New Zealand, 2024).

Major trawl and bottom-set longline fisheries for Patagonian toothfish and mackerel icefish occur on some southern plateaus of the Indian Ocean, especially the Kerguelen Plateau. This has been the focus of extensive food web modelling (Subramaniam and others, 2020, 2021, Hindell and others, 2022, McCormack and others, 2021).

Globally, ridge and plateau habitats are affected by marine litter largely originating from lost fishing gear (Canals and others, 2021; Duncan and others, 2023).

[1] https://www.nafo.int/.
[2] http://www.fao.org/gfcm/en/.

Mining (subsect. 5A, chap. 7)

Deep-sea mining on ridges and plateaus remains in the exploration phase under contracts issued by the International Seabed Authority (ISA) that proposes regional environmental management plans for mining areas. (Blanchard and others, 2023). Please refer also to part 4 (Region-specific changes) below, and to subsection 5A, chapter 7 on mineral resources.

Climate change

The deep ocean is warming more slowly than surface waters, but analysis of shifts in expected species' range (climate velocity), indicates that deep-ocean biodiversity is highly sensitive to projected climate changes (Brito Morales and others, 2020). Direct evidence has been recorded in the South Pacific Ocean off New Zealand where warming over the Chatham Rise is five times faster than the global rate with implications for local sustainability of fish stocks (Sutton and others, 2024).

4. Region-specific changes

Since 2020, several regions across the world's oceans have experienced significant environmental and human pressures, including fisheries, mineral resource exploration, climate change and pollution. In the Arctic Ocean, for example, the Chukchi Borderland plateau has been impacted by both fisheries and climate change. Protection measures such as the Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean, effective since June 2021, and Norwegian regulations in the Yermak Plateau, have been put in place. Similarly, in the North Atlantic Ocean, areas like the Hatton-Rockall Bank and Azores Plateau have faced fisheries pressure, with the closure of multiple regions to bottom fishing gears and the development of draft regional environmental management plans for the area. These protective actions aim to mitigate the effects of human activity, while pollution remains a significant concern.

In the South Atlantic and Indian Oceans, fisheries, mineral exploration and pollution continue to affect marine ecosystems. The South Atlantic, with regions like the Rio Grande Rise and Walvis Ridge, has seen significant protective measures, including fully protected MPAs such as Ascension Island and Tristan da Cunha, and various fishing closures across important areas like the Southern Mid-Atlantic Ridge. Brazil has also terminated cobalt crust exploration contracts in the Rio Grande Rise, claiming it as part of its extended EEZ. The Indian Ocean has seen similar pressures, with areas like the Sunda Trench and Amirante to Fortuna Banks being fully protected. Fishing closures have been enforced in regions like the Atlantis Bank and Walter's Shoal, while developments like the Central Indian Basin regional environmental management plan are being implemented to safeguard these fragile ecosystems.

In the Pacific and Southern Oceans, the situation mirrors that of the other regions, with key areas facing both human-induced and natural challenges. The North Pacific, for instance, has seen the development of a draft regional environmental management plan for the Northwest Pacific, and the establishment of protected areas such as the Hawaiian Papahānaumokuākea National Monument. Meanwhile, in the South Pacific, countries like New Zealand and Australia have implemented strict protections, such as prohibiting bottom trawling along the Kermadec Ridge and creating networks of MPAs. In the Southern Ocean, the Ross Sea and South Orkney Islands are subject to comprehensive protection, with commercial fishing prohibited in specific areas. These ongoing efforts across diverse oceans emphasize the importance of international collaboration and proactive conservation strategies to address the growing pressures on marine ecosystems.

5. Key advances in knowledge and understanding

New knowledge based on advances in technology: exploration, artificial intelligence tools and the resulting implications

Knowledge of hadal trenches is being revolutionized by the advent of human occupied vehicles capable of repeated dives to maximum ocean depth (11 km) (e.g. the United States' Deep Submergence Vehicle *Limiting Factor* and the Chinese Human Occupied Vehicle *Fendouzhe*) (Zhou and Peng, 2023). Together with autonomous landers, these have enabled global sampling programmes, the Five Deeps Expedition (Jamieson, 2020) and the Global Trench Exploration and Diving Programme to all the major trenches with detailed mapping, discovery of new species and studies of biogeological processes.

Increasing use of sea-floor imagery enabled by advances in digital camera technology is providing non-destructive means of surveying the sea floor (Bell and others, 2022). Beyond the area surveyed by cameras, habitat suitability modelling can extrapolate the predicted distribution of faunal communities to data-poor areas. Off New Zealand, for example, habitat suitability maps for deep-sea corals have been developed based on seafloor imagery (Anderson and others, 2023) and modelled coral densities were used to identify areas for conservation efforts. The South Pacific Regional Fisheries Management Organization has used zonation decision-support software to help define management areas that can protect predicted vulnerable marine ecosystems habitat while permitting deep-sea commercial fishing. This analysis identified priority areas for conservation where the impact on fisheries is small (Australia-New Zealand, 2023) within the Lord Howe Rise, South Tasman Rise, Challenger Plateau and West Norfolk Ridge. Mapping at an unprecedented scale, coupled with rapidly evolving artificial intelligence is rapidly increasing habitat suitability modelling capability. Deep learning, specifically, can both accelerate and standardize the interpretation of biological imagery data (Clark and others, 2024).

