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Governing Open Ocean and Fish Carbon: Perspectives and Opportunities

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Marine life plays a vital role in the ocean's biological pump by sequestering and mediating fluxes of carbon to the deep sea and sea floor. The roles that fish and other marine vertebrates play in the biological pump are increasingly attracting scientific and policy attention. In this paper, we investigated the interest in and possibilities for the international governance of open ocean and fish carbon ecosystem services. We used semi-structured interviews with representatives from environmental non-governmental organisations (ENGOs), policy makers, and policy experts, along with an exploratory review of grey and peer-reviewed literature to: 1) trace the pathway of important milestones, key actors, and their strategies to influence governance of ocean carbon, and, 2) investigate which frameworks might be used to govern open ocean and fish carbon. Strategies of key actors to direct attention to open ocean and fish carbon included collaborating with scientists, organising side events at climate and biodiversity negotiations and seminars to engage policy makers, as well as educational campaigns directed to the public and policy makers about the co-benefits of open ocean and fish carbon. While we found a strong focus of ENGO activities related to the UN Framework Convention on Climate Change, we also found strong opposition against active governance of open ocean and fish carbon by key Intergovernmental actors in this forum. Opposition stems from a lack of scientific information on how long open ocean and fish carbon is stored, difficulties in attributing carbon flows with individual countries mitigation actions, and fewer perceived co-benefits (e.g. coastal protection in the case of coastal blue carbon) for coastal communities. More viable routes for the future governance of open ocean and fish carbon may lie in international fisheries management and in current negotiations of a treaty for biodiversity conservation in the high seas.

Keywords: ocean governance, biodiversity conservation, fisheries management, sustainable fishing, climate change, blue carbon, biological pump, carbon sequestration

1 INTRODUCTION

The ocean is the largest heat and carbon sink globally, absorbing 90% of excess anthropogenic heat gained by the planet between 1971 and 2010 (Zanna et al., 2019). The ocean also absorbs CO_2 *via* a physical carbon flow and through the biological pump (Sarmiento and Gruber, 2006). The biological pump is the set of processes by which inorganic carbon (CO_2) is fixated in organic carbon by phytoplankton and exported to the deep ocean (Sarmiento and Gruber, 2006). If carbon moves from the surface layers to the deep sea (i.e. deeper than 1,000 m) it is removed from the atmosphere for at least 100 years (Passow and Carlson, 2012). There are several mechanisms through which the carbon absorbed by phytoplankton can reach the deep-sea, and marine species such as fish and a diversity of zooplankton contribute to carbon export (Sarmiento and Gruber, 2006; Wilson et al., 2009; Boyd et al., 2019). Zooplankton, fish, and whales contribute to passive carbon fixation with their biomass, this carbon is stored in food webs or can be exported through deadfall to the seafloor (Boyd et al., 2019). The vertical migrations of fish and zooplankton also actively export carbon into the deep ocean by feeding at the ocean surface and excreting carbon at depth (Davison et al., 2013; Saba et al., 2021).

There is a growing recognition that ocean biodiversity and climate are intertwined in science and policy (Rantala et al., 2019; Pörtner et al., 2021). Ocean-climate nexus and blue carbon discussions that are on-going also have led to increasing attention to carbon cycling and storage processes in the open ocean as Nature-Based Solutions to climate change (Lutz and Martin, 2014; Dobush et al., 2021). Ocean carbon refers to all biologically-driven carbon fluxes and storage in marine systems. While coastal blue carbon focuses on rooted vegetation in the coastal zone, such as tidal marshes, mangroves and seagrasses (IOC-R, 2021), open ocean and fish carbon refers to biologically-driven carbon fluxes and storage in the open ocean (including those of marine life such as marine mammals, marine plants invertebrates including a diversity of zooplankton), particularly those mediated by fish as fish carbon.

There is a continuum of exploitation of species that contribute to carbon sequestration. Many top marine predators have declined in biomass and are at historical lows in abundance (Lotze and Worm, 2009; McCauley et al., 2015). For instance, in the past half century oceanic sharks and rays have declined by ca. 70% in abundance (Pacoureau et al., 2021). In contrast, cetaceans used to be highly exploited but are beginning to recover in abundance globally (Duarte et al., 2020; Durfort et al., 2021). Rebuilding populations to historical abundance could help sequester ca. 1.66 megatons carbon (MtC) per year for whales (Pershing et al., 2010) and ca. 1.63 MtC per year for large marine predators (Mariani et al., 2020). Mesopelagic fish also play a crucial role in active carbon sequestration (Saba et al., 2021), yet, there is increasing interest in their exploitation (Hidalgo and Browman, 2019; Alvheim et al., 2020; Grimaldo et al., 2020). Moreover, there are growing concerns about the vulnerability of these ecosystems to impacts of deep sea mining as well as oil and gas extraction (Drazen et al., 2020; Morzaria-Luna et al., 2022). In summary, rebuilding the abundance of overexploited and precautionary management of yet unexploited species provides an opportunity to enhance and maintain vital carbon sequestration services.

Climate change and ocean governance, including protection of marine biodiversity, are issues that extend beyond countries' national borders (Dellmuth and Bloodgood, 2019). In this article, ocean governance is seen as interactions among, and between, networks of state and non-state actors that share power, perceive and interpret information and steer human interactions with ocean ecosystems, guided by a combination of international and national laws such as those discussed below, as well as norms and rules of conduct (Ojo and Mellouli, 2018; Brodie Rudolph et al., 2020). To address such issues of "global commons" states have formed international organisations which have been handed power to handle these transnational issues (Merrie et al., 2014).

The UN Convention of the Law of the Sea (UNCLOS) implemented in 1982 established nation states' sovereignty at 200 nautical miles from their territorial borders into the sea, countries' exclusive economic zones (EEZ). The ongoing negotiations for an agreement on biodiversity beyond national jurisdiction (BBNJ agreement) and the UN Fish Stock Agreement (UNFSA) are legally binding instruments under UNCLOS. The BBNJ agreement will promote the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction. The UNFSA mandated Regional Fisheries Management Organizations (RFMOs) to manage and conserve straddling and highly migratory fish stocks. Other key frameworks for ocean carbon include the United Nations Framework Convention for Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD) which was created during the Earth Summit in Rio de Janeiro in 1992. Other conventions of relevance are the 1973 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the 1979 Convention on the Conservation of Migratory Species of Wild Animals (CMS), the 1946 International Convention for the Regulation of Whaling (ICRW), and the 1964 London Fisheries Convention (LC). The recent Sustainable Development Goals (SDG's) under the 2030 agenda and in particular SDG14 on the ocean and SDG13 on climate action are also considered an important agenda for the governance of the ocean and climate. Mechanisms through which such frameworks are implemented can be economic sanctions/rewards, local implementation into law, and creation of shared norms and ambitions (Buchanan and Keohane, 2006). Combining issues such as climate change either within a single policy framework or across, (such as climate change and marine biodiversity) could be synergistic and address governance gaps between regimes or result in lower costs to management. However, combining issues in this way could also result in issue dilution or distraction (Chan, 2021).

Non-state actors such as Environmental non-governmental organisations (ENGO), industry representatives and academic experts participate in and influence international policy fora such as those described above [alongside state representatives and intergovernmental organisations (IGOs) representatives], through formal and informal policy processes. Such processes may include supplying policy-relevant information to policy makers, informing the public about the state of the problem, coordinating across actors, or assisting in policy implementation (Orach et al., 2017; Dellmuth and Bloodgood, 2019; Dellmuth et al., 2020; Sénit, 2020). ENGOs are non-profit groups, independent from government, which are organised on a local, national, or international level to address issues of concern for civil society, and/or protect public goods (Grip, 2017). They are particularly important for the topics of climate change, ocean topics and biodiversity protection as they are thought to bring global and regional perspectives to discussions, in contrast to individual states, which would often pursue their own national interests (Grip, 2017). IGOs such as the IPCC are mandated to serve collective interests of sovereign states and are of crucial importance in global issues such as climate change and biodiversity loss and to implement international laws and conventions such as those described above (Biermann and Dingwerth, 2004).

In this paper, we investigate the evolution of the debate on ocean and open ocean and fish carbon in the context of ocean and climate governance using semi-structured interviews and a literature review. Our guiding research questions are: 1) Which milestones were important in shaping governance discussions from oceans and climate towards ocean and fish carbon? 2) Which processes and key actors were influential in shaping these milestones? and 3) Under which framework, and using which management tools, might open ocean and fish carbon be governed? We first present a timeline of milestones for the evolution of the debate on ocean and fish carbon policy. Secondly, we identify key actors and their strategies in influencing this debate. Finally, we assess which policy fora would be most suitable to govern open ocean and fish carbon.

2 METHODS

We used a mix of qualitative research methods including semi-structured interviews and literature review to answer our research questions. We conducted twenty semi-structured interviews (Bryman, 2016) with key informants (those close to the policy making sphere on the specific topics or those with expert knowledge on the specific topics) in ocean, climate, and fish carbon governance. One of the goals of the interviews was to collect data on what participants viewed as important in explaining and understanding key events (Brinkman and Kvale, 2015; Bryman, 2016). 20 of the 33 informants we reached out to, agreed on being interviewed. We investigated how the participants framed and understood the key issues, and events related to how open ocean and fish carbon appeared on the international policy agenda. Finally, we asked about the ongoing and future policy fora and instruments that could potentially regulate the open ocean and fish carbon sequestration services. We reached the saturation level with the interviews at n= 20 (Charmaz, 2014), when each new interview did not result in new information.

To find key informants we followed the lines of purposive sampling (Onwuegbuzie and Leech, 2007), we created an initial list of participants based on a preliminary literature review of reports, organisations' websites, and social media related to the topic of open ocean and fish carbon governance. We completed the list of interviewees following a snowball approach (Bryman, 2016). All interviewees were working with ocean governance but with a variety of backgrounds (**Table 1**).

We conducted the interviews *via* Zoom. They lasted between 40 – 60 minutes and were carried out between May and July 2021. All interviews but one were recorded and we took notes simultaneously.

We structured the interview questionnaire to collect relevant information for the three research questions (see SI1 for the interview guide). We organised the questionnaire subsequently into three sections. First, we asked about milestones such as events, working groups, and publications that in the interviewees' perspective advanced the ocean and climate discussion towards ocean carbon. Second, we asked questions concerning key actors in ocean climate, coastal blue carbon, and open ocean and fish carbon governance and how they were able to influence the milestones and discussions (Orach et al., 2017; Sénit, 2020). The last set of questions investigated the possible future governance for open ocean and fish carbon including under which frameworks and using which management tools open ocean and fish carbon could be governed. In the email and prior to the interview, we informed participants of the aims of the research and how we would use the information. Anonymity was granted to create an open space to discuss personal viewpoints.

We transcribed the interviews and organised the data following each of the three overarching themes covered by the interview inspired by the processes of initial and focused coding (Charmaz, 2014). We sought interviewee permission for direct quotes from the interviews. We also identified emergent sub-topics (e.g. need for measurability within the UNFCCC forum,

TABLE 1 | Number of interviewees and their backgrounds.

