frontiers | Frontiers in Marine Science

TYPE Original Research
PUBLISHED 04 October 2022
DOI 10.3389/fmars.2022.880424

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OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to
Marine Affairs and Policy,
a section of the journal
Frontiers in Marine Science

RECEIVED 21 February 2022
ACCEPTED 22 August 2022
PUBLISHED 04 October 2022

CITATION
Elsler LG, Oostdijk M, Levin LA,
Satterthwaite EV, Pinsky ML,
Crespo GO and Wisz MS (2022)
Protecting ocean carbon through
biodiversity and climate governance.
Front. Mar. Sci. 9:880424.
doi: 10.3389/fmars.2022.880424

Protecting ocean carbon through biodiversity and climate governance

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Global policy goals for halting biodiversity loss and climate change depend on each other to be successful. Marine biodiversity and climate change are intertwined through foodwebs that cycle and transport carbon and contribute to carbon sequestration. Yet, biodiversity conservation and fisheries management seldom explicitly include ocean carbon transport and sequestration. In order to effectively manage and govern human activities that affect carbon cycling and sequestration, international biodiversity and climate agreements need to address both biodiversity and climate issues. International agreements that address issues for climate and biodiversity are best poised to facilitate the protection of ocean carbon with existing policies. The degree to which the main international biodiversity and climate agreements make reference to multiple issues has however not been documented. Here, we used a text mining analysis of over 2,700 binding and non-binding policy documents from ten global ocean-related agreements to identify keywords related to biodiversity, climate, and ocean carbon. While climate references were mostly siloed within climate agreements, biodiversity references were included in most agreements. Further, we found that six percent of policy documents (n=166) included ocean carbon keywords. In light of our results, we highlight opportunities to strengthen the protection of ocean carbon in upcoming negotiations of international agreements, and *via* area-based management, environmental impact assessment and strategic environmental assessment.

KEYWORDS

carbon sink, carbon sequestration, blue carbon, mesopelagic, international policy, BBNJ Agreement, UNFCCC, Convention on Biological Diversity (CBD)

10.3389/fmars.2022.880424

Introduction

Climate change and biodiversity are tightly intertwined (Pörtner et al., 2021; Shin et al., 2022). Thus, global policies to halt and reverse biodiversity loss by 2030 and limit climate change to 1.5°C depend on each other to be successful (UNFCCC, 2016; CBD, 2022). Climate change is anticipated to reduce ocean biomass by 4.8% - 17.2% under low and high emission scenarios by 2100 (Lotze et al., 2019). In turn, marine biodiversity, ecological processes, and species dynamics in the ocean are vital to preserving global climate stability (Pörtner et al., 2021). The ocean has sequestered more than 25% of anthropogenic carbon dioxide emissions since the mid-1990s (Gruber et al., 2019; Watson et al., 2020), significantly mitigating climate change. However, this carbon uptake causes ocean acidification (Doney et al., 2009). Long- to mid-term carbon sequestration involving the biological carbon pump are important to reduce carbon in the atmosphere and the water column (Matthews et al., 2022). Maintaining the integrity of marine biodiversity and marine carbon sequestration processes must lie at the heart of achieving global biodiversity and climate goals (Pörtner et al., 2021).

Biological processes in the ocean, i.e., the biological carbon pump, account for ~90% of total particulate carbon export (De La Rocha and Passow, 2007; Sarmiento and Gruber, 2013; Honjo et al., 2014) but can be affected by human impacts. Marine species cycle and sequester vast quantities of carbon in the ocean through carbon capture, transport, and storage (Sarmiento and Gruber, 2013). Carbon captured by phytoplankton is transferred through the food web and is transported through gravitational forces, currents, or vertically migrating species (Sarmiento and Gruber, 2013). Mesopelagic fish are significant contributors; they transport an estimated 1,800 – 16,000 MtC yr^{-1} of carbon from the euphotic zone through their diurnal vertical migrations (Box 1; Proud et al., 2019). Mesozooplankton contribute 250 - 1,000 MtC yr^{-1} through seasonal migrations (Boyd et al., 2019). Predatory fish and whales contribute smaller amounts through their sinking carcasses respectively 17.4-26.2 MtC yr^{-1} for fish (Mariani et al., 2020), and 2.9×10^{-5} MtC yr^{-1} for whales (Pershing et al., 2010). Once carbon is stored in the sediment, it can stay there for centuries (Boyd et al., 2019). Human impacts can disrupt carbon sequestration processes. For example, disturbance to the seabed can re-suspend carbon sinks (Levin et al., 2020). Harvesting biomass from the ocean can also disrupt carbon sequestration processes (Lotze and Worm, 2009; McCauley et al., 2015; Duarte et al., 2020) by, for instance, changing the velocity with which carbon is sinking (Boyd et al., 2019).

There are concerns that valuable ocean carbon transport and sequestration may be lost without specific regulations in place (Oostdijk et al., 2022). Ocean carbon, a component of blue carbon, refers to all biologically-driven carbon fluxes and storage in marine systems amenable to management in the open ocean (Pörtner et al., 2019). In area-based management, ocean carbon processes seldom feature in the design or selection of marine protected areas (CBD, 2012; Roberts et al., 2017). Moreover, established targets for fisheries management, such as maximum sustainable yield, often approximated 30-50% of the unexploited population size (Schaefer, 1957; Cochrane and Garcia, 2009), do not yet account for ocean carbon. Rebuilding populations of large marine predators to biomass levels above maximum sustainable yield could bolster carbon sequestration rates with an additional 1.63 MtC per year (Mariani et al., 2020).

