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Fishing in the Twilight Zone: Illuminating governance challenges at the next fisheries frontier

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The Ocean is fundamental to our survival and wellbeing, but our use of the marine environment and its resources is unsustainable. Governments have long committed to ensuring that all fish stocks are sustainably harvested and managed, but overfishing persists. Aquaculture has rapidly developed to meet ever-growing demand and the search for new fishing grounds is intensifying.

The mesopelagic, or "twilight" zone—the waters of the open ocean at a depth of approximately 150-1,000 metres—hosts significant fish stocks. These fish are unpalatable to humans, but proposals are emerging to harvest these stocks and process them into fishmeal and nutritional supplements.

Owing to the daily migration of mesopelagic fishes through the water column, this vast midwater realm is a critical component of the global carbon cycle and wider marine food webs. Fishing in the mesopelagic zone could have profound global ramifications, yet our scientific understanding is extremely limited and the existing governance framework is inadequate to ensure effective management.

The ongoing negotiations for an international agreement on the conservation and sustainable use of marine biodiversity in areas beyond national jurisdiction (ABNJ) provide a timely opportunity to strengthen the governance framework. A new agreement could support the work of existing fisheries management organisations, require thorough environmental assessments for new extractive activities, and provide a process for the designation of marine protected areas.

Decision-makers also have a range of options for taking strong precautionary action needed in the near-term. In particular, States could agree to refrain from exploiting the mesopelagic zone until the science can support effective management measures.

KEY MESSAGES

The mesopelagic or "twilight" zone plays a critical role in the global carbon cycle and marine food webs, but there are considerable gaps in our scientific knowledge.

There is growing interest in exploring commercial fisheries in the mesopelagic zone, yet current governance frameworks may not be equipped to manage a new fishery with unique characteristics.

The UN Convention on the Law of the Sea and Fish Stocks Agreement require States to cooperate to manage fisheries, but States, acting through regional fisheries management organisations (RFMOs), have been slow to integrate biodiversity into management processes.

A future agreement on high seas biodiversity could strengthen environmental assessments and provide for new management tools, such as marine protected areas (MPAs).

In the near-term, a moratorium on mesopelagic fishing in international waters would allow for the development of scientific knowledge and appropriate governance mechanisms.

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ACRONYMS

ABNJ	Marine areas beyond national jurisdiction
AUV	Automated underwater vehicle
BBNJ	Biodiversity beyond national jurisdiction
CAO Agreement	Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean (2018)
CBD	Convention on Biological Diversity (1992)
CMM	Conservation and management measure
COP	Conference of the Parties
EBSA	Ecologically or biologically significant marine area
EIA	Environmental impact assessment
EU	European Union
FAO	UN Food and Agriculture Organization
FOP	Fisheries Operation Plan
IPCC	Intergovernmental Panel on Climate Change
IPOA-IUU	International Action Plan to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing
IUU	Illegal, unreported and illegal fishing
IWC	International Whaling Commission
MPA	Marine protected area
NEAFC	North-East Atlantic Fisheries Commission
NGO	Non-governmental organization
RFMO	Regional fisheries management organisation
SDGs	Sustainable Development Goals
SEA	Strategic environmental assessment
SPRFMO	South Pacific RFMO
UN	United Nations
UNCLOS	UN Convention on the Law of the Sea (1982)
UNFSA	UN Fish Stocks Agreement (1995)
UNGA	UN General Assembly
VME	Vulnerable marine ecosystem
WHOI	Woods Hole Oceanographic Institution

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LIST OF TABLES, FIGURES AND BOXES

1. INTRODUCTION

The Ocean is fundamental to our survival and wellbeing, but our use of the marine environment and its resources is unsustainable (World Ocean Assessment I, 2016; IPCC, 2019). Maritime activities are intensifying and expanding, causing pollution, overexploitation and habitat destruction (Jouffray *et al.,* 2020; Merrie *et al.,* 2014). The impacts of the climate crisis and ocean acidification are placing further pressure on marine ecosystems, reducing their resilience and compounding existing threats (Gattuso *et al.,* 2015; Howes *et al.,* 2015; IPCC, 2019; Levin *et al.,* 2020).

Governments have made a range of commitments concerning the health of the Ocean and the sustainability of fisheries. At the Rio+20 conference in 2012,[1] world leaders agreed on "The Future We Want", committing to

> *protect, and restore, the health, productivity and resilience of oceans and marine ecosystems, to maintain their biodiversity, enabling their conservation and sustainable use for present and future generations, and to effectively apply an ecosystem approach and the precautionary approach (…)*

Targets set under the Convention on Biological Diversity (CBD) and in United Nations (UN) Sustainable Development Goal 14 (SDG14) similarly call for all fish stocks to be sustainably harvested and managed by 2020, applying an ecosystem approach and developing science-based management plans.[2]

While scientific assessment and intensive management have improved the health of fish stocks in some regions (Hilborn *et al.,* 2020), the UN Food and Agriculture Organization (FAO) estimates that a third of fish stocks are now overexploited (FAO, 2020).[3] In the 1980s, as coastal stocks collapsed, fishing activity rapidly industrialised and expanded into deeper and more distant waters, including in areas beyond national jurisdiction (ABNJ) (Bensch *et al.,* 2009; Maguire *et al.,* 2006; Merrie *et al.,* 2014). Today, aquaculture is rapidly developing to meet ever-growing demand and there is once again growing interest in identifying and exploiting new fish stocks in international waters.

The mesopelagic zone, the waters of the open ocean at a depth of approximately 150-1,000 metres, hosts one such potential fishery, but there are considerable gaps in our scientific knowledge of mesopelagic ecosystems and the current international governance framework may not be equipped to manage a new fishery with unique characteristics. History is replete with examples of mismanagement and stock collapse (Pinsky *et al.,* 2011; Yletyinen *et al.,* 2018) and the international community has previously been slow to regulate new fisheries in international waters (Maguire *et al.,* 2006).[4] As mesopelagic species and ecosystems play a critical role in the global carbon cycle and marine food webs, mismanagement could have profound global ramifications.

This report first introduces the mesopelagic zone and the current status of scientific research and fishery development. Section 3 summarises the existing regulatory framework for

1 The United Nations Conference on Sustainable Development (Rio de Janeiro, Brazil, 20-22 June 2012). Rio+20 took place 20 years after the first "Earth Summit", held 3-14 June 1992.

2 Target 6 of the CBD "Aichi Targets" (COP 10, Decision X/2, Strategic Plan for Biodiversity 2011/2020—see https://www.cbd.int/sp/) and SDG 14.4 (UNGA A/RES/70/1, 25 September 2015, "Transforming our world: the 2030 Agenda for Sustainable Development"—see https://www.un.org/sustainabledevelopment/sustainable-development-goals/).

3 I.e. 34% of stocks were fished at "beyond biologically sustainable levels" in 2017, compared with just 10% in 1974. This estimate is likely to be conservative, as FAO figures are based on catch data provided by fishing States, which a number of studies suggest are significantly underreported (Golden *et al.,* 2016; Pauly and Zeller, 2016; Victorero *et al.,* 2018) and do not account for illegal, unreported and unregulated fishing (IUU) (Sumaila *et al.,* 2006).

4 For example, the UN General Assembly (UNGA) first expressed concern regarding the impacts of deep-sea bottom trawling in 2002 (resolution 57/141). A series of subsequent resolutions calling for urgent action spurred significant improvements in the management of deep-sea fisheries in ABNJ, but management measures remain insufficient (Gianni *et al.,* 2016) and there has been "no major changes in the overall state of stocks and fisheries catches since the first review prepared by FAO in in 2005. The majority of the species for which information is available are considered either fully exploited or overexploited." (FAO, 2016)

the management of mesopelagic fisheries in ABNJ.[5] Section 4 assesses some possible approaches to governance, including regulation through regional fisheries management organisations (RFMOs), environmental impact assessment (EIA) and management measures under a future international treaty on biodiversity beyond national jurisdiction (BBNJ Agreement), and a moratorium on mesopelagic fishing.

In concluding, we emphasise the significant risks inherent in developing a new commercial fishery in the poorly understood mesopelagic zone. Of particular concern is the lack of scientific knowledge regarding the role that mesopelagic species and ecosystems play in climate regulation. The potential for disruption of critical life-support systems necessitates strong application of the precautionary principle and early action to ensure effective governance. Though the existing governance framework is insufficient, decision-makers have a range of options at their disposal to ensure the development of scientific knowledge and appropriate management measures prior to the authorization of mesopelagic fisheries.

2. THE TWILIGHT ZONE

Little light reaches the mesopelagic or "twilight" zone (150-1,000 metres) (Costello and Breyer, 2017; Del Giorgio and Duarte, 2002). The mesopelagic zone spans about 60% of the planet's surface and constitutes approximately 20% of the ocean's volume (Proud *et al.,* 2017; Sutton *et al.,* 2017). The bulk of the world's fish live there, by number as well as by biomass,[6] and it is a diverse zone hosting crustaceans, gelatinous zooplankton (jellies) and cephalopods.

Many organisms migrate vertically through the water column during the transition from day to night (up in the evening, down at first light), a phenomenon known as "diel vertical migration" (Hays, 2003; Proud *et al.,* 2018). This massive migration transfers energy from the highly productive surface layer to the dark waters below (Irigoien *et al.,* 2014; Willis and Pearcy, 1982).[7]

Mesopelagic species play an important role in active carbon transport. As they release waste or die, particles descend and aggregate as "marine snow", ultimately settling on the ocean floor and sequestering carbon (Boyd *et al.,* 2019; Jin *et al.,* 2020; Robinson *et al.,* 2010). This "biological pump" plays a key role in global carbon cycles (Davison *et al.,* 2013; Hudson *et al.,* 2014; Jin *et al.,* 2020; Luo *et al.,* 2020).

Lanternfish (*myctophids*), a family of about 250 species of small fish (generally under 15cm), are particularly abundant and widely distributed across the global ocean (Catul *et al.,* 2011; Davison *et al.,* 2015). Given their abundance, their daily migration contributes significantly to the exchange of energy and carbon between ocean layers (Davison *et al.,* 2013; Hudson *et al.,* 2014; Trueman *et al.,* 2014). Lanternfish connect primary consumers to higher trophic level predators and are an important part of the diet of many commercially exploited species, such as tuna (Catul *et al.,* 2011; Choy *et al.,* 2016, 2017, 2013; Drazen and Sutton, 2017; Koslow *et al.,* 2000; Naito *et al.,* 2013). Recent research suggests that they may also be potential sources of anticancer and antimicrobial compounds (Lauritano *et al.,* 2020). See **Figures 1** and **2**.

2.1. Status of scientific knowledge

The mesopelagic zone is "chronically under-explored" (Sutton *et al.,* 2020) and "mesopelagic fishes remain one of the least investigated components of the open-ocean ecosystem" (Irigoien *et al.,* 2014). Observing mesopelagic organisms is technically challenging and costly because many species are shy and fragile, making it difficult to locate them and bring them to the surface for closer analysis. The biogeochemical consequences of diel vertical migration are not yet well known (Irigoien *et al.,* 2014; Robinson *et al.,* 2010), biomass estimates vary widely (Irigoien *et al.,* 2014; Kaartvedt *et al.,* 2012; Proud *et al.,* 2019), and there are considerable gaps in our understanding of the role of the mesopelagic zone in the global carbon cycle (Costello and Breyer, 2017; Jin *et al.,* 2020; Liu *et al.,* 2020; St. John *et al.,* 2016).

A range of initiatives are underway to further explore and characterise the mesopelagic zone (see Annex I), including: highly complex, well-funded scientific expeditions that use expensive equipment and extensive physical and scientific infrastructure; remote sensing projects that can be carried out from labs on land; and observations using relatively small and cheap instruments.

Technology and equipment is being developed to observe, monitor and identify organisms in the mesopelagic zone (See Box 1), shedding new light on the ecosystems and food webs (Choy *et al.,* 2017; Hoagland, 2020). Scientists observe factors such as light, water temperature and composition, microorganisms, and animal behaviour; monitor and quantify vertical particle flux in various locations; use DNA sequences to identify organisms from water column samples; and build models and maps to understand and explain large-scale migrations.

In 2019, the European Union (EU) funded two projects on mesopelagic fisheries with a combined budget of just over €13 million (Annex I):[8]

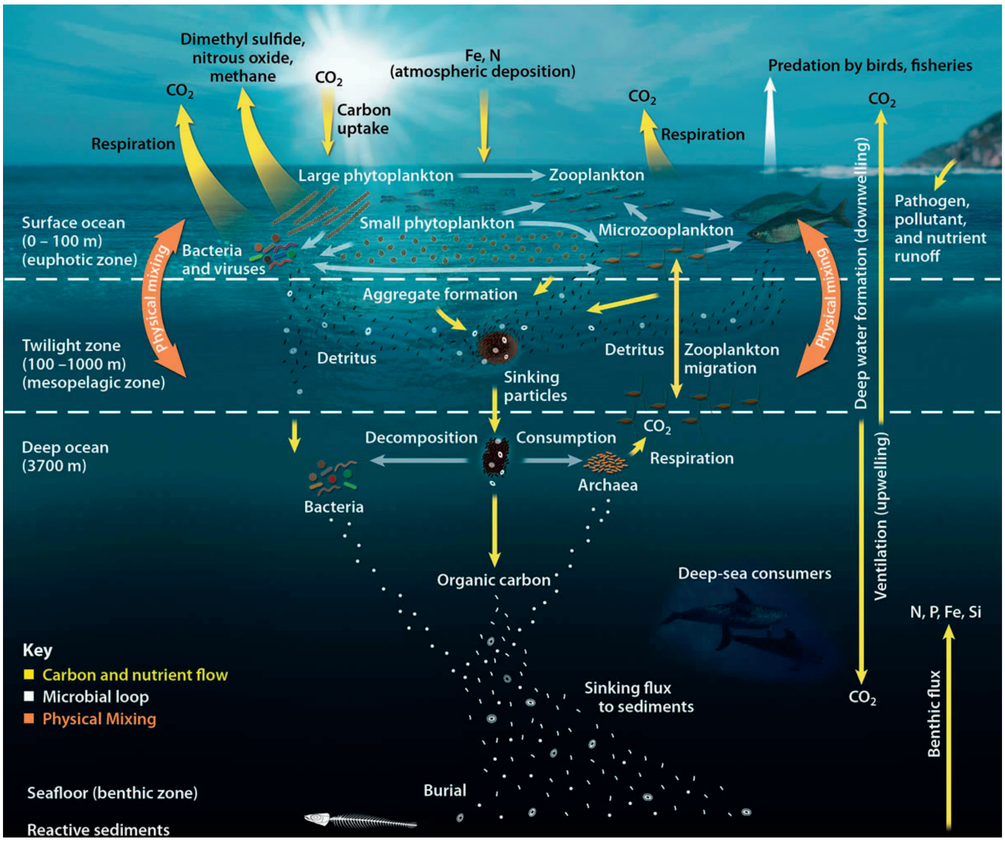
5 The potential for exploitation of mesopelagic fish stocks within national jurisdiction is also being considered, e.g. in Norway (Standal and Grimaldo, 2020), the Bay of Biscay (France and Spain) (Prellezo and Maravelias, 2019) and Pakistan (Patil *et al.,* 2018; WHOI, 2017).