Sector	Number	Geographical backgrounds interviewees
Policy maker	1	EU
Intergovernmental Organisation (IGO)	3	EU (n=2), Pacific (n=1)
Environmental Non-Government Organisation (ENGO)	7	North America (n=3), EU (n=2), Europe (non-EU) (n=2)
Academia	7	North America (n=5), Carribean (n=1), Europe (non-EU) (n=1)
Private sector	2	Europe (non-EU) (n=2)

Interviewees were from US, Sweden, Norway, Canada, UK, Fiji, Trinidad and Tobago, and Australia.

and the importance of collaborating with leading countries) which are reported in the Results section as well.

We complemented the empirical data from the interviews with information collected from reports, publications, and peer-reviewed literature. This was particularly relevant for covering gaps in the process of constructing the timeline of key events in the international governance of open ocean and fish carbon (**Figure 1**).

Finally, we also investigated which international governance frameworks currently engage most with topics related to the ocean, climate and biodiversity. We identified keywords from a comprehensive policy dataset containing >3,000 policy documents from eight global, ocean-related conventions and related instruments. These were previously mentioned in the Introduction (UNCLOS, UNCLOS PART XI, BBNJ (under negotiation), CBD, CITES, CMS, ICRW, and LC). We extracted keywords for the ocean and climate interface (*ocean* and *climate*), the keyword for *blue carbon, ocean carbon* and two keywords that could indicate aspects of the biological pump (*remineralization* and *respiration*), or the biological pump itself (*biological pump and biological carbon pump, carbon pump*). The result of this analysis (see **Box 1**) gave us some first indications of the suitability of these frameworks for governing the open ocean and fish carbon sequestration services.

3 RESULTS

3.1 Key Milestones in the International Governance of Open Ocean and Fish Carbon

Through the interviews a series of milestones (events, working groups and publications) were identified for mainstreaming the ocean as an inclusive element in the climate agenda, and for enabling the emergence of the open ocean and fish carbon discussions (**Figure 1**). These events were not isolated, and many actions, initiatives, and publications (not depicted in **Figure 1**) have contributed to their development (**Table S1** for the full list of milestones and reports mentioned by interviewees). Because this article focuses on open ocean and fish carbon we selected more milestones that involved carbon sequestration in the open ocean (by marine vertebrates such as fish and whales).

As early as 1992, the UNFCCC article 4.1, mentioned the sustainable management and conservation of appropriate sinks and reservoirs of all greenhouse gases (GHGs), including the ocean, coastlines, and marine ecosystems (UNFCCC, 1992). Furthermore, the first Ocean Action Day at the UNFCCC COP15 in 2009 marked a turn into establishing research needs and policy action for coastal blue carbon in the UNFCCC process (COP15 Presidency, 2009). In 2017, during Fiji's presidency of COP23, the "*Oceans Pathways Partnership*" was launched to encourage the climate negotiations process to address the relationship between climate change and the ocean (COP23 Presidency, 2017; IGO representative, interviewee nr. 16). Chile's 2019 COP25 was themed the Blue COP for its heavy emphasis on the ocean, impacts and the role of the ocean as a carbon sink (COP25 Presidency, 2019; IGO representative, interviewee nr. 16). Blue climate discussions started around coastal ecosystems and quantification tools for these have been developed since (e.g., carbon credits under UNFCCC) (ENGO representative, interviewee nr. 1). Fish, whale, and carbon storage in the seabed emerged later in mainstream international governance discussions and were also highlighted in public reports (ENGO representative, interviewee nr. 7). The 2019 High-Level Panel report on ocean mitigation, which discussed carbon storage in the seabed as an important carbon sink (Hoegh-Guldberg et al., 2019) was highlighted by interviewees as an important milestone for ocean carbon, as well as a highly publicised scientific paper (Sala et al., 2021) on the impact of trawling on carbon stored in the seabed. The joint 2021 IPBES-IPCC report was also reported by the interviewees, this report mentioned the contributions of fish to the biological pump (e.g. Academic, interviewee nr. 18).

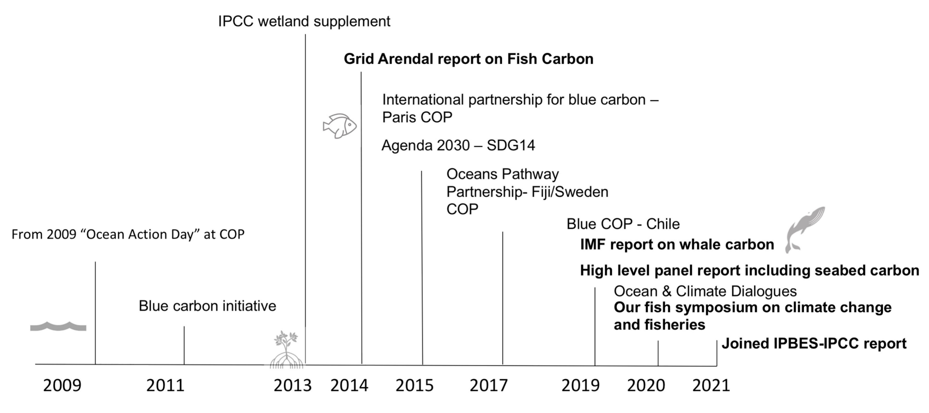

FIGURE 1 | Timeline of ocean (carbon) on the climate agenda. Events and reports printed in bold include or are about ocean and/or fish carbon. See **Table S1** for the full list of milestones and reports mentioned by interviewees.

BOX 1 | Policy documents and their focus on climate-ocean topics.

Figure 2 shows the frequency of mentions of certain topics of interest in the climate-ocean nexus, including topics that relate to the ocean as a carbon sink. We found that the CBD and UNCLOS documents have the most simultaneous mentions of climate and ocean (197 and 113 respectively). UNCLOS, CBD, UNFCCC and CMS were the only agreements that mentioned "blue carbon", and "ocean carbon" was mentioned only in the CBD. We also found that keywords indicative of the carbon pump like "respiration" and "remineralization" were mainly used in UNCLOS Part XI. This could be explained because some of these processes are discussed in the context of seabed mining which could impact carbon storage in the seabed and remineralization, which could then be respired by benthic communities (Sala et al., 2021). The CBD was the only forum that mentions "ocean carbon" and also has frequent mentions of mangroves. We found no mention of "whale carbon", "fish carbon" and "biological pump" or "carbon pump" in any of the governance documents.

Examples from some of the documents underlying the data presented in **Figure 2** are the mentioning of climate and ocean co-benefits in countries NDC's:

Example 1: "Evaluation of co-benefits the area offers in adaptation and mitigation of climate change and adjustment of management to enhance these co-benefits" (Chile NDC, 2020)

Example 2: "[...]enhancing the ocean as a carbon sink. As such, Fiji, through its National Ocean Policy, will be allocating 30% of its EEZ as Marine Protected Areas and work towards 100% management of its EEZ by 2030. (...) highlights the need to sustainably manage and protect marine and coastal ecosystems, strengthen their resilience, and restore them when they are degraded. This includes conserving ocean reservoirs as carbon sinks through supporting the restoration, enhancement and conservation of coastal ecosystems such as mangroves, sea grasses and coral reefs." (Fiji NDC, 2020)

Interviewees mostly talked about UNFCCC processes, which is to some extent in agreement with the keyword results, UNFCCC documents often mentioned ocean and climate together. However, the CBD which was hardly ever referenced by interviewees also had a high amount of joint mentioning of ocean and climate. UNCLOS was also hardly ever mentioned by interviewees but it and the CBD were the only governance frameworks that referenced elements of the biological pump in Part XI. One interviewee mentioned that fora focused on biodiversity, such as the CBD, do not often consider the climate, but this was not supported by the keyword analysis.

3.2 Key Actors and Their Role in the Evolving Awareness of the Ocean and Climate Regulation Processes

3.2.1 The Ocean as a Place of Impact and as a Place of Co-Benefits

The impact of climate change on the ocean has been highlighted in international policy making spheres such as the UNFCCC for years; it was also an important topic raised during the interviews. For instance, a number of interviewees highlighted the need for climate adaptation to help societies cope with shifts in fish stocks and the impacts of warming and acidification on marine organisms such as coral reefs. The interviewees also described a shift in attention toward the ocean as preserving ocean health for the "co-benefit" of preserving the ocean's climate regulating ecosystem services (Quote 1 & Quote 2 **Table S2**). Co-benefit, as conceptualised by the interviewees that referred to it, means that protecting ocean ecosystems is beneficial for the ecosystems and for the people that rely on them (also in light of the impacts of climate change on the ocean), but also that benefits are derived in terms of mitigating climate change. This concept of co-benefits has also been presented in the literature (Gallo et al., 2017; Chan, 2021).

3.2.2 Ocean and Climate Regulation Processes: An Evolving Awareness

Several interviewees indicated that the ocean is generally not considered a priority for those working on climate mitigation policy, whether it be at the UNFCCC, or domestically. It was reported by the interviewees that ENGOs, UN officers and policy makers from coastal countries, continuously need to push for attention towards the ocean by those working on climate change. For instance, the ENGO Ocean Conservancy used a side-event during the Climate Leaders' Summit (2021) with U.S. Special Presidential Envoy for Climate John Kerry to highlight the role of the ocean in climate change. Participants and invited policy makers "[…] *who don't normally think about oceans have a reason why they have to get smart on oceans and start to think and talk about it* […]. *I think that's been helpful.*" (ENGO representative, interviewee nr. 13). ENGO representatives and other key informants stated that this message needed to be repeated often because delegates and policy makers are frequently replaced. As mentioned in section 3.1, several COPs in which the ocean featured highly (i.e. COP23 and COP25) and the 2019 Intergovernmental Panel on Climate Change (IPCC) report on the ocean and cryosphere were mentioned several times as key milestones that convinced many actors of the important impacts of climate change on the ocean.

From the interviews it became clear that the potential to enhance and protect the sequestering services of the ocean are still predominantly associated with coastal ecosystems such as mangroves, saltmarshes, seagrasses. As reported by the interviewees, the focus on mangroves in climate agreement policy circles was thought to arise from earlier carbon offsetting methods that involved trees (REDD+), which allowed for a natural extension to mangroves in coastal areas (Quote 3, **Table S2**). Several countries such as Fiji, Chile, Costa Rica, Australia and Kenya have expressed interest in adding coastal blue carbon as a carbon mitigation strategy to their Nationally Determined Contributions (NDCs, the national level strategies to implement the Paris agreement under UNFCCC) (**Box 1**). The IPCC wetland supplement, updated in 2013, included coastal ecosystems and an approved methodology to calculate carbon stocks and changes in this system so that countries can get carbon credits for wetland restoration (IPCC, 2013). This process can only be used for coastal ecosystems where carbon is stored in the soil (ENGO representative, interviewee nr. 1).

3.2.3 Fish and Other Marine Animals as Carbon Sequesters

The interviews highlighted that awareness and knowledge about ocean and fish carbon is growing. While the fish contribution to the carbon cycle has been receiving scientific attention since at least since the 1980s, it was the ENGO Grid Arendal who coined and popularised the term "fish carbon" (Lutz and Martin, 2014).

The report (titled: Fish Carbon: Exploring Marine Vertebrate Carbon Services) was launched at the 2014 Blue Forest Meeting in Abu Dhabi, and it presented and introduced the idea of oceanic carbon sequestration in various meetings, scientific conferences, and reports in the following years.