Ocean carbon is a topic of rising international importance, although currently, it is in an early stage of issue identification and formulation (Jann and Wegrich, 2006). It could be possible to protect ocean carbon with multiple policies that manage and govern a variety of human activities. For example, efforts to regulate ocean carbon could simultaneously link to biodiversity, climate, fishing, and mining agreements *via* environmental impact assessments, area-based protection, and fisheries management (Hilmi et al., 2021; Krabbe et al., 2022). Some ocean-related agreements may be well-poised to develop ocean carbon policies. Policies that foster integrative modes of thinking can more easily be used to address multiple issues than siloed policies (Rayner and Howlett, 2009). For example, ocean carbon policy development may be more relevant to agreements that jointly integrate biodiversity and climate issues (Oostdijk et al., 2022). In addition, agreements that already cover important ocean carbon components such as nutrient cycling and species related to the biological carbon pump would allow policymakers to expand existing policy instruments rather than concern themselves with costly and time-consuming new negotiations (Tiller et al., 2019).

Here, we quantify the extent to which international agreements make reference to biodiversity, climate, and oceancarbon. First, we identified all marine biodiversity and climate governance agreements that could at least partially protect ocean carbon (n=10, Table 1). We then compiled more than 2,700 binding and non-binding policy documents from these agreements in a database, including decisions, guidelines, resolutions, actions, and strategic plans. All of these documents are listed in Table S1. Second, we used a text mining approach to search for selected keywords within the respective policy documents of the ten agreements. The keywords related to the following broad issues: biodiversity, climate, or ocean carbon. For each agreement, we computed a biodiversity, climate, and ocean carbon focus factor (Gallo et al., 2017). The focus factors quantify keyword frequency and diversity (i.e., the number of different keywords), quantifying references made to climate and biodiversity within the international agreements. The focus factors do not allow us to assess policy instrument types and the extent to which policies were implemented and effective. Finally, we compared the focus factors across the main agreements for the terms carbon, climate and biodiversity. Evaluating the degree to which biodiversity and climate policies can support one another through references made to shared issues can help to inform the protection of ocean carbon with existing policies. This can likewise help to inform the development of any refined policies that may be needed to help achieve ocean carbon protection. Our analysis thus has implications for policy negotiations, such as the UN Framework Convention on Climate Change (UNFCCC), the draft Agreement on Biodiversity Beyond

TABLE 1 The ten agreements include international legally binding and non-binding agreements at the intersection of ocean, biodiversity, and climate governance.

Agreements	Year signed (upcoming negotiations)	Summary of objective
Agreement on Biological Diversity in Areas Beyond National Jurisdiction (BBNJ Agreement)	Not yet signed Fifth substantive session to be resumed in 2023	Broad mandate for the conservation and sustainable use of marine biodiversity in areas beyond national jurisdiction under UNCLOS
Convention on Biological Diversity (CBD)	1992 Fifteenth meeting of the Conference of the Parties to the Convention on Biological Diversity (Part 2, 7-19 Dec 2022); Tenth meeting of the Conference of the Parties serving as the meeting of the Parties to the Cartagena Protocol on Biosafety (Part 2, 5-17 Dec 2022)	Broad mandate for conservation of biodiversity and the equitable and sustainable use of its components, including the sharing of benefits from genetic resources
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)	1973	Specialized on preventing or restricting trade of species threatened with extinction
Convention on the Conservation of Migratory Species of Wild Animals (CMS)	1979	Specialized on research, cooperation, and protection for migratory species and their habitats
International Convention for the Regulation of Whaling (ICRW)	1946	Specialized on research and conservation of large cetaceans and regulating whaling through a moratorium
London Convention/London Protocol (LC/LP)	1972	Specialized on preventing marine pollution caused by dumping of pollutants and the placement of other wastes including carbon dioxide
United Nations Convention of the Law of the Sea (UNCLOS)	1982 (UNGA resolutions; annual)	Defines rights and responsibilities of nations with respect to their use of the world's ocean in various jurisdictional zones
Part XI	1982 Ongoing development of exploitation regulations, with multiple meetings each year.	Specialized on regulating and controlling mineral-related activities in the seabed and ocean floor beyond the limits of national jurisdiction under UNCLOS. Also responsible for protection of the marine environment from harmful effects of activities in the Area.
United Nations Fish Stock Agreement (UNFSA)	1996	Broad mandate for long-term conservation and sustainable use of straddling and highly migratory fish stocks under UNCLOS
United Nations Convention Framework on Climate Change (UNFCCC)	1992 (Conference of Parties 27 in Sharm El-Sheikh, Egypt 7-18 November 2022)	Broad mandate for stabilization of greenhouse gas concentrations in the atmosphere and coordinated global response to climate change

Full version and references to the objectives provided in Table S2.

National Jurisdiction (BBNJ Agreement), and the Convention on Biological Diversity (CBD).

Methods

International ocean governance dataset

Our analysis aimed to understand how international ocean-related agreements consider biodiversity, climate, and ocean carbon in past and present policies. Agreement herein refers to both international conventions (e.g., UNCLOS) and legally binding instruments of conventions (e.g., UNFSA). We identified agreements that i) address human activities in the ocean, ii) address biodiversity or climate objectives, and iii) have global or near-global coverage; we defined global coverage either by the geographic mandate of an agreement or by the geographic coverage of the signing parties (usually States). We excluded regional agreements such as Regional Seas Conventions as they are not near-global in extent.

Ten agreements met our selection criteria (Table 1): the agreement on Biodiversity Beyond National Jurisdiction (BBNJ Agreement), the Convention on Biological Diversity (CBD), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Convention on the Conservation of Migratory Species of Wild Animals (CMS), the International Convention for the Regulation of Whaling (ICRW), London Convention/London Protocol (LC/LP), Part XI, United Nations Convention of the Law of the Sea (UNCLOS), the UN Framework Convention on Climate Change (UNFCCC), and the United Nations Fish Stock Agreement (UNFSA). We created a comprehensive international ocean governance dataset containing these ten global agreements.