6 One recent estimates suggests a total biomass of 10 billion tonnes (Irigoien *et al.,* 2014), i.e. around 100 times the current global annual catch (FAO, 2020).

7 The mesopelagic zone is also believed to be the main site for organic matter mineralization, which re-supplies the upper layer with inorganic nutrients (Del Giorgio and Duarte, 2002; Vidal *et al.,* 1999).

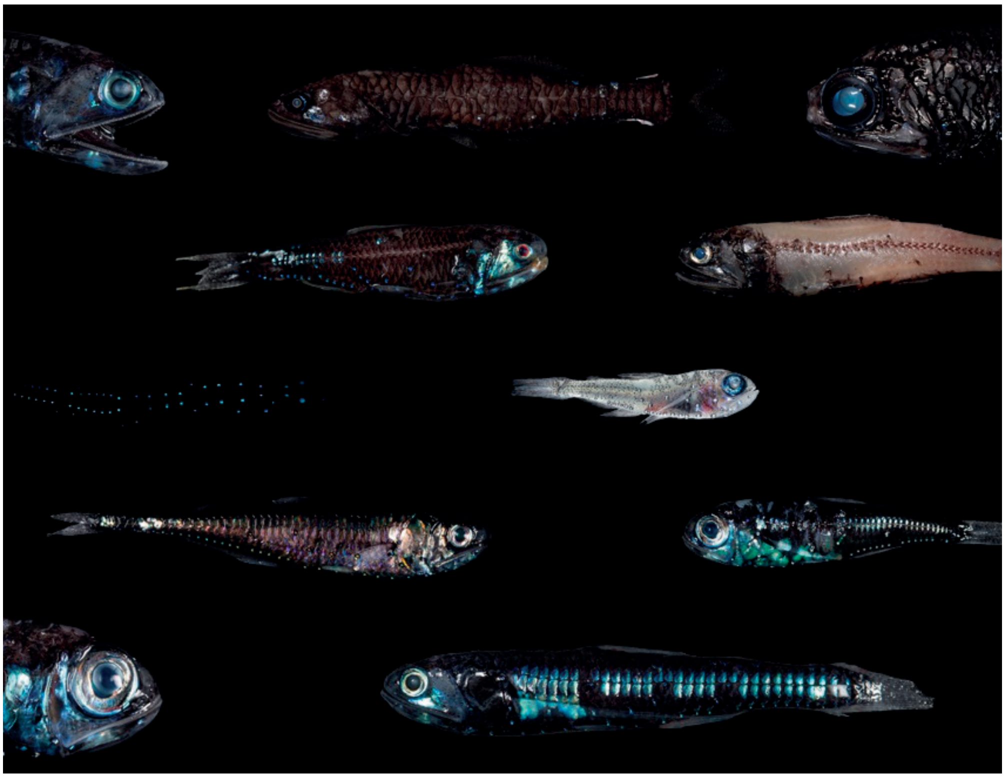
8 Partners include private sector actors with interests in fisheries. Antecedents to such projects include a 2004 meeting of fisheries scientists from Iceland, the Faroe Islands, Norway, and Russia, which discussed the development of a "Nordic project" to explore possible fishery development ("Workshop on mesopelagic fish," 2004) and a 2017 proposal by the Norwegian Institute of Marine Research for a project entitled, "Mesopelagic Initiative: Unleashing new marine resources for a growing human population" (Norwegian Institute of Marine Research, 2017).

FIGURE 1. Marine food web and carbon flows



Source: U.S. Department of Energy. Carbon Cycling and Biosequestration: Report from the March 2008 Workshop, DOE/SC-108, U.S. Department of Energy Office of Science (p. 81), https://public.ornl.gov/site/gallery/detail.cfm?id=326.

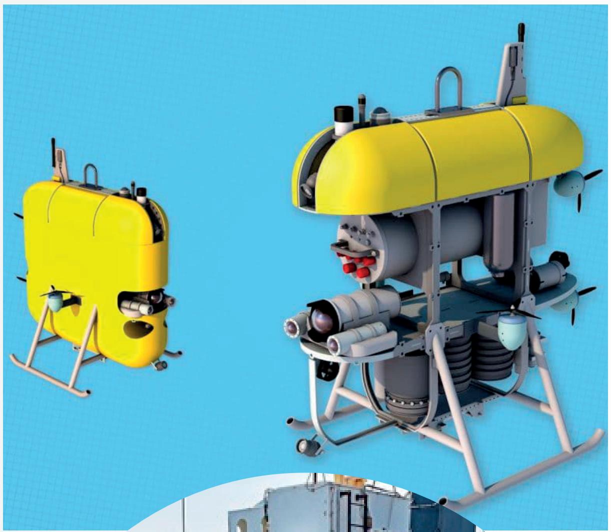
FIGURE 2. Lanternfish



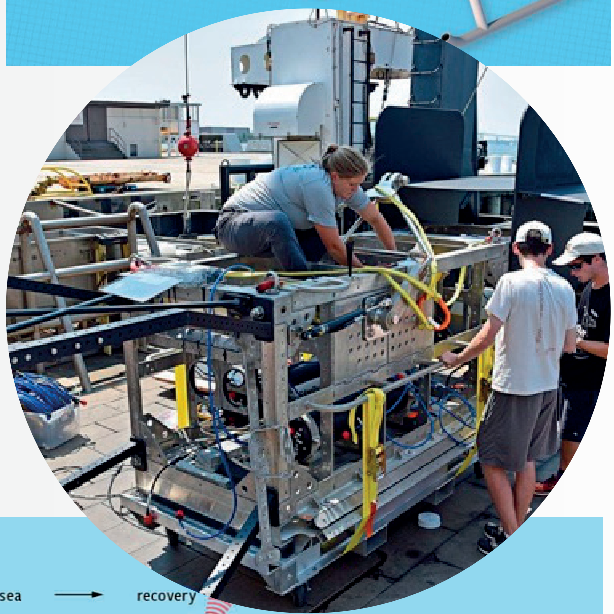
Light-producing photophores are visible on the side and belly, which may be used for camouflage and communication. © Paul Caiger, WHOI

BOX 1. INNOVATIVE OBSERVATION TECHNIQUES UNDER DEVELOPMENT AT WOODS HOLE

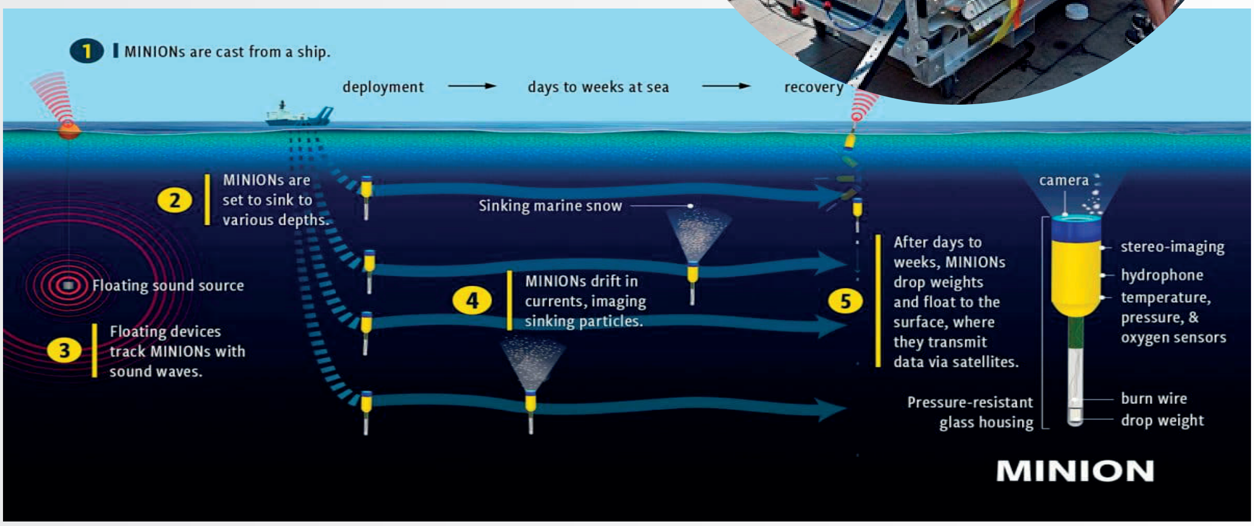
MesoBot [(1)] is an automated underwater vehicle (AUV) that uses cameras and lights to non-invasively follow meso-pelagic animals, track the fate of descending particles, and follow rising bubbles and droplets. This enables scientists to characterise behaviour over extended periods. The Mesobot can follow animals for a full day as they undertake their migrations, follow particles and aggregates as they sink, and track bubbles from seeps as they rise. The robot will also carry a pumped-filter sampler, enabling it to capture geochemical samples, plankton, microbes, or seawater.



Deep-See [(2)] is a sensor-filled platform for observing mesopelagic animals, allowing scientists to estimate their biomass and identify their species. The vehicle is towed behind a research ship and transmits data back to scientists on board in real-time. The Deep-See carries camera systems, sonars, and sensors for measuring oxygen, currents, and other seawater properties, as well as a sampling device to collect water for genetic analysis.



MINION [(3)] is a small, inexpensive instrument equipped with cameras, seawater sensors and an acoustic recorder. Once deployed, MINION sinks to and drifts through the mesopelagic zone, allowing its cameras to record the rate and quantity of particles falling. The MINION also has a clear glass panel on top that accumulates particles that can be studied through a camera.



1. https://www.whoi.edu/what-we-do/explore/underwater-vehicles/auvs/mesobot/
2. https://twilightzone.whoi.edu/deep-see/ Photo by Veronique LaCapra, WHOI
3. https://www.whoi.edu/multimedia/minion-robots-in-the-ocean-twilight-zone/

— **The MEESO project** ("Ecologically and Economically Sustainable Mesopelagic Fisheries") aims to better understand mesopelagic biomass and ecosystem services and to "assess options to sustainably manage and govern exploitation of mesopelagic resources".[9]
— **The SUMMER project** ("Sustainable Management of Mesopelagic Resources") aims to "evaluate whether and how mesopelagic resources can be exploited without compromising the essential ecosystem services they provide", including exploring "the potential of mesopelagic organisms for pharmaceutical and nutraceutical products, processed human food and animal feed, and to evaluate the intangible value of the ecosystem for production of high-value products".[10]

2.2. Status of fishery development

The possibility that the mesopelagic zone could support commercial fisheries has been known since the 1960s (Shotton, 1997), but few concerted attempts have been made to exploit the stocks (Standal and Grimaldo, 2020).[11] Mesopelagic species are unlikely to be harvested for direct human consumption as they are unpalatable (Gewin, 2016) and may contain unsafe levels of harmful environmental pollutants, such as cadmium and arsenic (Olsen *et al.,* 2020; Wiech *et al.,* 2020). They could nonetheless be processed for use in fish meal and, owing to their high omega-3 content, nutritional supplements (Alvheim *et al.,* 2020; Koizumi *et al.,* 2014; Norwegian Institute of Marine Research, 2017; Olsen *et al.,* 2020; St. John *et al.,* 2016).

World annual catch of mesopelagic fish averaged just 10,640 tonnes per year between 1970 and 2015 (Remesan *et al.,* 2019), with efforts concentrated in the following regions:

— **North Atlantic** Russian vessels caught 13,000 tonnes of lanternfish between 2001-2002 and Icelandic vessels caught 73,000 tonnes of silvery lightfish between 2009-2011, but Russia and Iceland have not subsequently pursued the fishery (Thorvik, 2017). In recent years, Norway has seen a "very keen interest among vessel owners" (Thorvik, 2017) and has issued a number of fishing licences.[12]
— **South Atlantic** A Soviet fishery in the Southern Atlantic began in 1977, with catches by former USSR countries reaching 51,680 tonnes in 1992, after which the fishery ceased (Shotton, 1997). About 20,000 tonnes of lanternfish were caught per year in the waters around South Georgia between 1988-1990, increasing to 78,488 tonnes in 1991 (Hulley, 1996). In 2011, two South African companies caught about 8,000 tons that they successfully processed into fishmeal and fish oil. A total of 5,830 tons of lanternfish were subsequently landed off the coast of South Africa in 2018 (Daly, 2019).
— **Indian Ocean** The Arabian Sea, and the Gulf of Oman in particular, is one of the most investigated and potentially productive areas (FAO, 2001; Gjsaeter, 1984; Remesan *et al.,* 2016; Shotton, 1997; Valinassab *et al.,* 2007), with biomass estimated at 5-20 million tonnes (Norwegian Institute of Marine Research, 2017; Remesan *et al.,* 2016).

3. LEGAL FRAMEWORK

3.1. UN Convention on the Law of the Sea (1982)

The United Nations Convention on the Law of the Sea (UNCLOS) is widely considered to be the "Constitution for the Ocean" (Koh, 1982), establishing a

> *legal order for the seas and oceans which will facilitate international communication, and will promote the peaceful uses of the seas and oceans, the equitable and efficient utilisation of their resources, the conservation of their living resources, and the study, protection and preservation of the marine environment.*[13]

UNCLOS sets out a number of maritime zones under State jurisdiction, which are measured from a defined baseline, generally the low-water mark. See **Figure 3.**

The high seas encompass the water column beyond the exclusive economic zones (EEZ) of coastal States[14] and are governed by the longstanding "freedom of the high seas" principle. UNCLOS provides a non-exhaustive list of these freedoms,[15] including the freedom to fish and conduct scientific research. UNCLOS places conditions on the exercise of these freedoms, making them subject to a range of obligations and responsibilities to other States and to the marine environment (Young, 2016). Other agreements also restrict these freedoms through the imposition of obligations and the application of modern legal principles, such as the precautionary principle (Brooks *et al.,* 1995; Freestone, 2008; Freestone *et al.,* 2006).