It was pointed out by several interviewees that an increasing amount of research is emerging on the role of fishes (e.g. mesopelagic) and other marine animals such as whales and zooplankton in the ocean biological carbon pump. One interviewee pointed to the growing political attention on the topic, and that some among members of the European Union (EU) Parliament, had invited and that scientists had been invited to present on the topic at the Parliament. The contribution of fish to the biological pump was noted as a new of interest for several of the interviewees. Interviewees however also stressed that the topic (i.e. the contribution of fish to the carbon pump) is still predominantly taking place in the scientific sphere (i.e. conferences) so far only and being pushed forward by some ENGOs and scientists (Academic, interviewee nr. 18, Policy maker, interviewee nr. 8).

As mentioned in section 3.1, the 2019 IMF report (Chami et al., 2019) was considered by some of the interviewees as an important milestone. Although the IMF report is about whale carbon, it was considered to have great significance for discussions on fish carbon: '[…] *with the IMF publishing on this [whale carbon] and having it discussed at the World Economic Forum has really significantly changed this [fish carbon concept for policy making] over the past two years.*' (ENGO representative, interviewee nr. 7).

A number of interviewees referred to mesopelagic fish and their contribution to carbon cycles, (**Box 2**). The mesopelagic zone recently received increased attention in policy; exemplified by several EU funded research projects (e.g. MEESO SUMMER and MESOPP). The key motivating factor emphasised by interviewees was the high biomass estimates (Irigoien et al., 2014) highlighting mesopelagic fishes as a potentially valuable resource. In parallel to funding opportunities, a suite of reports and meetings were held featuring the mesopelagic (e.g. NAAFE, IDDRI). Interviewees emphasised the high stakes with regards to carbon flows and ecosystem processes that were supported by mesopelagic fish. They mentioned these processes as a reason for a precautionary approach regarding harvesting mesopelagic fish.

Many of the interviewees highlighted the scientific and technological uncertainties concerning fish carbon. Some of these uncertainties include, for instance, how to measure the flow of carbon, and how much of the carbon is sequestered and for how long. Interviewees mentioned that there are few concrete policy proposals that aim to integrate the carbon value of fish,

BOX 2 | Governance of mesopelagic species carbon sequestration services.

Recent scientific literature highlights the vast quantities of fish that could potentially be harvested in the mesopelagic zone (St. John et al., 2016; Alvheim et al., 2020). Mesopelagic fish are not directly consumable but could potentially be processed as nutraceuticals and fishmeal (St John et al., 2016). Experimental fisheries have thus far mainly taken place in ABNJ but in proximity to countries' EEZ (Gjerde et al., 2021). Mesopelagic fishing, if it were to be realized, would pose a trade-off between fishing and carbon sequestration. This is due to the active transport of carbon by mesopelagic species that migrate vertically (Boyd, 2019; Martin et al., 2021; Saba et al., 2021). Mesopelagic fish play a key role in food webs (Drazen and Sutton, 2017), and they and may not be very resilient to cumulative changes arising from climate change, direct harvesting, and deep-sea mining (Drazen et al., 2020).

Development of mesopelagic fisheries:

Today's mesopelagic fisheries are small and experimental (Hidalgo and Browman, 2019). Several interviewees noted that interest from the fishing industry may rise if the prospects for profitable harvesting would rise; however, highly variable catches and lack of knowledge for the causes of this variability are major barriers for fishery development. Since current fisheries are only experimental, fisheries management tools are not yet available for the mesopelagic. After catches started to be recorded under the management system in Iceland in 2010, very little mesopelagic fish were harvested (Standal and Grimaldo, 2020). A major concern for management mentioned by one interviewee was that consequences of harvesting may be experienced in a very different place where fishing occurs: "[...] *if you were try to truly assess the impact of the fishery on a species or a suite of species the scale you would look at would have to be much larger, than the footprint of the fishery itself*" (Academic Expert, interviewee nr. 12).

Governance options mentioned in the interviews for mesopelagic fish:

A number of different governance fora could proactively govern mesopelagic fish and their carbon sequestration services (Wright et al., 2020). The BBNJ agreement could be one policy instrument for governing mesopelagic fish particularly as they are not yet fished, and the number of groups potentially interested in fishing in the mesopelagic are limited (Wright et al., 2020). The agreement will use EIA, SEA, and area based management as governing mechanisms (Gjerde et al., 2021). An international, strategic environmental assessment process is conducted independent of any specific project and would aim to steer development policies (Gjerde et al., 2021). Such a process could improve understanding of the mesopelagic ecosystem before considering any exploitation. Such an assessment could, for instance, identify carbon sequestration hotspots that could be governed using area based management. Some interviewees noted that the high focus on marine genetic resources in the BBNJ could detract attention from the need to govern mesopelagic fish carbon in ABNJ. "W*e thought that it [the BBNJ agreement] would be a natural place to look because it's "Global governance of everything" but now it is really narrowing down [to marine genetic resources]"* (Academic Expert, Interviewee nr. 9). In part, this is linked to the fact that the BBNJ agreement may not undermine existing agreements and bodies (Young and Friedman, 2018). For fisheries management under UNFSA, the importance of accurate stock assessments were mentioned (Interviewee nr. 4 and nr. 12). Harvest quotas could be implemented by RFMO's and nation states based on such assessments. However, the wide-ranging distributions of mesopelagic fish and limited knowledge about their life history pose a challenge for science-based management (St. John et al., 2016) and there is some scepticism concerning the effectiveness of RFMO policies amongst interviewees (Bell et al., 2019). A collaboration between RFMOs and BBNJ agreement could be effective (Wright et al., 2020). In addition, a moratorium on mesopelagic fishing (Wright et al., 2020) has come up as a governance possibility. As a precautionary approach, the Pacific coast USA has implemented a moratorium. Motivated by the unknown consequences exploitation might have on the food web (Pacific Fishery Management Council, 2016). A moratorium on mesopelagic fishes was also mentioned by one of the interviewees, however, it is less clear which governance forum could implement such a moratorium. Finally, under the UNFCCC, one key consideration is the quantification and allocation of carbon fluxes. If carbon sequestration could be properly quantified then monetary incentives for conservation could be aligned such as putting a price on preserving mesopelagic fish for their carbon sequestration services. However, because carbon flows are not protected under UNFCCC, the limited knowledge about the magnitude of carbon stored for long-term in the seabed from those species represents one of several major barriers several interviewees explained (see Section 3.4.).

which in addition to the much-needed science information, both on the natural science side as on the legal and policy side would assist key actors to continue pushing the topic forward.

3.3 Processes Used by Key Actors to Create Attention for the Climate-Ocean Nexus

Interviewees discussed several ways in which they considered having impacted the debate around the nexus of the ocean and climate change in international policy fora. They mainly discussed events related to the UNFCCC. Potential approaches mentioned by the interviewees included the provision of technical information, the establishment of relationships with key actors including "champion" countries (countries leading on an issue in the international policy sphere), the coordination of events, and the formation of coalitions (see **Table S4** for a complete list of reported activities).

One interviewee (Policy maker, interviewee nr. 8) explained that ENGOs were instrumental in pushing the climate-ocean nexus debate. This interviewee highlighted, for example *The Ocean Pathway* which is an initiative that started during COP23 to mainstream the ocean in future COPs and is composed by a group of countries advised by (amongst others) ENGOs and IGOs. Another aim of this *Pathway* is to increase the role of the ocean in countries' NDCs. As reported by one of the interviewees, although this initiative is no longer active, it is worth mentioning it here for its pioneering work. The Marrakesh Platform and Friends of the Ocean is a new ocean pathway which is currently more active and which, similar to *The Ocean Pathway*, tries to mainstream the discussion of the ocean in climate change negotiations (IGO representative, interviewee nr. 17).

Some interviewees highlighted bridges that have been created between ENGOs, scientists and the policy sphere. For instance, as stated during the interviews, the ENGO Our Fish collaborates with scientists to present on the subject of fish carbon and mesopelagic fisheries for members of the European Parliament.

Another important collaborative strategy of ENGOs highlighted during the interviews was the establishment of good relations with representatives on government delegations. One strategy, as reported by several ENGO interviewees, is the search for "champion" countries that are leading in a certain sustainability issue. In these cases, the interviewees noted their efforts to highlight their activities while supporting countries that have a limited budget or capacity to send delegates to each negotiation. "*That's something we think about; which countries are pushing the most ambitious ocean climate action and how can we support them. How do we give them a bigger voice?*" (ENGO representative, interviewee nr. 13).

Interviewees mostly referred to impacting the policy debate around coastal blue carbon. The formation of coalitions (e.g. ENGOs and IGOs) were considered instrumental to advance the issue of coastal blue carbon. For example, the Blue Carbon Initiative, brought up by one of the interviewees, is a collaboration between the ENGO Conservation International, IOC-UNESCO and IUCN. This collaboration pushes for increased adoption of blue carbon mitigation strategies, coastal wetland preservation and carbon accounting. **Table S5** presents the list of key actors and coalitions mentioned during the interviews, as well as the policy fora with which they most frequently engage.

An event which was presented by one of the interviewees as having had an impact on policy discussions for fish carbon was "Ending overfishing as climate action". The event took place during the 2019 Blue COP co-organized among others by OurFish, and Seas At Risk. According to the interviewees, disussions have developed from this event in the UNFCCC. Moreover, an informal working group has since been established to provide the scientific basis to document the role of fish carbon in increasing climate resilience of fisheries. Moreover, a recent action plan to the European Commission from Our Fish contained the description of fish carbon sequestering services as an additional reason to conserve marine biodiversity (ENGO representative, interviewee nr. 19).

While there are some coalitions formally working together around the topic of coastal blue carbon, the interviewees did not mention any coalitions formally working on open ocean and fish carbon (Quote 4, **Table S2**).

3.4 Policy Fora for Open Ocean and Fish Carbon

Several policy fora were mentioned by the key informants interviewees that could play a role in governing open ocean and fish carbon sequestering ecosystem services. Respondents suggested six different fora. These included the BBNJ agreement, the UNFCCC, the CBD, the UNCLOS/UNFSA (including RFMO's), EU policy fora (including CFP and MSFD), and national level fisheries management (**Table 2**).

The BBNJ was the most frequently mentioned international policy forum (6 of 20 respondents), as an overarching framework that could potentially manage fish and other marine life in international waters (e.g. nascent mesopelagic fishes, **Box 2**). Management instruments under the BBNJ that were mentioned included Environmental Impact Assessment (EIA), Strategic Environmental Assessment (SEA), and Area Based Management (ABM). Interviewees suggested that if biodiversity is preserved, so are the carbon sequestering services of marine life, even if these ecosystem services are not quantified in detail. The BBNJ agreement at the moment does not specify carbon sequestration services of open ocean biodiversity (as specified by our search terms, see **Box 1** and **Figure 2**). However, there seems to be scope for taking these contributions under consideration with the specific policy instruments that are suggested to be implemented under the BBNJ (Gjerde et al., 2021; **Box 2**).