Each agreement featured several associated policy documents. We included convention texts and annexes, national commitments, implementations, and binding and non-binding policy documents such as decisions, guidelines, resolutions, action, and strategic plans (Table S1). We included draft policy documents and summary documents of stakeholder consultations (e.g., draft text to BBNJ Agreement dated 27th November 2019; CBD Post-2020 Global Biodiversity Framework) to capture recent developments. Finally, we included policy documents establishing cooperation with other bodies and agreements, such as memoranda of understanding to capture coordination between agreements. Many agreements are implemented by signing parties, meaning that policy documents could be at the regional or national level. For example, the Paris Agreement is implemented by States which have signed the agreement. States have an obligation to submit nationally determined contributions that are non-binding national plans for climate actions (UNFCCC, 2016). We excluded documents with a purely administrative purpose, such as annual reporting, rules of procedure, and meeting documents without binding or non-binding decisions. However, some policy documents described above could also contain administrative elements. We also excluded bulletins, newsletters, meetings, and project reports with a sole informatory purpose. For instance, we excluded impact assessment reports but included resolutions prescribing the use of impact assessments.

For all agreements, we cataloged a total of 2,725 publicly available policy documents in PDF files published between 1946 and 2020. We searched for policy documents on the respective Secretariat website of each agreement (links provided in Table S1). We used the website categories provided by the agreements' secretariats as the basis for our choice of including or excluding documents. We would include rather than exclude documents in the dataset if in doubt. For example, if documents in a section were deemed relevant, we cataloged all documents it contained, even if they contained documents we would have otherwise excluded. Some Secretariat websites used the same terms to describe different types of documents. For instance, in cases where the agreements use 'decisions' to refer to resolutions, we included these in our dataset. However, policy documents that used 'decisions' to refer to instructions to committees or the secretariat were excluded from our dataset.

The policy documents included under each agreement span widely from binding to non-binding policies and convention texts. We gathered all policy documents to analyze the entire set of policies to compare agreements to one another. We acknowledge that these documents serve different purposes, and naturally, we expect different levels of integration between them. Thus, any reference to individual well-integrated policy documents in our analysis must be understood in comparison to other similar policy documents in objectives, legal characteristics, and means of implementation.

Text mining approach and keyword selection

We employed a text mining approach on the ocean governance dataset comprising 2,725 policy documents as PDF files. We used the *pdftools* package (Ooms, 2021) in R (R Core Team, 2020) to extract keywords from the PDFs. The data collected from the PDFs in CSV format contained the agreement name, PDF name, detected keywords, and the text sections, line, and page numbers in which keywords were extracted.

We developed a comprehensive set of keywords for each category of terms commonly used in ocean, biodiversity, climate science, and policy. For the keyword selection, we took a two-step approach. We first selected keyword sets based on the authors' knowledge of terms. For each set, we added keywords through multiple iterations to contain all terms which were 1) commonly used to describe ecological aspects of biodiversity, climate, and ocean carbon, and 2) names of agreements and bodies regulating biodiversity, climate, and ocean carbon (Table S3).

We iteratively refined the keyword selection by analyzing the output of a keyword search on the whole dataset. We evaluated the keywords detected in the context of a text section; we omitted keywords with multiple meanings (e.g., 'plant' was often mentioned as 'industrial or power plant') and added new relevant keywords (e.g., 'seaweed', 'carbon flux', 'wildlife'). We excluded keywords in the climate category that exclusively focus on the impacts of climate change, such as ocean acidification, warming, and sea level rise. We also excluded keywords that solely referred to terrestrial ecosystems as four of the included agreements govern climate and biodiversity on land and in the sea. Therefore we excluded keywords from these agreements if one of a set of conditional keywords was included (Table S3). For instance, 'biomass carbon' was frequently used to describe terrestrial forests, and 'terrestrial' was used as a conditional keyword. Despite our effort to identify a comprehensive set of keywords, we might not fully capture certain concepts. Policies may use other terms to refer to the same concept leading to a lower keyword frequency.

Most policy documents were available in English, but we did not evaluate an additional 562 policy documents from 58 States that were not in English. These included French, Spanish, Arabic, Bosnian, Bulgarian, Chinese, German, Latvian, Portuguese, Russian, Slovakian, and Slovenian documents. Taking these documents into account in the future could increase the geographic scope of our analysis in Latin America, Asia, and Europe.

Computation of keyword frequency and focus factors

We calculated keyword frequency and focus factors from the CSV files of detected keywords. Keyword frequency was computed as the average number of keywords per policy document. Following the best practices developed by Gallo et al. (2017), we computed a Biodiversity Focus Factor (BFF), a Climate Focus Factor (CFF), and an Ocean Carbon Focus Factor (OFF). The focus factor is a quantitative metric of keyword frequency and diversity in policy documents for evaluating how much biodiversity, climate, and ocean carbon-related terms were considered across the agreements and policy documents. Our analysis allows evaluating the extent to which policies integrated biodiversity, climate, and ocean carbon references. It does not allow assessing the extent to which regulations were implemented and effective.

The keyword sets for biodiversity focus factor (BFF) are 'Biodiversity agreements', 'Biodiversity related-terms', 'Fishing-related terms', 'Common species names', and 'OBIS species names' from the *Ocean Biodiversity Information System* database (OBIS, 2020). The climate focus factor (CFF) keyword sets include 'Carbon cycle related-terms', 'Climate change related-terms', and 'Climate agreements'. The ocean carbon focus factor (OFF) keyword sets include 'Carbon types' and 'Ocean carbon cycle related-terms'. In addition, the ocean carbon focus factor contains a keyword set called 'Joint biodiversity-climate keywords'. This keyword set overlaps with and complements the biodiversity and climate focus factor, calculated at the document level; it detects biodiversity and climate focus factor keywords mentioned in a text section together and accompanied by the words' sequester' or 'sequestration' (conditional keywords in Table S3). Due to this joint keyword set, we decided to keep 'Carbon cycle related-terms', which could be associated with physical processes in the climate focus factor category.

