ISA TECHNICAL STUDY NO. 33

Potential interactions between fishing and mineral resource-related activities in areas beyond national jurisdiction: a spatial analysis

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CONTENTS

ABBREVIATIONS

ABNJ	areas beyond national jurisdiction
AIS	automatic information system
APEI	area of particular environmental interest
CBD	United Nations Convention on Biological Diversity
CCZ	Clarion-Clipperton Zone
CMC	cobalt-rich ferromanganese crusts
ISA	International Seabed Authority
LTC	Legal and Technical Commission
PMN	polymetallic nodules
PMS	polymetallic sulphides
REMP	regional environmental management plan
RFMO	Regional Fisheries Management Organization
UNCLOS	United Nations Convention on the Law of the Sea

FOREWORD

One of the main impacts which may arise from future deep-sea mineral resource exploitation is the potential impacts on fish stocks and fishing activities in surrounding waters. In this context, I am pleased to introduce this important spatial analysis of the potential interactions between fishing and mineral resource-related activities in areas beyond national jurisdiction (ABNJ). This study assesses the extent of spatial overlap between fishing activities and areas allocated or reserved by the International Seabed Authority (ISA) for mineral resource exploration and environmental protection. This study represents an initial step undertaken by ISA to fully assess the impacts of future mineral resource exploitation on fishing activities and stocks in ABNJ. Such knowledge is essential for achieving an integrated and coordinated approach to sustainable resource management and environmental protection in ABNJ, which ISA firmly supports.

The study concludes that direct spatial conflicts between fisheries and future mineral resource exploitation in ABNJ are likely to be infrequent and manageable, while recognizing the need for further research to fully assess the indirect interactions between the two activities. Between 2012 and 2020, the fishing hours recorded in ISA contract areas and reserved areas were under 2 per cent of the total fishing hours in ABNJ for all years and under 1 per cent for most of the years. The most common fishing gears that occur in ISA contract areas and reserved areas are pelagic gears. Drifting longliners contributed to over 80 per cent of recorded fishing hours in all regions of the international seabed area (the "Area"). The occurrence of trawlers, the only fishing gear with the potential to reach the depth at which future deep-sea mining would operate, was close to zero in all ISA contract areas, reserved areas and areas of particular environmental interest.

Under the United Nations Convention on the Law of the Sea (UNCLOS), the mandate of ISA is to administer mineral resources and control and organize exploration and future exploitation activities in the Area for the benefit of humankind as a whole. Under UNCLOS, ISA also has the mandate to take necessary measures to ensure effective protection of the marine environment from harmful effects which may arise from activities in the Area, to promote and encourage the conduct of marine scientific research with respect to activities in the Area and to coordinate and disseminate the results of such research. The results of the present study will inform the future efforts of ISA and its stakeholders in environmental planning and management of future activities in the Area in a way that minimizes environmental impacts and potential conflicts with other activities, as provided for under the UNCLOS. This study also identifies a few priorities for further inquiry.

ISA will continue to expand its efforts to ensure the effective protection of the marine environment and promote marine scientific research, especially through its regional environmental management planning process and implementation of the Action Plan in support of the United Nations Decade of Ocean Science for Sustainable Development. In so doing, it will actively seek to collaborate with competent international and regional organizations to ensure coherence in spatial planning and management measures for sustainable ocean governance in ABNJ.

In closing, I wish to express my gratitude to Dr. Jake Rice for advising and leading this study. I would also like to extend my appreciation to Dr. Gabriel Englander, and Dr. Kioshi Mishiro and Dr. Wanfei Qiu from the Office of Environmental Management and Mineral Resources of the ISA Secretariat for their inputs and contributions to this study.

Michael W. Lodge
Secretary-General
International Seabed Authority

EXECUTIVE SUMMARY

This technical study examines the extent of spatial overlap between fishing activities in areas beyond national jurisdiction (ABNJ) and three types of areas allocated or designated by the International Seabed Authority (ISA): the contract areas for exploration for mineral resources (contract areas), areas reserved for access by developing countries or for the Enterprise (reserved areas) and areas of particular environmental interest (APEIs) for the protection of biodiversity and preservation of ecosystem structure and function. If approved by ISA, the future exploitation of deep-sea mineral resources is most likely to take place in existing contract areas and reserved areas. Analyses were conducted for five regions in ABNJ where there is currently exploration activity: the South Atlantic Ocean, Indian Ocean, Clarion-Clipperton Zone (CCZ), Mid-Atlantic Ridge and the Western Pacific Ocean. Reserved areas have been designated only in the Indian Ocean, CCZ and Western Pacific Ocean[1], and APEIs have only been designated in the CCZ (ISA, 2011). These analyses are one step in the full quantitative (to the extent possible) assessment of the potential for interactions between future deep-sea resource exploitation and fishing activities.

The results of this study could contribute to ISA's efforts to minimize the potential impacts of future mining activities on fisheries through spatial planning and management. The results could also contribute to a dialogue and coordination in planning between fishing and mineral resource-related activities in ABNJ, managed by respective regional fisheries management organizations and ISA. Such a dialogue and coordination, in advance of any approvals of commercial exploitation of mineral resources in the ABNJ, could help inform efforts to minimize spatial conflicts between those industries, as each industry strives to ensure their respective activities operate sustainably but efficiently.

This study uses the most updated information on ISA contract areas, reserved areas and APEIs. The information on the distribution of fish species was taken from the RAM Legacy Stock Assessment Database, the best available database for information on the distributions of commercially exploited fish stocks on the high seas. Although this database was found to be incomplete for deep-sea fish and macro-invertebrate species overall, its coverage of species important for existing fisheries on the high seas was reasonably good. The data would not have been sufficient to document overlaps of *all* fish species within the ISA areas, but it was sufficient to scope the occurrence of

[1] Reserved Areas. Available at https://www.isa.org.jm/exploration-contracts/reserved-areas/ (assessed January, 2023).

fish species important to current fisheries relative to the ISA areas.

The information on spatial distribution of fishing vessels and fishing efforts was extracted from the Global Fishing Watch dataset. It is the best available data source on actual fishing activities on the high seas collected in standardized and validated ways globally. Since both satellite coverage and data processing techniques have improved over the nine years between 2012 and 2020 this technical study covers, the data are limited in their ability to identify trends in fishing activity during the period. However, across the period, from over half to substantially more than two-thirds of all fishing activities were detected and geo-located by the Global Fishing Watch data. Vessel identifications were sufficiently accurate to account for the fleet and gear composition of the fisheries. The spatial distribution patterns of various fisheries in the ISA areas were robust at the available sampling intensity and sufficient for these spatial analyses. The documented intensity of fishing in areas preferred by fisheries might increase with even more complete satellite coverage of the ocean, however, the overall spatial patterns are not expected to change noticeably with additional records from the satellite coverage and data processing algorithms.

The analysis showed that the number of grid cells included in ISA contract areas, reserved areas and APEIs comprise 0.71 per cent, 0.44 per cent and 1.12 per cent of the total number of grid cells in ABNJ. Some levels of fishing were found in all contract areas, reserved areas and APEIs. The intensities of fishing were measured in the number of vessels recorded as present and the number of hours vessels were present and recorded as fishing. Between 2012 and 2020, the number of fishing vessels observed within ISA contract areas and reserved areas accounted for between 5 and 12 per cent of the total number of vessels fishing in ABNJ. The fishing hours were under 2 per cent of the total hours of fishing in ABNJ throughout the period. APEIs in the CCZ attracted some fishing. and the fishing vessels and hours accounted for similar percentages of the total in ABNJ compared with contract areas and reserved areas despite the relatively smaller size of the APEIs.

Among the different gears that fish in the ABNJ, bottom trawling is often considered to have the most harmful impacts on deep-sea ecosystems. The results showed that only 3 per cent of the fishing vessels observed passing through the entire ABNJ were trawlers. and that trawling accounted for less than 0.5 per cent of the active fishing hours recorded for ABNJ. The occurrence of trawlers was close to zero in all ISA contract areas, reserved areas and APEIs. This result is consistent with the findings of a recent report by the Food and Agricultural Organization (FAO) that "only a very small fraction of the high seas seabed has ever been, or ever will be, fished by bottom-fishing gears" (FAO, 2020, p. 8).

For contract areas and, when designated, reserved areas, most metrics indicated that overall fishing intensity was highest in the Indian Ocean and the CCZ, and the lowest in the South Atlantic Ocean. Metrics of vessels recorded and hours of documented fishing were quite variable over time and space, a variation attributable to possible changes in fisheries from year to year but confounded with the increases over time in satellite coverage of all areas and improvements in algorithms to extract data from the satellite signals. All differences in metrics among years and types of areas in the Indian Ocean, Western Pacific Ocean and Mid-Atlantic Ridge were within the range of inter-annual variations for the metrics within each zone and type of area.

In the three zones (Indian Ocean, Pacific Ocean, the CCZ) where reserved areas have been designated, when modest differences in relative sizes of the contracted areas and reserved areas are accounted for statistically, there are no noteworthy differences in fishing intensity between the contracted areas and reserved areas of each zone. There is relatively more fishing effort in the CCZ APEIs than in corresponding contract areas and reserved areas. This was expected because when the APEIs were designated, one consideration was to minimize spatial interactions of fishing fleets with future mining operations.

Although there was noticeable fishing in most contract areas and reserved areas, the vast majority of fishing was by drifting longlines. It comprised over 95 per cent of all fishing hours except for the CCZ and the Western Pacific Ocean. In the CCZ, longlining still comprised over 80 per cent of the recorded fishing hours, with purse seining comprising almost all the remaining effort. In the Western Pacific Ocean, longlining comprised over 85 per cent of all fishing hours. Assorted Other Fishing Gears comprised all the remaining hours of fishing and fishing vessels observed.

Of all the fishing gears recorded in the extracted data, only trawling uses gears that reach the depths where deep-sea mineral exploration and exploitation would be conducted. It is noteworthy that trawling does not constitute even 1 per cent of all fishing in any of the ISA areas. and overall is less than 0.02 per cent of the total fishing recorded. The total number of trawler vessels recorded in the ISA areas is slightly larger (slightly over 0.1 per cent of all fishing vessels recorded). However, this is likely to reflect that vessels capable of bottom trawling in the deep sea are likely to be larger than the average size for all fishing vessels and, consequently, more likely to have been detected when they were in a grid cell.

Of the 229 fish stocks recorded in the RAM Legacy Stock Assessment Database, 27 intersect with ISA contract areas, 13 with reserved areas and two with APEIs. Pelagic species, such as tuna, are the most common among the stocks that intersect with contract areas, reserved areas and APEIs. Only one species in the RAM Legacy Stock Assessment Database, Pacific halibut, is known to be fished by bottom gear.

Overall, the analyses document a negligible overlap between the occurrence of fishing with gears that operate at or near the seafloor in ABNJ and areas allocated as contract areas or reserved areas for deep-sea mineral resource exploration. However, there is fishing with pelagic gears, especially drifting longlines, but also purse seines in contract areas or reserved areas. There is also substantial fishing with pelagic gears, particularly drifting longlines and purse seines in the APEIs in the CCZ.

These findings suggest that *direct* conflicts for operating space between fisheries and deep-sea mineral exploration and exploitation are expected to be infrequent and readily managed. The structures or platforms on the surface in support of the mining operations will be highly visible (visually and with navigation instruments) and fixed in position for long periods, so they can be avoided readily by pelagic fishing vessels. The operations extracting minerals on the seabed may cover a larger area, but there is very little fishing with gears deployed at those depths, making direct conflicts few and readily avoided.

This study does not assess indirect interactions between fishing activities and deep-sea mining operations, which could be more likely to occur. In addition, any impacts of deep-sea mining operations at any depth of the water column on animal populations, ecosystem productivity, or ecological processes could indirectly impact fisheries in those zones or even at greater distances if sediment plumes or other materials released from the mining operations spread widely. These indirect interactions are current research priorities for ISA and the scientific community and should be followed closely. On the fisheries side, a better understanding of the potential for indirect interactions would require greater knowledge of fish stock distribution in the water column and the behavior of target species of fisheries. From the ISA side, any such understanding will require staying current as the knowledge advances on how deep-sea mineral resource exploitation will be conducted and how sediment plumes and other operating wastes and byproducts may spread in the three dimensions of the water column.

Overall, the results from this study can inform spatial planning and management of future exploitation of deep-sea mineral resources in several ways. First, the impacts on fishing activity and fish stocks can be substantially reduced if future mining operations can reduce their impacts on the top 200 metres of the water column by taking measures such as releasing mid-water discharges as close to the seafloor as technologically feasible, as recommended in ISA's draft REMP for the northern Mid-Atlantic Ridge. Second, the priority areas for future research and investigation may likely be parts of the CCZ and the Indian Ocean, where relatively high intensities of fishing activity have been detected. In these priority areas, more detailed information on the spatial and temporal distributions of fish stocks and their behavior can help guide site-level management of future exploitation of mineral resources at the mining site. Third, the absence of trawling and relatively high levels of pelagic fishing in APEIs do not seem to compromise the conservation of the benthic habitats in these APEIs, but may need to be considered when assessing the cumulative impacts on the benthic habitats.

1. INTRODUCTION

Deep-sea mineral resource exploitation is an industry in the very early stages of development. Draft regulations on the exploitation of mineral resources in the international seabed area (the Area) are under consideration by the International Seabed Authority (ISA). At the same time, there have been growing concerns about the possible environmental effects of deep-sea mineral resource exploitation. As it is expected that future deep-sea mineral resource exploitation will involve the use of new technologies, there are concerns about the potential environmental impacts from the application of such technologies and effectiveness of management and governance (Dunn et al. 2018; Folkersen et al. 2019; Miller et al. 2021; Kung et al. 2021). There are also concerns over the potential impacts of future exploitation of deep-sea mineral resources on fish stocks and fishing activities (Jones et al. 2018; Washburn et al. 2019; Christiansen et al. 2020; Drazen et al. 2020). Building an understanding of the fish stock and fishing activities in areas with potential mineral resource interests presents an important step toward assessing any potential impact of deep-sea mineral exploitation on fisheries.

This technical study examines the extent of potential spatial overlap between global distribution patterns of fishing activity and fish stocks and the areas allocated or reserved by ISA for mineral resource exploration in the Area. The study also looks at the extent of potential spatial overlap between global distribution patterns of fishing activity and fish stocks and the areas established by ISA to protect biodiversity and the marine environment in the Area, in which no future exploitation of mineral resources will be permitted. These analyses are one step in the full quantitative (to the extent possible) assessment of the potential for interactions between future mineral resource exploitation and fishing activities.

Mineral resources-related activities and fishing in the areas beyond national jurisdiction (ABNJ) are managed by different organizations. Under the United Nations Convention on the Law of the Sea (UNCLOS) and the Agreement relating to the Implementation of Part XI of the UNCLOS of 10 December 1982, ISA has the mandate and responsibility to organize and control all mineral resources-related activities in the Area for the benefit of humankind as a whole. In so doing, ISA is also mandated to ensure the effective protection of the marine environment from harmful effects that may arise from activities in the Area (UNCLOS, Article 145).