A concern raised by the interviewees in relation to BBNJ managing carbon sequestering services of marine life is that fisheries in international waters are already under the mandate of RFMOs. As reported by interviewees, some countries joining the BBNJ negotiations are cautious with regard to what extent the BBNJ agreement can address issues that are already supposed to be addressed elsewhere. Nevertheless, a stated aim of the BBNJ is to broadly regulate activities that may affect biodiversity in areas beyond national jurisdiction (ABNJ) (Quote 5, **Table S2**).

TABLE 2 | Interviewee reflections on potential policy fora, their possibilities for governance of open ocean and fish carbon sequestration services, possible barriers and concrete tools for management.

Policy forum	Possibilities (tools) for governance mentioned	Possible barriers mentioned
BBNJ (Biodiversity of Areas Beyond National Jurisdiction; under UNCLOS) (Currently being negotiated)	Address impacts on carbon sequestering contributions through EIA, SEA, and area based management.	May not address key pressures such as deep-sea mining and fishing (push from certain nations to exclude fishing); increasingly narrow focus on marine genetic resources.
UNFCCC (United Nations Convention Framework for Climate Change)	Carbon credits, NDC pledges towards increasing marine protected areas (**Box 1**).	Measurability and traceability concerns were mentioned, as was the fact that regulation *via* UNFCCC will only work if there is a way to account for carbon stored in the open ocean. Another concern mentioned is that biodiversity concerns could arise from interventions (i.e. geoengineering).
CBD (Convention on Biological Diversity)	Marine biodiversity conservation, more integration between biodiversity conservation and UNFCCC domain so that the benefit of biodiversity conservation for climate are addressed (and impact of climate change on)	*
UNFSA (United Nations Fish Stocks Agreement; under UNCLOS)	End overfishing of straddling stocks, governance of mesopelagic fisheries.	Concerns over RFMO effectiveness
	Management tools such as Stock assessments, fisheries regulation.	RFMO's designed only for target species, not biodiversity/ecosystem services
UNCLOS/National Level Fisheries management under UNCLOS	Fisheries management through e.g. quota, stock assessments.	Fisheries management has mainly been preoccupied with target stocks and not ecosystem services such as biodiversity and climate regulation.
CFP (Common Fisheries Policy)	EIA and area based management for fisheries, quota allocation based on good environmental (including carbon) performance.	Focused only on target species, not biodiversity/ecosystem services.
MSFD (Marine Strategy Framework Directive)	EIA and area based management for fisheries, marine biodiversity conservation.	Climate change concerns are not very well integrated in the MFSD.

**Policy fora are organized from most frequently mentioned to least frequently mentioned. Lack of enforcement and volunarity of national implementations were mentioned as a general concern for many conventions. Although no barriers to the CBD were specifically mentioned during the interviews, it does not mean there are no barriers to the CBD managing carbon sequestration services from fish.*

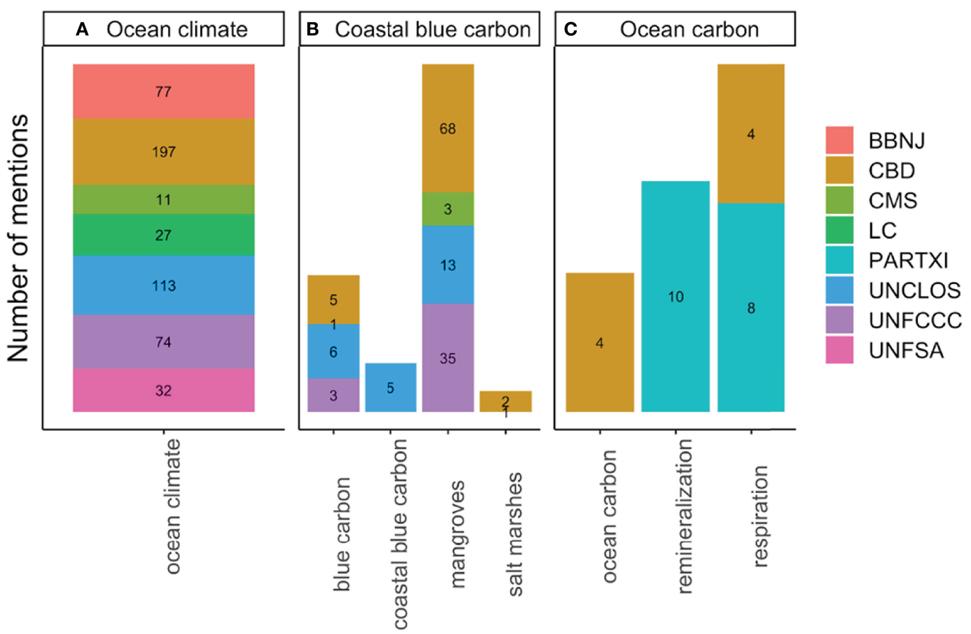

FIGURE 2 | Number of mentions per keyword in studied policy documents; BBNJ (Biodiversity of Areas Beyond National Jurisdiction); CBD (Convention on Biological Diversity); CMS (Convention on the Conservation of Migratory Species of Wild Animals); ICRW (International Convention for the Regulation of Whaling); LC (London Convention); UNCLOS (United Nations Convention of the Law of the Sea); Part XI (Part XI of UNCLOS); UNFCCC (United Nations Framework Convention on Climate Change); UNFSA (United Nations Fish Stocks Agreement). For keywords referring to **(A)** ocean and climate in the same sentence **(B)** coastal blue carbon **(C)** open ocean carbon. Note that the y-axis is log-transformed to ease interpretation.

The second most frequently mentioned forum was the UNFCCC (5 out of 20 respondents) where countries could potentially add open ocean and fish carbon sequestration to their NDC's). Policy interventions mentioned by interviewees included the 30% protection of the ocean by 2030 which is a goal that was considered feasible with our current (limited) knowledge of the ocean biological pump and the contribution of marine fauna to it (i.e. protection of large areas of ocean may protect marine habitats and animals and their carbon sequestering services) (Quote 6, **Table S2**). Fiji, for instance, aims to protect 30% of its EEZ by 2030 in its NDC to the Paris agreement, and even if the carbon contribution of that protection is not fully quantified, it is still mentioned by Fiji as a marine policy that also advances progress towards climate goals (**Box 1**). It should be noted, however, that enhancing the carbon sink contributions of the ocean was according to the interviewees, mostly directed towards coastal ecosystems, predominantly mangroves. None of the NDC's mentioned the ocean biological pump or fish carbon (**Box 1**).

Voluntary carbon markets were also mentioned as a governance strategy, however many interviewees pointed out that a much larger knowledge base would be needed for such policies. Measurability and accountability of climate mitigation actions is a big concern for NDC's as countries get carbon credits for mitigation measures. As indicated by one interviewee: "*To get blue carbon into the reporting* [of the NDC's] *we still lack robust methods for accounting of the carbon circulated in the ocean. How much is absorbed, how much is then long-term stored in the ocean floor and seabed. And how much of the carbon is stored for mid-term to centuries, in living material.*" (Policy officer, interviewee nr. 8)

Other concerns, beyond measurability, may also hamper the adoption of fish and ocean carbon mitigation into actual policy goals, especially so within the UNFCCC. First, concerns of "bluewashing" were noted in relation to the fact that if policy actions are implemented to preserve ocean carbon sinks or flows, then these actions are not fully quantifiable. Moreover, much of the marine biota that are present in the high seas are also highly mobile, which could lead to "double counting" of carbon credits in the case of e.g. implementing a voluntary carbon market for fish. This is an issue that interviewees highlighted as a major concern by those working on climate action within the UNFCCC fora (Quote 7, **Table S2**). Another type of concern that was voiced was that increasing attention to open ocean and fish carbon mitigation solutions would pull precious attention and resources away from coastal blue carbon solutions (mangroves, seagrasses, saltmarshes) for which established and measurable protocols for carbon accounting already exist.

3 of 20 interviewees also mentioned the CBD as a potential forum. One interviewee mentioned that CBD could set biodiversity targets that could be regulated under the BBNJ agreement. Interviewees also mentioned that climate contributions of biodiversity and the nexus between climate and biodiversity could be potentially better addressed in the CBD than for instance the UNFCCC. Unfortunately, the interviewees did not provide any concrete ideas or opportunities for regulatory tools that could be used to manage carbon sequestering services of marine life (see **Table 2**).

UNFSA in its capacity to regulate fishing of straddling stocks in international waters and RFMO's were also mentioned (3 of 20 respondents) as important for managing nascent mesopelagic fisheries, and fisheries in the high seas in general. However, several interviewees expressed scepticism concering their effectiveness (Quote 8, **Table S2**). The interviewees also mentioned that RFMOs may be limited in their capacity to manage open ocean and fish carbon because RFMO's are more equipped to manage target species and are not focused on biodiversity impacts of fishing (e.g. through bycatch or indirect impacts).

The EU setting was also mentioned during the interviews as potential fora for carbon sequestration services of marine life (2 out of 20); both interviewees mentioned the Common Fisheries Policy (CFP) and Marine Strategy Framework Directive (MSFD). In addition, one interviewee mentioned that within the EU regulatory framework, EIA needs to be performed for certain types of activities (Directive 2014/52/EU). This interviewee mentioned that EIA for fishing (currently not practiced), could be a future way to regulate the carbon sequestration done by fish, by quantifying the (approximate) impact the fishery has on the (potential) carbon sequestering services of marine animals during the allocation of fishing opportunities (Quote 9, **Table S2**).

Interviewees also brought up the topic that ending the overfishing of marine populations and ending destructive fishing practises (e.g. overfishing, habitat destructive practises such as trawling) that are harmful for marine biodiversity would have several climate co-benefits which align with recent research (e.g. Sumaila and Tai, 2020). For instance, restored fish populations could lead to shorter fishing trips and hence the use of less fuel.

Quota allocation with environmental and carbon sequestration concerns in mind were also mentioned as a potential tool available at the national level. Local fisheries management in national waters was mentioned (3 of 20 interviewees) as the main framework under which carbon sequestering services of marine life could be managed, mainly through the setting of fishing quota and the importance of proper stock assessments was also stressed.

A number of interviewees did not think that carbon sequestration services of marine animals such as fish and marine mammals should be actively managed, and that other ecosystem services of fish such as food provisioning should be enough to manage them. Among the mentioned reasons was that a better scientific understanding of the carbon sequestering ecosystem services was needed before deciding on suitable policy fora. Other interviewees talked about governance in general terms without mentioning specific policy fora. **Box 3** discusses different pathways for the management of fish carbon and possible knowledge requirements.

4 DISCUSSION

In this study we interviewed 20 key informants that comprised experts and policy makers on topics related to the governance of

BOX 3 | Should open ocean and fish carbon be governed?