An individual FF_i is computed for each category (biodiversity, climate, and ocean carbon) and policy document and then averaged for all policy documents belonging to an agreement. We adapted the original equation (Gallo et al., 2017) to:

$$FF_i = \gamma \times \left(\frac{Number\ of\ keywords\ in\ policy\ document}{Total\ policy\ word\ count}\right) \times \left(\frac{Different\ keywords\ detected\ in\ policy\ document}{maximum\ number\ of\ detected\ keywords}\right) \quad (1)$$

Where γ is a multiplier here set to be 100,000 of the ratio of the number of keywords detected in a policy document and the total word count of a policy document and the ratio of the number of different keywords detected in a policy document, and the maximum number of detected keywords in a category.

As noted above, the focus factors were computed for each policy document and then averaged for all policy documents belonging to an agreement. Zero is the minimum value a focus factor can take. A high focus factor implies that the frequency of keywords is high and that many different keywords were mentioned. In our analysis, the maximum focus factor of an individual policy document was BFF=13,645 (UNFSA policy document entitled *Recommendation to amend the Scheme of Control and Enforcement* from the North East Atlantic Fisheries Commission). The maximum value averaged for all policy documents in an agreement was BFF=1,723 (UNFSA). We computed a coefficient of variation (CV) to compare how dispersed biodiversity, climate, and ocean carbon focus factor values of agreements were. The CV is calculated by dividing the focus factor standard deviation by its mean. Finally, we examined and discussed policy documents to identify characteristics of policies related to a high focus factor (Table S4).

Results

Ten international agreements for integrating marine biodiversity and climate

We identified ten international agreements for analysis (Table 1; Table S2). The UNCLOS obliges States to protect and preserve the marine environment (Article 192). Under UNCLOS, we included PART XI, which regulates human activities in the seabed, and the UNFSA. The UNFSA requires States to 'adopt measures to ensure long-term sustainability of straddling fish stocks and highly migratory fish stocks' (UNFSA, 1995). Regional Fisheres Management Organizations (RFMOs) are tasked with implementing suitable targets such as maximum sustainable yield. This target is considered sustainable regarding population dynamics but does not account for carbon sequestration by fished stocks.

The draft BBNJ Agreement and the CBD designate protected and biologically significant areas to protect marine species or conduct environmental assessments. These could, in the future, account for carbon sinks and sequestration (Gjerde et al., 2021; Sala et al., 2021). Another suite of biodiversity agreements, including the ICRW, CITES, and CMS, oversees the conservation, harvest, and trade of marine species responsible for significant carbon sequestration, such as whales and large marine predators.

Finally, we analyzed the UNFCCC and the LC/LP, which promote climate change mitigation. Preserving existing ocean carbon sequestration processes is not considered mitigation action to meet national commitments to the Paris Agreement (IUCN, 2014; Hilmi et al., 2021). Yet, the agreement can prevent ocean climate mitigation measures that harm biodiversity (Pörtner et al., 2021). The LC/LP primarily regulates dumping in the ocean but also provides mechanisms to regulate carbon dioxide storage in the seabed.

Keyword frequency

We found that 1,142 policy documents mentioned biodiversity, 712 mentioned climate, and 166 mentioned ocean carbon keywords. The average policy document mentioned a high number of keywords from the biodiversity category (Figure 1; n=64.8), followed by the climate category (n=6.1) and lastly by the ocean carbon category (n=0.4). Some keywords were not mentioned in any of the documents, such as the 'biological carbon pump', 'fish carbon', and 'whale carbon' (Table S3). In the ocean carbon category, the most frequently mentioned keyword set detected was the 'Joint biodiversity-climate keywords'. This keyword set included text sections in which biodiversity and climate keywords used to calculate the biodiversity and climate focus factor were mentioned together.

Agreements with broad mandates such as the CBD, UNFCCC, and UNFSA had a high average number of keywords per policy document when compared to agreements with specialized mandates (Figure 1). The CBD (n=214) featured the highest frequency of any of our keywords, followed by the UNFCCC (n=56), the CMS (n=52) and the UNFSA (n=40). We detected the lowest frequency of our keywords in the draft BBNJ Agreement (n=13), Part XI (n=9), and the LC/LP (n=7).

While the CBD is a biodiversity-focused agreement, it featured the second highest number of climate keywords (n = 10; the UNFCCC ranked highest with n = 50). For example, Mauritius' implementation of the CBD outlined in the *Mauritius' National Biodiversity Strategy and Action Plan* included 215 climate keywords. The plan discussed ecosystem-based management in relation to the effects of climate variability on fishing and marine protected area roles in carbon sequestration (keywords: 'CO_2', 'climate', 'carbon stocks', and 'carbon sink'). For instance, the plan accounts for carbon sequestration in Mauritius' protected area network and states that methods for quantifying carbon sequestration in marine protected areas are still under development.

Overall, the draft BBNJ Agreement (dated 27th November 2019) was the biodiversity-related agreement with the lowest frequency of any of our keywords (n = 12). The policy document with the single highest number of any of our keywords was the *Textual Proposals Submitted by Delegations by 20th February 2020* (n = 228). Also, the Deep Ocean Stewardship Initiative referred to carbon sequestration and storage benefits of biodiversity beyond national jurisdiction in this document (keywords: 'climate change' and 'carbon sequestration').