ISA is developing a system of rules, regulations and procedures to regulate the prospecting, exploration and exploitation of marine minerals in the Area in line with its mandate and responsibilities. Three sets of exploration regulations have been adopted on prospecting and exploration for polymetallic sulphides (PMS),[2] cobalt-rich ferromanganese crusts (CFC)[3] and polymetallic nodules (PMN).[4] These are supplemented by a series of recommendations issued by the Legal and Technical Commission (LTC). The regulations and the standard clauses for exploration contracts included therein impose many obligations on ISA, sponsoring States and contractors. In particular, the ISA and sponsoring States shall apply a precautionary approach, as reflected in Principle 15 of the Rio Declaration,[5] and best environmental practices. Contractors are required to assess and monitor the effects of their activities on the marine environment. In doing so, they must establish monitoring programmes, report annually to the ISA on the implementation and results of their monitoring programmes, and submit environmental baseline data.

ISA is also developing and implementing regional environmental management plans (REMPs) in the Area. The first environmental management plan was approved by the Council in 2012 for the Clarion Clipperton Zone (CCZ), upon the recommendation from the LTC.[6] This plan and its subsequent review in 2021 established a network of 13 areas of particular environmental interest (APEIs) covering 2 million km^2 of the seabed to protect biodiversity and ecosystem structure and function (ISA, 2021b). The process is also underway to establish REMPs in the Mid-Atlantic Ridge, Northwest Pacific and Indian Oceans (ISA, 2020b).

Fishing on the high seas is regulated under UNCLOS and the United Nations Agreement for the Implementation of the Provisions of the UNCLOS of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks. Under the Agreement, regional fisheries management organizations (RFMOs) and arrangements are the primary vehicles for cooperation between costal States and high-seas fishing States in the conservation and management of straddling and highly migratory fish stocks (United Nations, 2020). To assist Member States and RFMOs in the sustainable management of high-seas fisheries, the United Nations Food and Agriculture Organization (FAO) published the international guidelines for the management of deep-sea fisheries in the high seas and the protection of vulnerable marine ecosystems (FAO, 2008). These voluntary guidelines provide recommendations on governance frameworks and management of deep-sea fisheries with the aim to ensure long-term conservation and sustainable use of marine living resources in the deep sea and to prevent significant adverse impacts on vulnerable marine ecosystems.

Against this background, the analyses presented in this technical study serve as

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[2] ISA. 2010. Decision of the Assembly of the International Seabed Authority relating to the regulations on prospecting and exploration for polymetallic sulphides in the Area (ISBA/16/A/12/Rev.1). Available at: https://www.isa.org.jm/wp-content/uploads/2022/04/isba-16a-12rev1_0.pdf.

[3] ISA. 2012. Decision of the Assembly of the International Seabed Authority relating to the Regulations on Prospecting and Exploration for Cobalt-rich Ferromanganese Crusts in the Area (ISBA/18/A/11). Available at: https://www.isa.org.jm/wp-content/uploads/2022/04/isba-18a-11_0.pdf.

[4] ISA. 2013. Decision of the Council of the International Seabed Authority relating to amendments to the Regulations on Prospecting and Exploration for Polymetallic Nodules in the Area and related matters (ISBA/19/C/17). Available at: https://www.isa.org.jm/wp-content/uploads/2022/04/isba-19c-17_0-2.pdf.

[5] United Nations General Assembly. 1992. Report of the United Nations Conference on Environment and Development (A/CONF.151/26 (Vol. I)). Available at: https://digitallibrary.un.org/record/160453?ln=en.

[6] ISA. 2012. Decision of the Council relating to an environmental management plan for the Clarion-Clipperton Zone (ISBA/18/C/22). Available at: https://www.isa.org.jm/wp-content/uploads/2023/04/isba-18c-22_0.pdf.

an initial step towards informing dialogue and coordination in planning between fishing and mineral resource-related activities in the ABNJ. Such a dialogue and coordination, before consideration of commercial exploitation of mineral resources in the ABNJ, could minimize spatial conflicts between those industries, as each industry strives to ensure their respective activities operate sustainably but efficiently.

This technical study includes an analysis of spatial overlap of global fishing activity and fish stock with ISA contract areas, reserved areas and APEIs. It uses daily, vessel-level data from the Global Fishing Watch to measure fishing activity and the stock boundaries from the RAM Legacy Stock Assessment Database to measure fish stocks.[7] When combined with information on the location of current contract areas, reserved areas and APEIs, the data on fishing effort and fish stocks allow quantification of the spatial overlap between fishing activity, fish stocks and the current contract areas and reserved areas.

This study is structured as follows: Chapter 2 describes the data and methods for data analysis, Chapter 3 presents the results of the analyses, including an overview of results and the analysis of spatial overlap between fishing activities and fish stocks and the current contract areas, reserved areas and APEIs, and Chapter 4 presents the conclusions and suggestions for future study.

[7] RAM Legacy Stock Assessment Database. Available at: https://www.ramlegacy.org.

2. DATA AND METHODS

2.1 GIS data on current contract areas, reserved areas and APEIs

Three types of areas approved or established by ISA were included in the present analysis:

- **Contract areas for exploration for mineral resources:** ISA has entered into 31 fifteen-year contracts for the exploration for three mineral resources in the Area – PMS,[8] CFC[9] and PMN.[10] Exploration activities in these contract areas include resource-related surveys and environmental baseline studies.
- **Areas reserved for access by developing countries or the Enterprise:** these reserved areas are contributed by developed States when they apply to ISA for exploration rights. They are then held in a "site bank," reserved for access by developing countries or the Enterprise. Designation of these reserved areas presents one of the ways by which UNCLOS ensures that developing countries can access deep-sea mineral resources (UNCLOS, Article 170).
- **APEIs:** areas established under the environmental management plan for the CCZ to maintain biodiversity and ecosystem structure and function. The exploitation of mineral resources will not be permitted in these areas. Currently, APEIs are only established in the CCZ. However, similar protected sites are also considered in other regions of the Area.

The total size of exploration contract areas and reserved areas approval by ISA was 1.4 and 1.3 million km^2, respectively (ISA, 2020a). Currently, the total size of APEIs is 1.97 million km^2 (ISA, 2021b). In this report and consistent with ISA approaches, the contract areas and reserved areas have been grouped into five zones: (A) South Atlantic Ocean, (B) Indian Ocean, (C) Mid-Atlantic Ridge, (D) Western Pacific Ocean and (E) CCZ. Shapefiles were extracted from the ISA website to delineate the boundaries of current contract areas, reserved areas and APEIs.[11]

Future exploitation of mineral resources may likely start in the existing contract areas and reserved areas, subject to approval by ISA upon adoption of the regulations for the exploitation of mineral resources

[8] ISA. Exploration contracts, Polymetallic sulphides. Available at: https://www.isa.org.jm/exploration-contracts/polymetallic-sulphides.
[9] ISA. Exploration contracts, Cobalt-rich ferromanganese crusts. Available at: https://www.isa.org.jm/exploration-contracts/cobalt-rich-ferromanganese-crusts.
[10] ISA. Exploration contracts, Polymetallic nodules. Available at: https://www.isa.org.jm/exploration-contracts/polymetallic-nodules.
[11] ISA. Exploration contracts, Maps. Available at: https://www.isa.org.jm/exploration-contracts/maps.

in the Area. The exploitation areas will be much smaller than the contract areas and reserved areas, due to a system of relinquishment where contractors may be required to relinquish a portion of their contract areas following a schedule specified in the exploration regulations.[12] The relinquished areas revert to the Area.

It should also be noted that the contract areas, reserved areas and APEIs are not static, as all three types of areas have increased over time. This study uses the most recent GIS boundaries to analyze spatial overlap between these areas and fishing activities between 2012 and 2020. Therefore, the size of contract areas, reserved areas and APEIs were overestimated in the earlier years when they were smaller than today.

2.2 Fishing data

Global fishing activity was estimated using a publicly available dataset from the Global Fishing Watch. The fishing activity data, entitled Daily Fishing Effort at 10th Degree Resolution by MMSI, 2012-2020, is inferred from automatic identification system vessel movements between 2012 and 2020. After extraction, the fishing activity data were combined with a second Global Fishing Watch dataset, called Fishing Vessels Included in Fishing Effort Data. The second dataset contains the gear (type of fishing activity) and flag (country that the vessel is registered to) of each vessel. For both data sets, vessel gear was inferred from the automatic identification system vessel movements using a convolutional neural network (Kroodsma et al. 2018). Since the surveillance process could track individual vessels, it was possible to differentiate the time a fishing vessel was steaming through an area from the time when the vessel was moving in ways consistent with having its fishing gear deployed. There are five possible gears in the data set: trawlers, purse seines, squid jiggers, drifting longlines and other fishing gears.[13] The data was used to quantify the hours of presence (all the time a vessel was recorded in a grid cell) and active fishing hours (the time the vessel was moving in ways consistent with gear being deployed) for each vessel, day and .1° grid cell (approximately 11 by 11 km at the equator). Chapter 3 presents results for all gears cumulatively and individually.

Satellite coverage and algorithms for processing satellite records have both improved over the period between 2012 and 2020. It was estimated that this data set captured 50-70 per cent of the total fishing effort that occurred more than 100 nautical miles from shore by the mid-2010s (Kroodsma et al. 2018). That percentage has continued to increase over the period. Even if the exact rate of increase in satellite coverage was calculated at the spatial scale of this study, the relative detectability of fishing vessels of various sizes operating differently due to the gears they deployed, among other factors, would very unlikely be equal across fishing vessel sizes and gear types. It would also be unlikely that the improvements in processing algorithms would improve the detectability of all types of vessels at the same rate.

[12] ISA. 2013. Decision of the Council of the International Seabed Authority relating to amendments to the Regulations on Prospecting and Exploration for Polymetallic Nodules in the Area and related matters (ISBA/19/C/17), Regulation 25. Available at: https://www.isa.org.jm/wp-content/uploads/2022/06/isba-19c-17_0.pdf. ISA. 2012. Decision of the Assembly of the International Seabed Authority relating to the Regulations on Prospecting and Exploration for Cobalt-rich Ferromanganese Crusts in the Area (ISBA/18/A/11), Regulation 27. Available at: https://www.isa.org.jm/wp-content/uploads/2022/06/isba-18a-11_0.pdf.

[13] No vessels associated with the use of fixed gear were recorded in the contract areas, reserved areas or APEI. Therefore, they do not appear in any of the tables or figures in this report. However, as a possible type of a fishing vessel that the algorithms could identify, they are mentioned here in the methods.

Rather than trying to calculate correction factors that would be highly uncertain at the spatial scale and diversity of vessels involved, the annual Daily Fishing Records were used at face value. Because this study intended to estimate the extent of spatial overlap between the fishing activity of various gears and the areas designated by the ISA as contract areas, reserved areas and APEIs, improvements in coverage and data extraction algorithms only improve those estimates over the period under observation, particularly when used in aggregate. The upward trends in the presence and activity of fishing vessels between 2012 and 2020 undoubtedly reflect real increases in fishing efforts. However, the absolute magnitudes of overall and year-by-year changes are unreliable indicators of change in fishing practices over time. Moreover, the magnitudes of change in detectability will likely be increasingly unreliable for smaller vessels. This is because the detectability of the larger vessels was likely to be substantially higher at the start of the period, allowing less scope for further increase in detectability. Consequently, the inter-annual trends in these data need to be interpreted with the same caution, whether looking at aggregated data or information disaggregated by gear.

Since these data do not contain 100 per cent of fishing activity between 2012 and 2020 in the current contract areas, reserved areas and APEIs, the results presented in this technical study will underestimate the amount of fishing in these areas. Nonetheless, these results are a useful benchmark. The data contains most fishing activity between 2012 and 2020 in contract areas, reserved areas and APEIs (Kroodsma et al. 2018). It is also expected that the fishing fleets and gears most likely to interact with deep-sea mineral resource activities are underestimated to a lesser extent than most other fleets due to their larger sizes.

The data sets do not include the depth at which fishing was performed or information on target species. In most cases, the information on gear type could be used to infer whether fishing using that gear was likely to have targeted deep-sea fish. Trawling may target deep-sea fish (Victorero et al. 2018). However, purse seines, squid jiggers, drifting longlines, fixed gear and other fishing gears rarely, if ever, can be deployed at depths that target deep-sea fish.

2.3 Fish stock data

Spatial boundaries for fish stocks were extracted from the RAM Legacy Stock Assessment Database. The analysis of Rising (2017)[14] was applied to create spatial boundaries for stocks in the RAM Legacy Stock Assessment Database. A depth range was added for each of these stocks from Free et al. (2019). Such data processing allowed for estimations of spatial boundaries and depth ranges for 229 fish stocks. Multiple geographically separated stocks were identified, consistent with the practice of flag states and RFMOs (e.g., skipjack tuna in the Western Atlantic Ocean comprises one fish stock and skipjack tuna in the Indian Ocean comprises another). There are many more than 229 fish stocks in the oceans. The best available fish stocks data include many species targeted by fisheries in the open ocean (Rising 2017). They were sufficient to provide informative estimates of spatial overlap between ranges of individual fish stocks and boundaries of areas currently designated as contract areas, reserved

[14] Rising, James. 2017. RAM Legacy Stock Assessment Database Geospatial Regions [Dataset]. Zenodo. https://doi.org/10.5281/zenodo.834755.

areas and APEIs for the large majority of stocks targeted by fisheries in the deep waters, at least.

2.4 Data analyses

Chapter 3 presents the first results of the analysis of the spatial overlap of fishing effort and fish stocks in the various contract areas, reserved areas and APEIs. In all three types of areas, the spatial overlap was estimated by spatially overlaying the location of fishing activity or the spatial boundaries of fish stocks on the relevant contract area, reserved area or APEIs. The analysis, including extraction of spatial interaction and statistics, was performed using R package, Python and ArcGIS.

To document the overlap of fishing with a given ISA contract area, reserved area, or APEI, the analysis measured intersections of the centers of the grid cells in terms of fishing occurrences and these ISA designated areas of each grid cell, rather than the areas of overlap within individual grid cell boundaries. Data sources were not considered accurate and precise enough to justify finer scales of disaggregation of the number of fishing hours, or fishing vessels present inside each contract area, reserved area or APEI. Nor was there sufficient information for a finer resolution of the spatial scale of the information in the RAM Legacy Stock Assessment Database. Consequently, if the center of the fishing grid cell is inside the polygon of an ISA contract area, reserved area or APEI, 100 per cent of the fishing hours or fishing vessels in that grid cell were assigned to the polygon. If the center of the fishing grid cell is outside the polygon, none of the fishing hours or fishing vessels is attributed to the specific polygon, even if the fishing grid cell partially overlaps with the polygon. The boundaries of the grid cells for fishing activity and occurrences of fish species were set wholly independently of the boundaries of the ISA-designated areas, so the approach should result in little or no bias in estimates of overlap due to over- or underrepresenting the intersection area of grid cells on the boundary of the ISA-designated areas. This assumption is reasonable given that the boundaries of the contract areas, reserved areas and APEIs do not depend on the number of fishing hours or fishing vessels inside them. For all fishing grid cell centers that intersect with a given polygon defined by ISA designation, the number of hours of fishing activity was summed over all grid cells in the polygon. Numbers of fishing vessels avoided "double-counting" by recording each vessel when it was first detected inside a polygon but not counted again as long as it continued to fish within the same polygon. A vessel that might leave a polygon and return later was counted again, which was considered an appropriate way to measure the attention given to an area by highly mobile fleets.