6. Key remaining knowledge and capacity gaps and new gaps

Despite progress since the publication of the first *World Ocean Assessment*, gaps remain and research on ridges continues to be focussed on chemosynthetic environments, seamounts and deep-sea mining, neglecting the wider ridge environment so that most of the global ridge system remains poorly known, in particular in the Arctic which is inaccessible for most of the year. Plateaus in active fishing areas are well surveyed, but no new research has been done on plateaus in the Arctic. Deep-sea ecosystems include slow-growing, long-lived and late reproducing species, making them particularly vulnerable to anthropogenic impacts yet individual and cumulative effects remain poorly known.

Management of ridges, plateaus and trenches in areas beyond national jurisdiction exists for fisheries and mining under RFMOs and the International Seabed Authority (ISA). The new Agreement under the United Nations Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas beyond National Jurisdiction may provide additional biodiversity protection and potential solutions for conflicts.

Sampling the deep-sea requires access to large ships and advanced technologies available only in a few institutions in a few nations. This creates a lack of equitability in access and the problem of parachute, colonial or parasitic science whereby highly resourced agencies extract samples and data from poorer regions with no reference to local populations or their expertise (Stefanoudis and others, 2021) which needs to be addressed urgently. Collaborative networks developing low-cost deep-sea imaging systems

that can be used from small indigenous fishing vessels may overcome some of these problems (Bell and others, 2020)

Human pressures on these high-seas ecosystems continue. Calls for capacity-development and knowledge transfer get louder (including in international agreements such as the Kunming-Montreal Global Biodiversity Framework and the Agreement on Marine Biological Diversity of Areas beyond National Jurisdiction) but their targets are still far from being achieved.

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Table

Region	***New data***	***Human pressures***	**Protection measures**
Arctic Ocean	Chukchi Borderland plateau	Fisheries Exploration for mineral resources (chap. 7) Climate change	Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean entered into force on 25 June 2021 The Government of Norway to regulate fisheries in the Yermak plateau, northwest of Spitsbergen/Svalbard
North Atlantic Ocean	Puerto Rico Trench Vema Fracture zone (11°N) survey Hatton-Rockall Bank Azores plateau	Fisheries Exploration for mineral resources (chap. 7) Climate change Pollution	-Nine areas on the Hatton-Rockall Bank are closed to all bottom fishing gears (NEAFC, 2024) -Three areas between the Azores and Iceland including the Charlie-Gibbs Fracture Zone are closed to bottom fishing until 2027 (NEAFC, 2024) when they will be reviewed. -Development of Northern Mid-Atlantic Ridge draft regional environmental management plan (International Seabed Authority (ISA) document, 2022).
South Atlantic Ocean	Rio Grande Rise, São Paulo Plateau Walvis Ridge	Fisheries Exploration for mineral resources (chap. 7) Climate change Offshore hydrocarbons (chap. 19) Pollution	Ascension Island and Tristan da Cunha marine protected area (MPA) - Fully protected against fishing and mining -Fishing closure areas in the Walvis Ridge (South East Atlantic Fisheries Organization) -Valdivia Bank closed to bottom trawling (SEAFO, 2015). - Six areas on the Southern Mid-Atlantic Ridge and the Wüst seamount segment of the Walvis Ridge (SEAFO, 2015)

			- Brazil's sponsored cobalt crust exploration contract with International Seabed Authority in the Rio Grande Rise terminated. The region claimed as extended Brazilian EEZ.
Indian Ocean	Sunda trench	Fisheries Exploration for mineral resources (chap. 7) Climate change Pollution	-Amirante to Fortuna Banks;fully protected Fishing closure at the Atlantis Bank of the Broken Ridge Plateau in the east and Walter's Shoal on the Madagascar Plateau in the west (SIOFA, 2024). Development of the Central Indian Basin and western Indian Ocean ridge systems regional environmental management plan (ISA, 2024)
North Pacific Ocean	Northwest Hawaiian Ridge Mariana Trench Emperor Though	Fisheries Exploration for mineral resources (chap. 7) Climate change Pollution Concentrations of discarded cables from scientific expeditions to the Mariana Trench	Development of North West Pacific Ocean draft regional environmental management plans (ISA, document 2022) Northwest Hawaiian Ridge protected as part of the United States of America exclusive economic zone, Hawaiian Papahānaumokuākea National Monument Fishery targetting North Pacific armorhead _*Pentaceros wheeleri*_ and splendid alfonsino _*Beryx splendens*_ is managed by North Pacific Fishery Commission (NPFC)
South Pacific Ocean	East and West Pacific Trenches.	Fisheries Exploration for mineral resources (chap. 7) Climate change Pollution	-Palau MPA. - fully protected Coco Islands and Christmas Islands MPA. - fully protected -Cook Islands Marae Moana management zones, 50km exclusion zones around the islands for deep-sea mineral exploration

			-New Zealand, no bottom trawling allowed along the Kermadec Ridge and complete protection 12 miles around each island on the ridge. -Australia, A network of Marine Parks offshore where uses are managed, including areas closed to fishing. - South Pacific Regional Fisheries Management Organization spatial management planning includes the Challenger Plateau, Lord Howe Rise and West Norfolk Ridge. -Bottom trawling prohibited in areas of the Tasman Rise, Lord Howe Rise, Challenger Plateau and Norfolk Ridge (SPRFMO, 2023). -Bottom trawling prohibited on part of the Three Kings Ridge. (SPRFMO, 2023)
Southern Ocean	East Scotia Ridge South Sandwich Trench	Fisheries Climate change Pollution	Ross Sea MPA. General protection zones where no fishing is allowed. -The Ross Sea region MPA. prohibits all commercial fishing on the Antarctic Continental shelf and slope and on a segment of the Pacific Antarctic Ridge. (CCAMLR, 2023) In the Southern Ocean, all commercial fishing prohibited in the South Orkney Islands Southern Shelf MPA. (CCAMLR, 2023)

Source: Prepared by the writing team.