Biodiversity, climate, and ocean carbon focus factors

The variation of the biodiversity focus factor (CV = 0.66) was considerably lower than the climate focus factor (CV = 1.40; Figure 2). The UNFSA (BFF=1,723), the CMS (BFF=1,558), and the CBD (BFF=1,313) ranked as the top three agreements in the biodiversity focus factor. Whereas the UNCLOS (BFF=452), the draft BBNJ Agreement (BFF=167), and the UNFCCC (BFF=151) ranked at the bottom (Figure 2). The LC/LP (CFF=1,700) and the UNFCCC (CFF=996) ranked highest by far in the climate focus factor. The ICRW (CFF=106), the draft BBNJ agreement (CFF=47), and CITES (CFF=32) ranked last. The UNFSA is an exception: it had both high biodiversity (BFF=1,723) and climate focus factor (CFF=280), ranking first

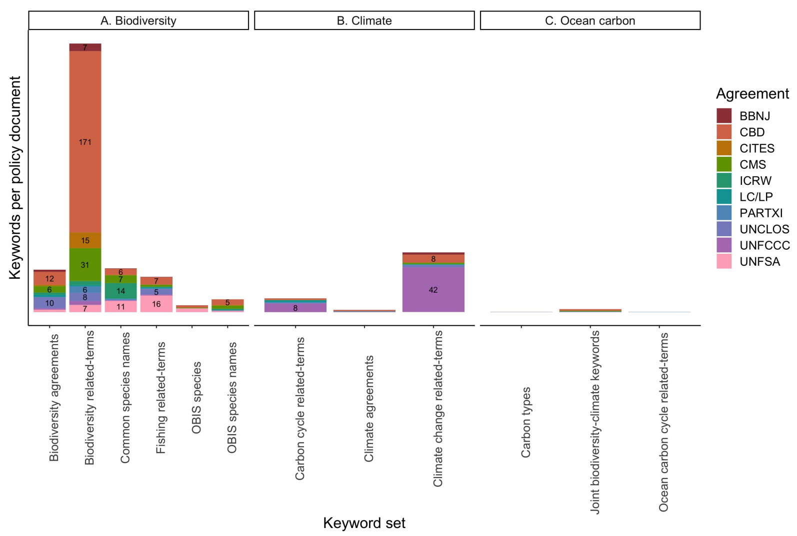

FIGURE 1
Number of keywords per policy document mentioned in different agreements. Keywords were summarized and displayed in keyword sets (e.g., 'Common species names' and 'Fishing related-terms') and per category **(A)** Biodiversity, **(B)** Climate, and **(C)** Ocean carbon. Table S3 lists all keywords contained in each set and category. Values are rounded and displayed if ≥10. OBIS refers to the Ocean Biodiversity Information System.

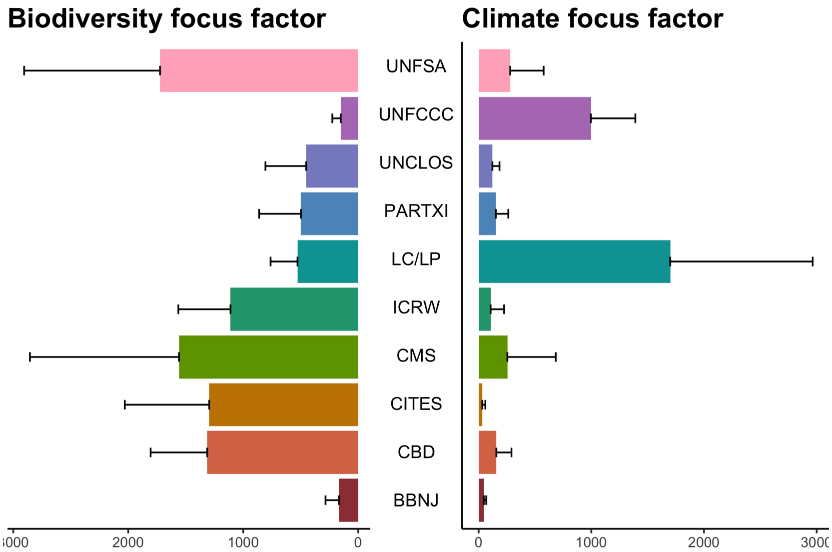

FIGURE 2
The biodiversity and climate focus factors of international agreements (in alphabetical order). The focus factor derives from text mining the policies and their implementing documents for keywords and text sections discussing biodiversity and climate. It is calculated from the frequency and diversity of climate and species keywords in the documents (Eq. 1). High values of focus factors imply high integration of biodiversity and climate topics, respectively. Abbreviations of agreements are listed in Table 1.

and third of all agreements, respectively (Figure 2). For instance, the *Commission for the Conservation of Antarctic Marine Living Resources Resolution 30/XXVIII Climate Change* was the policy document that had the highest climate focus factor of any UNFSA policy document (CFF=1,346). The document discusses the threat of climate change on the Antarctic marine ecosystem (keyword: 'climate change') and encourages the dissemination of scientific results of the impact of climate change in the Southern Ocean with other agreements (keyword: 'UNFCCC'). The only CITES policy document that mentioned climate-related keywords was in the resolution for *Implementation of the Convention for Species in Appendix III*. It considered the vulnerability of threatened species under climate change (keyword 'climate change').

Variation in the ocean carbon focus factor (CV = 1.39) was similarly high as in the biodiversity focus factor. It was higher in specialized agreements than in those with broad mandates to address biodiversity, climate, and the oceans (Figure 3). The CMS (OFF=392), the ICRW (OFF=238), and the LC/LP (OFF=116) are examples of specialized agreements with high ocean carbon focus factors. In the CMS, for example, the *UNEP/CMS/Resolution 12.17: Conservation and Management of Whales and Their Habitats in the South Atlantic Region* discussed other international frameworks that call for the protection of cetaceans such as 'CITES', 'ICRW', and 'UNCLOS'. This resolution also explicitly acknowledged the importance of whales to nutrient distribution and carbon sequestration from the atmosphere and the effect of climate change on whales (keywords: 'carbon sequestration', 'climate change', and 'whale') (Table S4). Although the resolution is primarily biodiversity-focused, it explicitly acknowledges the contribution of marine species, such as cetaceans, to the global carbon cycle as one of the important reasons to protect these species. The UNFSA (OFF=7), the draft BBNJ Agreement (OFF=6), and CITES (OFF=0) ranked last in the ocean carbon focus factor.