In relation to the living resources of the high seas, all States have the duty to:[16]

9 https://www.meeso.org/About/Objectives.

10 https://summerh2020.eu/about-summerh2020/.

11 Mesopelagic fishing faces some technical challenges, but recent studies have proposed various possible approaches (Grimaldo and Grimsmo, 2018; Remesan *et al.,* 2019).

12 46 licences were reportedly issued between July 2016-April 2017 (WHOI, 2017), though in 2019 only 3 "preliminary licenses for trial fisheries" were issued (Standal and Grimaldo, 2020).

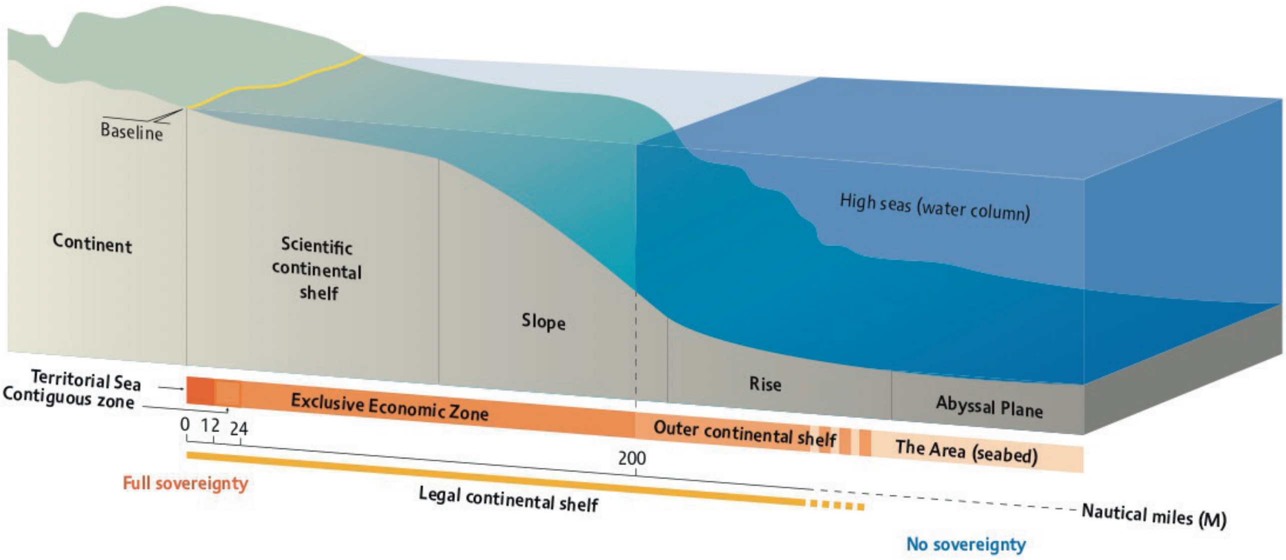
13 United Nations Convention on the Law of the Sea (UNCLOS, 1982), preamble.

14 I.e. "all parts of the sea that are not included in the exclusive economic zone, in the territorial sea or in the internal waters of a State, or in the archipelagic waters of an archipelagic State". UNCLOS, Article 86.

15 Article 87.

16 Articles 117-119.

FIGURE 3. Maritime zones under UNCLOS



Source: Riccardo Pravettoni, GRID-Arendal. http://www.grida.no/graphicslib/detail/marittime-zones_e96c.

— "take, or to cooperate with other States in taking, such measures for their respective nationals as may be necessary for the conservation of the living resources of the high seas";
— "cooperate with each other in the conservation and management of living resources in the areas of the high seas";
— "enter into negotiations with a view to taking the measures necessary for conservation of the living resources concerned" where their nationals exploit living resources in the same area;
— cooperate to establish subregional or regional fisheries organizations; and
— take a range of measures, including considering associated and dependent species and contribute and exchange available scientific information, catch and fishing effort statistics, and other data.

3.2. Convention for Biological Diversity (1992)

Under the Convention on Biological Diversity (CBD), Parties are responsible for ensuring that activities within their jurisdiction or control do not cause damage to the environment of other States or ABNJ.[17] Parties must cooperate, directly or through competent international organizations, to ensure the conservation and sustainable use of marine biodiversity.[18]

Parties to the CBD have adopted voluntary guidelines for the consideration of biodiversity in environmental impact assessments (EIA) and strategic environmental assessments (SEA) in ABNJ.[19] Parties have also developed a scientific process to describe "ecologically or biologically significant marine areas" (EBSAs) (Bax *et al.,* 2015; Dunn *et al.,* 2014; Johnson *et al.,* 2018).[20] Description of an EBSA does not establish any management measures, though a decision of the CBD COP encourages Parties, Governments and competent intergovernmental organizations to cooperate to adopt measures for conservation and sustainable use (including by establishing MPAs).[21] Given the limited available scientific knowledge, few EBSAs have focused on the mesopelagic zone.[22]

17 Article 3. The CBD applies, in relation to each Contracting Party, "in the case of processes and activities, regardless of where their effects occur, carried out under its jurisdiction or control, within the area of its national jurisdiction or beyond the limits of national jurisdiction" (Article 4 (b)). The CBD therefore expressly applies to processes and activities that may affect biodiversity in ABNJ, though not to the components of biodiversity themselves. While the extent of the CBD's mandate in ABNJ has been debated (Gjerde and Rulska-Domino, 2012), Parties have, in practical terms, limited the role of the CBD in relation to ABNJ to the provision of scientific and technical information and advice.

18 Article 5.

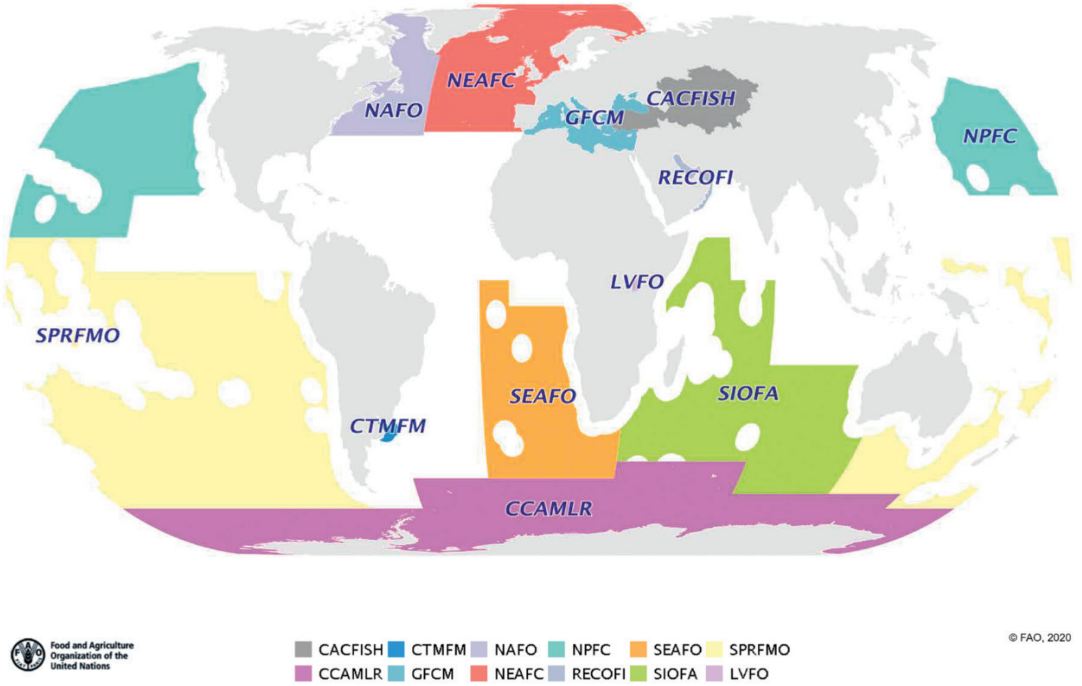
19 CBD Decision XI/18 (2012) Marine and Coastal Biodiversity (UNEP/CBD/COP/DEC/XI/18) https://www.cbd.int/doc/decisions/cop-11/cop-11-dec-18-en.pdf.

20 I.e. "geographically or oceanographically discrete areas that provide important services to one or more species/populations of an ecosystem or to the ecosystem as a whole, compared to other surrounding areas or areas of similar ecological characteristics (…)". CBD Decision XI/17 (2012) Marine and coastal biodiversity: ecologically or biologically significant marine areas (UNEP/CBD/COP/DEC/XI/17) https://www.cbd.int/doc/decisions/cop-11/cop-11-dec-17-en.pdf.

21 CBD Decision X/29 (2010) Marine and coastal biodiversity (UNEP/CBD/COP/10/27) https://www.cbd.int/doc/decisions/cop-10/full/cop-10-dec-en.pdf.

22 The Arabian Sea Oxygen Minimum Zone is one notable EBSA based on the productivity of mesopelagic ecosystems and lanternfish (https://chm.cbd.int/database/record?documentID=237787). The North-East Pacific White Shark Offshore Aggregation Area EBSA was described based partly on its unexpectedly high productivity, which may be due the diel migrations of mesopelagic species (https://chm.cbd.int/database/record?documentID=204043).

FIGURE 4. General RFMOs (i.e. non-tuna)



Source: Løbach *et al.* (2020).

3.3. The UN Fish Stocks Agreement (1995)

The 1995 UN Fish Stocks Agreement (UNFSA)[23] further specifies how States are to give effect to their duties to cooperate under UNCLOS for the conservation and management of "highly migratory fish stocks and straddling fish stocks". The Agreement imposes an obligation on contracting parties to cooperate with and through RFMOs to manage such stocks[24] and to establish RFMOs where they do not exist.[25] It also defines some guiding principles, including the precautionary and ecosystem approaches. See **Figure 4.**

With regards to exploratory fisheries, UNFSA requires that States:[26]

> *adopt as soon as possible cautious conservation and management measures, including, inter alia, catch limits and effort limits. Such measures shall remain in force until there are sufficient data to allow assessment of the impact of the fisheries on the long-term sustainability of the stocks, whereupon conservation and management measures based on that assessment shall be implemented. The latter measures shall, if appropriate, allow for the gradual development of the fisheries.*

UN General Assembly (UNGA) resolution 60/31 (2005)[27] encouraged States to recognize that the general principles of the UNFSA should apply to discrete fish stocks in the high seas as well as straddling and highly migratory stocks.[28] Since the 2006 UNFSA Review Conference,[29] States have applied UNFSA to discrete high seas stocks and RFMOs have been established to manage deep-sea fisheries. The obligations contained in UNCLOS and UNFSA therefore appear to require States to cooperate to manage mesopelagic fish stocks, either through an RFMO or by entering into other appropriate arrangements consistent with the principles of UNFSA.[30]

23 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. The UNFSA was the second Implementing Agreement to UNCLOS following the 1994 Agreement related to the implementation of Part XI of UNCLOS (regarding seabed minerals). The Agreement entered into force in 2001.

24 Article 8(3).

25 Article 8(5).

26 Article 6.

27 UNGA resolution 60/31 (10 March 2006). A/Res/60/31. At https://documents-dds-ny.un.org/doc/UNDOC/GEN/N05/489/40/PDF/N0548940.pdf?OpenElement (paragraph 12; see also paragraph 65).

28 UNFSA applies to highly migratory and straddling fish stocks. Though not formally defined in any instrument, the term "discrete high seas fish stock" is commonly used to denote stocks that occur wholly outside EEZs (Maguire *et al.*, 2006; Takei, 2013).

29 https://www.un.org/depts/los/reference_files/Compilation_recommendations_adopted_at_Review_Conf_2006_and_resumed_Review_Conf_2010.pdf, paragraph 18(c), (e), 19.

30 UNFSA, Article 8

Although RFMOs currently only monitor and manage a small fraction of high seas fish species (Crespo *et al.,* 2019), their conventions provide broad legal mandates covering mesopelagic fish stocks.[31] A State planning to fish in the mesopelagic zone would therefore be required to inform the relevant RFMO of its plans and comply with any applicable provisions (e.g. protocols concerning the approval of an exploratory fishery).

3.4. UN General Assembly resolution 61/105 (2006)

In 2006, UNGA resolution 61/105[32] called upon all States to apply the precautionary and ecosystem approaches to the conservation, management and exploitation of fish stocks, including discrete high seas fish stocks, to the prevention of significant adverse impacts on vulnerable marine ecosystems (VMEs), and to the protection of marine biodiversity. States "individually and, as appropriate, through regional and subregional fisheries management organizations and arrangements with competence over discrete high seas fish stocks, are to adopt the necessary measures to ensure the long-term conservation, management and sustainable use of such stocks".[33] The resolution also calls upon States and RFMOs to collect catch and effort data, and fishery-related information and, where appropriate, report this to the FAO.[34]

3.5. Guidance in non-binding instruments

The FAO Code of Conduct for Responsible Fishing (1995) sets out general principles applicable to all fisheries and echoes UNFSA in calling for the adoption of cautious conservation and management measures for new fisheries. The FAO International Action Plan to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (IPOA-IUU, 2001) defines "unregulated" fishing as fishing "in areas or for fish stocks in relation to which there are no applicable conservation or management measures and where such fishing activities are conducted in a manner inconsistent with State responsibilities for the conservation of living marine resources under international law". This definition suggests that any fishery commenced without a prior assessment of sustainability and biodiversity impacts would be strongly discouraged by the international community.

31 For example, the objective of the North-East Atlantic Fisheries Commission (NEAFC) is to "ensure the long-term conservation and optimum utilisation of the fishery resources", which is defined as "resources of fish, molluscs, crustaceans and including sedentary species" (excluding, "in so far as they are dealt with by other international agreements, highly migratory species listed in [UNCLOS], and anadromous stocks"). Convention on Future Multilateral Cooperation in North-East Atlantic Fisheries, https://www.neafc.org/system/files/Text-of-NEAFC-Convention-04.pdf. Other RFMO conventions contain similar provisions.