Stock boundaries intersected directly with ISA contract areas, reserved areas and APEIs. If a stock boundary overlapped with a given polygon in any part, it was counted as fully overlapping. This was a conservative strategy considering a species present in the entire ISA polygon as long as its range in the RAM Legacy Stock Assessment Database overlapped with the polygon in any part. The species present counts thus represent the number of stocks that intersect each polygon, even if some stock boundaries only partially overlap with the polygon. When management plans for individual contract areas, reserved areas and APEIs are developed, finer-scale species distribution information will be needed. Information on species not currently exploited by fisheries will also be important. However, for this first attempt at evaluating the potential for interactions between fisheries and deep-sea mineral resource activities, the analyses would call attention to the possibility of such interactions in at least parts of the ISA-designated areas. Those interactions should be followed up in the subsequent development of management plans at a finer scale.

All data extraction and preliminary analyses were performed using the R programming language (R version 3.6.1). The following R packages were used: cowplot, dplyr, ggplot2, ggnewscale, lwgeom, parallel, purrr, raster, readr, rgeos, rworldmap, scales, sf, stringdist, viridis and xtable. All code is reproducible and available upon request.

Where appropriate, data values in the following tables have been rounded up to the closest full number. The values for the 9-year total in the tables were calculated from the actual numbers for each year, not from the full numbers.

3. RESULTS AND DISCUSSION

This technical study analyzes nine years of spatial fishing effort data covering the period between 2012 and 2020. Over that period, there were changes to fishing activities as RFMOs made progress on the requirement to identify vulnerable marine ecosystems under United Nations General Assembly Resolutions on sustainable fisheries 61/105 from 2007[15] and 64/72 from 2010.[16] The RFMOs also responded to the calls by the Conference of Parties of the Convention on Biological Diversity in 2016[17] and 2018[18] to mainstream biodiversity considerations into fisheries management. In addition, national flag state authorities changed fishery regulations in response to changing regulations of RFMOs and implemented their national development and conservation strategies.[19] However, there were also changes in the technologies used to quantify fishing presence and pressure in the study areas (*see* Section 2.2). The progressive upward trends in the fishery activities data reflect the combined consequences of both factors. Information and algorithms to disentangle the two factors are not available, but both factors must be considered when interpreting the results presented below.

3.1 Overview of the potential for spatial interaction between fishing and mineral resource activities in ABNJ

In this section, information was reviewed for the extent of spatial overlap between fishing and combined contract areas, reserved areas and APEIs. As explained in Section 2.1, the combined contract and reserved areas indicate areas where future mineral resource exploitation could

[15] United Nations General Assembly. 2007. Sustainable fisheries, including through the 1995 Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, and related instruments (A/RES/61/105). Available at: https://digitallibrary.un.org/record/588357?ln=en.
[16] United Nations General Assembly. 2010. Sustainable fisheries, including through the 1995 Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, and related instruments (A/RES/64/72). Available at: https://digitallibrary.un.org/record/672687?ln=en.
[17] Convention on Biological Diversity. 2016. Strategic actions to enhance the implementation of the Strategic Plan for Biodiversity 2011-2020 and the achievement of the Aichi Biodiversity Targets, including with respect to mainstreaming and the integration of biodiversity within and across sectors (CBD/COP/DEC/XIII/3). Available at: https://www.cbd.int/doc/decisions/cop-13/cop-13-dec-03-en.pdf.
[18] Convention on Biological Diversity. 2018. Other matters related to marine and coastal biodiversity (CBD/COP/DEC/14/10). Available at: https://www.cbd.int/doc/decisions/cop-14/cop-14-dec-10-en.pdf.
[19] FAO. 2012. FAO Fisheries and Aquaculture Circular No. 1072. Performance reviews by regional fishery bodies: introduction, summaries, synthesis and best practices, Volume I: CCAMLR, CCSBT, ICCAT, IOTC, NAFO, NASCO, NEAFC (FIPI/C1072 (En)). Available at: https://www.fao.org/3/i2637e/i2637e00.pdf.

occur in the Area, should ISA approve applications for exploitation contracts. APEIs are areas established to protect biodiversity from the impacts of future exploitation.

The number of grid cells included in the combined contract and reserved areas and APEIs comprise 1.15 per cent and 1.12 per cent of the total number of grid cells in ABNJ (Table 1), based on the automatic identification system data from the Global Fishing Watch.

The number of fishing vessels observed in the contract areas and reserved areas indicates that there would be more vessels than expected if vessels were randomly and independently distributed in ABNJ, with the proportion of vessels observed in contract and reserved areas (out of all vessels observed in ABNJ) slowly increasing over the nine years from nearly 5 per cent of all observed vessels in 2012 to over 12 per cent of all vessels by 2020 (Figure 1). This increase may still be influenced, to some degree, by changes in the satellite coverage, but it is unlikely that the improved satellite coverage was selectively directed at the ISA contract areas and reserved areas. It is reasonable to conclude that at least a moderate amount of this doubling in the proportion of vessels that visited the contract areas over the nine years is real. However, despite the overrepresentation of vessels recorded in the contract areas and reserved areas compared to ABNJ as a whole, the proportion of fishing effort in the contract and reserved areas never reached 2 per cent of all fishing hours in ABNJ, was less than 1 per cent in most years and showed no noteworthy trend over the study period (Figure 1). It is possible that due to the wide spread of contract and reserved areas from east to west in the Pacific Ocean, some fishing vessels may have used these areas to transit rather than to conduct fishing. However, the pattern of increase was present in all areas to varying degrees, suggesting that there has been some increase in fishing in these areas during the period.

Although the APEIs comprise a much smaller proportion of the total ABNJ, they attracted amounts of fishing activity comparable to those observed in the contract areas and reserved areas (Figure 2). The percentage of vessels observed in the APEIs varied between 11 per cent and 5 per cent of all vessels in ABNJ. There is a slight downward trend, which may be partially obscured by the improving likelihood of detecting fishing vessels due to improved satellite coverage and better processing algorithms. The percentage of total hours of fishing in ABNJ that occurred in the CCZ APEIs is comparable to the percentage in the contract and reserved areas, varying without noticeable trend between just under 0.5 per cent to just over 2 per cent, with a very slightly higher overall percentage (0.91 per cent) than for the contract and reserve areas (0.89 per cent).

To illustrate the distribution of fishing activity in ISA contract areas, reserved areas and APEIs, the numbers of fishing vessels and hours of fishing summed over the nine-year period are illustrated in figures 3 and 4. The results are displayed on five regional maps, one for each region with contract areas. It is not possible to separate the possible effects of increased satellite coverage and improvements in processing algorithms from any annual changes in fishing effort or specific fishing locations. That compromises the ability to interpret any annual variations in the distribution of fishing effort and vessel presence. therefore the year-by-year maps are not presented. The results show that the highest intensity of fishing activity, measured by active fishing hours per grid cell, occurred in the Indian Ocean, followed by the CCZ (Figure 3). The highest number of fishing vessels per grid cell was observed in the CCZ, particularly in the APEIs, followed by the Western Pacific Ocean (Figure 4).

Out of the 229 fish stocks recorded in the RAM Legacy Stock Assessment Database, 27 intersect with ISA contract areas, 13 with reserved areas and two with APEIs. Among the stocks that intersect with contract areas, reserved areas and APEIs, the most common are pelagic species, such as tuna. Only one species in the RAM Legacy Stock Assessment Database, Pacific halibut, is known to be fished by a bottom gear. The number of fish stocks per grid cell is highest in the Mid-Atlantic Ridge. Since data on many fish species are not available (*see* Section 2.3), the results from the stock analysis are only indicative and need to be interpreted with great caution.

Overall, fishing with a trawling gear that may interact directly with ISA areas only constitutes a very small percentage of the total fishing activities in ABNJ. The results indicate that trawlers account for 3 per cent of the total fishing vessels, 0.5 per cent of active fishing hours and 0.92 per cent of present hours in ABNJ between 2012 and 2020 (Table 2). Among the trawlers that fished in ABNJ, 0.39 per cent of vessels, 0.08 per cent of active fishing hours and 0.16 per cent of present hours were found to occur in ISA contract areas and reserved areas. The percentages are even lower and close to zero in APEIs. The nearly total absence of trawling in the contract areas, reserved areas and, particularly, in the APEIs highlights that although the designation of status by the ISA has no legal implications for how fishers distribute their effort, deep-sea fishing vessels do not show a selective preference for contract areas, reserved areas or APEIs over other areas of the high seas. These results reflect the fact that fishing in ABNJ is overwhelmingly by gears that only operate in the pelagic zone and first couple of hundred metres of the water column. The results indicate that efforts to protect benthic habitats and biodiversity by ISA through the establishment of APEIs do not appear to be compromised by fishing activities in these areas.

The results of this analysis indicate that direct spatial conflicts between fishing and deep-sea mining in the ABNJ are likely to be infrequent. The results have several implications for spatial planning and management of future mineral resource exploitation activities. First, as fishing in all contract areas and reserved areas is dominated by pelagic gears that operate on the surface and upper 200 metres of the water column, it will substantially reduce the impacts of future deep-sea mining on fishing if the mid-water discharge from mining operations can be released as close to the seafloor as possible. This is consistent with the recommendations in ISA's draft REMP for the northern Mid-Atlantic Ridge (ISA, 2022).

Second, the contract areas and reserved areas with a relatively high intensity of fishing, such as Indian Ocean PMN contract areas and contract and reserved areas in the southern and eastern parts of the CCZ, are areas where fishing and mining vessels are likely to come into close range on the surface waters. Such places are priority areas where more in-depth studies will be needed to guide finer-scale planning and management. To fully assess the impacts of future mining, more detailed information will be needed on the technology of future mineral-resource activities and their impacts, as well as the spatial and temporal distribution of fish stocks in these areas, including their depth distribution, the behavior of fish species and their dependence on the habits occurring in those areas. In addition, safety measures, such as buffer zones, can be established to avoid any direct encounters between fishing and mining vessels.

Third, the relatively high intensities of fishing in APEIs, particularly the APEIs located in the southern part of CCZ, may warrant further monitoring and investigation. As fishing gears in these areas are several thousand metres above the benthic habitats in the APEIs, which are protected from future mining, it is expected that the effectiveness of APEIs would not be compromised. Studies are already being conducted on the habitat representativity and resilience of APEIs to climate change (Jones et al. 2021; Levin et al. 2021). The occurrence of relatively high levels of fishing may be a factor that needs to be considered when assessing the cumulative impacts on biodiversity and habitats in the APEIs as it may have implications for future review of the APEI network design.

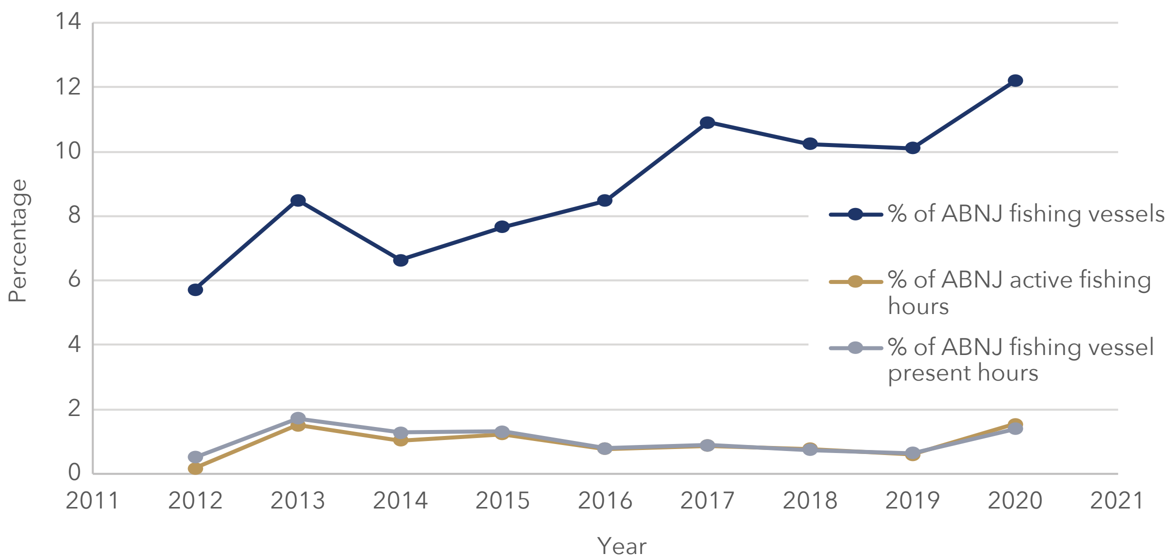


Figure 1. Percentage of total ABNJ fishing vessels, active fishing hours and fishing vessel present hours in contract areas and reserved areas