Currently there is a lack of knowledge on ecosystem trade-offs arising from fishing for nutrition and species' contribution to carbon fluxes (Saba et al., 2021; Martin et al., 2021). Estimates of the contributions of fish to the sequestration of carbon to the deep sea vary widely. A recent synthesis reports that fish contribute 16.1% (±13%) to total carbon flux out of the euphotic zone, which could equate to an annual flux of 1.5 ± 1.2 PgC per year, an estimated 8% of which gets extracted by marine fisheries (Saba et al., 2021). Quantification of these carbon flows is still ongoing as mentioned by several interviewed experts in this study. Saba et al. (2021) and Martin et al. (2021) list several recommendations for science on the role of the fish-based contribution to the ocean carbon flux, including a better integration of field, lab and modeling studies and more experiments on representative species for functional taxa. Once more data becomes available on fish-based contributions to carbon flux, and these contributions become more specific for the different taxa and regions, more clarity can arise around the carbon trade-offs associated with exploiting marine populations, or other impactful activities such as deep-sea mining (Drazen et al., 2020). For instance, the estimated carbon footprint of fishing of 0.73 GtC, between 1950-2014 (Mariani et al., 2020) is still much lower than the carbon footprint of livestock production (Hilborn et al., 2018). Next to the natural science knowledge needs, studies are needed on how governance of open ocean and fish carbon can be materialized, legally and practically. For instance, if instruments such as EIA and SEA were to consider open ocean and fish carbon, more knowledge would be needed on how to implement the assessment and evaluate trade-offs between carbon flux and the social cost of carbon (Nordhaus, 2017).

There are four potential management options that we identified through our interviews: Option 1) exploiting fish stocks to a lesser degree while considering their carbon sequestration value in fisheries management systems. Maximum sustainable yield (MSY), a common fisheries management target could include a carbon sequestration target. Interviewee nr. 7 referred to this simple heuristic as MSY+C, which in some fisheries may lead to lower rates of extraction than those for MSY as found by Jennings and Wilson (2009) for carbonate production by fish. Incentives for this approach could come from voluntary carbon markets. Option 2) investing more in efforts to halt illegal and unreported fishing as well as overfishing. Option 3) taking a precautionary approach for new fisheries, i.e. a moratorium on exploitation of certain fish populations that play an especially important role in the global carbon cycle, e.g. mesopelagic fish Martin et al., 2021). Option 4) When considering human activities, account for carbon emissions lost carbon sequestration services, and possibly cascading ecosystem effects on carbon sequestration in EIA and SEA (Martin et al., 2021). Knowledge needs will differ for all those options, with most needed to consider the value of carbon in fisheries management (option 1) EIA or SEA (option 4), than for the precautionary approach and the knowledge on the damaging effects of overfishing (option 2 and 3, respectively).

ocean and fish carbon. Based on the interview results, we mapped out a timeline of milestones in the governance of coastal and open ocean and fish carbon (**Figure 1**) and we asked interviewees about opportunities for policy action with regards to ocean carbon (see results in **Table 2**). Key findings were that while much of the attention ENGOs directed toward fish carbon was focussed on the UNFCCC, many interviewees found this forum an unlikely arena for the management of open ocean and fish carbon. These doubts were raised due to key uncertainties with regards to the tracking of open ocean and fish carbon and the mobility of marine fauna. Several interviewees mentioned the BBNJ as a promising avenue for governance of open ocean and fish carbon, however important barriers of this governance forum were also highlighted (**Table 2**).

4.1 The Evolving Science and Debate on the Oceans and Climate Change

The international debate on ocean and climate has evolved over the years. Earliest discussions focussed primarily on climate impacts on the ocean. This grew to also include Nature-Based Solutions (Roberts et al., 2017; Seddon et al., 2019) such as carbon sequestration ecosystem services of the ocean, with an emphasis on coastal ecosystems (Chan, 2021). This has further progressed to discussions of open ocean and fish carbon sequestration (Mariani et al., 2020; Pörtner et al., 2021). Scientific attention at the nexus of oceans and climate has mainly focused on climate change impacts on marine ecosystems and societies that depend on them (e.g. Cheung et al., 2010; Pinsky et al., 2013; Olsen et al., 2018; Rogers et al., 2019). Work on adaptation to those impacts were a natural extension to this research and policy focus (Fulton et al., 2011; Ojea et al., 2017; Young et al., 2019; Woods et al., 2022). Related governance challenges on this climate and ocean space include fisheries conflict, and static, non-adaptive management arrangements (Spijkers and Boonstra, 2017; Pinsky et al., 2018; Spijkers et al., 2018). Fisheries have grown to be a major issue for coastal nations in their NDCs, primarily in the adaptation sections (Gallo et al., 2017), and RFMOs are increasingly under pressure to consider climate adaptive management approaches (Pentz et al., 2018). In the BBNJ agreement, impacts from climate change may be considered in the assessment of cumulative impacts (Gjerde et al., 2021).

4.2 Climate Co-Benefits of a Healthy Ocean and the Emergence of the Topic "Fish and Open Ocean Carbon"

Healthy marine and coastal ecosystems sequester more carbon than ocean ecosystems that are heavily affected by anthropogenic degradation (Chmura et al., 2003; Saba et al., 2021). The presentation of policy making for the ocean-climate nexus has now resulted in a lively discourse on the carbon sequestering capabilities of marine ecosystems at important policy fora such as the UNFCCC (Chan, 2021) but to a lesser extent at policy fora aimed at biodiversity protection such as the BBNJ agreement or the CBD. Coastal blue carbon is carbon that is absorbed and stored by marine plants, and has received substantial attention both as a climate mitigation and adaptation strategy in policy fora such as UNFCCC, attention which has be supported and pushed for by IUCN and ENGOs (Howard et al., 2017; Lovelock and Duarte, 2019). To date, this push for, and increase in blue carbon measuring and offsetting has concentrated on coastal blue carbon, including rooted vegetation in the coastal zone, such as tidal marshes, mangroves and seagrasses, where the carbon is stored in the soil (Howard et al., 2017). Such ecosystems both store more carbon per m^2 than terrestrial forests (Chmura et al., 2003; Sapkota and White, 2020) and assist with coastal protection, which is especially needed with sea level rise (Marois and Mitsch, 2015). The interest in open ocean and fish carbon associated with marine organisms' carbon sequestration and cycling has emerged recently, with increasing publications in the contributions of different species to carbon cycling in the open ocean (Mariani et al., 2020; Bianchi et al., 2021; Martin et al., 2021; Saba et al., 2021). However, the body of scientific literature on the carbon sequestering services of coastal blue carbon is much larger (Kelleway et al., 2017), but even for these ecosystems actual implemented policies are still sparse (Cooley et al., 2019). There will thus be several important hurdles that need to be cleared before open ocean and fish carbon could be governed explicitly. However, the increasing awareness of this ecosystem service of fish and the developing science around it may create increased awareness of the trade-offs associated with actions that have negative consequences for fish populations (e.g. direct exploitation, or habitat damage) (Saba et al., 2021).

4.3 ENGOs and Intergovernmental Organisations' Role in the International Policy Fora on the Topic of Open Ocean Carbon

ENGOs and intergovernmental organisations such as IUCN or IOC-UNESCO have highlighted the co-benefits derived from a healthy ocean for the climate. This message is now embedded in the international policy space, especially within the UNFCCC (Chan, 2021). In the case of ENGOs this is an interesting result because it highlights their role in international policy fora. ENGOs bring a global and regional perspective to the policy-making fora, a perspective which contrasts to the protection of national interests brought by individual states (Grip, 2017). Some individual states for which the ocean is particularly important (i.e. small island developing states, or states with long coastlines) have particularly pushed for ocean action in the climate realm (as opposed to e.g. landlocked countries). We learned from our interviews that ENGOs have formed alliances with some of these countries, and in this way have helped to increase attention to the ocean in the climate regime as after all "*the making of international agreements remain the domain of states*" (Sénit, 2020).

ENGOs representatives talked about a mix of strategies, with a heavy emphasis on insider tactics in the case of ocean carbon (inside negotiating hubs, i.e. information, expertise and opinions provided in oral or written interventions during formal and informal settings (Blasiak et al., 2017; Sénit, 2020). While ENGOs engaged in outreach to create awareness on the ocean, and some of the co-benefits that can be derived from a healthy ocean, the topic of climate-ocean nexus seemed to be a story that is being told within ENGOs. At the same time, while interviewed actors noted a growing interest by policy makers on the topic of ocean and fish carbon, it is too early to say that the interest is merely in the research itself, or to develop actual policies.

4.4 Possible Policy Fora for Open Ocean and Fish Carbon

Interviewees were asked the question *how can carbon sequestration in the ocean be effectively managed*? Six different fora were suggested: BBNJ, UNFCCC, CBD, UNCLOS, UNFSA (RFMOs), EU policy fora (CFP and MSFD), and national fisheries management. The BBNJ, UNFCCC, and UNFSA are current fora which discuss open ocean and fish carbon to varying degrees (**Box 1**). Preserving biodiversity for climate regulation is beneficial, both for addressing rapidly declining biodiversity, and for its sequestration capacities. However, a number of interviewees concluded that the time is not ripe to actively manage carbon sequestering capabilities of marine life such as fish and whales under the UNFCCC framework. Some of the concerns that were raised by the interviewees related to the measurability and traceability issues in connection to the open ocean fish carbon. The science is still at very early stages which may mean that avenues for "bluewashing" (unquantifiable actions related to ocean mitigation solutions) are opened and that countries may use the carbon sequestering capabilities of the ocean to avoid other difficult transitions. This concern is more widely applicable to carbon offsets using biodiversity targets (Rantala et al., 2019).

Although many uncertainties remain, the science on carbon sequestering capabilities of fish and marine life is growing rapidly (Martin et al., 2021; Saba et al., 2021). It is not unimaginable that in a further future also flows of carbon could be protected within UNFCCC. It should however be noted that most carbon sequestered by the ocean is released back into the atmosphere on longer timescales (Passow and Carlson, 2012), and this sequestration is thus not a permanent solution to the amount of carbon released into the atmosphere by anthropogenic activity.

Results of this paper regarding policy fora largely confirmed their role in protecting ecosystems and biodiversity described in previous literature. RFMO's for instance were mentioned by the interviewees for their importance in the management of high seas fisheries (and for their relevance to the future management of e.g. mesopelagic fishes). However, interviewees also indicated that RFMO's were not very effective in enforcing ecosystem based management, something that is also reflected in the literature (Koubrak and VanderZwaag, 2020). In a similar vein national level fisheries management was also mentioned as a possible solution for managing ecosystem services of fish, amongst which would be their carbon sequestering capabilities. Interviewees mentioned the focus on single species as a possible barrier, an issue which is also reflected in previous literature (Link, 2002). The BBNJ agreement was mentioned as a possible forum using its tools such as EIA and area based management, which has been emphasised before (Gjerde et al., 2021). Nevertheless, a number of interviewees were concerned that negotiations for the BBNJ agreement were currently dominated by the issues of Marine Genetic resources, as has been noted elsewhere (Blasiak et al., 2017; De Santo et al., 2020).

4.5 Integration Between Policy Fora

Interviewees suggested that agreements could benefit from increased cooperation and integration with each other. For instance, it was mentioned that in biodiversity agreements such as the CBD and BBNJ, the consideration of carbon sinks is lacking and within the UNFCCC the role of biodiversity is currently not considered. It was stressed that those agreements could benefit from increased cooperation and integration with each other between themselves and the UNFCCC. "Within the *UNFCCC few think about the impacts of climate on biodiversity or whether biodiversity might have an impact on climate; they don't really talk to each other. It is worth thinking about whether* *we can bridge the silos between those working on biodiversity and those working on climate."* (ENGO representative, interviewee nr. 13).