32 UNGA resolution 61/105. A/RES/61/105. 6 March 2007. https://undocs.org/en/A/RES/61/105&Lang=E.

33 Ibid, para. 5.

34 UNGA resolution 61/105, para. 6.

BOX 2. SUMMARY OF LEGAL OBLIGATIONS APPLICABLE TO DEVELOPMENT OF A NEW MESOPELAGIC FISHERY

— Protect the marine environment and ensure that activities do not cause damage to the environment of other States or ABNJ.
— Adopt measures to ensure long-term conservation, management and sustainable use.
— Apply the precautionary and ecosystem approaches.
— Cooperate to manage mesopelagic fish stocks, either through an RFMO or by entering into other appropriate arrangements consistent with the principles of UNFSA.
— Where the stock is covered by an RFMO, comply with relevant RFMO regulations (e.g. on exploratory fisheries).

4. GOVERNANCE CHALLENGES

4.1. Limited scientific knowledge

A scientifically valid stock assessment is the foundation of fisheries management (Hilborn *et al.,* 2020; Melnychuk *et al.,* 2017), but the best available science does not currently allow for such an assessment to be made for mesopelagic fish. Effective governance will therefore not be possible without further development of our scientific understanding of the mesopelagic zone. As noted by the FAO Fishery Managers Guidebook (Cochrane, 2002), "uncertainty pervades fisheries management and hinders informed decision-making. The greater the uncertainty, the more conservative should be the approach".[35]

4.2. Weak obligations on environmental assessment for exploratory fisheries

The UNFSA provisions on exploratory fisheries only require assessment and management of the target stock, rather than a more comprehensive environmental assessment of the potential impacts of a proposed fishery on marine biodiversity as a whole. Such an assessment would therefore not consider potential impacts on non-target species, the food web, associated habitats, and the wider ecosystem. Similarly, RFMO processes for approving exploratory fishing, where there are

35 I.e. "as uncertainty increases, realised yield as a proportion of estimated maximum average yield should be decreased".

such processes in place, generally focus on bottom fishing and would likely not result in the conduct of a comprehensive environmental assessment.[36]

4.3. Inadequate institutional framework

As UNFSA imposes an obligation on contracting parties to cooperate with and through RFMOs, these bodies have become the preferred vehicle for international cooperation on the management of high seas fisheries, but there are significant constraints on their capacity to effectively regulate a new mesopelagic fishery. A lack of stakeholder consultation and limited integration of biodiversity considerations into management are of particular concern, as these are critical components of an ecosystem approach (Fischer, 2020; Garcia *et al.,* 2003). In addition, decision-making modalities limit the adoption of effective conservation measures (McDorman, 2005; Pentz and Klenk, 2017), cooperation between RFMOs is limited (Bell *et al.,* 2019; Haas *et al.,* 2020b), and they are not currently well-equipped to effectively respond to the emerging management challenges posed by climate change (Pentz *et al.,* 2018; Pentz and Klenk, 2017; Pinsky, 2018).

As flag States are ultimately responsible for the development of management measures and compliance with these measures, the performance of RFMOs is highly dependent on national interests and external factors (Fischer, 2020; Pons *et al.,* 2018a).[37] Participation and influence of developing coastal States is often limited (Fischer, 2020)[38] and members frequently act counter to the advice of RFMO scientific bodies (Galland *et al.,* 2018; Gianni *et al.,* 2016; Wright *et al.,* 2015). Even RFMOs that exemplify best practices "still exhibit compliance shortfalls" because they “cannot be expected to completely prevent or eliminate infractions by its members” (Koehler, 2018).

4.3.1. Limited participation, consultation and transparency

Only States having a “real interest” in a fishery—usually interpreted as requiring involvement in extractive fishing activities —may become a member of an RFMO (Molenaar, 2000; Serdy, 2017).[39] As RFMOs do not consult with external stakeholders as part of management processes (Fischer, 2020), there is limited opportunity for the interests of non-fishing States and other stakeholders, or the information and expertise of external scientists, to be effectively represented and considered (Fischer, 2020; Guggisberg, 2019; Petersson *et al.,* 2019). Although RFMOs generally provide a high level of external transparency (Clark *et al.,* 2015; Fischer, 2020), internal decision-making procedures are often opaque (Fischer, 2020), and it is “difficult to grasp these organizations’ activity as a whole [as] the technical nature and sheer variety of measures adopted by RFMOs often hinder understanding of a subject that is already complex in and of itself” (Oanta, 2018).

4.3.2. Limited integration of biodiversity concerns into fisheries management

The priority of RFMO Members has generally been "first and foremost to guide the exploitation of fish stocks" and while "conservation is part of nearly all their mandates, they have yet to demonstrate a genuine commitment to it on the water" (Cullis-Suzuki and Pauly, 2010). Progress has been made in recent years (Friedman *et al.,* 2018; Haas *et al.,* 2020b; Scanlon, 2018) and RFMOs are “slowly improving over time and learning from each other” (Scanlon, 2018), but major shortcomings remain. RFMO Members are not taking the management actions necessary to manage non-target species (Gilman *et al.,* 2014), protect vulnerable marine ecosystems (see Section 5.3), and apply an ecosystem approach (Juan-Jordá *et al.,* 2018). As such, RFMOs have had only limited success in ensuring the conservation and sustainable use of marine biodiversity (Bell *et al.,* 2019; Crespo *et al.,* 2019; Haas *et al.,* 2020b; Juan-Jordá *et al.,* 2018; Pons *et al.,* 2018b).

5. OPTIONS FOR STRENGTHENING GOVERNANCE

5.1. Proactive engagement by RFMO members

Members of RFMOs could take proactive steps to strengthen the governance framework for mesopelagic fisheries by, for example:

- Developing more comprehensive provisions and procedures for the assessment and approval of exploratory fisheries. Such provisions could better account for the specificities of the mesopelagic zone by requiring consideration of the potential impacts of fishing on the broader ecosystem, including on the carbon cycle and food web.
- Providing for meaningful stakeholder consultation and observer participation. This would allow for the integration of a wide range of “important expertise, data, and views

36 Some RFMOs have developed more detailed and generally applicable approval procedures for exploratory fisheries. For example, the South Pacific RFMO (SPRFMO) would require the submission of a Fisheries Operation Plan (FOP) for a proposed mesopelagic fishery, wherein the proponent provides a range of information, to the extent it is available. The FOP is then considered by the SPRFMO Scientific Committee and the Compliance and Technical Committee, and approved by the SPRFMO Commission. No public consultation is required, but the documents are made available online. See CMM 13-2020, https://www.sprfmo.int/assets/Fisheries/Conservation-and-Management-Measures/2020-CMMs/CMM-13-2020-Exploratory-Fisheries-31Mar20.pdf.

37 I.e. RFMOs tend to engage less in research, management and enforcement where there is a greater number of member countries, greater economic dependency on the resources, lower mean per capita gross domestic product, a greater number of fishing vessels, and smaller vessels.

38 Despite the potentially significant impacts of high seas fishing on ecosystems and species within their national waters (Popova *et al.,* 2019).

39 UNFSA Article 8. Pinsky (2018) notes that participatory rights are “ zealously guarded by current constituents”.

that are of interest for scientific assessments and can benefit the adoption of practicable and efficient measures" (Fischer, 2020).

— Recognising that the current interpretation of the "real interest" requirement precludes ecosystem-based management as it focuses narrowly on economic activities and excludes States with non-extractive interests in a fishery. RFMO mandates and procedures could be updated to allow for broader participation.
— Committing to enhanced transparency, which could "ensure the equal participation of all institutional actors in the activities and outcomes of an RFMO" (Fischer, 2020). This would help ensure that the interests of the international community in maintaining the ecosystem services provided by the mesopelagic zone receive consideration alongside fishing interests.
— Requiring Members to report any planned research cruises investigating the mesopelagic zone. This would ensure that the secretariat and members are aware of ongoing activities.[40]
— Actively participating in RFMO scientific bodies, seeking to place mesopelagic fisheries on the agenda and foster awareness of possible future developments.

5.2. International guidelines

A set of international guidelines could be developed for mesopelagic fisheries. The FAO has previously played an active role in guiding the development of fisheries through various instruments and guidelines, such as the Code of Conduct for Responsible Fisheries (1995) and the International Guidelines for the Management of Deep-Sea Fisheries in the High Seas (2009).

The current lack of scientific knowledge upon which to base such guidelines again presents a major challenge, so it may be more opportune to consider this option once the science is further advanced. Alternatively, such guidelines could tentatively describe approaches for exploratory fisheries and recommend that commercial-scale exploitation not be approved pending further scientific developments.

5.3. A United Nations General Assembly resolution

Discussions related to the law of the sea, and to UNCLOS and ABNJ in particular, have historically been held under the auspices of the UNGA (Wright *et al.,* 2018). States have frequently discussed emerging ocean issues at the UNGA and have cooperated to pass resolutions that advance the conservation and sustainable use of marine resources.

States could therefore seek to call attention to mesopelagic fisheries through a UNGA resolution, calling for action, individually and through RFMOs, to:

— Apply a high level of precaution to the development of fisheries known to play a critical role in global climate processes and food webs;
— Cooperate to conduct a strategic environmental assessment of potential fisheries (see Section 5.4);
— Ensure that a thorough environmental impact assessment is conducted prior to commencement of any new fishing activity;
— Ensure that new fishing activities are not authorized unless they can be managed in a way that avoids significant adverse impacts on mesopelagic ecosystems, associated and dependent species, and ecosystem services; and
— Close certain areas to mesopelagic fishing to protect the full range of biodiversity and ecosystem services.

Experience with the implementation of the high seas bottom fisheries resolutions suggests that a UNGA resolution could raise awareness and build momentum for action, but would be far from sufficient to ensure effective protection of mesopelagic ecosystems and sustainable use of fish stocks. Following the passage of UNGA resolution 61/105 in 2006, there was broad support in the international community to ensure that all high seas bottom fisheries were covered by an RFMO. A number of new RFMOs were established, but there remained "reluctance on the part of many States and RFMOs to close high seas areas to protect VMEs" (Gianni *et al.,* 2011) and implementation has been slow and uneven (Gianni *et al.,* 2016; Rogers and Gianni, 2010; Weaver *et al.,* 2011; Wright *et al.,* 2015).[41]

5.4. A high seas treaty

States are currently negotiating an international legally binding instrument under UNCLOS on the conservation and sustainable use of marine biodiversity in ABNJ (BBNJ Agreement),[42] which provides a unique opportunity to strengthen existing environmental obligations and impetus for closer cooperation (Gjerde and Wright, 2019; Wright *et al.,* 2019). The instrument could strengthen the governance framework for mesopelagic fisheries by supporting RFMOs, guiding appropriate environmental assessments, and providing for the designation of protected areas.

40 For example, trial fishing has been conducted within the NEAFC management area (Grimaldo *et al.,* 2018), though this has not been discussed at the Commission.

41 In addition to requiring protection and assessment, "move-on" rules were implemented in an attempt to allow fishing in a precautionary manner. Such rules required vessels to cease fishing in an area when bycatch of certain "indicator species" exceeded an agreed threshold, but flawed design and implementation (Auster *et al.,* 2011) meant that few vessels ever reported having ceased fishing operations in compliance with such rules (Gianni *et al.,* 2016; Wright *et al.,* 2015).

42 UNGA resolution 72/249. International legally binding instrument under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction. https://undocs.org/en/a/res/72/249.

5.4.1. Supporting RFMOs

The BBNJ Agreement presents an opportunity to support and complement RFMOs, e.g. by providing:

— An overarching set of governance and conservation principles that can guide decision making, encourage RFMOs to integrate biodiversity considerations into their deliberations and management measures, and harmonise understanding and implementation of an ecosystem approach across organisations.[43]

— A Scientific and Technical advisory body, assisted by a clearing house mechanism, that could help collate the best available science concerning the mesopelagic zone.

— Greater coherence and exchange between management bodies and measures.[44]

— A forum or process through which RFMOs can engage external stakeholders, involve the wider scientific community, and report on progress, thereby increasing transparency.

In turn, RFMOs could play an important role in implementation of the BBNJ Agreement, for example by contributing their significant regional and sectoral expertise to global governance processes.

5.4.2. Strengthening environmental assessments

Although UNCLOS requires States to carry out an environmental assessment when they have "reasonable grounds for believing that planned activities under their jurisdiction or control may cause substantial pollution of or significant and harmful changes to the marine environment",[45] it does not provide any guidance, minimum standards, or reporting mechanism. As a result, these provisions have seen limited implementation (Ma *et al.,* 2016; Warner, 2009).

The BBNJ Agreement is expected to strengthen these provisions, though it is not yet clear to what extent it will reflect accepted good practice in environmental assessment. Ideally the process should be, *inter alia* (Doelle and Sander, 2020): jointly designed and implemented; appropriate for the scale and complexity of the proposal; transparent and accountable; and accompanied by meaningful public participation.

No coherent approach to environmental assessment emerges from the current draft text (much of which remains in brackets, denoting a lack of consensus), though two broad alternatives can be discerned:

— 1. An "internationalized" process, developing global minimum standards and providing for global consultation and review;

— 2. A minimal State-based process that would exempt proposed activities from EIA requirements if a relevant body already has rules and guidelines in place[46] or "a competent body with a mandate for EIAs already exists."[47]

The first approach provides clarity by harmonizing standards across organisations and sectors. Under this vision, the proponent of a mesopelagic fishery would be required to apply the EIA standards and procedures in the BBNJ Agreement, in addition to meeting any applicable obligations under RFMO regulations.

The second approach appears to reduce clarity by raising further questions as to the applicable EIA requirements in different situations. Under some of the proposed textual suggestions, a mesopelagic fishery would be exempt from complying with EIA standards and procedures in the BBNJ Agreement,[48] even if no EIA would actually be required by the relevant body or if the assessment is lacking.[49] This would leave approval of a new fishery in the hands of a small number of RFMO member States, based upon a rudimentary assessment that does not account for the full range of potential impacts (such as the role of the species in the wider ecosystem and the global carbon cycle).