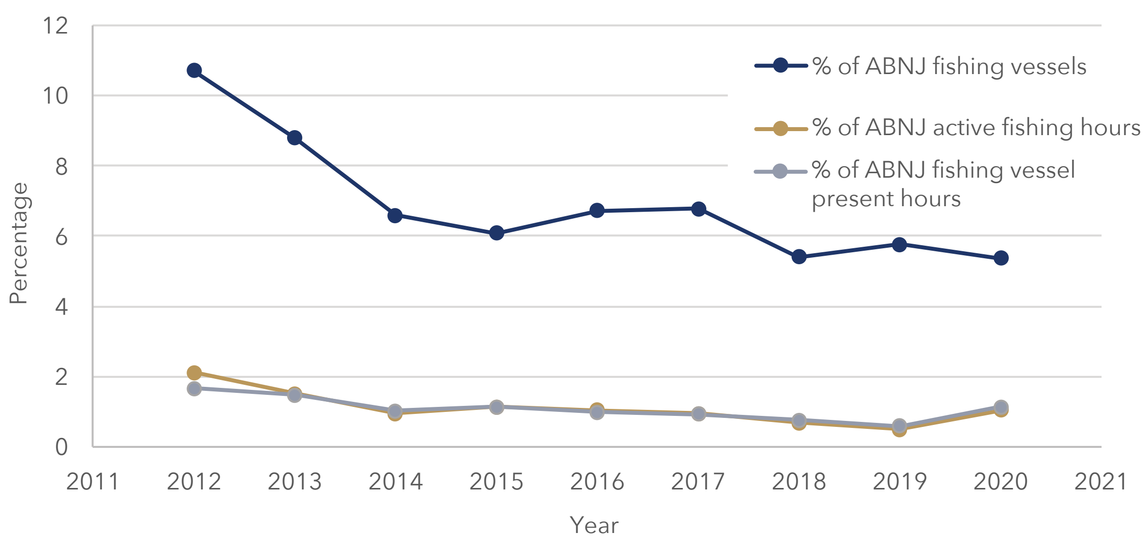
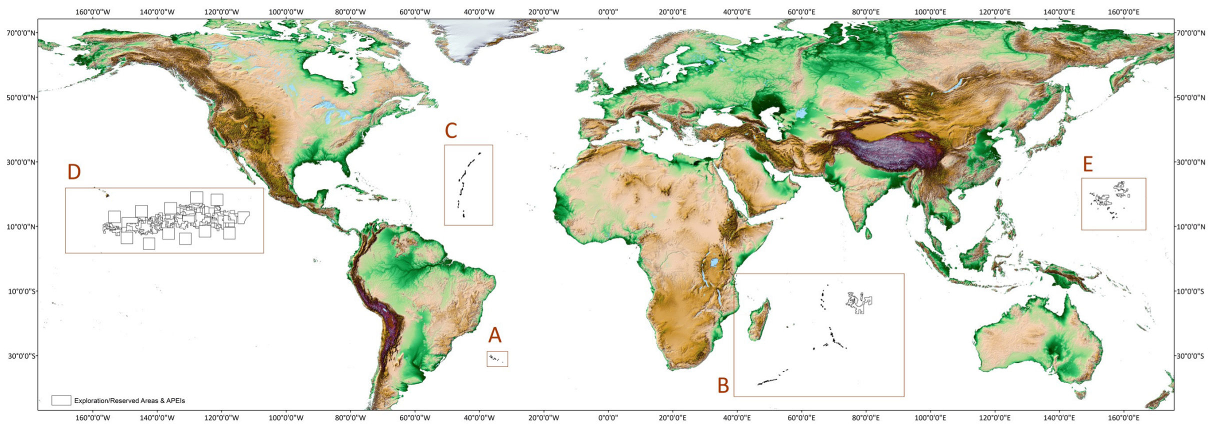
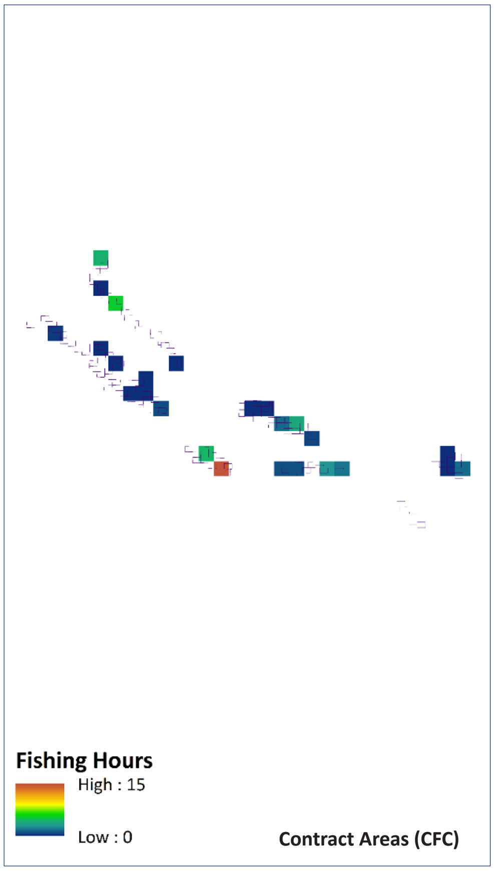


Figure 2. Percentage of total ABNJ fishing vessels, active fishing hours and fishing vessel present hours in APEIs

Table 1. Total fishing activity in combined contract areas, reserved areas and APEIs, including the percentage of ABNJ fishing activity in these areas

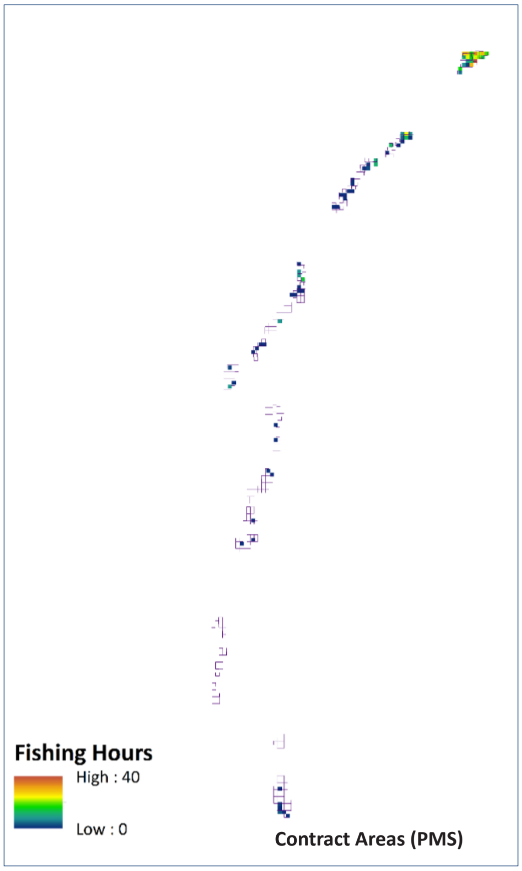
Zone	Variable	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total	Total cells
ABNJ	No. of vessels	821	1,330	1,761	2,414	2,901	3,319	3,640	3,908	3,294	23,388	1,270,814
	Fishing hours	1,140,320	1,983,694	2,494,614	3,242,523	4,433,077	5,579,525	6,313,776	6,385,372	2,857,729	34,430,630	
	Present hours	2,023,037	3,313,541	4,321,998	5,583,796	7,548,398	9,452,972	10,877,756	11,486,018	6,616,908	61,224,425	
Contract areas and reserved areas	No. of vessels (% of ABNJ)	47 (5.72)	113 (8.50)	117 (6.64)	185 (7.66)	246 (8.48)	362 (10.91)	373 (10.25)	395 (10.11)	402 (12.20)	2,240 (9.57)	19,351 (Contract areas: 12,116; Reserved areas: 7,235)
	Fishing hours (% of ABNJ)	2,054 (0.18)	29,864 (1.51)	25,764 (1.03)	40,122 (1.24)	33,914 (0.77)	48,350 (0.87)	42,233 (0.77)	38,373 (0.60)	44,301 (1.55)	304,975 (0.89)	
	Present hours (% of ABNJ)	10,416 (0.52)	57,428 (1.73)	55,162 (1.28)	73,307 (1.31)	60,471 (0.80)	84,386 (0.89)	80,339 (0.74)	73,025 (0.64)	92,449 (1.40)	586,982 (0.96)	
APEIs	No. of vessels (% of ABNJ)	88 (10.72)	117 (8.80)	131 (6.6)	147 (6.09)	195 (6.72)	225 (6.78)	197 (5.41)	225 (5.76)	177 (5.37)	1,502 (6.42)	15,521
	Fishing hours (% of ABNJ)	24,038 (2.11)	29,139 (1.50)	23,608 (0.94)	36,444 (1.12)	45,630 (1.03)	52,452 (0.94)	42,711 (0.68)	30,908 (0.48)	29,688 (1.04)	314,678 (0.91)	
	Present hours (% of ABNJ)	33,522 (1.66)	48,358 (1.46)	44,128 (1.02)	62,835 (1.13)	72,809 (0.97)	86,111 (0.91)	80,932 (0.74)	66,897 (0.58)	74,281 (1.12)	569,872 (0.93)	



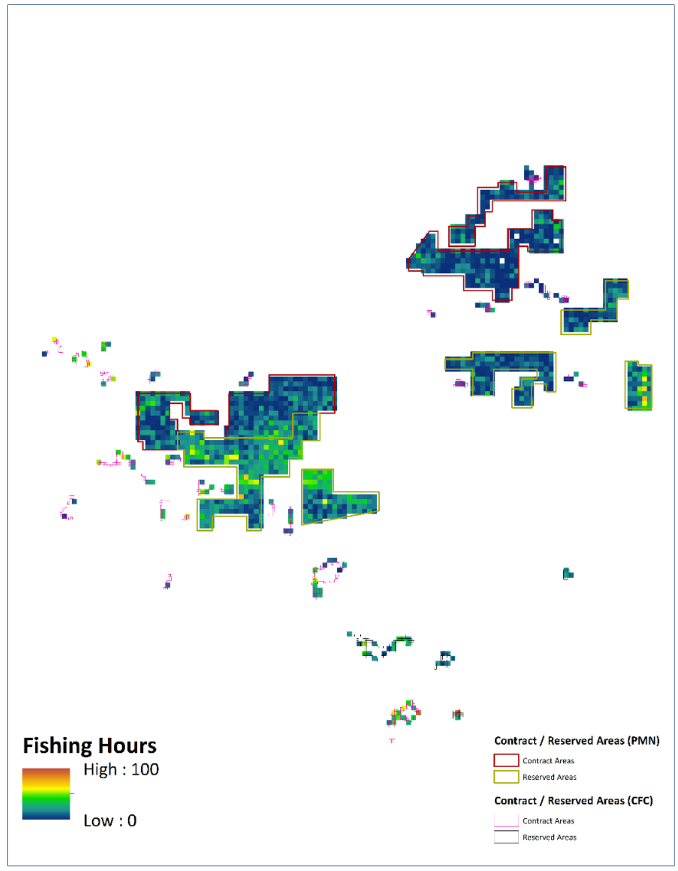


(A) South Atlantic Ocean

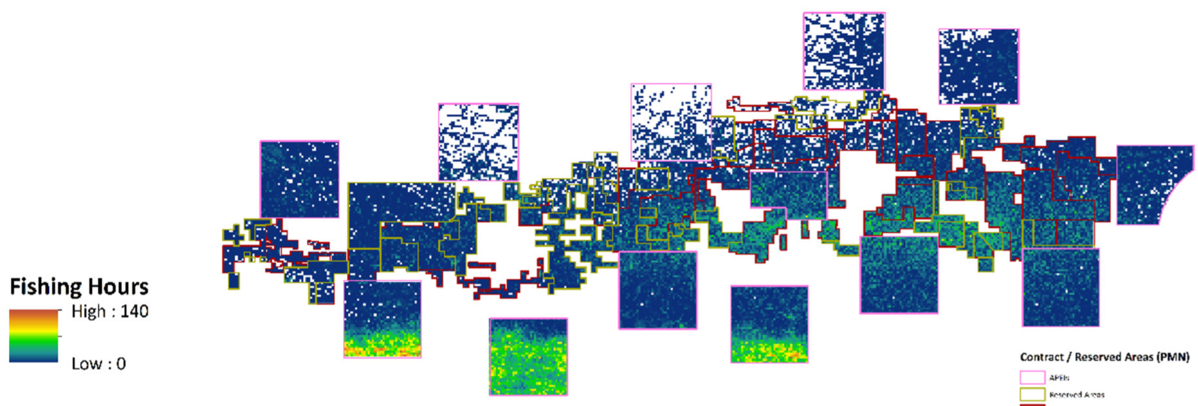
(B) Indian Ocean



(C) Mid-Atlantic Ridge



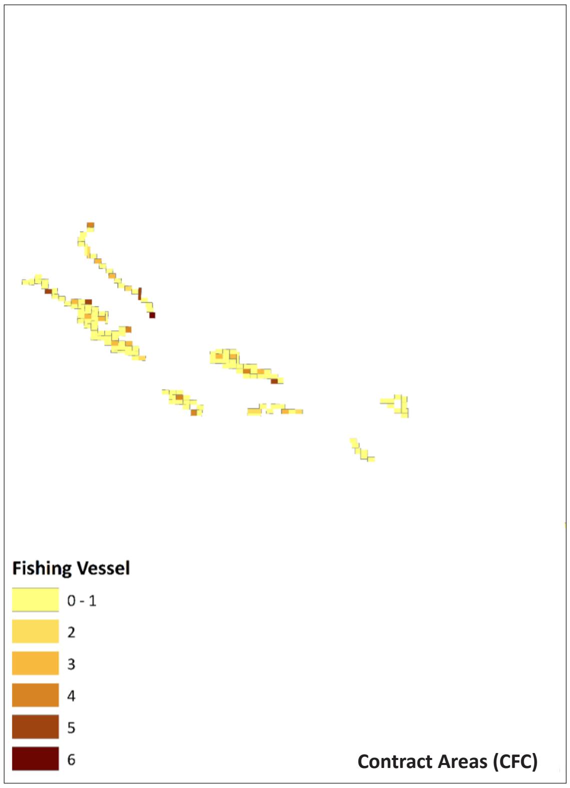
(D) Western Pacific Ocean



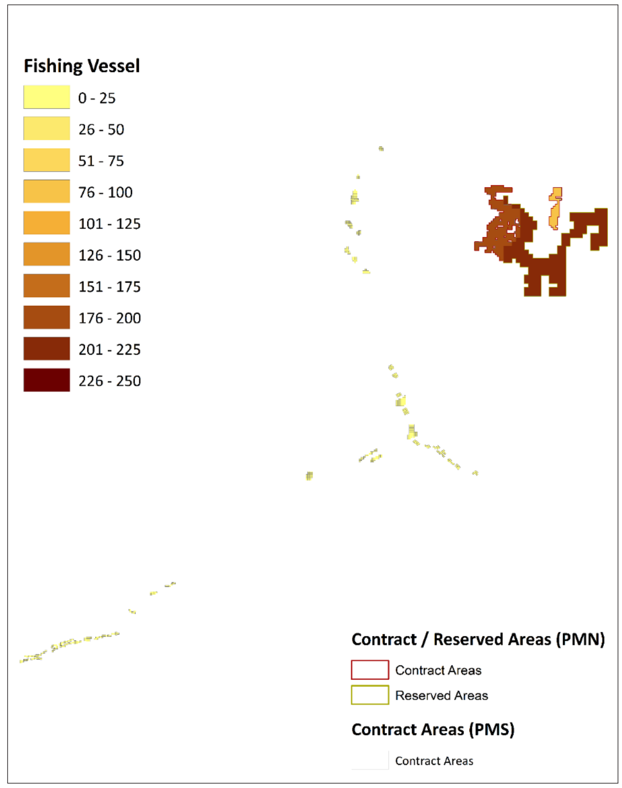
(E) CCZ

Figure 3. Total fishing hours for all gears and all years between 2012 and 2020 in the contract areas and reserved areas

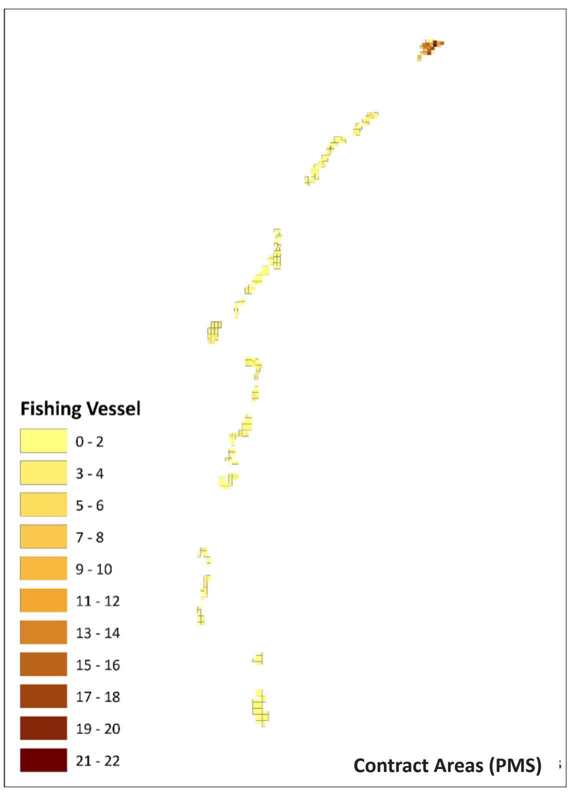
Legend: The color code of each cell indicates the number of total active fishing hours in it between 2012 and 2020 (all gears). A different scale for each Zone is used because the absolute number of fishing hours differs so greatly between zones that a common color code for all figures would provide little information on differences in fishing effort within each zone.