A number of interviewees also mentioned the creation of a working group between several policy fora (UNFCCC, UNCLOS, CBD) as an option to find synergies between biodiversity and climate change targets, as well as impacts that go both ways (climate change impacting biodiversity, biodiversity impacting climate change). The synergy (and possible trade-offs) between biodiversity protection and climate regulation, and the role that existing UN frameworks could play in this cross-cutting issue has been addressed previously (Azizi et al., 2019; Rantala et al., 2019; Pörtner et al., 2021). Rantala et al. (2019) focused mostly on terrestrial ecosystems and found that concrete measures towards sustainable agriculture that addresses both carbon and other greenhouse gas emissions and biodiversity protection are mostly missing from the CBD and UNFCCC. Azizi et al. (2019) found some level of overlap between ocean and biodiversity international agreements, but concluded that clusters of agreements were largely self-referential and operated in silos.

Surprisingly, there was not a single mention of UNCLOS Part XI by interviewees as a potential forum for the management of open ocean and fish carbon. This was surprising as deep sea mining would be regulated under this convention in areas beyond national jurisdiction (Thompson et al., 2018) and could have a large impact on carbon sequestration in the deep sea (Nagender Nath et al., 2012; Stratmann et al., 2018).

4.6 Trade-Offs and Synergies Between Carbon Sequestering, Biodiversity and Food Provisioning of Marine Fishes

Possible trade-offs between climate action and biodiversity enhancement deserve further attention. Climate regulation action could also negatively affect biodiversity and ecosystem functioning (Rantala et al., 2019). In the case of fish carbon leaving more fish biomass in the sea, people could switch to other foods. This switch could result in more greenhouse gas emissions in the case of animal-based products (Hilborn et al., 2018). Halting overfishing however, will likely only be synergistic, both for food security (Srinivasan et al., 2010; Cabral et al., 2019), greenhouse gas emissions from fuel used for fishing (Hornborg and Smith, 2020; Byrne et al., 2021), but also for preserving the carbon sequestering services of fish populations (Mariani et al., 2020; Cavan and Hill, 2022).

Our study has several important caveats that need to be considered when interpreting the results. We have focused on ENGOs, IGOs, policy experts, and policy makers but we did not consider the industry perspective. During the interviews it was mentioned that industry could become engaged with the topic of open ocean and fish carbon if there are concrete policy proposals, policy action, or regulations put into place. It would be of interest to examine what would motivate industry groups to allocate time and effort to the topic of fish and ocean carbon. Moreover, using the snowball approach for sampling we may have missed voices in the debate (Parker et al., 2019). The approach also gives us a biased sample of interviewees that may share a similar message (Parker et al., 2019) Moreover, the approach for selecting key informants, both the web-based search and the snow-ball approach has probably been the cause for the fact that most of our interviewees work for North American or European institutions, despite actively trying to include a more diverse perspective. The article should therefore not be read as representative of the fields of coastal blue carbon and open ocean and fish carbon. The snowball approach was however a very useful tactic for us to find voices in the debate that were not as prominent in the public sphere.

An example of voices that we missed were indigenous communities. Small island developing states (SIDS) and indigenous communities often rely heavily on natural resources for their livelihoods, and for some indigenous and SIDS communities, seafood and fisheries are important for livelihoods, food security and cultural heritage (Bess, 2001; Cisneros-Montemayor et al., 2016; Blanchard et al., 2017). Governance for open ocean and fish carbon could have implications for these communities, by for instance restricting fishing access (Mascia et al., 2010; Ban and Frid, 2018). Therefore, it is crucial that indigenous voices are represented when policy solutions are designed, to pursue sustainable and equitable pathways for ocean and fish carbon governance (Klain et al., 2014). The governance of open ocean ecosystems can potentially affect the lives of indigenous communities through food-web effects on top predators e.g. many tuna and sea turtles feed in the open ocean and also provide ecosystem services (e.g. fishing, tourism, respectively) to indigenous communities. Moreover, since these communities, including SIDS, are more at risk from climate change the inclusion of these voices is also needed for these debates and governance designs (such as the BBNJ). In addition, our interview results showed, for instance, that SIDS such as Fiji have been key in raising awareness for the oceans in particular (Chan, 2021) and creating leverage for climate interventions (Benwell, 2011).

5 CONCLUSION

We found that many of the key events that were mentioned by the interviewees were UNFCCC initiatives. However, given the strict requirements within UNFCCC for measurability and traceability, other governance fora (e.g. CBD or BBNJ agreement) seem a more likely venue for the governance of open ocean and fish carbon sequestration services. Increased attention to open ocean and fish carbon in these fora (CBD or BBNJ) may facilitate the establishment of feasible policy proposals. Moreover, based on the interviews it seems that opposition to the "fish carbon" concept from specialists working with coastal blue carbon may slow down policy adoption in intergovernmental fora such as UNFCCC. The results of our interviews highlighted that the area based management and EIA tools facilitated through the BBNJ agreement are the most promising candidates to govern mesopelagic fish and their important carbon sequestering ecosystem services (which is in line with Gjerde et al., 2021), especially if combined with other governance fora (i.e. RFMO's or UNFSA). This is an important finding to keep in mind for the ongoing negotiations regarding biodiversity in ABNJ.

DATA AVAILABILITY STATEMENT

The data sets presented in this article are not readily available because the information provided in the confidential interviews was used for research purposes. The results from these interviews are included in this article which is published online and made available to the public. Personal information and interview transcripts are anonymous.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by WMU Research Ethics Committee, REC DECISION # REC-21-05(R). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

Conceptualization, MSW, MO and LE. Analysis, MO, LE, and PR-M. Visualization, MO and LE. Writing, MO, LE, PR-M, and MSW. Editing, all authors. Supervision, MSW. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2022.764609/full#supplementary-material

REFERENCES

Alvheim, A. R., Kjellevold, M., Strand, E., Sanden, M., and Wiech, M. (2020). Mesopelagic Species and Their Potential Contribution to Food and Feed Security—a Case Study From Norway. *Foods* 9, 1–19. doi: 10.3390/foods9030344

Azizi, D., Biermann, F., and Kim, R. E. (2019). Policy Integration for Sustainable Development Through Multilateral Environmental Agreements. *Glob. Gov.* 25, 445–475. doi: 10.1163/19426720-02503005

Ban, N. C., and Frid, A. (2018). Indigenous Peoples' Rights and Marine Protected Areas. *Mar. Policy* 87, 180–185. doi: 10.1016/j.marpol.2017.10.020

Bell, J. B., Guijarro-Garcia, E., and Kenny, A. (2019). Demersal Fishing in Areas Beyond National Jurisdiction: A Comparative Analysis of Regional Fisheries Management Organisations. *Front. Mar. Sci.* 6. doi: 10.3389/fmars.2019.00596

Benwell, R. (2011). The Canaries in the Coalmine: Small States as Climate Change Champions *Round Table* 100, 199–211. doi: 10.1080/00358533.2011.565632

Bess, R. (2001). New Zealand's Indigenous People and Their Claims to Fisheries Resources. *Mar. Policy* 25, 23–32. doi: 10.1016/S0308-597X(00)00032-4

Bianchi, D., Carozza, D.A., Galbraith, E.D., Guiet, J., and DeVries, T. (2021). Estimating Global Biomass and Biogeochemical Cycling of Marine Fish With and Without Fishing. *Sci. Adv.* 7, eabd7554. doi: 10.1126/sciadv.abd7554

Biermann, F., and Dingwerth, K. (2004). *Global Environmental Change and the Nation State* (MIT Press), 1–23.

Blanchard, J. L., Watson, R. A., Fulton, E. A., Cottrell, R. S., Nash, K. L., Bryndum-Buchholz, A., et al. (2017). Linked Sustainability Challenges and Trade-Offs Among Fisheries, Aquaculture and Agriculture. *Nat. Ecol. Evol.* 1, 1240–1249. doi: 10.1038/s41559-017-0258-8

Blasiak, R., Durussel, C., Pittman, J., Sénit, C. A., Petersson, M., and Yagi, N. (2017). The Role of NGOs in Negotiating the Use of Biodiversity in Marine Areas Beyond National Jurisdiction. *Mar. Policy* 81, 1–8. doi: 10.1016/j.marpol.2017.03.004

Boyd, P. W. (2019). Physiology and Iron Modulate Diverse Responses of Diatoms to a Warming Southern Ocean. *Nat. Clim. Change* 9, 148–152. doi: 10.1038/s41558-018-0389-1

Boyd, P. W., Claustre, H., Levy, M., Siegel, D. A., and Weber, T. (2019). Multi-faceted Particle Pumps Drive Carbon Sequestration in the Ocean. *Nature* 568, 327–335. doi: 10.1038/s41586-019-1098-2

Brinkman, S., and Kvale, S. (2015). *Interviews: Learning the Craft of Qualitative Research Interviewing* (Thousand Oaks, CA: Sage Publications).

Brodie, R. T., Ruckelshaus, M., Swilling, M., Allison, E. H., Österblom, H., Gelcich, S., et al. (2020). A Transition to Sustainable Ocean Governance. *Nat. Commun.* 11, 3600. doi: 10.1038/s41467-020-17410-2

Bryman, A. (2016). *No Social Research Methods* (Oxford: Oxford University Press).

Buchanan, A., and Keohane, R. O. (2006). The Legitimacy of Global Governance Institutions. *Ethics. Int. Aff.* 20, 405–437. doi: 10.1111/j.1747-7093.2006.00043.x

Byrne, C., Agnarsson, S., and Davidsdottir, B. (2021). Fuel Intensity in Icelandic Fisheries and Opportunities to Reduce Emissions. *Mar. Policy* 127, 104448. doi: 10.1016/j.marpol.2021.104448

Cabral, R. B., Halpern, B. S., Lester, S. E., White, C., Gaines, S. D., and Costello, C. (2019). Designing MPAs for Food Security in Open-Access Fisheries. *Sci. Rep.* 9, 1–10. doi: 10.1038/s41598-019-44406-w

Cavan, E. L., and Hill, S. L. (2022). Commercial Fishery Disturbance of the Global Ocean Biological Carbon Sink. *Glob. Change Biol.* 28, 1212–1221. doi: 10.1111/gcb.16019

Chami, R., Cosimano, T., Connel, F., and Oztosun, S. (2019). Nature's Solution to Climate Change: A Strategy to Protect Whales can Limit Greenhouse Gases and Global Warming. *Financ. Dev.* 56, 34–38. doi: 10.5089/9781498316880.022

Chan, N. (2021). Linking Ocean and Climate Change Governance. *WIREs. Clim. Chang.* 1–12. doi: 10.1002/wcc.711

Charmaz, K. (2014). *Constructing Grounded Theory.* (London: Sage Publications).