The draft BBNJ Agreement ranked consistently low across all three focus factors. For the marine biodiversity and climate focus factors, it ranked 9th out of ten. In the ocean carbon focus factor, the BBNJ Agreement ranked 8th out of ten agreements (Table S4). This may at least partially be explained by the low number of keywords in the BBNJ Agreement text. We did not find any of the keywords in more than half of the BBNJ Agreement's policy documents. The policy document entitled *Intergovernmental Conference on an International Legally Binding Instrument under the United Nations Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas Beyond National Jurisdiction (Second Session)* had the highest ocean carbon focus factor (OFF=10) of all the documents included under the draft BBNJ Agreement (Table S4). It contains several ocean carbon mentions in a section on sustainable use and area-based management. This document also refers to other agreements (keywords: 'Paris Agreement', and 'CBD').

Discussion

Earth's climate and life in the ocean are indivisibly linked and provide the conditions necessary for ecosystems and humans to

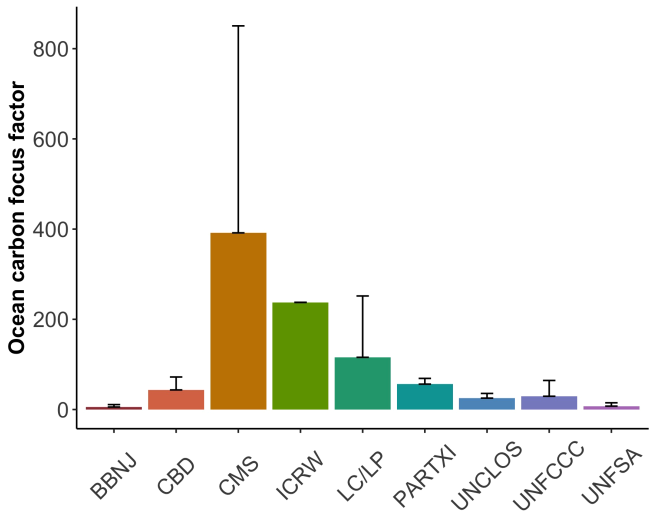

FIGURE 3
The ocean carbon focus factor of international agreements. Abbreviations of agreements are listed in Table 1 International agreements are listed in alphabetical order.

flourish (Pörtner et al., 2021). Maintaining the integrity of marine biodiversity and marine carbon sequestration processes lies at the heart of climate governance and management for the ocean. First, our analysis provides evidence that several specialized agreements (CMS, LC/LP, and ICRW) make more and broader references to ocean carbon than agreements with broad mandates (BBNJ, UNFSA, UNCLOS). Second, we found that 6% of the policy documents (n=166) included ocean carbon keywords. In addition, key terms such as fish carbon and the biological carbon pump were not referred to in any of the ~2,700 policy documents. Finally, while climate keywords were mostly found in climate agreements (exception being the CBD agreement), biodiversity keywords occurred in most agreements.

Several specialized agreements and related management plans had high focus factors, and thus referred to multiple biodiversity, climate and ocean carbon issues. This was in contrast to agreements with broad mandates such as UNCLOS. The age of the UNCLOS agreement might explain its lack of ocean carbon keywords. UNCLOS was signed in 1982 when climate change was an emerging issue (Telesetsky, 2021). The policies with the highest focus factors for ocean carbon were specialized agreements [e.g. those focusing on specific marine taxa (CMS, ICRW) and ocean pollution (LC/LP)]7. Research investigating the role of whales in the carbon cycle (e.g. Lavery et al., 2010; Nelleman et al., 2010; Pershing et al., 2010) might have led to the incorporation of biodiversity, climate and ocean carbon in the ICRW and CMS, which address the conservation and management of whale populations. This example indicates that future research on linkages between biodiversity, climate and ocean carbon could drive increasing attention to ocean carbon protection in international agreements.

Our analysis indicates that although some of the agreements refer to climate, biodiversity and even ocean carbon, there seems to be scope to strengthen the degree to which multiple issues are addressed within the agreements. For example, the UNFSA, CMS, and CBD referred to more climate keywords than other fisheries and biodiversity-related agreements (ICRW, CITES, BBNJ Agreement). One reason for the higher climate focus factor for the CBD might be the endorsement of an ecosystem approach (CBD, 2000). An example that illustrates this very well is the *Mauritius' National Biodiversity Strategy and Action Plans*, which explicitly discusses integrated management of ecosystem services (CBD, 2000; CBD, 2012). Frameworks such as the UNFSA also include elements of an ecosystem approach to fisheries management but do not explicitly call for preserving processes such as carbon capture or sequestration (Engler, 2020). Policy silos focusing on a single issues or species can obstruct effective policy-making for issues shared between different policy issues (Froy and Giguère, 2010; Kelly et al., 2019); in contrast, an ecosystem approach can help to address multiple policy objectives.

We provided a first quantitative analysis of the extent to which international agreements make reference to biodiversity, climate, and ocean carbon. Our work is a starting point for future fine-grained analysis. A higher focus factor does not necessarily translate into better management tools or policy effectiveness. Future work could differentiate between binding and non-binding regulation using a more comprehensive and possibly automated content analysis of the policy documents. It could compare and contrast agreements' focus factors to their policy effectiveness (see Cullis-Suzuki and Pauly, 2010; Sala et al., 2018; Bell et al., 2019 for indicators of policy effectiveness).