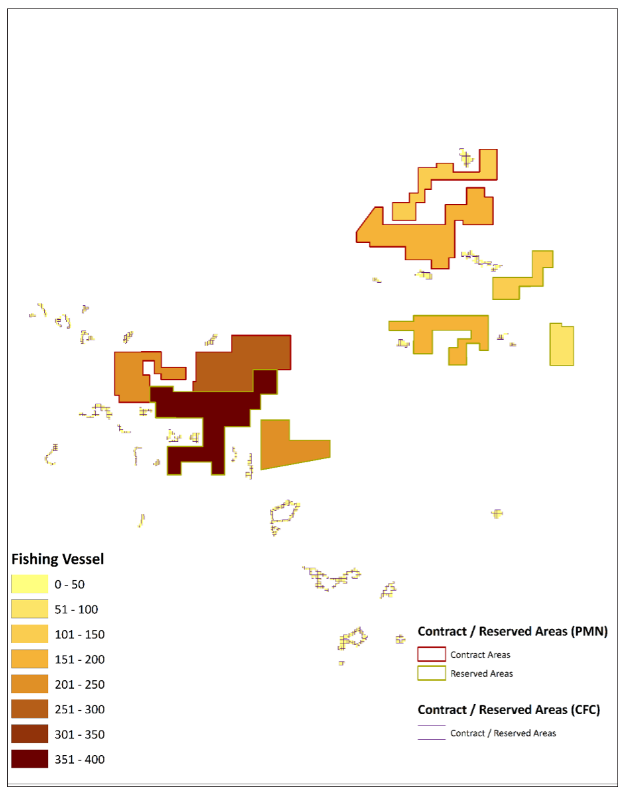
(A) South Atlantic Ocean



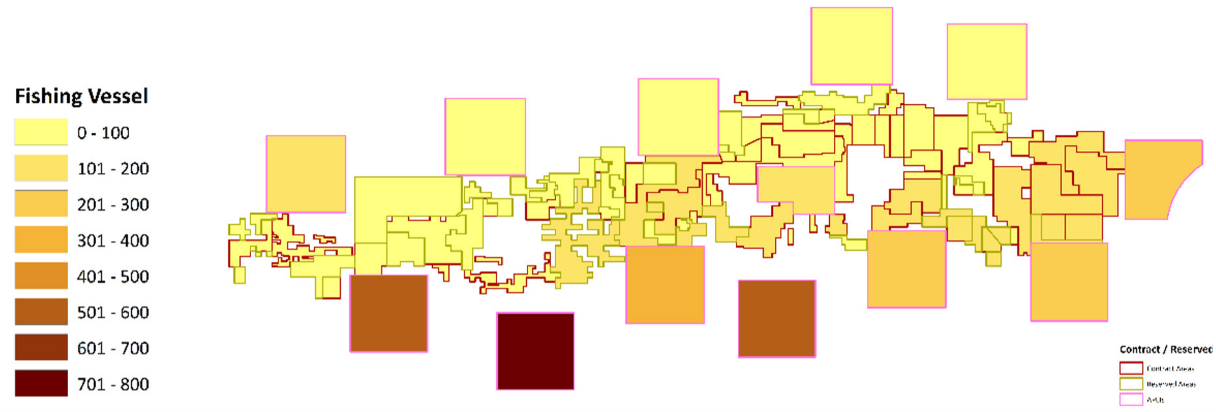
(B) Indian Ocean



(C) Mid-Atlantic Ridge



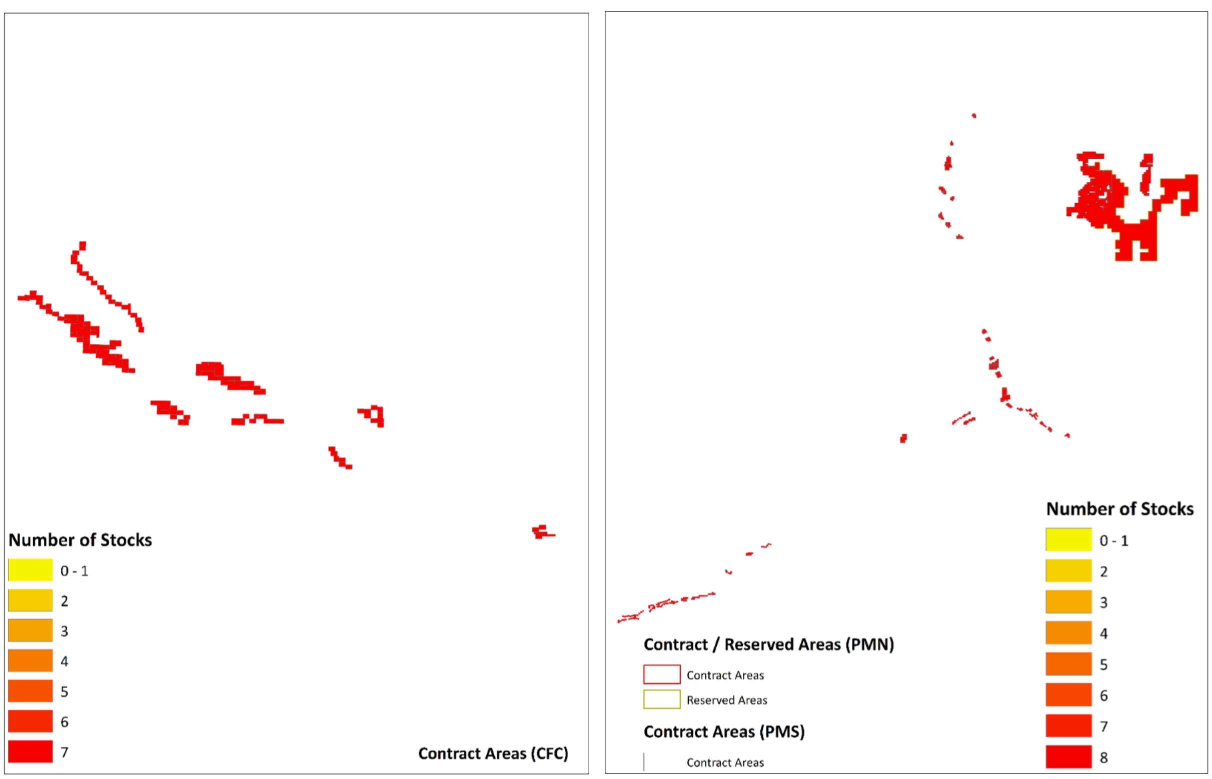
(D) Western Pacific Ocean



(E) CCZ

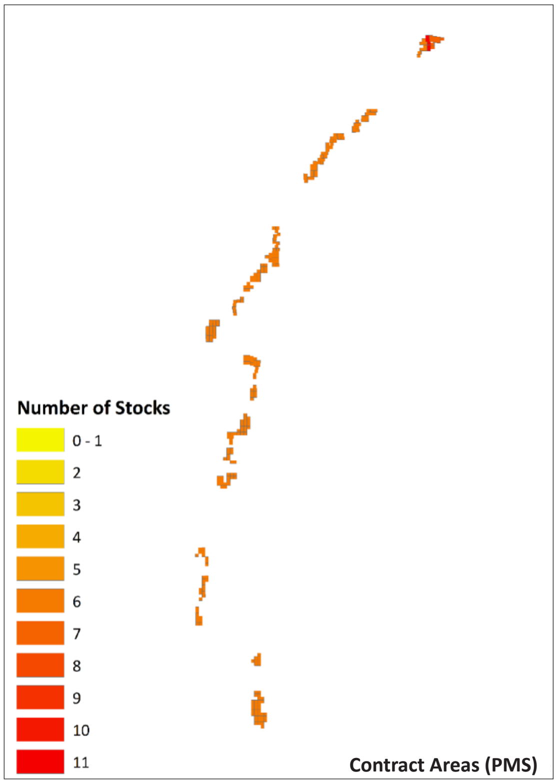
Figure 4. Total fishing vessels for all gears and all years between 2012 and 2020 in the contract areas and reserved areas in (A) South Atlantic Ocean, (B) Indian Ocean, (C) Mid-Atlantic Ridge, (D) the Western Pacific Ocean and (E) the CCZ

Legend: The color code of each cell indicates the number of total active fishing hours in it between 2012 and 2020 (all gears). A different scale for each Zone is used because the absolute number of fishing hours differs so greatly between zones that a common color code for all figures would provide little information on differences in fishing vessels within each zone.

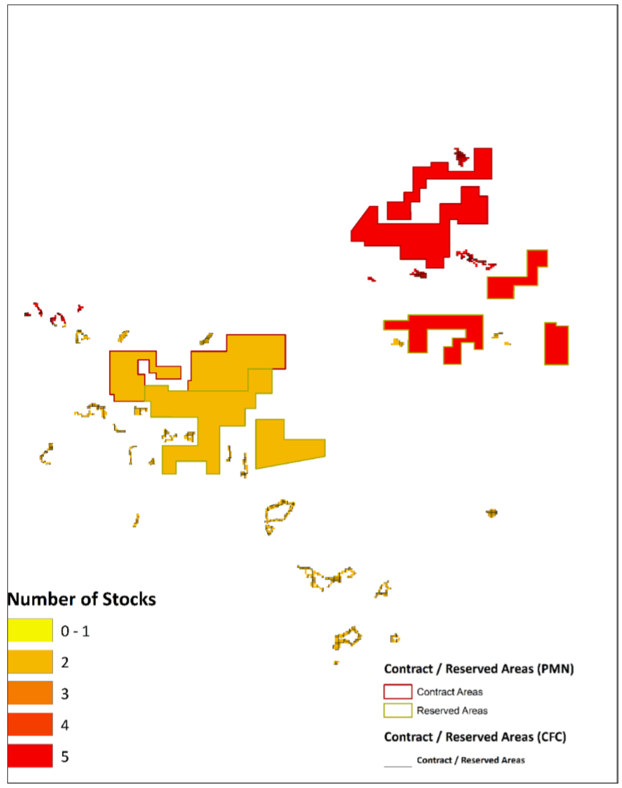


(A) South Atlantic Ocean

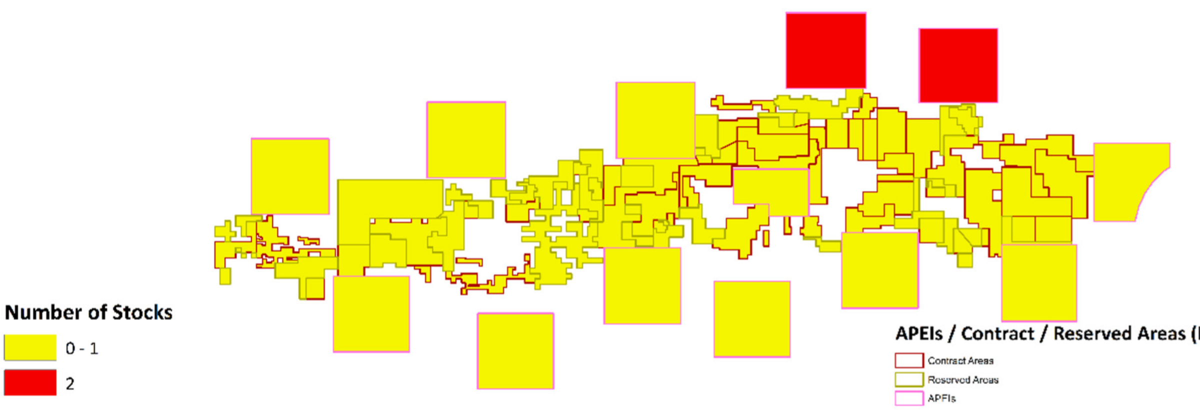
(B) Indian Ocean



(C) Mid-Atlantic Ridge



(D) Western Pacific Ocean



(E) CCZ

Figure 5. Total number of fish stocks in the contract areas and reserved areas in (A) South Atlantic Ocean, (B) Indian Ocean, (C) Mid-Atlantic Ridge, (D) the Western Pacific Ocean and (E) CCZ

Legend: The color of each polygon indicates the number of fish stocks with distributions intersecting with each grid cell. The color code of the scale is different for each map allowing the display of spatial patterns within a particular region.

Table 2. Total fishing activity using trawlers in ABNJ, including the percentage of ABNJ trawlers and their active fishing and present hours in the ISA areas

Zone	Variable	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total	Percentage of total ABNJ fishing vessels and hours between 2012 and 2020
ABNJ	No. of vessels	76	77	101	106	81	75	85	105	57	763	3
	Fishing hours	18,301	18,522	25,228	28,718	27,436	20,253	14,926	15,931	2,702	172,016	0.5
	Present hours	68,997	61,241	74,086	78,219	78,523	64,746	59,973	59,543	21,366	566,694	0.92
Zone	Variable	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total	Percentage of total ABNJ trawling vessels and hours between 2012 and 2020
Contract and reserved areas	No. of vessels	1	1	0	0	0	0	0	1	0	3	0.39
	Fishing hours	13	26	63	0	0	0	0	37	0	143	0.08
	Present hours	32	103	107	174	206	119	61	120	7	929	0.16
APEIs	No. of vessels	0	0	0	0	0	0	0	1	0	1	0.13
	Fishing hours	0	0	0	0	0	0	0	10	0	10	0
	Present hours	0	0	0	61	139	0	27	71	0	297	0.05

3.2 Spatial overlap between fishing activity and ISA contract areas for exploration for mineral resources in ABNJ

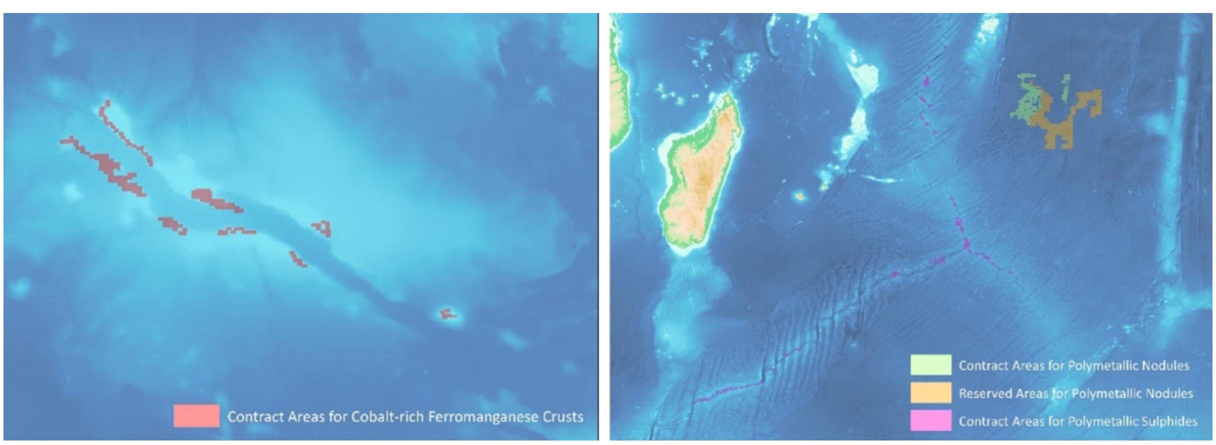
This section presents the information on existing contract areas in five regions: the CCZ, the western Pacific Ocean, the Mid-Atlantic Ridge, the South Atlantic Ocean and the Indian Ocean. The results from the analyses detail the distribution of fishing efforts and fish stocks in the contract areas. The results are disaggregated for each gear type for each year during the period 2012-2020.