5.4.3. Providing for strategic environmental assessment

While the focus of negotiations has been on the thresholds and procedures for EIAs, interest in the potential role of broader SEAs is growing. Given the global significance of mesopelagic ecosystems, a proposal to start a new fishery would be a clear candidate for an international SEA process. An SEA would require a study of the mesopelagic ecosystem to better understand the interconnectedness of the food webs, the distribution of fish stocks, and the ecosystem services that these stocks provide.

43 In particular, "significant differences exist between the objectives of some of the older RFBs, which are exclusively aimed at the sustainable utilisation and conservation of target species, and the newer RFBs, which pursue an ecosystem approach to fisheries" (Billé *et al.,* 2016; Rochette *et al.,* 2015).

44 For example, exploitation of a mesopelagic fish stock may have implications for tuna management—such linkages could be identified and communicated through the Conference of Parties or subsidiary bodies.

45 UNCLOS, Article 206. States must also publish reports of the results obtained from such processes or "provide such reports at appropriate intervals to the competent international organizations, which should make them available to all States" (Article 205).

46 Article 23.4. Alt. 2.

47 Article 23.4. Alt. 3.

48 Article 23.4. Alt 2 & Alt 3.

49 Including Article 23.4. Alt 4.

TABLE 1. Comparison of EIA and SEA

	EIA	SEA
Scale	Project	Policy, program, plan, region
Focus	Determining whether a proposed project or activity is allowed to proceed, and under what conditions	Understanding the potential impacts of longer-term policies, plans and programmes
Process	Linear process with clearly defined stages, from proposal to decision and review	Multi-stage, iterative process with feedback loops
Scope	Emphasis on mitigating environmental impacts of a specific project Considers limited range of project alternatives Limited review of cumulative impacts	Emphasis on meeting balanced environmental, social and economic objectives and steering development and implementation of policies, programmes and plans Considers a broad range of alternative scenarios Incorporates consideration of cumulative impacts
Responsibility	Usually prepared and/or funded by the project proponents	Conducted independently of any specific project proponent, generally by a mandated body

Marine protected areas

Ecologically connected networks of MPAs are crucial for sustaining high seas ecosystems and increasing resilience to climate change (Ceccarelli and Fernandes, 2017; Green *et al.*, 2014; Grüss *et al.*, 2014; O'Leary *et al.*, 2018; Roberts *et al.*, 2017; Scales *et al.*, 2014; Sumaila *et al.*, 2007). The Aichi Biodiversity Targets and SDG14 require protection of 10% of the Ocean,[50] but there is currently no global mechanism for the establishment of MPAs in ABNJ. The BBNJ Agreement is intended to provide such a mechanism, though States are yet to reach consensus on many key provisions concerning how an MPA would be proposed and implemented.

Mesopelagic ecosystems could ultimately be the subject of a proposal for an MPA under a new agreement, owing to:

— The interconnectedness of the mesopelagic zone, which necessitates integrated three-dimensional protection (O'Leary and Roberts, 2018);

— The need to protect the entire water column ecosystem in order to ensure protection for other elements of high seas biodiversity (Drazen *et al.*, 2020; O'Leary and Roberts, 2018); and

— The need to protect the carbon pump and increase resilience to climate change (Hoagland, 2020; Roberts *et al.*, 2017 - see **Figure 5**).

50 Though recent scientific research suggests that at least 30% is necessary (*30x30: A Blueprint for Ocean Protection*, 2019; O'Leary *et al.*, 2016).

BOX 3. COMPLEMENTARITY OF THE BBNJ AGREEMENT AND EXISTING MANAGEMENT BODIES

The extent to which a new instrument could be applied to mesopelagic fisheries will depend both on the provisions that are ultimately agreed and the political will of parties. According to the resolution establishing the negotiation process, the instrument must "not undermine existing relevant legal instruments and frameworks and relevant global, regional and sectoral bodies".[51] Determining what this means in practice has proven to be a serious point of contention (Friedman, 2019; Scanlon, 2018; Wright *et al.*, 2018, 2016) and a range of interpretations and alternative wordings have been offered.[52]

A few States have argued that any consideration of fisheries would necessarily undermine RFMOs. Most States agree that if a BBNJ Agreement is to be successful in enhancing coherence and complementarity, it will necessarily play a role in supporting fisheries management efforts and strengthening the inclusion of biodiversity considerations in sectoral decisionmaking (Barnes, 2016; Friedman, 2019; Haas *et al.*, 2020a; Marciniak, 2017; Scanlon, 2018; Tladi, 2015; Wright *et al.*, 2016).

5.5. A moratorium on mesopelagic fishing

Given the high level of uncertainty concerning the potential impacts of mesopelagic fisheries, States could agree to refrain from exploiting mesopelagic fisheries in order to allow time for scientific knowledge and management capacity to develop.

Scientists and non-governmental organizations (NGOs)[53] have also begun to express their belief that exploitation should not commence before the science is sufficiently developed to enable effective management (Hidalgo and Browman, 2019; Martin *et al.*, 2020):

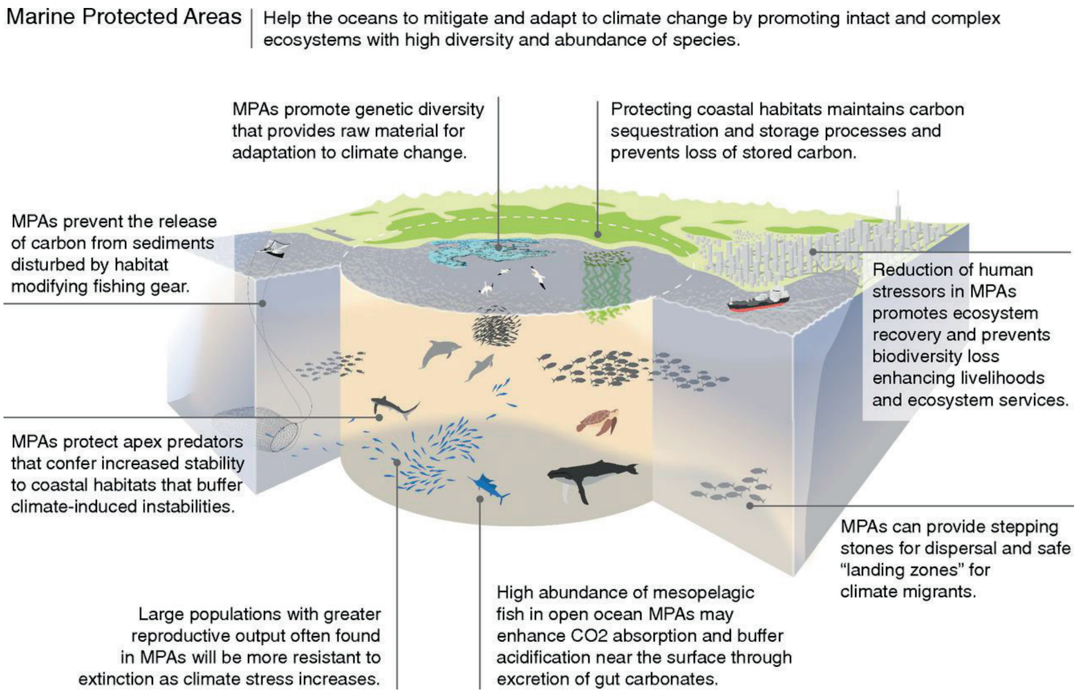
> *considerably more resources will be required to conduct the research needed to support knowledge based management of mesopelagic resources (…) large-scale exploitation of the mesopelagic should not begin until that information is incorporated into management tools (Hidalgo and Browman, 2019).*

51 UNGA Resolution 72/249, paragraph 7. See note 47.

52 E.g. "respects the competences of and does not undermine" (bracketed text in draft treaty) and "does not undermine the effectiveness of…" (proposed by the G77).

53 E.g. Blue Marine Foundation, https://www.bluemarinefoundation.com/2019/08/20/protecting-the-twilight-zone/.

FIGURE 5. **MPAs can mitigate and promote adaptation to the effects of climate change in the Ocean**



Source: Roberts *et al.* (2017).

Exploitation of mesopelagic fisheries on the west coast of the U.S. has already been prohibited until the management authority "has had an adequate opportunity to both assess the scientific information relating to any proposed directed fishery and consider potential impacts to existing fisheries, fishing communities, and the greater marine ecosystem".[54]

There are a number of precedents for such a course of action at the international level, including:

- A moratorium on commercial whaling adopted by the International Whaling Commission (IWC, 1982);[55]
- A UNGA resolution establishing a moratorium on all large-scale pelagic driftnet fishing on the high seas (1989);[56]
- A moratorium on fishing for Alaska pollock, instituted pending negotiation of the Convention on the Conservation and Management of Pollock Resources in the Central Bering Sea (1994);[57] and
- The Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean (CAO Agreement, 2018).

The CAO Agreement is of particular interest owing to its recent conclusion and to similarities with the mesopelagic issue (global significance, high levels of scientific uncertainty and absence of an effective governance framework). Following multiple calls for a moratorium,[58] ten Parties[59] agreed to prohibit unregulated commercial fishing in the CAO through the "application of precautionary conservation and management measures as part of a long-term strategy to safeguard healthy marine ecosystems and to ensure the conservation and sustainable use of fish stocks". The Agreement requires Parties to refrain from fishing until a management mechanism is agreed[60] and implements a *de facto* commercial fishing moratorium for an initial period of 16 years.[61]

54 Pacific Council, Comprehensive Ecosystem-Based Amendment 1 (2016) https://www.fisheries.noaa.gov/action/fisheries-west-coast-states-comprehensive-ecosystem-based-amendment-1-amendments-fishery.

55 See IISD, Summary of the 67th meeting of the International Whaling Commission: 10-14 September 2018 (Earth Negotiations Bulletin 34(2), 2018) https://enb.iisd.org/download/pdf/enb3402e.pdf.https://enb.iisd.org/download/pdf/enb3402e.pdf.

56 UNGA resolution 44/225 (1989).

57 The moratorium came too late to prevent one of "the most spectacular fishery collapses to occur in the modern history of fisheries in the northern hemisphere" (Bailey, 2011).

58 E.g. from the Inuit Circumpolar Council and the Arctic 5 (see https://www.inuitcircumpolar.com/press-releases/icc-applauds-adoption-of-central-arctic-ocean-fishing-moratorium/) and the Declaration Concerning the Prevention of Unregulated High Seas Fishing in the Central Arctic Ocean (the Oslo Declaration, https://www.regjeringen.no/globalassets/departementene/ud/vedlegg/folkerett/declaration-on-arctic-fisheries-16-july-2015.pdf) respectively.

59 The United States, Canada, the Kingdom of Denmark, the European Union, Iceland, Japan, the Republic of Korea, the Kingdom of Norway, the People's Republic of China, and the Russian Federation.

60 The Agreement allows fishing if either: 1. NEAFC were to allow commercial fisheries in its management area, in which case Parties to both could authorize their vessels to fish; or 2. negotiations to establish an RFMO were commenced, in which case commercial fisheries could begin during those negotiations and pending entry into force of the new instrument, provided mechanisms are also agreed to ensure that any such fishing is sustainable (Articles 3 & 5).

61 Central Arctic Ocean Agreement, Article 13(1). This period can then be followed by consecutive five-year extension periods under Article 13(2).

A Joint Program of Scientific Research and Monitoring was established to consider whether the distribution, migration and abundance of fish in the CAO would support a sustainable commercial fishery.[62] On that basis, Parties may determine whether to commence negotiations for fishing, including interim measures.[63] Measures for exploratory fishing are to be developed, ensuring that exploration is appropriately limited in duration, scope and scale.[64]

6. CONCLUSION

Scientific understanding of mesopelagic ecosystems is underdeveloped and there are considerable risks inherent in developing a new fishery. Given the critical role mesopelagic ecosystems play in global carbon cycles and food webs, precaution requires early and strong action to minimise the possibility of significant adverse impacts.

The existing regional management framework for high seas fisheries appears to be inadequate to ensure the effective management of these globally important species and ecosystems. Of particular concern are insufficient obligations concerning environmental assessment, a lack of scientific knowledge, and limited implementation of ecosystem-based management approaches.

A new agreement on high seas biodiversity could play a key role in advancing the management framework for mesopelagic fisheries, providing a clear global standard for effective environmental assessment and potentially allowing for the conduct of an international strategic environmental assessment process, as well as the possibility of designating protected areas.

In the meantime, States have a range of possible options for ensuring a precautionary approach to mesopelagic fisheries, including: taking proactive steps to enhance the capacity and effectiveness of RFMOs; passing a UN General Assembly resolution calling for concrete action to protect mesopelagic ecosystems; and agreeing to a moratorium on mesopelagic fishing in order to allow for time for further development of scientific knowledge and management measures.