Cheung, W. W. L., Lam, V. W. Y., Sarmiento, J. L., Kearney, K., Watson, R., Zeller, D., et al. (2010). Large-scale Redistribution of Maximum Fisheries Catch Potential in the Global Ocean Under Climate Change. *Glob. Change Biol.* 16, 24–35. doi: 10.1111/j.1365-2486.2009.01995.x

Chmura, G. L., Anisfeld, S. C., Cahoon, D. R., and Lynch, J. C. (2003). Global Carbon Sequestration in Tidal, Saline Wetland Soils. *Global Biogeochem. Cycles.* 17, 1–12. doi: 10.1029/2002gb001917

Cisneros-Montemayor, A. M., Pauly, D., Weatherdon, L. V., and Ota, Y. (2016). A Global Estimate of Seafood Consumption by Coastal Indigenous Peoples. *PloS One* 11, 1–16. doi: 10.1371/journal.pone.0166681

Cooley, S. R., Bello, B., Bodansky, D., Mansell, A., Merkl, A., Purvis, N., et al. (2019). Overlooked Ocean Strategies to Address Climate Change. *Glob. Environ. Chang.* 59, 1–5. doi: 10.1016/j.gloenvcha.2019.101968

COP15 Presidency (2009) in *Conference of the Parties (Cop), Fifteenth session*, Copenhagen, Denmark, December 2009. 7–18. Available at: https://unfccc.int/process-and-meetings/conferences/past-conferences/copenhagen-climate-change-conference-december-2009/cop-15/cop-15-documents.

COP23 Presidency (2017) *Fiji and Sweden Launch Ocean Pathway to Draw Stronger Link Between Climate Change and the Ocean.* Available at: https://cop23.com.fj/fiji-sweden-launch-ocean-pathway-draw-stronger-link-climate-change-ocean/.

COP25 Presidency (2019) in *UN Climate Change Conference*,, December 2019. Available at: https://unfccc.int/cop25.

Davison, P. C., Checkley, D. M., Koslow, J. A., and Barlow, J. (2013). Carbon Export Mediated by Mesopelagic Fishes in the Northeast Pacific Ocean. *Prog. Oceanogr.* 116, 14–30. doi: 10.1016/j.pocean.2013.05.013

Dellmuth, L. M., and Bloodgood, E. A. (2019). Advocacy Group Effects in Global Governance: Populations, Strategies, and Political Opportunity Structures. *Interes. Groups. Advocacy.* 8, 255–269. doi: 10.1057/s41309-019-00068-7

Dellmuth, L. M., Petersson, M. T., Dunn, D. C., Boustany, A., and Halpin, P. N. (2020). Empowering NGOs? Long-Term Effects of Ecological and Institutional Change on Regional Fisheries Management Organizations. *Glob. Environ. Chang.* 65. doi: 10.1016/j.gloenvcha.2020.102197

De Santo, E. M., Mendenhall, E., Nyman, E., and Tiller, R. (2020). Stuck in the Middle With You (and Not Much Time Left): The Third Intergovernmental Conference on Biodiversity Beyond National Jurisdiction. *Mar. Policy* 117. doi: 10.1016/j.marpol.2020.103957

Dobush, B. J., Gallo, N. D., Guerra, M., Guilloux, B., Holland, E., Seabrook, S., et al. (2021). A New Way Forward for Ocean-Climate Policy as Reflected in the UNFCCC Ocean and Climate Change Dialogue Submissions. *Clim. Policy* 0, 1–18. doi: 10.1080/14693062.2021.1990004

Drazen, J. C., Smith, C. R., Gjerde, K. M., Haddock, S. H. D., Carter, G. S., Anela Choy, C., et al. (2020). Midwater Ecosystems Must be Considered When Evaluating Environmental Risks of Deep-Sea Mining. *Proc. Natl. Acad. Sci. U.S.A.* 117, 17455–17460. doi: 10.1073/pnas.2011914117

Drazen, J. C., and Sutton, T. T. (2017). Dining in the Deep: The Feeding Ecology of Deep-Sea Fishes. *Ann. Rev. Mar. Sci.* 9, 337–366. doi: 10.1146/annurev-marine-010816-060543

Duarte, C. M., Agusti, S., Barbier, E., Britten, G. L., Castilla, J. C., Gattuso, J. P., et al. (2020). Rebuilding Marine Life. *Nature* 580, 39–51. doi: 10.1038/s41586-020-2146-7

Durfort, A., Mariani, G., Tulloch, V., Troussellier, M., and Mouillot, D. (2021). The Collapse and Recovery Potential of Carbon Sequestration by Baleen Whales in the Southern Ocean. *Res. Sq.* 33, 1–28. doi: 10.21203/rs.3.rs-92037/v1

Fiji NDC. (2020). *Fiji's Updated Nationally Determined Contribution* Retrieved from: https://www4.unfccc.int/sites/ndcstaging. (Accessed on August 2021).

Fulton, E. A., Link, J. S., Kaplan, I. C., Savina-Rolland, M., Johnson, P., Ainsworth, C., et al. (2011). Lessons in Modelling and Management of Marine Ecosystems: The Atlantis Experience. *Fish. Fish.* 12, 171–188. doi: 10.1111/j.1467-2979.2011.00412.x

Gallo, N. D., Victor, D. G., and Levin, L. A. (2017). Ocean Commitments Under the Paris Agreement. *Nat. Clim. Change* 7, 833–838. doi: 10.1038/nclimate3422

Gjerde, K. M., Wright, G., and Durussel, C. *Strengthening High Seas Governance Through Enhanced Environmental Assessment Processes. A Case Study of Mesopelagic Fisheries and Options for a Future Bbnj TreatySTRONG High Seas Project* (2021) 1–56. doi: 10.48440/iass.2021.001

Grimaldo, E., Grimsmo, L., Alvarez, P., Herrmann, B., Tveit, G. M., Tiller, R., et al. (2020). Investigating the Potential for a Commercial Fishery in the Northeast Atlantic Utilizing Mesopelagic Species. *Ices. J. Mar. Sci.* 77, 2541–2556. doi: 10.1093/icesjms/fsaa114

Grip, K. (2017). International Marine Environmental Governance: A Review. *Ambio* 46, 413–427. doi: 10.1007/s13280-016-0847-9

Hidalgo, M., and Browman, H. I. (2019). Developing the Knowledge Base Needed to Sustainably Manage Mesopelagic Resources. *Ices. J. Mar. Sci.* 76, 609–615. doi: 10.1093/icesjms/fsz067

Hilborn, R., Banobi, J., Hall, S. J., Pucylowski, T., and Walsworth, T. E. (2018). The Environmental Cost of Animal Source Foods. *Front. Ecol. Environ.* 16, 329–335. doi: 10.1002/fee.1822

Hoegh-Guldberg, O., Caldeira, K., Chopin, T., Gaines, S., Haugan, P., Hemer, M., et al. (2019). *The Ocean as a Solution to Climate Change: Five Opportunities for Action. Report* (Washingt: World Resour. Institute). Available at: http://www.oceanpanel.org/climate116.

Hornborg, S., and Smith, A. D. M. (2020). Fisheries for the Future: Greenhouse Gas Emission Consequences of Different Fishery Reference Points. *Ices. J. Mar. Sci.* 77, 1666–1671. doi: 10.1093/icesjms/fsaa077

Howard, J., Sutton-Grier, A., Herr, D., Kleypas, J., Landis, E., Mcleod, E., et al. (2017). Clarifying the Role of Coastal and Marine Systems in Climate Mitigation. *Front. Ecol. Environ.* 15, 42–50. doi: 10.1002/fee.1451

IOC-R (2021). *Integrated Ocean Carbon Research: A Summary of Ocean Carbon Research, and Vision of Coordinated Ocean Carbon Research and Observations for the Next Decade*. Eds. R. Wanninkhof, C. Sabine and S. Aricò (Paris, UNESCO: IOC Technical Series, 158Rev), 46 pp. doi: 10.25607/h0gj-pq41

IPCC (2013). *Methodological Guidance on Lands With Wet and Drained Soilds, and Constructed Wetlands for Wastewater Treatment 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (Wetlands (Switzerland: IPCC).

Irigoien, X., Klevjer, T. A., Røstad, A., Martinez, U., Boyra, G., Acuña, J. L., et al. (2014). Large Mesopelagic Fishes Biomass and Trophic Efficiency in the Open Ocean. *Nat. Commun.* 5, 3271. doi: 10.1038/ncomms4271

Jennings, S., and Wilson, R. W. (2009). Fishing Impacts on the Marine InorganicCarbon Cycle. *J. Appl. Ecol.* 46, 976–982.

Kelleway, J., Serrano, O., Baldock, J., Cannard, T., Lavery, P., Lovelock, C. E., et al. (2017). Technical Review of Opportunities for Including Blue Carbon in the Australian Government's Emissions Reduction Fund. *CSIRO. Aust.* 295, 61–296.

Klain, S. C., Beveridge, R., and Bennett, N. J. (2014). Ecologically Sustainable But Unjust? Negotiating Equity and Authority in Common-Pool Marine Resource Management. *Ecol. Soc.* 19, 1–15. doi: 10.5751/ES-07123-190452

Koubrak, O., and VanderZwaag, D. L. (2020). Are Transboundary Fisheries Management Arrangements in the Northwest Atlantic and North Pacific Seaworthy in a Changing Ocean? *Ecol. Soc* 25, 1. doi: 10.5751/ES-11835-250442

Link, J. S. (2002). What Does Ecosystem-Based Fisheries Management Mean? *Fisheries* 27, 18–21. doi: 10.1577/1548-8446(2002)027<0010:ECIFM>2.0.CO;2

Lotze, H. K., and Worm, B. (2009). Historical Baselines for Large Marine Animals. *Trends Ecol. Evol.* 24, 254–262. doi: 10.1016/j.tree.2008.12.004

Lovelock, C. E., and Duarte, C. M. (2019). Dimensions of Blue Carbon and Emerging Perspectives. *Biol. Lett.* 15, 1–5. doi: 10.1098/rsbl.2018.0781

Lutz, S., and Martin, A. (2014). Fish Carbon: Exploring Marine Vertebrate Carbon Services. *Grid-Arendal.* 1–36.

Mariani, G., Cheung, W. W. L., Lyet, A., Sala, E., Mayorga, J., Velez, L., et al. (2020). Let More Big Fish Sink: Fisheries Prevent Blue Carbon Sequestration-Half in Unprofitable Areas. *Sci. Adv.* 6, 1–9. doi: 10.1126/sciadv.abb4848

Marois, D. E., and Mitsch, W. J. (2015). Coastal Protection From Tsunamis and Cyclones Provided by Mangrove Wetlands - A Review. *Int. J. Biodivers. Sci. Ecosyst. Serv. Manage.* 11, 71–83. doi: 10.1080/21513732.2014.997292

Martin, A. H., Pearson, H. C., Saba, G. K., and Olsen, E. M. (2021). Integral Functions of Marine Vertebrates in the Ocean Carbon Cycle and Climate Change Mitigation. *One Earth* 4, 680–693. doi: 10.1016/j.oneear.2021.04.019

Mascia, M. B., Claus, C. A., and Naidoo, R. (2010). Impacts of Marine Protected Areas on Fishing Communities. *Conserv. Biol.* 24, 1424–1429. doi: 10.1111/j.1523-1739.2010.01523.x

McCauley, D. J., Pinsky, M. L., Palumbi, S. R., Estes, J. A., Joyce, F. H., and Warner, R. R. (2015). Marine Defaunation: Animal Loss in the Global Ocean. *Science (80-)* 347, 247–255. doi: 10.1126/science.1255641

Merrie, A., Dunn, D. C., Metian, M., Boustany, A. M., Takei, Y., Elferink, A. O., et al. (2014). An Ocean of Surprises - Trends in Human Use, Unexpected Dynamics and Governance Challenges in Areas Beyond National Jurisdiction. *Glob. Environ. Change* 27, 19–31. doi: 10.1016/j.gloenvcha.2014.04.012

Morzaria-Luna, H., Ainsworth, C., and Scott, R. (2022). Impacts of Deep-Water Spills on Mesopelagic Communities and Implications for the Wider Pelagic Food Web. *Mar. Ecol. Prog. Ser.* 681, 37–51. doi: 10.3354/meps13900

Nagender Nath, B., Khadge, N. H., Nabar, S., Raghukumar, C., Ingole, B. S., Valsangkar, A. B., et al. (2012). Monitoring the Sedimentary Carbon in an Artificially Disturbed Deep-Sea Sedimentary Environment. *Environ. Monit. Assess.* 184, 2829–2844. doi: 10.1007/s10661-011-2154-z

Nordhaus, W. (2017). The Social Cost of Carbon: Updated Estimates. *Proc. U. S. Natl. Acad.* 114 (7), 1518–1523.