3.2.1 Contract areas for exploration for mineral resources in the Area

The mineral resources of primary interest, namely the PMS, PMN and CFC, differ among the contract areas in the five regions in the Area. The South Atlantic Ocean is explored for CFC and the Mid-Atlantic Ridge is explored for PMS. The CCZ is explored for PMN and has more contract areas than other regions. The Indian Ocean is explored for PMN and PMS, and the Western Pacific Ocean is explored for PMN and CFC.

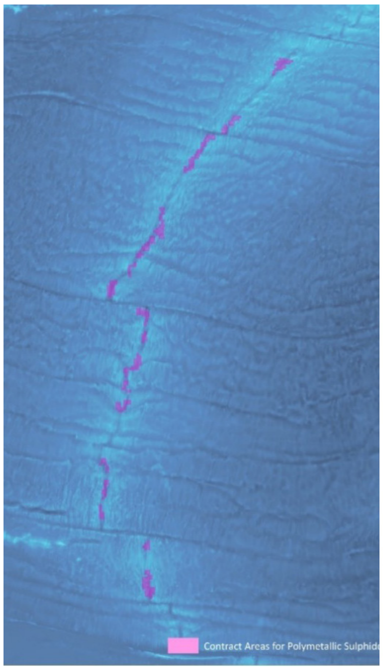
These differences in types of mineral deposits may affect the technologies used in any future commercial mineral exploitation, which may, in turn, result in differences in the spatial footprint of the impacts on fish populations and other ecosystem components. This will have implications for spatial planning and environmental management at a finer scale for a specific area and operation, which needs to be examined in further studies.

Three regions also have reserved areas, the distribution of which is included in the maps below. The results for the reserved areas are discussed in the following section.

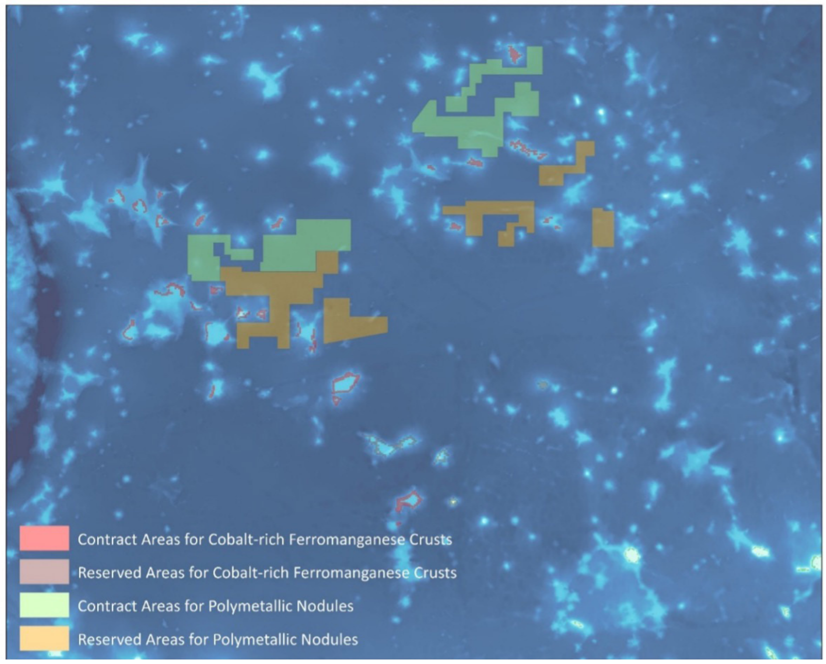


(A) South Atlantic Ocean

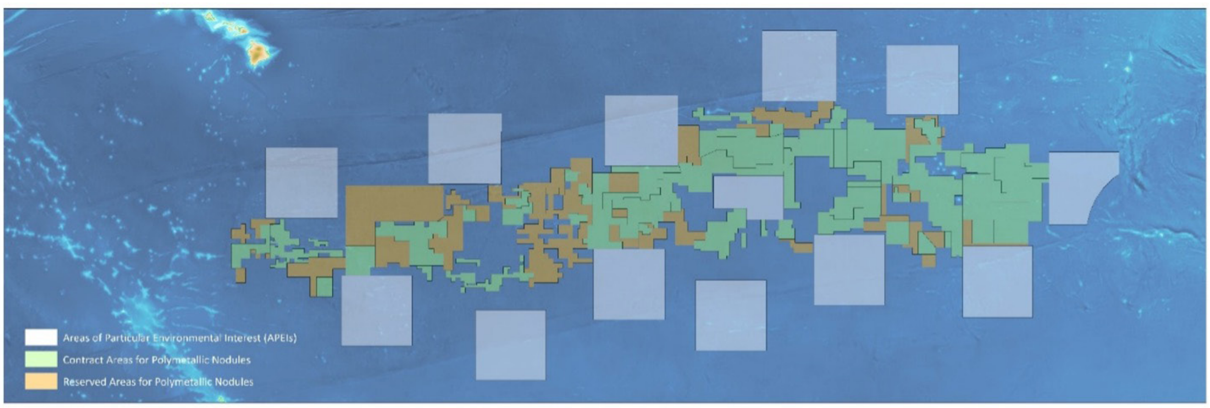
(B) Indian Ocean



(C) Mid-Atlantic Ridge



(D) Western Pacific Ocean



(E) CCZ

Figure 6. Distribution of contract areas and reserved areas for exploration for mineral resources in the Area

3.2.2 Occurrence of fishing activity in contract areas for exploration

This section presents the information on occurrences of fishing activity in the 12,116 grid cells in all contract areas between 2012 and 2020 (Table 1). Fishing vessels were recorded in all the contract areas and in all years. They were recorded both as hours simply observed as present and hours when actively fishing in each contract area for each year (Table 3). There was some degree of increase in most measures of fishing vessel presence and activity, but the pattern is irregular in all areas. As explained in Section 2, some part of this trend is very likely due to the improved ability to detect and record presence and activity of vessels. Consequently, although fishing activity probably did increase in most or all areas between 2012 and 2020, the numbers in these tables below might overestimate those increases.

Among the contract areas, the greatest total fishing effort measured in both hours of vessels recorded as present and actively fishing was in the CCZ contract areas. Not only were there more hours of fishing vessel presence and activity in the CCZ contract areas than in all the other regions combined, but the actual fleets present must also have been quite different than the characteristic of fleets in the other regions. Although more vessels were observed in the Indian Ocean and Western Pacific Ocean contract areas than in the CCZ (598 and 783 vs. 465 vessels), there is a more than four-fold greater number of hours of fishing activity in the CCZ than in the Indian Ocean and Wester Pacific Ocean contract areas. The ratio of total hours observed fishing over the number of vessels observed is not a robust indicator of relative fishing power because there is substantial skew in the raw hours-fishing-per-vessel observations. However, the ratio for the CCZ is between four-fold and twenty-fold larger than for any other regions with contract areas, indicating that vessels spend much longer trips at sea in the CCZ than in other regions.

These differences among contract aeras in the nature as well as the amount of fishing are at least partly explained by the differences in the fishing gears used in the various areas. The only gear used in all contract areas and all years was drifting longlines (Table 4). The drifting longlines comprised nearly 100 per cent of the recorded fishing in the South Atlantic Ocean, the Indian Ocean and Mid-Atlantic Ridge contract areas, but only just over 86 per cent of the recorded fishing in the Pacific Ocean and 82 per cent in the CCZ contract areas. Vessels that were squid jigging were more than minimal (at least ten recorded hours of fishing or four vessels observed) only in the CCZ contract areas, but those vessels still conducted much less than 1 per cent of all observed fishing in the area. Aside from fishing attributable to drifting longlines, purse seiners comprised nearly all the remaining recorded fishing efforts in the CCZ contract areas and were present every year. Otherwise, purse seines were only recorded in the Indian Ocean contract areas, comprising less than 1 per cent of the observed fishing hours and were observed in fewer than half of the years between 2012 and 2020. Aside from trawlers, which will be reviewed separately, a mixture of other fishing gears were recorded in the Indian Ocean and Western Pacific Ocean contract areas and the most recent three years in the CCZ contract areas. Over the period under observation, other fishing gears comprised slightly over 15 per cent of the recorded fishing activity in the Western Pacific Ocean; the activity may have been increasing. Uses of other fishing gears constituted approximately 1 per cent of all recorded fishing in the Indian Ocean and far less than 1 per cent of the effort in the CCZ contract areas.

The longlines (Table 4), jiggers (Table 6), purse seines (Table 7) and other fishing gears (Table 8) are all pelagic gears, rarely operating deeper than 100-200 m below the sea surface. However, in deep waters, only trawlers use fishing gears that may operate near or in contact with the seafloor and have greater potential to interact with deep-sea mineral activities. This study found no trawling vessels in contract areas in three Zones and minimal operations in the other two zones (Table 5). A trawler was recorded as present and operating in one recent year (2019) in the CCZ contract areas. In 2012, 2013 and 2014, a single trawler was observed each year as present and operating in the Indian Ocean contract areas. The trawling never comprised even 0.002 per cent of the fishing in that area in any year.

Table 3. Total fishing activity recorded as measured in the number of vessels, active fishing hours and present fishing hours for all gears in the contract areas between 2012 and 2020

Region	Measure	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
South Atlantic Ocean	No. of vessels	2	1	2	0	1	2	9	6	5	28
	Fishing hours	12	6	28	0	2	2	62	130	73	313
	Present hours	29	20	49	14	14	12	96	168	181	584
Indian Ocean	No. of vessels	8	29	30	36	57	89	93	117	139	598
	Fishing hours	69	1,177	996	1,218	1,726	4,955	2,767	4,023	5,400	22,332
	Present hours	1,077	2,522	2,364	3,168	3,361	7,583	5,026	6,282	8,632	40,016
Mid-Atlantic Ridge	No. of vessels	8	13	8	8	8	13	15	7	22	102
	Fishing hours	61	140	100	106	138	129	216	92	383	1,364
	Present hours	117	159	140	146	172	207	273	125	460	1,798
CCZ	No. of vessels	18	31	41	48	56	83	64	57	67	465
	Fishing hours	977	20,661	16,537	24,866	11,900	17,463	13,951	8,837	13,323	128,514
	Present hours	4,107	36,179	32,422	41,222	23,177	33,447	31,325	23,258	35,630	260,767
Western Pacific Ocean	No. of vessels	6	22	23	71	98	143	142	157	121	783
	Fishing hours	75	684	793	2,052	4,776	7,667	6,210	5,968	3,728	31,953
	Present hours	1,030	2,396	3,431	5,291	7,884	12,318	10,912	9,880	8,142	61,285

Table 4. Drifting longlines activity as measured in the number of vessels, active fishing hours and present fishing hours for all gears in the contract areas between 2012 and 2020

Zone	Measure	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
South Atlantic Ocean	No. of vessels	2	1	2	0	1	2	9	6	5	28
	Fishing hours	12	6	28	0	2	2	62	130	73	313
	Present hours	29	20	49	2	14	12	96	166	180	569
Indian Ocean	No. of vessels	5	27	28	34	55	88	90	117	138	582
	Fishing hours	38	1,100	886	1,068	1,696	4,954	2,757	4,023	5,394	21,916
	Present hours	192	1,526	1,498	1,899	2,447	6,441	3,873	5,390	7,579	30,845
Mid-Atlantic Ridge	No. of vessels	8	13	8	8	8	13	15	7	22	102
	Fishing hours	61	140	100	106	138	129	216	92	383	1,364
	Present hours	117	159	130	125	172	207	270	124	452	1,755
CCZ	No. of vessels	11	23	22	22	28	44	36	26	34	246
	Fishing hours	828	20,572	15,697	22,871	9,659	11,468	10,511	4,644	8,829	105,078
	Present hours	2346	34,017	27,508	31,863	14,097	16,981	18,655	9,383	15,464	170,314
Western Pacific Ocean	No. of vessels	0	16	9	51	78	118	117	134	97	620
	Fishing hours	0	576	446	1,474	4,347	6,724	5,182	5,655	2,987	27,392
	Present hours	250	1,911	1,389	2,939	6,353	9,586	7,891	8,495	5,169	43,985

Table 5. Trawler activity as measured in the number of vessels, active fishing hours and present fishing hours for all gears in the contract areas between 2012 and 2020

Zone	Measure	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
South Atlantic Ocean	No. of vessels	0	0	0	0	0	0	0	0	0	0
	Fishing hours	0	0	0	0	0	0	0	0	0	0
	Present hours	0	0	0	12	0	0	0	0	0	12
Indian Ocean	No. of vessels	1	1	1	0	0	0	0	0	0	3
	Fishing hours	17	26	63	0	0	0	0	0	0	106
	Present hours	23	54	107	1	12	15	13	9	7	241
Mid-Atlantic Ridge	No. of vessels	0	0	0	0	0	0	0	0	0	0
	Fishing hours	0	0	0	0	0	0	0	0	0	0
	Present hours	0	0	0	14	0	0	0	1	0	15
CCZ	No. of vessels	0	0	0	0	0	0	0	1	0	1
	Fishing hours	0	0	0	0	0	0	0	37	0	37
	Present hours	0	0	0	63	168	0	15	97	0	343
Western Pacific Ocean	No. of vessels	0	0	0	0	0	0	0	0	0	0
	Fishing hours	0	0	0	0	0	0	0	0	0	0
	Present hours	9	0	0	26	1	48	0	0	0	85

Table 6. Squid jigger activity as measured in the number of vessels, active fishing hours and present fishing hours for all gears in the contract areas between 2012 and 2020