TABLE 2. Summary of key options for the regulation of mesopelagic fisheries

Option	Opportunities	Challenges
Application of UNFSA; regulation by RFMOs	• No need for global action • Self-executing	• Unequal response by regional actors • No mechanisms for consultation by global community or potentially affected States • Leaves decision-making in hands of most economically interested States and excludes Stakeholders and ecosystems that may suffer the consequences
UNGA resolution	• Can set global standards • Can call for science cooperation, data sharing and consultation • Can call for FAO to develop new global guidelines for research and/or exploratory fisheries specifically for these types of fisheries	• UNGA resolutions have no implementation mechanism and are not binding; most effective when followed up by regular review of progress
BBNJ Agreement	• Strengthen cooperation and coordination; provide support to RFMO processes • Global standards for all impact assessments; possibility of an international SEA process to better understand mesopelagic ecosystems • Establishment of MPAs covering mesopelagic ecosystems • Ensure effective consultation, transparency, and informed decision making	• Ensure that specific activities such as fisheries are made subject to BBNJ Agreement EIA standards; ensure RFMOs not exempt • Monitoring and follow-up to ensure EIA measures and conditions to avoid significant harm are implemented • Preparation and implementation of management and research plan • Developing means to ensure compliance with MPA conservation and management plan
Negotiation of fisheries agreement; moratorium	• Potential to pause development of new fisheries pending development of scientific knowledge and governance mechanisms • Strong application of the precautionary principle, in line with international legal obligations	• Concerted political will required to negotiate effective agreement

62 Article 5(1)(c).

63 Article 5(1)(c) (ii).

64 Article 5(1)(d) (ii).

ANNEX I: SELECTED ONGOING RESEARCH PROJECTS AND COLLABORATIONS

Objective	Overview of partners	Funder
Joint Exploration of the Twilight Zone Ocean Network (JETZON)[65]		
Act as an international coordinator and focal point for Twilight Zone studies	APERO, COMICS, CUSTARD, EXPORTS, FLUXES, GOCART), MEESO, OCEAN DEOXYFISH, Ocean Twilight Zone, ORCAS, PICCOLO, RADASO, REFINE, SOLACE, SUMMER, SeaPump	NERC, NASA, OCB, SCOR
Sustainable Management of Mesopelagic Resources (SUMMER)[66]		
"Establish a protocol to accurately estimate mesopelagic fish biomass, quantify the ecosystem services provided by the mesopelagic community (food, climate regulation and potential for bioactive compounds) and develop a decision support tool to measure the trade-offs between the different services."	AZTI, Univ. of Bremen, Univ. of St. Andrews, IMAR, NOC, GEOMAR, SINTEF, Univ. of Strathclde, Univ. of Oslo, Univ. of Bergen, CSIC, IFREMER, Univ. de la Rochelle, ULPGC, DTU, Havforsknings instituttet, IRD, METU, MFRI, LEITAT, BARNA, KAUST	EU, Horizon 2020
Ecologically and economically sustainable mesopelagic fisheries (MEESO)[67]		
"Quantify the spatio-temporal distributions of biomass, production and ecosystem role of mesopelagic resources…to fill in major knowledge gaps on [mesopelagic] organisms and their role in and interactions with the full marine ecosystem and to evaluate whether they can be exploited in an ecologically and economically sustainable way".	Lead: Institute of Marine Research (IMR), Norway. Partners: European Fishmeal; SINTEF Ocean (Norway) - develop harvesting technology for commercial operations.	EU, Horizon 2020
EXport Processes in the Ocean from Remote Sensing (EXPORTS)[68]		
"To develop a predictive understanding of the export and fate of global ocean net primary production (NPP) and its implications for present and future climates."	NASA, NSF	TED
Tara Oceans[69]		
To study the biogeography of open ocean plankton.		
Controls over Ocean Mesopelagic Interior Carbon Storage (COMICS)[70]		
To quantify the flow of carbon in the ocean's 'twilight' zone in order to more accurately model global climate change.	NOC, British Antarctic Survey, Univs. Of Queen Mary London, Liverpool, Oxford, and Southampton	NERC
Carbon Uptake and Seasonal Traits in Antarctic Remineralisation Depth (CUSTARD)[71]		
Examine how seasonal changes in food availability for phytoplankton at a key junction of the global ocean circulation influences how long carbon is trapped in the ocean rather than escape to the atmosphere as carbon dioxide.	NOC	NERC
SeaPump[72]		
To understand the Seasonal and regional food web interactions with the biological pump.	Helmholtz Society, Univ. of Bremen, MARUM	Alfred Wegener Institute
ORganic CArbon Sequestration in the ocean (ORCAS)[73]		
To bring new light to the biological carbon pump, the process by which atmospheric carbon dioxide is sequestered in the deep ocean in the form of sinking particles produced by plankton.	Barcelona Supercomputing Center	Fundacion Bancaria "la Caixa"
Gauging ocean Organic Carbon fluxes using Autonomous Robotic Technologies (GOCART)[74]		
To establish the characteristics and significance of temporal variability in organic carbon flux and remineralisation depth.	COMICS program	ERC

65 http://www.jetzon.org/
66 https://summerh2020.eu/
67 http://www.meeso.org/
68 https://oceanexports.org/
69 https://www.nature.com/articles/s41579-020-0364-5#Sec1
70 http://www.comics.ac.uk/
71 https://roses.ac.uk/custard/
72 https://www.awi.de/en/science/junior-groups/seapump.html
73 https://www.bsc.es/research-and-development/projects/orcas-organic-carbon-sequestration-the-ocean-constraining-model/project-people
74 https://projects.noc.ac.uk/gocart/

REFERENCES

30x30: A Blueprint for Ocean Protection (2019). University of Oxford, University of York, Greenpeace.

Alvheim, A.R., Kjellevold, M., Strand, E., Sanden, M., Wiech, M. (2020). Mesopelagic species and their potential contribution to food and feed security—a case study from Norway. Foods 9. https://doi.org/10.3390/foods9030344

Auster, P.J., Gjerde, K., Heupel, E., Watling, L., Grehan, A., Rogers, A.D. (2011). Definition and detection of vulnerable marine ecosystems on the high seas: Problems with the "move-on" rule. ICES Journal of Marine Science 68, 254–264. https://doi.org/10.1093/icesjms/fsq074

Bailey, K.M. (2011). An Empty Donut Hole: the Great Collapse of a North American Fishery. Ecology and Society 16.

Barnes, R. (2016). The Proposed LOSC Implementation Agreement on Areas Beyond National Jurisdiction and Its Impact on International Fisheries Law, The International Journal of Marine and Coastal Law. https://doi.org/10.1163/15718085-12341411

Bax, N.J., Cleary, J., Donnelly, B., Dunn, D.C., Dunstan, P.K., Fuller, M., Halpin, P.N. (2015). Results and implications of the first global effort to identify ecologically or biologically significant marine areas CSIRO Oceans and Atmosphere Flagship , Hobart , TAS , 7001 , Australia Institute for Marine and Antarctic Studies , University of Tasmani. Conservation Biology 00, 1–11. https://doi.org/10.1111/cobi.12649.This

Bell, J.B., Guijarro-Garcia, E., Kenny, A. (2019). Demersal Fishing in Areas Beyond National Jurisdiction: A Comparative Analysis of Regional Fisheries Management Organisations. Frontiers in Marine Science 6, 1–11. https://doi.org/10.3389/fmars.2019.00596

Bensch, A., Gianni, M., Gréboval, D., Sanders, J., Hjort, A. (2009). Worldwide review of bottom fisheries in the high seas, 1st ed. FAO Fisheries and Aquaculture Department, Rome.

Billé, R., Chabason, L., Drankier, P., Molenaar, E.J., Rochette, J. (2016). Regional Oceans Governance: Making Regional Seas Programmes, Regional Fishery Bodies and Large Marine Ecosystem Mechanisms Work Better Together, UNEP Regional Seas Report and Studies. UNEP.

Boyd, P.W., Claustre, H., Levy, M., Siegel, D.A., Weber, T. (2019). Multi-faceted particle pumps drive carbon sequestration in the ocean. Nature. https://doi.org/10.1038/s41586-019-1098-2

Brooks, C.M., Weller, A.J.B., Gjerde, K., Sumaila, C.U.R., Ardron, J., Ban, E.N.C., Freestone, F.D., Seto, K., Unger, H.S., Costa, D.P., Fisher, I.K., Crowder, J.L., Halpin, P., K, A.B. (1995). Challenging the ' Right to Fish ' in a Fast-Changing Ocean 289–324.

Catul, V., Gauns, M., Karuppasamy, P.K. (2011). A review on mesopelagic fishes belonging to family Myctophidae. Reviews in Fish Biology and Fisheries 21, 339–354. https://doi.org/10.1007/s11160-010-9176-4

Ceccarelli, D.M., Fernandes, L. (2017). The value of offshore marine protected areas for open ocean habitats and species.

Choy, A.C., Wabnitz, C.C., Weijerman, M., Woodworth-Jefcoats, P.A., Polovina, J.J. (2016). Finding the way to the top: How the composition of oceanic mid-trophic micronekton groups determines apex predator biomass in the central North Pacific. Marine Ecology Progress Series 549, 9–25. https://doi.org/10.3354/meps11680

Choy, C.A., Haddock, S.H.D., Robison, B.H. (2017). Deep pelagic food web structure as revealed by *in situ* feeding observations. Proceedings of the Royal Society B: Biological Sciences 284, 20172116. https://doi.org/10.1098/rspb.2017.2116

Choy, C.A., Portner, E., Iwane, M., Drazen, J.C. (2013). Diets of five important predatory mesopelagic fishes of the central North Pacific. Marine Ecology Progress Series 492, 169–184. https://doi.org/10.3354/meps10518

Clark, N.A., Ardron, J.A., Pendleton, L.H. (2015). Evaluating the basic elements of transparency of regional fisheries management organizations. Marine Policy 57, 158–166. https://doi.org/10.1016/j.marpol.2015.03.003

Cochrane, K.L. (2002). A Fishery Manager's Guidebook - Management Measures and Their Application[2]. Rome.

Costello, M.J., Breyer, S. (2017). Ocean Depths: The Mesopelagic and Implications for Global Warming. Current Biology. https://doi.org/10.1016/j.cub.2016.11.042

Crespo, G.O., Dunn, D.C., Gianni, M., Gjerde, K., Wright, G., Halpin, P.N. (2019). High-seas fish biodiversity is slipping through the governance net. Nature Ecology & Evolution 3, 1273–1276. https://doi.org/10.1038/s41559-019-0981-4

Cullis-Suzuki, S., Pauly, D. (2010). Failing the high seas: A global evaluation of regional fisheries management organizations. Marine Policy 34, 1036–1042. https://doi.org/10.1016/j.marpol.2010.03.002

Daly, J. (2019). South Africa – Multi-species Experimental Pelagic trawl (mesopelagics). Global Standard for Responsible Supply of Marine Ingredients: Fishery Assessment Methodology and Template Report V2.0.

Davison, P.C., Checkley, D.M., Koslow, J.A., Barlow, J. (2013). Carbon export mediated by mesopelagic fishes in the northeast Pacific Ocean. Progress in Oceanography 116, 14–30. https://doi.org/10.1016/j.pocean.2013.05.013

Davison, P.C., Koslow, J.A., Kloser, R.J. (2015). Acoustic biomass estimation of mesopelagic fish: Backscattering from individuals, populations, and communities. ICES Journal of Marine Science 72, 1413–1424. https://doi.org/10.1093/icesjms/fsv023

Del Giorgio, P.A., Duarte, C.M. (2002). Respiration in the open ocean. Nature 420, 379–384. https://doi.org/10.1038/nature01165

Doelle, M., Sander, G. (2020). Next Generation EA in the BBNJ Regime ? An Assessment of the State of the Negotiations. International Journal of Maritime and Coastal Law.

Drazen, J.C., Smith, C.R., Gjerde, K.M., Haddock, S.H.D., Carter, G.S., Choy, C.A., Clark, M.R., Dutrieux, P., Goetze, E., Hauton, C., Hatta, M., Koslow, J.A., Leitner, A.B., Pacini, A., Perelman, J.N., Peacock, T., Sutton, T.T., Watling, L., Yamamoto, H. (2020). Opinion: Midwater ecosystems must be considered when evaluating environmental risks of deep-sea mining. Proceedings of the National Academy of Sciences of the United States of America 117, 17455–17460. https://doi.org/10.1073/pnas.2011914117

Drazen, J.C., Sutton, T.T. (2017). Dining in the Deep: The Feeding Ecology of Deep-Sea Fishes. Annual Review of Marine Science 9, 337–66. https://doi.org/10.1146/annurev-marine-010816-060543

Dunn, D.C., Ardron, J., Bax, N., Bernal, P., Cleary, J., Cresswell, I., Donnelly, B., Dunstan, P., Gjerde, K., Johnson, D., Kaschner, K., Lascelles, B., Rice, J., Von Nordheim, H., Wood, L., Halpin, P.N. (2014). The Convention on Biological Diversity's Ecologically or Biologically Significant Areas: Origins, development, and current status. Marine Policy 49, 137–145. https://doi.org/10.1016/j.marpol.2013.12.002

FAO (2020). The State of World Fisheries and Aquaculture 2020. Rome.

FAO (2016). FAO's Input to the UN Secretary-General's Comprehensive Report for the 2016 Resumed Review Conference on the UN Fish Stocks Agreement.

FAO (2001). Trilateral workshop on Lanternfish in the Gulf of Oman, Fisheries Report No. 665. FAO, Rome.

Fischer, J. (2020). How transparent are RFMOs? Achievements and challenges. Marine Policy 104106. https://doi.org/10.1016/j.marpol.2020.104106

Freestone, D. (2008). Principles Applicable to Modern Oceans Governance. The International Journal of Marine and Coastal Law 23, 385–391.

Freestone, D., Barnes, R., Ong, D. (2006). The Development of the Modern Law of the Sea, in: Freestone, D., Barnes, R., Ong, D. (Eds.), Freedoms of the High Seas in the Modern Law of the Sea. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199299614.001.0001

Friedman, A. (2019). Beyond "not undermining": possibilities for global cooperation to improve environmental protection in areas beyond national jurisdiction. ICES Journal of Marine Science 76, 452–456. https://doi.org/10.1093/icesjms/fsy192

Friedman, K., Garcia, S.M., Rice, J. (2018). Mainstreaming biodiversity in fisheries. Marine Policy 1–12. https://doi.org/10.1016/j.marpol.2018.03.001

Galland, G.R., Nickson, A.E.M., Hopkins, R., Miller, S.K. (2018). On the importance of clarity in scientific advice for fisheries management. Marine Policy 87, 250–254. https://doi.org/10.1016/j.marpol.2017.10.029

Garcia, S.M., Zerbi, A., Aliaume, C., Do Chi, T., Lasserre, G. (2003). The ecosystem approach to fisheries: Issues, terminology, principles, institutional foundations, implementation and outlook. Rome.

Gattuso, J.-P., Magnan, A., Bille, R., Cheung, W.W.L., Howes, E.L., Joos, F., Allemand, D., Bopp, L., Cooley, S.R., Eakin, C.M., Hoegh-Guldberg, O., Kelly, R.P., Portner, H.-O., Rogers, a. D., Baxter, J.M., Laffoley, D., Osborn, D., Rankovic, A., Rochette, J., Sumaila, U.R., Treyer, S., Turley, C. (2015). Contrasting futures for ocean and society from different anthropogenic CO2 emissions scenarios. Science 349, aac4722-1-aac4722-10. https://doi.org/10.1126/science.aac4722

Gewin, V. (2016). Fishing the Deep [WWW Document]. Hakai Magazine. URL https://www.hakaimagazine.com/news/fishing-deep/ (accessed 10.13.20).