Box 1 Governing mesopelagic fishing

Could international agreements simultaneously ensure the sustainable management of mesopelagic fish and ensure the protection of their ocean carbon sequestration processes?

The mesopelagic zone is defined by its level of light penetration (Kaartvedt et al., 2019) that is too low for photosynthesis but enough for some visibility (~200-1,000m depth). It has been estimated that the mesopelagic contains approximately 1 million undescribed species (Robison, 2009). Lanternfish (Myctophidae), pearlsides (Maurolicus spp.), and viperfish (Chauliodus sloani) are common mesopelagic taxa globally, and one genus of bristlemouths (Cyclothone) is the most abundant vertebrate genus on Earth (Sutton et al., 2010; Sutton, 2013). The mesopelagic zone has been estimated to be the most biomass rich ecosystem on our planet (1.8 to 16 Gt; Proud et al., 2019; Irigoien et al., 2014).

Many mesopelagic fish undergo diel vertical migrations to feed at the surface during the night, and sinking to the depths during the day to avoid visual predators. These daily vertical migrations (also known as the mesopelagic migrant pump) contribute to major ocean carbon fluxes by transporting carbon rich biomass from the ocean surface to the deep sea (Drazen and Sutton, 2017; Eduardo et al., 2020). This active transport mediated by mesopelagic fish accelerates the transport of carbon to ocean depths where it is stored for years to centuries. It is faster than passive gravitational particle fluxes of detritus and transfer carbon to deep long-term storage (Trueman et al., 2014). The mesopelagic migrant pump influences all important aspects of carbon sequestration: the total export rate, depth of peak flux, and the depth scale of flux attenuation (Boyd et al., 2019; Saba et al., 2021).

In recent years there has been an emerging discussion about the potential interest to harvest mesopelagic fish primarily to supply aquaculture and nutraceutical industries (St. John et al., 2016; Alvheim et al., 2020; Hoagland, 2020). A mesopelagic fishery would currently be difficult to manage under a quota system because there are great uncertainties associated with their population structure and dynamics in space and time (Martin et al., 2020). Moreover, commonly used fishery targets such as MSY (which typically targets 30-50% of unexploited biomass) would likely be unsustainable from a carbon sequestration and ecosystem-based management perspective (Durfort et al., 2020). In addition, deep sea mining activities and other pressures which might negatively impact mesopelagic fish need to be considered (Drazen et al., 2020; Amon et al., 2022).

Assessing the impact of an industrialized mesopelagic fishery on carbon sequestration requires enhanced knowledge about the biology, ecology, and relative abundance of many mesopelagic fish species (Anderson et al., 2019). Before exploitation, it is important to understand the impact of potential mesopelagic fishing (St. John et al., 2016; Standal and Grimaldo, 2021). Moreover, it is important to understand how removal of mesopelagic species could affect marine food webs, trophic pathways, and the biological carbon pump (Martin et al., 2020).

Despite the urgent need to safeguard the mesopelagic zone and its important ecological processes, there is no international, targeted framework protecting it. Developing rules to protect the mesopelagic now may be less contentious than after a fleet becomes established (Cabral et al., 2018). In absence of a targeted international framework, the UNFSA, associated FAO guidelines, the UNCLOS, and the CBD are the only global agreements and institutions that are currently relevant to managing human activities affecting the mesopelagic zone (Wright et al., 2020).

Some of these international agreements offer more opportunities to integrate biodiversity, climate, and ocean carbon policies than others. For example, a potential mesopelagic fishery would fall into the category of new and exploratory fisheries. The UNFSA requires RFMOs to 'adopt as soon as possible cautious conservation and management measures, including, inter alia, catch limits and effort limits.' (UNFSA, 1995) and the FAO prohibits unregulated fishing (FAO, 2016). Thus internationally, shared fisheries must be managed under an RFMO or another appropriate arrangement under the UNFSA. If a stock falls in the mandate of an RFMO it needs to comply with its regulations for new and exploratory fisheries. Requirements for these fisheries that are relevant for mesopelagic fishing are included to at least some degree in the mandates of non-tuna RFMOs (Caddell, 2018; Bell et al., 2019). RFMOs that address the management of tuna species would likely not concern mesopelagic fishing and large areas of the global ocean such as the Southwest Atlantic or Eastern Indian Ocean still lack an RFMO altogether.

The UNCLOS is the overarching ocean framework that mandates '[…] the equitable and efficient utilisation of [ocean] resources, the conservation of their living resources.' (UNCLOS, 1982). Despite its overarching call for preservation of ocean environments, our analysis showed that UNCLOS had one of the lowest ocean carbon focus factors among the agreements we examined. A major part of the mesopelagic zone is found in areas beyond national jurisdiction. The BBNJ Agreement to be implemented under UNCLOS features relevant management tools such as environmental assessments and protected areas in areas beyond national jurisdiction. Both tools could potentially be used, alongside RFMO management measures, to sustainably manage new mesopelagic fisheries in tandem with climate considerations (Gjerde et al., 2021). However, our findings point out that the BBNJ Agreement in its current form has a very low focus on biodiversity, climate, and ocean carbon. We recommend that the implementation policy instruments such as strategic environmental assessment, ecosystem impact assessment, and area-based management of the BBNJ Agreement incorporate ocean carbon protection.

The CBD works only with voluntary national commitments; with regards to the mesopelagic, the CBD would only be of use in countries that have a mesopelagic zone in their national jurisdiction. Under the CBD, a new mesopelagic fishery must undergo an impact assessment before its onset. The CBD uses impact assessments to monitor parties' responsibility 'for ensuring that activities within their jurisdiction or control do not cause damage to the environment' (CBD, 1992). Our results show that this obligation under the CBD is complemented with relatively strong considerations for biodiversity, climate, and ocean carbon.