Zone	Measure	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
South Atlantic Ocean	No. of vessels	0	0	0	0	0	0	0	0	0	0
	Fishing hours	0	0	0	0	0	0	0	0	0	0
	Present hours	0	0	0	0	0	0	0	2	1	3
Indian Ocean	No. of vessels	1	0	0	0	0	0	0	0	0	1
	Fishing hours	10	0	0	0	0	0	0	0	0	10
	Present hours	783	875	608	971	832	990	1,083	839	941	7,923
Mid-Atlantic Ridge	No. of vessels	0	0	0	0	0	0	0	0	0	0
	Fishing hours	0	0	0	0	0	0	0	0	0	0
	Present hours	0	0	0	0	0	0	0	0	0	0
CCZ	No. of vessels	1	0	0	0	0	0	1	1	1	4
	Fishing hours	6	0	0	0	0	0	5	5	3	20
	Present hours	114	404	799	784	1,682	1,713	1,722	2,520	5,125	14,866
Western Pacific Ocean	No. of vessels	0	0	0	0	0	0	0	0	0	0
	Fishing hours	0	0	0	0	0	0	0	0	0	0
	Present hours	2	27	99	161	175	286	160	227	895	2,031

Table 7. Purse seines activity as measured in the number of vessels, active fishing hours and present fishing hours for all gears in the contract areas between 2012 and 2020

Zone	Measure	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
South Atlantic Ocean	No. of vessels	0	0	0	0	0	0	0	0	0	0
	Fishing hours	0	0	0	0	0	0	0	0	0	0
	Present hours	0	0	0	0	0	0	0	0	0	0
Indian Ocean	No. of vessels	1	0	0	0	0	1	1	0	1	4
	Fishing hours	4	0	0	0	0	1	5	0	6	16
	Present hours	75	0	0	0	2	7	13	0	27	124
Mid-Atlantic Ridge	No. of vessels	0	0	0	0	0	0	0	0	0	0
	Fishing hours	0	0	0	0	0	0	0	0	0	0
	Present hours	0	0	10	7	0	0	3	0	7	27
CCZ	No. of vessels	5	7	19	26	28	39	25	29	31	209
	Fishing hours	80	87	841	1,995	2,241	5,996	3,232	4,151	4,063	22,684
	Present hours	1,342	1,598	3,995	8,324	6,966	14,225	9,916	10,614	13,047	70,027
Western Pacific Ocean	No. of vessels	0	0	0	0	0	0	0	0	0	0
	Fishing hours	0	0	0	0	0	0	0	0	0	0
	Present hours	56	21	104	245	30	15	33	60	37	602

Table 8. Fishing activity by other fishing gears as measured in the number of vessels, active fishing hours and present fishing hours for all gears in the contract areas between 2012 and 2020

Zone	Measure	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
South Atlantic Ocean	No. of vessels	0	0	0	0	0	0	0	0	0	0
	Fishing hours	0	0	0	0	0	0	0	0	0	0
	Present hours	0	0	0	0	0	0	0	0	0	0
Indian Ocean	No. of vessels	0	1	1	2	2	0	2	0	0	8
	Fishing hours	0	51	48	150	30	0	5	0	0	284
	Present hours	4	67	151	298	67	130	43	44	79	883
Mid-Atlantic Ridge	No. of vessels	0	0	0	0	0	0	0	0	0	0
	Fishing hours	0	0	0	0	0	0	0	0	0	0
	Present hours	0	0	0	0	0	0	0	0	1	1
CCZ	No. of vessels	1	1	0	0	0	0	2	0	1	5
	Fishing hours	63	2	0	0	0	0	203	0	428	696
	Present hours	305	159	119	187	263	528	1,017	643	1,994	5,217
Western Pacific Ocean	No. of vessels	6	6	14	20	20	25	25	23	24	163
	Fishing hours	75	108	347	578	429	943	1,029	313	741	4,561
	Present hours	714	436	1,838	1,921	1,325	2,384	2,828	1,098	2,040	14,583

3.2.3 Overlap between fish stocks and contract areas for exploration

Whereas Figure 5 plots the total number of fish stocks in the RAM Legacy Stock Assessment Database whose spatial boundaries intersect all types of ISA areas (contract area, reserved area and APEIs), Table 9 shows the number of stocks plotted in the RAM Legacy Stock Assessment Database intersecting ISA contract areas for exploration. It contains information on stocks found at depth ranges that reach a maximum depth greater than 200 m. This threshold was used because deep-sea fisheries are defined as those that occur between 200 and 2,000 m below the ocean's surface (FAO, 2021).

Only 27 of the 229 fish stocks in the RAM Legacy Stock Assessment Database have described distributions that intersect with a current contract area for exploration. The CCZ contract areas stand out because none of the stocks in the RAM Legacy Stock Assessment Database have distributions that intersect with grid cells in the contract areas. However, given the relatively large amount of fishing effort in the CCZ contract areas, particularly with purse seines and drifting longlines, both of which are deployed near the surface, this suggests the records in the RAM Legacy Stock Assessment Database may not capture the distribution of species fished with near-surface gears accurately.

The database may be more useful in characterizing distributions of deep-water species. This is because 26 of these 27 stocks with recorded distributions extending into contract areas also have maximum depth ranges greater than or equal to 200 m (Free et al. 2019). As noted in Section 2.3, the distributions of deep-sea fish species are less well documented than those of more pelagic and coastal species. The result from analyzing the RAM Legacy Stock Assessment Database can be taken as indicative. It likely underestimates the presence of deep-water species everywhere, including in the contract areas, reserved areas and APEIs. The slightly larger number of deep-water species with distribution records intersecting the Mid-Atlantic Ridge contract areas could warrant further consideration. Several possible explanations exist for why more stocks are in the RAM Legacy Stock Assessment Database. Some are ecological, such as the diversity of deep-sea habitats with areas with soft sediments and others of gravel or rocky bottoms, plus ridges and fracture zones (ISA, 2022). Yet, others may be simple consequences of the relatively greater amount of scientific research that has been conducted in that area.[20] Although trawling has not been observed in the Mid-Atlantic Ridge in the Global Fishing Watch records, it may have greater potential for future expansion of trawl fisheries than other contract areas.

Aside from the Pacific halibut, which is a deep-water stock, 26 of 27 stocks with distributions overlapping the contract areas include tuna (most common), marlin, swordfish, sailfish and shortfin mako.[21] All those species are primarily fished with pelagic gears rather than bottom trawls.[22] This suggests that the cut-off of maximum depth for species targeted by deep-sea fisheries should be greater than

[20] For example, A transatlantic assessment and deep-water ecosystem-based spatial management plan for Europe. Available at: https://www.eu-atlas.org. And the one conducted by the iAtlantic, a multidisciplinary research programme seeking to assess the health of deep-sea and open-ocean ecosystems across the full span of the Atlantic Ocean. Available at: https://www.iatlantic.eu.
[21] NOAA Fisheries. Pacific halibut. Available at: https://www.fisheries.noaa.gov/species/pacific-halibut.
[22] FAO. FIRMS on Tuna and Tuna fisheries. Available at: https://www.fao.org/fishery/en/topic/18037/en.

the 200 m used by the FAO, at least in ABNJ, where seabed depths are almost always much greater than 200 m. These species are likely targets of the large amounts of longlining and purse seining where the gears are recorded in the contract areas, but not targets of fishing in ABNJ with gears deployed near the seabed. Although the operations associated with the exploitation of deep-sea mineral resources could potentially affect pelagic stocks (Christiansen et al. 2020; Drazen et al. 2020), the most direct impacts of deep-sea mineral exploitation would likely be on demersal stocks that live on or near the ocean floor. The fact that only one demersal stock in the RAM Legacy Stock Assessment Database overlaps with a contract area for exploration suggests that the negative effects of potential seabed mining on fish stocks may not be as severe as previously anticipated (Jones et al. 2018; Washburn et al. 2019).

Table 9. Number of stocks plotted in the RAM Legacy Stock Assessment Database intersecting ISA contract areas for exploration

Region	Stocks intersecting contract areas	Stocks with maximum depths greater than 200 m intersecting contract areas
South Atlantic Ocean	7	6
Indian Ocean	8	8
Mid-Atlantic Ridge	11	11
CCZ	0	0
Western Pacific Ocean	5	5
Total	27	26

Notes: The number of stocks and deep-sea stocks in the five regions with contract areas does not add up to the values in the Total because some stocks occur in multiple regions.

3.3 Spatial overlap between fishing activity and fishing stocks and ISA reserved areas

This section presents the same information in the distribution of fishing effort in reserved areas and the occurrence of fish stocks in the 7,235 grid squares representing the reserved areas. Figure 6 shows the distribution of the reserved areas. Reserved areas are present in three regions with contract areas: the Indian Ocean, the Western Pacific Ocean and the CCZ. They are present only for PMN and CFC mineral resources. Reserved areas have not been explored for mineral resources and serve as "site banks" for exploration and exploitation by developing States or the Enterprise.

3.3.1 Overlap between fishing activity and reserved areas

The tabulations of fishing efforts in the reserved areas contain the same type of information presented in the earlier section for contract areas; they have been collected and tabulated identically as with the information from the contract areas. Tables 10 to 15 show a substantial increase in vessel numbers and fishing hours from 2012 to 2020. Again, although some of this increase is likely to reflect real increases in fishing, such increases cannot be separated from increases in satellite coverage and improved processing algorithms.

The total fishing effort has been fairly evenly distributed through the grid cells corresponding to reserved areas in the Indian Ocean between 2012 and 2020 (Figure 3). The effort was also fairly evenly distributed in the western and central portions of the Western Pacific Ocean reserved areas but has been somewhat higher in grid cells in the western portion of the Western Pacific Ocean reserved areas. In the CCZ reserved areas, fishing effort was somewhat higher in near-equatorial latitudes than in northern parts of the region; it was particularly high in the eastern portion, around 120°W longitude. In light of these distributional differences in fishing efforts within the Western Pacific Ocean and CCZ, the pattern of change in the recorded fishing effort was examined between 2012 and 2020. Proportionately comparable increases in recorded fishing effort in the period displayed in Figure 1 were noted both in the relatively more heavily fished grid cells of each reserved area and the grid cells less heavily fished in each reserved area. The comparably proportional increases meant that over the observed period, as fishing effort increased, the more preferred grid cells remained preferred, without disproportionately spreading to less preferred areas. This supports the use of the past spatial fishing patterns as generally informative about the distribution of fishing in the future unless regulatory measures require fleets to change their fishing practices or due to other factors, such as climate-driven changes in fish distributions.

In the Western Pacific Ocean, the numbers of vessels and hours of fishing recorded are not greatly different between contract areas and reserved areas. Ratios of the number of vessels observed were approximately 1.15 for contract areas/reserved areas count and 0.77 for hours of recorded fishing. These ratios may not reflect any major differences in fisheries between the contract and reserved areas. However, using the annual variation in each row of Table 10 as informative of year-to-year changes in fishing effort, the ratios of numbers of vessels and hours of fishing between contract areas and reserved areas are comparable to this magnitude of interannual variation in fishing activities, and not major differences in fleet configurations or practices between contract areas and reserved areas in the same zone. This is supported by the fact that drifting longlines make up just over 90 per cent of the fishing effort in the reserved areas, which is fairly comparable to 86 per cent of the fishing effort in the contract areas in the Western Pacific Ocean. Moreover, in the reserved areas and the contract areas of the Western Pacific Ocean, the other major fishing gear is recorded in the category Other Fishing Gears. Other individually differentiated gears comprise less than 1 per cent of fishing in the Western Pacific Ocean reserved areas, particularly bottom trawling, which was never recorded in neither the reserved area nor contract areas in the Western Pacific Ocean.

In the Indian Ocean, the patterns of recorded fishing in the reserved areas differed more markedly from those in the contract areas. A ratio of 2.74 for vessel counts showed more than two-and-a-half times more vessels in the contract areas than in the reserved areas. In contrast, the ratio of total recorded fishing hours of 0.81 suggests more active fishing in the reserved areas than in contract areas of the Indian Ocean. However, the fishing was by a larger fleet, possibly of smaller vessels, given the large difference in vessel counts between contract areas and reserved areas. Nevertheless, in reserved areas and contract areas in the Indian Ocean region, fishing was more than 95 per cent by drifting longlines, with a low and recent presence of other fishing gears and a large increase in records in recent years in both types of areas. Trawling was not observed in the reserved area of the Indian Ocean, comparable to the absence of trawling records in the Indian Ocean contract areas.

Table 10. Fishing activity as measured in the number of vessels, active fishing hours and present fishing hours for all gears in the reserved areas between 2012 and 2020

Zone	Measure	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Indian Ocean	No. of vessels	0	4	4	6	20	35	34	41	73	217
	Fishing hours	0	108	60	150	2,872	3,469	4,353	3,978	12,712	27,703
	Present hours	138	573	353	477	3,455	4,789	5,865	5,239	16,078	36,967
CCZ	No. of vessels	14	30	35	49	52	70	67	59	62	438
	Fishing hours	813	6,331	6,511	9,443	5,596	7,549	7,073	3,155	4,375	50,846
	Present hours	2,996	13,255	13,034	17,894	12,018	15,601	15,713	12,072	16,422	119,004
Western Pacific Ocean	No. of vessels	8	28	26	59	79	123	129	139	90	681
	Fishing hours	49	758	738	2,287	6,904	7,115	7,601	12,190	4,306	41,949
	Present hours	921	2,324	3,368	5,095	10,389	10,430	11,129	16,001	6,903	66,561

Table 11. Longline fishing activity as measured in the number of vessels, active fishing hours and present fishing hours in the reserved areas between 2012 and 2020

Zone	Measure	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Indian Ocean	No. of vessels	0	3	4	5	19	35	33	41	71	211
	Fishing hours	0	90	60	137	2,858	3,469	4,249	3,978	12,341	27,183
	Present hours	13	359	147	201	3,308	4,519	5,423	5,066	15,512	34,547
CCZ	No. of vessels	8	24	22	26	28	40	38	34	31	251
	Fishing hours	739	6,299	6,360	8,634	4,825	6,259	5,160	1,647	3,077	43,000
	Present hours	2,079	11,044	10,840	13,265	8,286	9,728	8,632	4,552	6,236	74,660
Pacific Ocean	No. of vessels	0	20	10	42	60	106	107	116	76	537
	Fishing hours	0	601	256	1,615	5,997	6,673	6,803	12,024	4,023	37,992
	Present hours	271	1,686	870	3,456	7,953	9,212	9,359	15,031	5,954	53,792

Table 12. Trawler activity as measured in the number of vessels, active fishing hours and present fishing hours for all gears in the reserved areas between 2012 and 2020

Zone	Measure	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Indian Ocean	No. of vessels	0	0	0	0	0	0	0	0	0	0
	Fishing hours	0	0	0	0	0	0	0	0	0	0
	Present hours	0	49	0	17	0	36	3	6	0	112
CCZ	No. of vessels	0	0	0	0	0	0	0	0	0	0
	Fishing hours	0	0	0	0	0	0	0	0	0	0
	Present hours	0	0	0	47	25	0	1	7	0	80
Pacific Ocean	No. of vessels	0	0	0	0	0	0	0	0	0	0
	Fishing hours	0	0	0	0	0	0	0	0	0	0
	Present hours	0	0	0	6	0	20	2	0	0	29