Ojea, E., Pearlman, I., Gaines, S. D., and Lester, S. E. (2017). Fisheries Regulatory Regimes and Resilience to Climate Change. *Ambio* 46, 399–412. doi: 10.1007/s13280-016-0850-1

Ojo, A., and Mellouli, S. (2018). Deploying Governance Networks for Societal ChallengesGovernment Information Quarterly. *Platform. Governance. Sustain. Dev.* 35, S106–S112. doi: 10.1016/j.giq.2016.04.001

Olsen, E., Kaplan, I. C., Ainsworth, C., Fay, G., Gaichas, S., Gamble, R., et al. (2018). Ocean Futures Under Ocean Acidification, Marine Protection, and Changing Fishing Pressures Explored Using a Worldwide Suite of Ecosystem Models. *Front. Mar. Sci.* 5. doi: 10.3389/fmars.2018.00064

Onwuegbuzie, A. J., and Leech, N. L. (2007). Sampling Designs in Qualitative Research: Making the Sampling Process More Public. *Qual. Rep.* 12, 19–20. doi: 110.1080/13645570500402447

Orach, K., Schlüter, M., and Österblom, H. (2017). Tracing a Pathway to Success: How Competing Interest Groups Influenced the 2013 EU Common Fisheries Policy Reform. *Environ. Sci. Policy* 76, 90–102. doi: 10.1016/j.envsci.2017.06.010

Pacific Fishery Management Council. (2016). *Coastal Pelagic Species Fishery Management Plan, As Amended Through Amendmen*. Available at: http://www.pcouncil.org/wp-content/uploads/2016/05/CPSFMPAmended_by_FinalAmendment15_amendatory_language.pdf.

Pacoureau, N., Rigby, C. L., Kyne, P. M., Sherley, R. B., Winker, H., Carlson, J. K., et al. (2021). Half a Century of Global Decline in Oceanic Sharks and Rays. *Nature* 589, 567–571. doi: 10.1038/s41586-020-03173-9

Parker, C., Scott, S., and Geddes, A. (2019). Snowball Sampling. *SAGE Res. Methods Found.* doi: 10.4135/9781526421036

Passow, U., and Carlson, C. A. (2012). The Biological Pump in a High Co2 World. *Mar. Ecol. Prog. Ser.* 470, 249–271. doi: 10.3354/meps09985

Pentz, B., Klenk, N., Ogle, S., and Fisher, J. A. D. (2018). Can Regional Fisheries Management Organizations (Rfmos) Manage Resources Effectively During Climate Change? *Mar. Policy* 92, 13–20. doi: 10.1016/j.marpol.2018.01.011

Pershing, A. J., Christensen, L. B., Record, N. R., Sherwood, G. D., and Stetson, P. B. (2010). The Impact of Whaling on the Ocean Carbon Cycle: Why Bigger was Better. *PloS One* 5, 1–9. doi: 10.1371/journal.pone.0012444

Pinsky, M. L., Reygondeau, G., Caddell, R., Palacios-Abrantes, J., Spijkers, J., and Cheung, W. W. L. (2018). Preparing Ocean Governance for Species on the Move. *Sci. (80-).* doi: 10.1126/science.aat2360

Pinsky, M. L., Worm, B., Fogarty, M. J., Sariemento, J. L., and Levin, S. A. (2013). Marine Taxa Track Local Climate Velocities. *Science (80-)* 341, 1239–1242. doi: 10.1126/science.1239352

Pörtner, H. O., Scholes, R. J., Agard, J., Archer, E., Arneth, A., Bai, X., et al. (2021). *Scientific Outcome of the IPBES-IPCC Co-Sponsored Workshop on Biodiversity and Climate Change* (Bonn, Germany: IPBES secretariat). doi: 10.5281/zenodo.4659158.IPBES

Rantala, S., Iacobuta, G., Minestrini, S., and Tribukait, J. (2019). Gaps and Opportunities for Synergies in International Environmental Law. *Int. Environ. Law-Making.* 58–99.

Rietig, K. (2014). 'Neutral' Experts? How Input of Scientific Expertise Matters in International Environmental Negotiations. *Policy Sci.* 47, 141–160. doi: 10.1007/s11077-013-9188-8

Roberts, C. M., O'Leary, B. C., Mccauley, D. J., Cury, P. M., Duarte, C. M., Lubchenco, J., et al. (2017). Marine Reserves Canmitigate and Promote Adaptation to Climate Change. *Proc. Natl. Acad. Sci. U.S.A.* 114, 6167–6175. doi: 10.1073/pnas.1701262114

Rogers, L. A., Griffin, R., Young, T., Fuller, E., St. Martin, K., and Pinsky, M. L. (2019). Shifting Habitats Expose Fishing Communities to Risk Under Climate Change. *Nat. Clim. Change* 9, 512–516. doi: 10.1038/s41558-019-0503-z

Saba, G. K., Burd, A. B., Dunne, J. P., Hernández-León, S., Martin, A. H., Rose, K. A., et al. (2021). Toward a Better Understanding of Fish-Based Contribution to Ocean Carbon Flux. *Limnol. Oceanogr.* 66, 1639–1664. doi: 10.1002/lno.11709

Sala, E., Mayorga, J., Bradley, D., Cabral, R. B., Atwood, T. B., Auber, A., et al. (2021). Protecting the Global Ocean for Biodiversity, Food and Climate. *Nature* 592, E25. doi: 10.1038/s41586-021-03496-1

St. John, M. A. S., Borja, A., Chust, G., Heath, M., Grigorov, I., Mariani, P., et al. (2016). A Dark Hole in Our Understanding of Marine Ecosystems and Their Services: Perspectives From the Mesopelagic Community. *Front. Mar. Sci.* 3. doi: 10.3389/fmars.2016.00031

Sapkota, Y., and White, J. R. (2020). Carbon Offset Market Methodologies Applicable for Coastal Wetland Restoration and Conservation in the United States: A Review. *Sci. Total. Environ.* 701, 134497. doi: 10.1016/j.scitotenv.2019.134497

Sarmiento, J. L., and Gruber, N. (2006). *Ocean Biogeochemical Dynamics. Xiii* (Princeton, Woodstock: Princeton University Press).

Seddon, N., Turner, B., Berry, P., Chausson, A., and Girardin, C. A. J. (2019). Grounding Nature-Based Climate Solutions in Sound Biodiversity Science. *Nat. Clim. Change* 9, 84–87. doi: 10.1038/s41558-019-0405-0

Sénit, C. A. (2020). Leaving No One Behind? The Influence of Civil Society Participation on the Sustainable Development Goals. *Environ. Plan. C. Polit. Sp.* 38, 693–712. doi: 10.1177/2399654419884330

Spijkers, J., and Boonstra, W. J. (2017). Environmental Change and Social Conflict: The Northeast Atlantic Mackerel Dispute. *Reg. Environ. Change* 17, 1835–1851. doi: 10.1007/s10113-017-1150-4

Spijkers, J., Morrison, T. H., Blasiak, R., Cumming, G. S., Osborne, M., Watson, J., et al. (2018). Marine Fisheries and Future Ocean Conflict. *Fish. Fish.* 19, 798–806. doi: 10.1111/faf.12291

Srinivasan, U. T., Cheung, W. W. L., Watson, R., and Sumaila, U. R. (2010). Food Security Implications of Global Marine Catch Losses Due to Overfishing. *J. Bioeco.* 12, 183–200. doi: 10.1007/s10818-010-9090-9

Standal, D., and Grimaldo, E. (2020). Institutional Nuts and Bolts for a Mesopelagic Fishery in Norway. *Mar. Policy* 119, 104043. doi: 10.1016/j.marpol.2020.104043

Stratmann, T., Lins, L., Purser, A., Marcon, Y., Rodrigues, C. F., Ravara, A., et al. (2018). Abyssal Plain Faunal Carbon Flows Remain Depressed 26 Years After a Simulated Deep-Sea Mining Disturbance. *Biogeosciences* 15, 4131–4145. doi: 10.5194/bg-15-4131-2018

Sumaila, U. R., and Tai, T. C. (2020). End Overfishing and Increase the Resilience of the Ocean to Climate Change. *Front. Mar. Sci.* 7. doi: 10.3389/fmars.2020.00523

Thompson, K. F., Miller, K. A., Currie, D., Johnston, P., and Santillo, D. (2018). Seabed Mining and Approaches to Governance of the Deep Seabed. *Front. Mar. Sci.* 5. doi: 10.3389/fmars.2018.00480

UNFCCC.s (1992). Article 4.1(d).

VERRA. (2021). *First Blue Carbon Conservation Methodology Expected to Scale Up Finance for Coastal Restoration & Conservation Activities*. Available at: https://verra.org/first-blue-carbon-conservation-methodology-expected-to-scale-up-finance-for-coastal-restoration-conservation-activities/ (Accessed 8.23.21).

Wilson, R. W., Millero, F. J., Taylor, J. R., Walsh, P. J., Christenssen, V., Jennings, S., et al. (2009). Contribution of Fish to the Marine Inorganic Carbon Cycle. *Science* 323, 359–362. doi: 10.1126/science.1157972

Woods, P. J., Macdonald, J. I., Bar, H., Bonanomi, S., Boonstra, W. J., Cornell, G., et al. (2022). A Review of Adaptation Options in Fisheries Management to Support Resilience and Transition Under Socio-Ecological Change. *Ices. J. Mar. Sci.* 79, 463–479. doi: 10.1093/icesjms/fsab146Review

Wright, G., Gjerde, K., Finkelstein, A., and Currie, D. (2020). Fishing in the Twilight Zone . *Front. IDDRI. Study.* 26, 1–29.

Young, T., Fuller, E. C., Provost, M. M., Coleman, K. E., Martin, K. S., McCay, B. J., et al. (2019). Adaptation Strategies of Coastal Fishing Communities as Species Shift Poleward. *Ices. J. Mar. Sci.* 76, 93–103. doi: 10.1093/icesjms/fsy140

Zanna, L., Khatiwala, S., Gregory, J. M., Ison, J., and Heimbach, P. (2019). Global Reconstruction of Historical Ocean Heat Storage and Transport. *Proc. Natl. Acad. Sci. U.S.A.* 116, 1126–1131. doi: 10.1073/pnas.1808838115

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