Our analysis advances prior assessments of agreements and policy instruments to govern ocean carbon. Our results showed that the draft BBNJ Agreement incorporates few references to ocean carbon issues.; its focus factor was among the lowest of the ten agreements we analyzed. With the agreement coming to a close this year, it is unlikely that ocean carbon will be integrated into the agreement itself. The draft BBNJ Agreement is an important opportunity for managing human activities in international waters *via* tools such as strategic environmental assessments (SEA), environmental impact assessment (EAI), and area-based management (Friedman, 2019; Gjerde et al., 2021; Tiller et al., 2019). These tools could be implemented to integrate concerns related to open ocean carbon, e.g., protection of mesopelagic fish (Gjerde et al., 2021; Krabbe et al., 2022). With proper incorporation of ocean carbon consideration in EIA, SEA and area-based management, these particular management tools could potentially help to protect ocean carbon from the impacts of deep sea mining and mesopelagic fishing (Box 1). Other agreements with implications for EIA, SEA and area-based management , such as the CBD (within national jurisdictions) and ISA (the seabed in international waters), could likewise address the protection of ocean carbon. The UNFCCC scored low on biodiversity and ocean carbon factors factors, which, in addition to ocean carbon traceability concerns (Oostdijk et al., 2022), make the UNFCCC seem like an unlikely platform for the explicit management of ocean carbon ecosystem services.

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Additionally, we found that the latest BBNJ draft agreement text featured 19 times fewer ocean carbon mentions than the draft including stakeholder proposals. Stakeholder consultation can enhance conservation outcomes because of the broader consideration of ecosystem services (Solomonsz et al., 2021). Participation from interest groups has previously helped to promote ocean carbon and nature based solutions in biodiversity and climate policy discussions (Oostdijk et al., 2022). To further support discussions of ocean carbon in upcoming negotiations (e.g. BBNJ, International Seabed Authority (Part XI), CBD, and UNFCCC), we suggest the inclusion of biodiversity, climate, and social justice organizations and other interest groups. It will be essential to include representatives from typically underrepresented stakeholders who can highlight the rights and interests of e.g. small-island developing states, indigenous groups and youth organizations (see Wisz et al., 2020; Kelly et al., 2022). It may be necessary to promote awareness about ocean carbon among these groups though targeted outreach efforts so that they can decide how to prioritize their participation in stakeholder events that support the negotiations.

Although interest in minerals found in the deep sea is growing, deep sea mining is not yet carried out in international waters. Mesopelagic fish, found predominantly in international waters, play a major role in the sequestration, transfer and injection of ocean carbon in the deep sea (Martin et al., 2020). Mesopelagic fisheries do not yet exist in international waters, but there is currently an interest to harvest mesopelagic biomass for the aquaculture industry (St. John et al., 2016). Protecting high seas ocean carbon from threats before they emerge (e.g. deep sea mining and mesopelagic fisheries) should potentially be easier than protecting ocean carbon from established industries (see e.g. Cabral et al., 2018; Gjerde et al., 2021; Oostdijk et al., 2022). It would be advantageous to prioritize protection now before industries become established.

Negotiations held during the Conference of the Parties (COP) and UN General Assembly meetings present an opportunity to adapt existing agreements to better capture topics of rising importance to both biodiversity and climate change, such as ocean carbon protection. Also, all agreements have informal and scientific consultations on specific topics and intersessional work. The coming years are critical for international biodiversity, climate, and ocean governance due to the UNFCCC COP 27, the CBD's development of a Post-2020 Biodiversity Agreement, and the substantive session of the draft BBNJ Agreement negotiations and planned implementation. Policy linkages between biodiversity and climate change have strengthened in recent years. Examples include the IPBES-IPCC joint report (Pörtner et al., 2021) and the ocean and climate change dialogue convened by the UNFCCC Subsidiary Body for Scientific and Technological Advice (Dobush et al., 2022). Our analysis has quantified the degree to which joint references to biodiversity, climate, and ocean carbon have been incorporated into ocean policies and highlights associated agreements that may be best poised to protect ocean carbon now and in the future. A substantial opportunity exists now for a joint effort to expand the basis for integrated climate and biodiversity governance; this could deliver necessary steps toward developing policies to safeguard ocean carbon.

Data availability statement

Data used in this study are available on World Maritime University's institutional Google drive folder: https://drive.google.com/drive/folders/11ixgiY0t7ET7_jdy7bcg5xCEq6doxzxp Code used in this study is available on Github: https://github.com/ChrisHoebeke/biodiversity_climate-1.

Author contributions

Conceptualization: MW and LE. Design and Methodology: LE, MO, LL, ES, MP, GC, and MW. Formal Analysis LE and MO. Writing: first draft LE, MO in close collaboration and dialogue with the co-authors. Subsequent drafts all co-authors. Visualization: LE and MO. Project leadership/senior author: MW. All authors contributed to the article and approved the submitted version

Funding

LE, MO, and MW benefited from funding from the MEESO (Ecologically and economically sustainable mesopelagic fisheries; Grant Agreement No. 817669) and the MISSION ATLANTIC (Grant Agreement No. 862428) project funded by the European Union's Horizon 2020 Research and Innovation Program. MP was funded by the US National Science Foundation grant #DEB-1616821. LL was funded by the US National Science Foundation grant #OCE1829623 and #OCE 2114717. ES was supported by a California Cooperative Oceanic Fisheries Investigations (CalCOFI) partnership among California Sea Grant, Scripps Institution of Oceanography, National Oceanic and Atmospheric Administration (NOAA) Southwest Fisheries Science Center, and California Department of Fish and Wildlife.

Acknowledgments

We are grateful for the support and shared insights from Webjorn Melle and Charles Stock and we thank Kristina Gjerde for feedback on an earlier draft of this paper. Our manuscript also benefited from valuable comments from two referees.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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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.2022.880424/full#supplementary-material

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