Gianni, M., Currie, D., Fuller, S., Speer, L., Ardron, J., Weeber, B., Gibson, M., Roberts, G., Sack, K., Owen, S., Kavanagh, A. (2011). Unfinished business: a review of the implementation of the provisions of United Nations General Assembly resolutions 61/105 and 64/72, related to the management of bottom fisheries in areas beyond national jurisdiction.

Gianni, M., Fuller, S.D., Currie, D.E.J., K., S., Goldsworthy, L., Pike, B., Weeber, B., Owen, S., Friedman, A. (2016). How much longer will it take? A ten-year review of the implementation of United Nations General Assembly resolutions 61/105, 64/72 and 66/68 on the management of bottom fisheries in areas beyond national jurisdiction. Deep Sea Conservation Coalition.

Gilman, E., Passfield, K., Nakamura, K. (2014). Performance of regional fisheries management organizations: Ecosystem-based governance of bycatch and discards. Fish and Fisheries 15, 327–351. https://doi.org/10.1111/faf.12021

Gjerde, K., Wright, G. (2019). Towards Ecosystem-based Management of the Global Ocean: Strengthening Regional Cooperation through a New Agreement for the Conservation and Sustainable Use of Marine Biodiversity in Areas Beyond National Jurisdiction. STRONG High Seas project. https://doi.org/10.2312/iass.2019.055

Gjerde, K.M., Rulska-Domino, A. (2012). Marine Protected Areas beyond National Jurisdiction: Some Practical Perspectives for Moving Ahead. The International Journal of Marine and Coastal Law 27, 351–373. https://doi.org/10.1163/157180812X633636

Gjsaeter, J. (1984). Mesopelagic fish, a large potential resource in the Arabian Sea. Deep Sea Research Part A, Oceanographic Research Papers 31, 1019–1035. https://doi.org/10.1016/0198-0149(84)90054-2

Golden, C.D., Allison, E.H., Dey, M.M., Halpern, B.S., McCauley, D.J., Smith, M., Vaitla, B., Zeller, D., Myers, S.S., Cheung, W.W.L., Dey, M.M., Halpern, B.S., McCauley, D.J., Smith, M., Vaitla, B., Zeller, D., Myers, S.S. (2016). Fall in fish catch threatens human health. Nature News 534. https://doi.org/10.1038/534317a

Green, A.L., Fernandes, L., Almany, G., Abesamis, R., McLeod, E., Aliño, P.M., White, A.T., Salm, R., Tanzer, J., Pressey, R.L. (2014). Designing Marine Reserves for Fisheries Management, Biodiversity Conservation, and Climate Change Adaptation. Coastal Management 42. https://doi.org/10.1080/08920753.2014.877763

Grimaldo, E., Grimsmo, L. (2018). Mesopelagic fish resources - development of fishing gear and process technology.

Grimaldo, E., Grimsmo, L., Schei, M., Toldnes, B., Selnes, M. (2018). Experimental fishery and utilization of mesopelagic species in the North East Atlantic - NEAFC RA 1 Reykjanes Ridge area 7010. https://doi.org/10.13140/RG.2.2.17407.10402

Group of Experts of the Regular Process (2016). The First Global Integrated Marine Assessment (World Ocean Assessment I).

Grüss, A., Robinson, J., Heppell, S.S., Heppell, S.A., Semmens, B.X. (2014). Conservation and fisheries effects of spawning aggregation marine protected areas: What we know, where we should go, and what we need to get there. ICES Journal of Marine Science. https://doi.org/10.1093/icesjms/fsu038

Guggisberg, S. (2019). The roles of nongovernmental actors in improving compliance with fisheries regulations. Review of European, Comparative and International Environmental Law 28, 314–327. https://doi.org/10.1111/reel.12304

Haas, B., Haward, M., Mcgee, J., Fleming, A. (2020a). Regional fisheries management organizations and the new biodiversity agreement : Challenge or opportunity ? Fish and Fisheries 1–6. https://doi.org/10.1111/faf.12511

Haas, B., McGee, J., Fleming, A., Haward, M. (2020b). Factors influencing the performance of regional fisheries management organizations. Marine Policy 113, 103787. https://doi.org/10.1016/j.marpol.2019.103787

Hays, G.C. (2003). A review of the adaptive significance and ecosystem consequences of zooplankton diel vertical migrations, in: Hydrobiologia. Springer, pp. 163–170. https://doi.org/10.1023/B:HYDR.0000008476.23617.b0

Hidalgo, M., Browman, H.I. (2019). Developing the knowledge base needed to sustainably manage mesopelagic resources. ICES Journal of Marine Science 76, 609–615. https://doi.org/10.1093/icesjms/fsz067

Hilborn, R., Amoroso, R.O., Anderson, C.M., Baum, J.K., Branch, T.A., Costello, C., De Moor, C.L., Faraj, A., Hively, D., Jensen, O.P., Kurota, H., Little, L.R., Mace, P., McClanahan, T., Melnychuk, M.C., Minto, C., Osio, G.C., Parma, A.M., Pons, M., Segurado, S., Szuwalski, C.S., Wilson, J.R., Ye, Y. (2020). Effective fisheries management instrumental in improving fish stock status. Proceedings of the National Academy of Sciences of the United States of America 117, 2218–2224. https://doi.org/10.1073/pnas.1909726116

Hoagland, P. (2020). Value Beyond View: illuminating the human benefits of the ocean twilight zone.

Howes, E.L., Joos, F., Eakin, M., Gattuso, J.-P. (2015). The Oceans 2015 Initiative, Part I: An updated synthesis of the observed and projected impacts of climate change on physical and biological processes in the oceans. Studies N° 02/15, IDDRI, Paris, France 52.

Hudson, J.M., Steinberg, D.K., Sutton, T.T., Graves, J.E., Latour, R.J. (2014). Myctophid feeding ecology and carbon transport along the northern Mid-Atlantic Ridge. Deep-Sea Research Part I: Oceanographic Research Papers 93, 104–116. https://doi.org/10.1016/j.dsr.2014.07.002

Hulley, P.A. (1996). Lantern fishes, in: Paxton, J.R., Eschmeyer, W.N. (Eds.), Encyclopedia of Fishes. Academic Press, London.

IPCC (2019). The Ocean and Cryosphere in a Changing Climate. https://doi.org/https://www.ipcc.ch/report/srocc/

Irigoien, X., Klevjer, T.A., Røstad, A., Martinez, U., Boyra, G., Acuña, J.L., Bode, A., Echevarria, F., Gonzalez-Gordillo, J.I., Hernandez-Leon, S., Agusti, S., Aksnes, D.L., Duarte, C.M., Kaartvedt, S. (2014). Large mesopelagic fishes biomass and trophic efficiency in the open ocean. Nature communications 5, 3271. https://doi.org/10.1038/ncomms4271

Jin, D., Hoagland, P., Buesseler, K.O. (2020). The value of scientific research on the ocean's biological carbon pump. Science of The Total Environment 749, 141357. https://doi.org/10.1016/j.scitotenv.2020.141357

Johnson, D.E., Barrio Froján, C., Turner, P.J., Weaver, P., Gunn, V., Dunn, D.C., Halpin, P., Bax, N.J., Dunstan, P.K. (2018). Reviewing the EBSA process: Improving on success. Marine Policy 88, 75–85. https://doi.org/10.1016/j.marpol.2017.11.014

Jouffray, J., Blasiak, R., Norström, A. V., Österblom, H., Nyström, M. (2020). The Blue Acceleration: The Trajectory of Human Expansion into the Ocean. One Earth 2, 43–54. https://doi.org/10.1016/j.oneear.2019.12.016

Juan-Jordá, M.J., Murua, H., Arrizabalaga, H., Dulvy, N.K., Restrepo, V. (2018). Report card on ecosystem-based fisheries management in tuna regional fisheries management organizations. Fish and Fisheries 19, 321–339. https://doi.org/10.1111/faf.12256

Kaartvedt, S., Staby, A., Aksnes, D.L. (2012). Efficient trawl avoidance by mesopelagic fishes causes large underestimation of their biomass. Marine Ecology Progress Series 456, 1–6. https://doi.org/10.3354/meps09785

Koehler, H. (2018). Tuna RFMO Compliance Assessment Processes: A Comparative Analysis to Identify Best Practices. International Seafood Sustainability Foundation, Washington, DC.

Koh, T.B. (1982). A Constitution for the Oceans, in: Remarks by Tommy T.B. Koh, of Singapore, President of the Third United Nations Conference on the Law of the Sea.

Koizumi, K., Hiratsuka, S., Saito, H. (2014). Lipid and Fatty Acids of Three Edible Myctophids, Diaphus watasei, Diaphus suborbitalis, and Benthosema pterotum: High Levels of Icosapentaenoic and Docosahexaenoic Acids. Journal of Oleo Science 63, 461–470. https://doi.org/10.5650/jos.ess13224

Koslow, J.A., Boehlert, G.W., Gordon, J.D.M., Haedrich, R.L., Lorance, P., Parin, N. (2000). Continental slope and deep-sea fisheries: Implications for a fragile ecosystem. ICES Journal of Marine Science 57, 548–557. https://doi.org/10.1006/jmsc.2000.0722

Lauritano, C., Martínez, K.A., Battaglia, P., Granata, A., de la Cruz, M., Cautain, B., Martín, J., Reyes, F., Ianora, A., Guglielmo, L. (2020). First evidence of anticancer and antimicrobial activity in Mediterranean mesopelagic species. Scientific Reports 10, 1–8. https://doi.org/10.1038/s41598-020-61515-z

Levin, L.A., Wei, C.L., Dunn, D.C., Amon, D.J., Ashford, O.S., Cheung, W.W.L., Colaço, A., Dominguez-Carrió, C., Escobar, E.G., Harden-Davies, H.R., Drazen, J.C., Ismail, K., Jones, D.O.B., Johnson, D.E., Le, J.T., Lejzerowicz, F., Mitarai, S., Morato, T., Mulsow, S., Snelgrove, P.V.R., Sweetman, A.K., Yasuhara, M. (2020). Climate change considerations are fundamental to management of deep-sea resource extraction. Global Change Biology 26, 4664–4678. https://doi.org/10.1111/gcb.15223

Liu, Q., Zhou, L., Wu, Y., He, X., Gao, N., Zhang, L. (2020). Estimation of carbon released by mesopelagic fish in the global open ocean using a carbon release model and model fish-derived parameters. Global Biogeochemical Cycles.

Løbach, T., Petersson, M., Haberkon, E., Mannini, P. (2020). Regional fisheries management organizations and advisory bodies: Activities and developments, 2000-2017.

Luo, J.Y., Condon, R.H., Stock, C.A., Duarte, C.M., Lucas, C.H., Pitt, K.A., Cowen, R.K. (2020). Gelatinous Zooplankton-Mediated Carbon Flows in the Global Oceans: A Data-Driven Modeling Study. Global Biogeochemical Cycles 34. https://doi.org/10.1029/2020GB006704

Ma, D., Fang, Q., Guan, S. (2016). Current legal regime for environmental impact assessment in areas beyond national jurisdiction and its future approaches. Environmental Impact Assessment Review 56, 23–30. https://doi.org/10.1016/j.eiar.2015.08.009

Maguire, J.-J., Sissenwine, M., Csirke, J., Grainger, R. (2006). The state of the world highly migratory, straddling and other high seas fish stocks, and associated species, FAO Fisheries Technical Paper.

Marciniak, K.J. (2017). New implementing agreement under UNCLOS: A threat or an opportunity for fisheries governance? Marine Policy 84, 320–326. https://doi.org/10.1016/j.marpol.2017.06.035

Martin, A., Boyd, P., Buesseler, K., Cetinic, I., Claustre, H., Giering, S., Henson, S., Irigoien, X., Kriest, I., Memery, L., Robinson, C., Saba, G., Sanders, R., Siegel, D., Villa-Alfageme, M., Guidi, L. (2020). The oceans' twilight zone must be studied now, before it is too late. Nature 580, 26–28. https://doi.org/10.1038/d41586-020-00915-7

McDorman, T.L. (2005). Implementing Existing Tools: Turning Words Into Actions – Decision-Making Processes of Regional Fisheries Management Organisations (RFMOs). The International Journal of Marine and Coastal Law 20, 423–457. https://doi.org/10.1163/157180805775098595

Melnychuk, M.C., Peterson, E., Elliott, M., Hilborn, R. (2017). Fisheries management impacts on target species status. Proceedings of the National Academy of Sciences of the United States of America 114, 178–183. https://doi.org/10.1073/pnas.1609915114

Merrie, A., Dunn, D.C., Metian, M., Boustany, A.M., Takei, Y., Elferink, A.O., Ota, Y., Christensen, V., Halpin, P.N., Österblom, H. (2014). An ocean of surprises – Trends in human use, unexpected dynamics and governance challenges in areas beyond national jurisdiction. Global Environmental Change 27, 19–31. https://doi.org/10.1016/j.gloenvcha.2014.04.012

Molenaar, E.J. (2000). The concept of "Real Interest" and other aspect of Co-operation through regional fisheries management mechanism. International Journal of Marine and Coastal Law 15, 475–531. https://doi.org/10.1163/157180800X00226

Naito, Y., Costa, D.P., Adachi, T., Robinson, P.W., Fowler, M., Takahashi, A. (2013). Unravelling the mysteries of a mesopelagic diet: A large apex predator specializes on small prey. Functional Ecology 27, 710–717. https://doi.org/10.1111/1365-2435.12083

Norwegian Institute of Marine Research (2017). Mesopelagic Initiative : Unleashing new marine resources for a growing human population.