Table 13. Squid jigger activity as measured in the number of vessels, active fishing hours and present fishing hours for all gears in the reserved areas between 2012 and 2020

Zone	Measure	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Indian Ocean	No. of vessels	0	0	0	0	0	0	0	0	0	0
	Fishing hours	0	0	0	0	0	0	0	0	0	0
	Present hours	104	136	177	177	100	206	179	158	172	1,409
CCZ	No. of vessels	0	1	0	0	0	0	0	2	1	4
	Fishing hours	0	13	0	0	0	0	0	16	8	36
	Present hours	128	1,064	886	1,574	1,556	2,181	1,657	3,326	5,125	17,497
Pacific Ocean	No. of vessels	0	0	0	0	0	0	0	1	1	2
	Fishing hours	0	0	0	0	0	0	0	6	6	12
	Present hours	0	63	34	10	19	62	42	97	171	498

Table 14. TPurse seines activity as measured in the number of vessels, active fishing hours and present fishing hours for all gears in the reserved areas between 2012 and 2020

Zone	Measure	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Indian Ocean	No. of vessels	0	0	0	1	1	0	0	0	0	2
	Fishing hours	0	0	0	13	14	0	0	0	0	27
	Present hours	21	0	0	63	23	0	4	0	1	112
CCZ	No. of vessels	5	5	13	23	24	30	27	23	28	178
	Fishing hours	29	19	151	809	771	1,290	1,829	1,492	1,235	7,626
	Present hours	629	856	1,128	2,810	1,888	3,111	4,526	3,364	3,607	21,920
Pacific Ocean	No. of vessels	0	0	0	0	0	0	0	0	1	1
	Fishing hours	0	0	0	0	0	0	0	0	8	8
	Present hours	82	29	165	177	22	24	23	62	63	647

Table 15. Fishing activity by other fishing gears as measured in the number of vessels, active fishing hours and present fishing hours for all gears in the reserved areas between 2012 and 2020

Zone	Measure	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Indian Ocean	No. of vessels	0	1	0	0	0	0	1	0	2	4
	Fishing hours	0	17	0	0	0	0	104	0	372	493
	Present hours	0	29	30	19	25	27	256	9	394	788
Clarion Clipperton Zone	No. of vessels	1	0	0	0	0	0	2	0	2	5
	Fishing hours	45	0	0	0	0	0	84	0	56	184
	Present hours	160	292	180	198	264	579	896	823	1,455	4,847
Pacific Ocean	No. of vessels	8	8	16	17	19	17	22	22	12	141
	Fishing hours	49	157	482	672	908	442	798	161	270	3,938
	Present hours	568	546	2,299	1,445	2,396	1,112	1,703	811	715	11,595

In the CCZ, the information from the reserved areas shows another pattern relative to the records from the CCZ contract areas. Ratios of individually identified vessels between contract areas and reserved areas (1.06) were extremely similar. There were 2.5 times as many recorded hours of fishing in the contract areas (2.53). However, the dominance of drifting longlines, with a secondary presence of purse seines, was very similar between contract and reserved areas, with similar but irregular patterns of increase over the observed period, particularly for the purse seines. It is worth repeating that trawling was absent from the reserved area throughout the period, as it was extremely rare in contract areas.

3.3.2 Spatial overlap between fish stocks and reserved areas

Thirteen of 229 fish stocks with distributions recorded in the RAM Legacy Stock Assessment Database intersect a reserved area. In the CCZ reserved areas, none of the stocks in the RAM Legacy Stock Assessment Database are recorded as present. This suggests that the RAM Legacy Stock Assessment Database does not capture the full distribution of many harvested fish stocks, particularly their presence in the shallow depths at which drifting longlines and purse seines are deployed. In the other two regions with reserved areas, the Indian Ocean and the Western Pacific Ocean, fish stocks are fairly homogenous, particularly in the Indian Ocean. All 13 stocks have a maximum depth range greater than or equal to 200 m (Free et al. 2019). However, all but one of these stocks, the Pacific halibut, which intersects reserved area grid cells in the Western Pacific Ocean, are considered pelagic fish, commonly found in the first few hundred metres of the water column rather than on or near the ocean floor.

Table 16. Number of stocks plotted in the RAM Legacy Stock Assessment Database intersecting reserved areas

Region	All stocks	Deep-sea stocks
Indian Ocean	8	8
Western Pacific Ocean	5	5
CCZ	0	0
Total	13	13

Note: The number of stocks and deep-sea stocks in the five regions with contract areas do not add up to the values in the Total because some stocks occur in multiple regions.

3.4 Spatial overlap between fishing activity and fish stocks and APEIs

The network of APEIs has been established in the CCZ to protect representative habitats from future mineral resource exploitation. Although exploitation of seabed mineral resources will not occur in these APEIs, concerns have been expressed that populations of fish and macro-invertebrates in the APEIs may be impacted by activities related to deep-sea mineral resource exploitation in adjacent areas, as well as other activities and changes, such as climate change.

There has been a substantial fishing effort in the APEIs. There have been over 1,500 vessels and over 300,000 hours of active fishing in the APEIs between 2012 and 2020. Fishing was extensive in 2012 (88 vessels and over 24,000 hours of recorded fishing) (Table 17). Regarding spatial patterns, the APEIs in the south appear to attract more fishing than APEIs in the north (Figure 3). The high presence of fishing activities was expected because when the APEIs were selected, one consideration was to minimize spatial interactions of fishing fleets with future mining operations.

As with the contract and reserved areas, drifting longline has been the most intensive fishing method, comprising 71.5 per cent of the number of vessels and 88 per cent of the hours recorded fishing over the period between 2012 and 2020 (Table 18). Purse seines were the only other methods with greater than negligible recorded presence or effort in the APEIs, contributing to 27 per cent of vessels and 11 per cent of hours of recorded fishing. There was an occasional presence of a vessel categorized as Other Fishing Gears in several of the years. However, these compromised far less than 1 per cent of recorded vessels or fishing activity. The very low effort by trawlers was observed. One vessel recorded fishing for 10 hours in 2019. For some years, vessels capable of trawling were recorded as transiting the APEI areas but not moving in ways consistent with the trawl gear deployed. Given that trawlers are the only gear that might contact or come close to the seabed, the data suggest that fishing activities did not undermine the primary intent of APEIs to protect deep-sea biodiversity. The relatively high intensity of fishing by pelagic fishing gears in the APEIs located in the south (Figure 3) may warrant further studies on their potential impacts on the benthic ecosystems.

Two of the 229 fish stocks plotted in the RAM Legacy Stock Assessment Database intersect an APEI, the Pacific halibut and shortfin mako. Both have a maximum depth range greater than 200 m, but only Pacific halibut are fished with potentially bottom-contacting fishing gears.

Table 17. Fishing activity by Other Fishing Gears as measured in the number of vessels, active fishing hours and present fishing hours for all gears in the reserved areas between 2012 and 2020

Measure	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
No. of vessels	88	117	131	147	195	225	197	225	177	1,502
Fishing hours	24,038	29,139	23,608	36,444	45,630	52,452	42,771	30,908	29,688	314,678
Present hours	33,522	48,358	44,128	62,835	72,809	86,111	80,932	66,897	74,281	569,872

Table 18. Fishing activity by gears as measured in the number of vessels, active fishing hours and present fishing hours for all gears in the reserved areas between 2012 and 2020

Zone	Measure	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Drifting longline	No. vessels	71	99	103	101	139	157	141	151	112	1,074
	Fishing hours	23,142	28,691	22,373	31,982	40,590	45,594	36,716	24,587	24,377	278,051
	Present hours	26,735	40,146	34,381	45,369	54,990	62,361	56,714	40,117	41,264	402,078
Trawlers	No. vessels	0	0	0	0	0	0	0	1	0	1
	Fishing hours	0	0	0	0	0	0	0	10	0	10
	Present hours	0	0	0	61	139	0	27	71	0	297
Squid jigger	No. vessels	0	0	0	1	3	0	0	1	4	9
	Fishing hours	0	0	0	11	44	0	0	11	16	81
	Present hours	208	1,985	1,638	2,891	3,691	4,305	4,724	7,176	12,629	39,248
Purse seine	No. vessels	16	17	28	45	53	68	55	70	54	406
	Fishing hours	425	425	1,236	4,450	4,996	6,858	5,459	6,149	5,117	35,115
	Present hours	5,503	5,711	7,943	14,165	13,418	18,091	17,006	17,717	16,896	116,450
Other fishing gears	No. vessels	1	1	0	0	0	0	1	2	7	12
	Fishing hours	471	23	0	0	0	0	596	152	179	1421
	Present hours	1,076	516	166	348	571	1,354	2,460	1,816	3,492	11,798

4. CONCLUSION AND SUGGESTIONS FOR FURTHER STUDIES

The results from the analyses suggest that direct spatial overlap between potential deep-sea mining and fisheries in ABNJ appears to be minimal. Between 2012 and 2020, the number of fishing vessels in ISA contract areas and reserved areas accounted for 5 to 12 per cent of the total in ABNJ. In the same period, the fishing hours in ISA contract areas and reserved areas were under 2 per cent of the total in ABNJ. Almost all fishing effort in ISA contract areas and reserved areas was recorded with pelagic fishing gears. APEIs in the CCZ attracted some fishing. The fishing vessels and hours in APEIs accounted for similar percentages of the total in ABNJ compared with contract and reserved areas, despite the relatively smaller size of the APEIs.

Among the five regions with ISA contract areas, the Indian Ocean has the highest intensity of fishing activity, and the CCZ has a high density of fishing vessels. Longlines contribute to most fishing activity among the different fishing gears, followed by purse seines in most regions with ISA contract areas and reserved areas.

Among the different gears that fish in the ANBJ, bottom trawling is considered to have the potential for the most harmful impacts on deep-sea ecosystems. Yet, trawling accounted only for 3 per cent of the fishing vessels and 0.5 per cent of the total fishing hours recorded for the ABNJ. The occurrence of trawlers is close to zero in all ISA contract areas, reserved areas and APEIs. This result is consistent with the findings of a recent report by FAO that "only a very small fraction of the high seas seabed has ever been, or ever will be, fished by bottom-fishing gears" (FAO, 2020, p. 8). Further, the results indicate that direct spatial conflicts between fishing and mineral resource activities in the ANBJ are extremely limited in extent and can be managed through coordinated planning between the industries.

The results of this technical study have several implications for spatial planning and management of future mineral resource exploitation activities.

First, as fishing in all contract areas and reserved areas is dominated by pelagic gears that operate on the surface and upper 200 m of the water column, it will substantially reduce the impacts of future deep-sea mining on fishing if the mid-water discharge from mining operations can be released as close to the seafloor as possible. This is consistent with the recommendations in ISA's draft REMP for the northern Mid-Atlantic Ridge (ISA, 2022).

Second, the contract areas and reserved areas with relatively high intensities of fishing, such as part of the Indian Ocean PMN contract areas and the contract and reserved areas in the southern and eastern parts of the CCZ, are areas where fishing and mining vessels are likely to come into close range on the surface waters. These are priority areas where more in-depth studies will be needed to guide finer-scale planning and management. More detailed information will be needed on the technology of future deep-sea mining activities and their impacts, as well as the spatial and temporal distribution of fish stocks and their biology, to fully assess the impacts.

Third, the relatively high fishing intensity in APEIs, particularly the APEIs located in the southern part of the CCZ, may warrant further monitoring and investigation. As fishing gears in these areas are several thousand metres above the benthic habitats in the APEIs, which are protected from future mining, it is expected the effectiveness of APEIs would not be compromised. However, this may be a factor that needs to be considered in assessing the cumulative impacts on biodiversity and habitats in the APEIs, with implications for future review of the APEI network design.

There are concerns that the intensity of fishing effort in ABNJ may be increasing, and gears may be changing and becoming more effective (FAO, 2009). Although increasing levels of surveillance and capacity to detect fishing increased over the period under observation, the temporal trends in the data cannot be reliably resolved. Given the data sources, possible constrained inferences suggest fishing in each zone has featured the same gears over the period and that the distribution of fishing activities within each zone has not changed substantially. This supports using the information on preferred fishing methods and spatial distribution from the past decade to inform planning for the coming years.

These inferences about the levels and patterns of fishing effort are consistent with the analyses of fish stocks that intersect ISA areas which have shown that all but two are pelagic stocks, such as tuna. Despite being constrained by various limitations in data, these results could inform further studies on the impacts of mineral resource exploitation on fish stocks and fishing activities at a finer scale and resolution. In turn, this can provide the basis for future management of exploitation activities. However, those studies would require careful efforts to untangle the changes in satellite coverage and analytical algorithms from actual changes in fishing activities or other more standardized methods to qualify the nature and intensity of fishing. Exploring other information sources, such as the Global Ocean Biodiversity Initiative and GEO Biodiversity Observation Network databases, will also be necessary to better assess the spatial distribution of fish stocks other than those assessed by RFMOs.

As stated in the Introduction, this study is an initial step toward quantifying the potential for spatial interactions between the two industries. Direct competition for operating space between deep-sea mineral resource exploration and deep-sea fishing is unlikely to be a major challenge for either industry. There is always scope for further investigations regarding indirect interactions between fishing activities and deep-sea mining operations. The specific nature of these interactions is unclear but could be more likely a simple competition for space to conduct their respective activities. On the fisheries side, such investigations would require greater knowledge of fish stock distribution in the water column and the behavior of target species of fisheries. It would also have to consider any changes in fisheries in response to the BBNJ Convention. From the ISA side, any such studies will have to stay current as the knowledge advances on how deep-sea mineral resource exploitation will be conducted and how sediment plumes and other operating wastes and byproducts may spread in the three dimensions of the water column.

In addition, any impacts of deep-sea mining operations at any depth of the water column on animal populations, ecosystem productivity, or ecological processes could have indirect impacts on fisheries in those zones or even at greater distances if sediment plumes or other physical, chemical or biological consequences of the mining operations spread widely. These indirect interactions are current research priorities for ISA and the scientific community and should be followed closely. Many of these research priorities will need long-term research and monitoring to fully assess the possible impacts of deep-sea mineral exploitation, which is a strategic priority under ISA's Action Plan for Marine Scientific Research in support of the United Nations Decade of Ocean Science for Sustainable Development (ISA, 2021a). This very focused study may provide one model for making timely use of incremental findings to progressively reduce uncertainties and focus further work on the highest priorities.

Finally, this technical study focuses on the potential for interaction between fishing activity and ISA contract areas, reserved areas and APEIs. Expanding this study to cover wider geographical areas, including areas considered for the development of REMPs, could guide the environmental management of future exploitation in a way that minimizes spatial conflicts between the two industries at a wider spatial scale.

TABLES AND FIGURES

TABLES

FIGURES

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