O'Leary, B.C., Ban, N.C., Fernandez, M., Friedlander, A.M., García-Borboroglu, P., Golbuu, Y., Guidetti, P., Harris, J.M., Hawkins, J.P., Langlois, T., McCauley, D.J., Pikitch, E.K., Richmond, R.H., Roberts, C.M. (2018). Addressing Criticisms of Large-Scale Marine Protected Areas. BioScience 68, 359–370. https://doi.org/10.1093/biosci/biy021

O'Leary, B.C., Roberts, C.M. (2018). Ecological connectivity across ocean depths: Implications for protected area design. Global Ecology and Conservation 15, e00431. https://doi.org/10.1016/j.gecco.2018.e00431

O'Leary, B.C., Winther-Janson, M., Bainbridge, J.M., Aitken, J., Hawkins, J.P., Roberts, C.M. (2016). Effective Coverage Targets for Ocean Protection. Conservation Letters 00, 1–6. https://doi.org/10.1111/conl.12247

Oanta, G.A. (2018). International organizations and deep-sea fisheries: Current status and future prospects. Marine Policy 87, 51–59. https://doi.org/10.1016/j.marpol.2017.09.009

Olsen, R.E., Strand, E., Melle, W., Nørstebø, J.T., Lall, S.P., Ringø, E., Tocher, D.R., Sprague, M. (2020). Can mesopelagic mixed layers be used as feed sources for salmon aquaculture? Deep-Sea Research Part II: Topical Studies in Oceanography 104722. https://doi.org/10.1016/j.dsr2.2019.104722

Patil, P., Kaczan, D., Roberts, J., Jabeen, R., Roberts, B., Barbosa, J., Zuberi, S., Huntington, T., Haylor, G., Hussain, S., Brugere, C., Goulding, I., Dillon, M. (2018). Revitalizing Pakistan's Fisheries: Options for Sustainable Development. World Bank & L'Agence Française de Développement, Washington, D.C.

Pauly, D., Zeller, D. (2016). Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining. Nature Communications 7, 10244. https://doi.org/10.1038/ncomms10244

Pentz, B., Klenk, N. (2017). The 'responsiveness gap' in RFMOs: The critical role of decision-making policies in the fisheries management response to climate change. Ocean and Coastal Management 145, 44–51. https://doi.org/10.1016/j.ocecoaman.2017.05.007

Pentz, B., Klenk, N., Ogle, S., Fisher, J.A.D. (2018). Can regional fisheries management organizations (RFMOs) manage resources effectively during climate change? https://doi.org/10.1016/j.marpol.2018.01.011

Petersson, M.T., Dellmuth, L.M., Merrie, A., Österblom, H. (2019). Patterns and trends in non-state actor participation in regional fisheries management organizations. Marine Policy 104, 146–156. https://doi.org/10.1016/j.marpol.2019.02.025

Pinsky, M. (2018). Preparing ocean governance for species on the move. Science 360, 1189–1191.

Pinsky, M.L., Jensen, O.P., Ricard, D., Palumbi, S.R. (2011). Unexpected patterns of fisheries collapse in the world's oceans. Proceedings of the National Academy of Sciences of the United States of America 108, 8317–8322. https://doi.org/10.1073/pnas.1015313108

Pons, M., Melnychuk, M.C., Hilborn, R. (2018). Management effectiveness of large pelagic fisheries in the high seas. Fish and Fisheries 19, 260–270. https://doi.org/10.1111/faf.12253

Popova, E., Vousden, D., Sauer, W.H.H., Mohammed, E.Y., Allain, V., Downey-Breedt, N., Fletcher, R., Gjerde, K.M., Halpin, P.N., Kelly, S., Obura, D., Pecl, G., Roberts, M., Raitsos, D.E., Rogers, A., Samoilys, M., Sumaila, U.R., Tracey, S., Yool, A. (2019). Ecological connectivity between the areas beyond national jurisdiction and coastal waters: Safeguarding interests of coastal communities in developing countries. Marine Policy 104, 90–102. https://doi.org/10.1016/j.marpol.2019.02.050

Prellezo, R., Maravelias, C. (2019). Exploring the economic viability of a mesopelagic fishery in the Bay of Biscay. ICES Journal of Marine Science 76, 771–779. https://doi.org/10.1093/icesjms/fsy001

Proud, R., Cox, M., Le Guen, C., Brierley, A. (2018). Fine-scale depth structure of pelagic communities throughout the global ocean based on acoustic sound scattering layers. Marine Ecology Progress Series 598, 35–48. https://doi.org/10.3354/meps12612

Proud, R., Cox, M.J., Brierley, A.S. (2017). Biogeography of the Global Ocean's Mesopelagic Zone. Current Biology 27, 113–119. https://doi.org/10.1016/j.cub.2016.11.003

Proud, R., Handegard, N.O., Kloser, R.J., Cox, M.J., Brierley, A.S., Demer, D. (2019). From siphonophores to deep scattering layers: Uncertainty ranges for the estimation of global mesopelagic fish biomass. ICES Journal of Marine Science 76, 718–733. https://doi.org/10.1093/icesjms/fsy037

Remesan, M.P., Prajith, K.K., Raj, F.D., Joseph, R., Boopendranath, M.R. (2016). Investigations on Aimed Midwater Trawling for Myctophids in the Arabian Sea. Fishery Technology 53, 190–196.

Remesan, M.P., Prakash, R.R., Prajith, K.K., Jha, P.N., Renjith, R.K., Boopendranath, M.R. (2019). A Review on Techniques and Challenges in the Harvest of Mesopelagics, in: Fishery Technology. pp. 243–253.

Roberts, Callum M, O'Leary, B.C., McCauley, D.J., Cury, P.M., Duarte, C.M., Lubchenco, J., Pauly, D., Sáenz-Arroyo, A., Sumaila, U.R., Wilson, R.W., Worm, B., Castilla, J.C. (2017). Marine reserves can mitigate and promote adaptation to climate change. Proceedings of the National Academy of Sciences of the United States of America 201701262. https://doi.org/10.1073/pnas.1701262114

Robinson, C., Steinberg, D.K., Anderson, T.R., Arístegui, J., Carlson, C.A., Frost, J.R., Ghiglione, J.F., Hernández-León, S., Jackson, G.A., Koppelmann, R., Quéguiner, B., Ragueneau, O., Rassoulzadegan, F., Robison, B.H., Tamburini, C., Tanaka, T., Wishner, K.F., Zhang, J. (2010). Mesopelagic zone ecology and biogeochemistry - A synthesis. Deep-Sea Research Part II: Topical Studies in Oceanography 57, 1504–1518. https://doi.org/10.1016/j.dsr2.2010.02.018

Rochette, J., Billé, R., Molenaar, E.J., Drankier, P., Chabason, L. (2015). Regional oceans governance mechanisms : A review 60, 9–19. https://doi.org/10.1016/j.marpol.2015.05.012

Rogers, A.D., Gianni, M. (2010). The Implementation of UNGA Resolutions 61/105 and 64/72 in the Management of Deep-Sea Fisheries on the High Seas, Dscc.

Scales, K.L., Miller, P.I., Hawkes, L.A., Ingram, S.N., Sims, D.W., Votier, S.C. (2014). On the front line: Frontal zones as priority at-sea conservation areas for mobile marine vertebrates. Journal of Applied Ecology. https://doi.org/10.1111/1365-2664.12330

Scanlon, Z. (2018). The art of "not undermining": Possibilities within existing architecture to improve environmental protections in areas beyond national jurisdiction. ICES Journal of Marine Science 75, 405–416. https://doi.org/10.1093/icesjms/fsx209

Serdy, A. (2017). Pacta tertiis and regional fisheries management mechanisms: The IUU fishing concept as an illegitimate short-cut to a legitimate goal. Ocean Development and International Law 48, 345–364. https://doi.org/10.1080/00908320.2017.1349525

Shotton, R. (1997). Lantern Fisheries: a potential fishery in the Northern Arabian Sea?, in: Review of the State of World Fishery Resources: Marine Fisheries, FAO Fisheries Circular No. 920 FIRM/C920. FAO, Rome.

St. John, M.A., Borja, A., Chust, G., Heath, M., Grigorov, I., Mariani, P., Martin, A.P., Santos, R.S. (2016). A Dark Hole in Our Understanding of Marine Ecosystems and Their Services: Perspectives from the Mesopelagic Community. Frontiers in Marine Science 3, 1–6. https://doi.org/10.3389/fmars.2016.00031

Standal, D., Grimaldo, E. (2020). Institutional nuts and bolts for a mesopelagic fishery in Norway. Marine Policy 119, 104043. https://doi.org/10.1016/j.marpol.2020.104043

Sumaila, U.R., Alder, J., Keith, H. (2006). Global scope and economics of illegal fishing. Marine Policy 30, 696–703. https://doi.org/10.1016/j.marpol.2005.11.001

Sumaila, U.R., Zeller, D., Watson, R., Alder, J., Pauly, D. (2007). Potential costs and benefits of marine reserves in the high seas. Marine Ecology Progress Series 345, 305–310. https://doi.org/10.3354/meps07065

Sutton, T., Clark, M.R., Dunn, D.C., Halpin, P.N., Rogers, A.D., Guinotte, J., Bograd, S.J., Angel, M. V., Perez, J.A.A., Wishner, K., Haedrich, R.L., Lindsay, D.J., Drazen, J.C., Vereshchaka, A., Piatkowski, U., Morato, T., Błachowiak-Samołyk, K., Robison, B.H., Gjerde, K.M., Pierrot-Bults, A., Bernal, P., Reygondeau, G., Heino, M. (2017). A global biogeographic classification of the mesopelagic zone. Deep-Sea Research Part I: Oceanographic Research Papers. https://doi.org/10.1016/j.dsr.2017.05.006

Sutton, T., Hulley, P.A., W., Ienerroither, R., Zaera-Perez, D., Paxton, J.R. (2020). Identification guide to the mesopelagic fishes of the central and south east Atlantic Ocean (No. FAO), Identification guide to the mesopelagic fishes of the central and south east Atlantic Ocean. https://doi.org/10.4060/cb0365en

Takei, Y. (2013). Filling regulatory gaps in high seas fisheries: discrete high seas fish stocks, deep-sea fisheries, and vulnerable marine ecosystems. Martinus Nijhoff Publishers.

Thorvik, T. (2017). Strategy for sustainable harvesting of mesopelagic species, in: North Atlantic Seafood Forum. Vergen.

Tladi, D. (2015). The Proposed Implementing Agreement: Options for Coherence and Consistency in the Establishment of Protected Areas beyond National Jurisdiction. The International Journal of Marine and Coastal Law 30, 654–673. https://doi.org/10.1163/15718085-12341375

Trueman, C.N., Johnston, G., O'Hea, B., MacKenzie, K.M. (2014). Trophic interactions of fish communities at midwater depths enhance long-term carbon storage and benthic production on continental slopes. Proceedings of the Royal Society B: Biological Sciences 281. https://doi.org/10.1098/rspb.2014.0669

Valinassab, B.T., Pierce, G.J., Johannesson, K. (2007). Lantern fish (Benthosema pterotum) resources as a target for commercial exploitation in the Oman Sea Lantern fish (Benthosema pterotum) resources as a target for commercial exploitation in the Oman Sea. https://doi.org/10.1111/j.1439-0426.2007.01034.x

Victorero, L., Watling, L., Deng Palomares, M.L., Nouvian, C. (2018). Out of Sight, But Within Reach: A Global History of Bottom-Trawled Deep-Sea Fisheries From >400 m Depth. Frontiers in Marine Science 5, 1–17. https://doi.org/10.3389/fmars.2018.00098

Vidal, M., Duarte, C.M., Agustí, S. (1999). Dissolved organic nitrogen and phosphorus pools and fluxes in the central Atlantic Ocean. Limnology and Oceanography. https://doi.org/10.4319/lo.1999.44.1.0106

Warner, R. (2009). Protecting the Oceans Beyond National Jurisdiction: Strengthening the International Law Framework. Brill Nijhoff.

Weaver, P.E., Benn, A., Arana, P.M., Ardron, J.A., Bailey, D.M., Baker, K., Billett, D.S.M., Clark, M.R., Davies, A.J., Durán Muñoz, P., Fuller, S.D., Gianni, M., Grehan, A.J., Guinotte, J., Kenny, A., Koslow, J.A., Morato, T., Penney, A.J., Perez, J.A.A., Priede, I.G., Rogers, A.D., Santos, R.S., Watling, L. (2011). The impact of deep-sea fisheries and implementation of the UNGA Resolutions, Report of an international scientific workshop. Southampton.

WHOI (2017). The mesopelagic: Cinderella of the oceans. Economist 413, 1–10.

Wiech, M., Silva, M., Meier, S., Tibon, J., Berntssen, M.H.G., Duinker, A., Sanden, M. (2020). Undesirables in mesopelagic species and implications for food and feed safet: insights from norwegian fjords. Foods 9. https://doi.org/10.3390/foods9091162

Willis, J.M., Pearcy, W.G. (1982). Vertical distribution and migration of fishes of the lower mesopelagic zone off Oregon. Marine Biology 70, 87–98. https://doi.org/10.1007/BF00397299

Workshop on mesopelagic fish (2004). Faroese Fisheries Laboratory, Tórshavn, Faroe Islands.

Wright, G., Ardron, J., Gjerde, K., Currie, D., Rochette, J. (2015). Advancing marine biodiversity protection through regional fisheries management: A review of bottom fisheries closures in areas beyond national jurisdiction. Marine Policy 61, 134–148. https://doi.org/10.1016/j.marpol.2015.06.030

Wright, G., Cremers, K., Rochette, J., Clark, N., Dunn, D., Gjerde, K.M., Harden-Davies, H., Mohammed, E., Crespo, G.O. (2019). High Hopes for the High Seas: beyond the package deal towards an ambitious treaty (No. 9), IDDRI Issue Brief. IDDRI.

Wright, G., Rochette, J., Blom, L., Currie, D., Durussel, C., Gjerde, K., Unger, S. (2016). High seas fisheries: what role for a new international instrument?, IDDRI Studies. IDDRI.

Wright, G., Rochette, J., Gjerde, K., Seeger, I. (2018). The Long and Winding Road: negotiating a treaty for the conservation and sustainable use of marine biodiversity in areas beyond national jurisdiction (No. 08), IDDRI Study, IDDRI Studies. IDDRI, Paris.

Yletyinen, J., Butler, W., Ottersen, G., Andersen, K., Bonanomi, S., Diekert, F., Folke, C., Lindegren, M., Nordström, M., Richter, A., Rogers, L., Romagnoni, G., Weigel, B., Whittington, J., Blenckner, T., Stenseth, N. (2018). When is a fish stock collapsed? bioRxiv 329979. https://doi.org/10.1101/329979

Young, M. (2016). Then and now: Reappraising freedom of the seas in modern law of the sea. Ocean Development and International Law 47, 165–185. https://doi.org/10.1080/00908320.2016.1159088

Fishing in the Twilight Zone: Illuminating governance challenges at the next fisheries frontier

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