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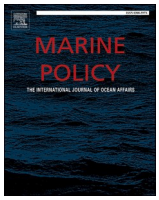

# Advancing multi-use in offshore wind energy planning: Perceived opportunities and barriers in southern New England, U.S.

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ABSTRACT

Offshore wind energy development has been accelerating at a rapid pace around the world to address renewable energy goals. As a new use of ocean space, offshore wind developments can create spatial and temporal conflicts with existing ocean uses. The concept of multi-use, which spans from promoting co-existence of uses to identifying synergies between uses, has become an important framework for marine spatial planning and offshore renewable energy development in Europe, where offshore wind farms have been integrated with aquaculture and tourism, among other uses. In the United States, however, where offshore wind energy is at a more nascent stage, multi-use concepts have not been applied to the planning, permitting, and development processes, and multi-use has been considered on a more ad hoc basis. Offshore wind development in the U.S. has consequently been rife with conflict, particularly with the commercial fishing industry, and a lack of consistent policy on multi-use has led to missed opportunities to consider ways to build on synergies. To better understand the state of multi-use in the U.S., we interviewed key informants in the Southern New England region from federal and state agencies, and development, research, conservation, and fisheries sectors. Based on the interviews, we identified perceived opportunities and barriers to multi-use among interviewees, and perceptions of the state of multi-use. Responses were used to share lessons learned in the region, and to develop a set of recommendations related to the implementation of multi-use policies in the U.S.

## 1. Introduction and background

As the climate warms and the importance of developing alternatives to fossil fuel use becomes even more urgent, global development of offshore wind energy is accelerating. In the United States, while offshore wind is predicted to have a cumulative generating capacity of as much as 80,000 MW of electricity in the coming years [41], this remains a nascent industry. At the time of writing, the first two commercial-scale offshore wind farms have only recently come into operation, with several more under construction [41], and new lease areas opening at a rapid pace in several areas of the United States [14]. The production of offshore wind energy (OWE) requires large areas of the ocean surface

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[64]. One recent study found that meeting clean energy targets set by the Paris Agreement will require a 35-fold increase in global capacity over existing OWE installations [54]. This rapid expansion of a new ocean use has brought to the forefront a debate about shared use of ocean space, and about the compatibility of various ocean uses. The overarching objective of this paper is to examine multi-use potential with ocean wind offshore of southern New England.

### 1.1. Multi-use to address conflicts of ocean space

Humans have used ocean and coastal space for numerous activities since time immemorial, including for food provisioning, trade, transport, and other uses (e.g., [2,4]). As resources from the oceans become steadily more exploited and ocean space used, there are increasingly trade-offs to be made between sectors, risks of conflicts with negative consequences, and a need to innovate solutions to mitigate these risks [50]. Furthermore, ocean space is not evenly occupied, but rather most uses tend to occur within proximity to the coastline and to human settlements, in shallower waters, leading to some areas being much busier than others. The concept of multi-use, defined as "the joint use of resources in close geographic proximity by either a single user or multiple users" [63], is touted as a way to create new economic opportunities, realize economies of scale, and possibly reduce pressure on marine ecosystems [27,50,68]. The definition of multi-use includes co-existence of multiple uses, as well as overlapping uses in space and/or time (co-location), and requires synergistic coordination of the activities with, for example, the creation of shared services, infrastructure, and costs [36,53,63,68]. A typology of multi-use, created by Schupp et al. [63] (Table 1), spans from subsequent use (MUIV), where uses exist in the same space, to co-existence or co-location (MUIII), where uses exist in the same space and at the same time, to multi-purpose (MUII), where uses may share some peripheral infrastructure, and finally symbiotic use (MUI), where uses exist simultaneously and share services and infrastructure. A further assumption of multi-use is that it is conducted purposefully, rather than occurring accidentally. Different uses of ocean space will fall at different points along this spectrum; while some uses may be highly synergistic and can exist together under a multi-purpose arrangement, others may not be able to occupy the same space at the same time. Multi-use (MU) structures associated with offshore wind farms are increasingly recognized for their potential to restore ecosystem services, enhance carbon capture, and support the production of nutritious seafood [69,73].

### 1.2. What examples of multi-use currently exist in natural resources/ocean uses?

Starting in the 21st century, there have been a number of efforts to promote the coexistence of different ocean uses and sectors, particularly through marine spatial planning (MSP) [22]. However, MSP has been focused on dividing up and assigning ocean spaces for various individual uses in order to limit conflict [26], whereas multi-use is focused on *shared space* simultaneously or consecutively [63]. Still, MSP has set the stage for developing strategies of multi-use, and is often considered the mechanism by which space for multi-use projects can be allocated [28,48,69]. In this sense, MSP plans in different countries have been encouraging combined exploitation [57,62], tending to be not just a sustainable planning option but a key issue in MSP.

**Table 1**
Multi-use types (recreated from [63]).

| Multi-use types | Multi-use Dimensions | | | |
|---|---|---|---|---|
| | Spatial | Temporal | Provisioning | Functional |
| Subsequent use (MUIV) | X | | | |
| Co-location (MUIII) | X | X | | |
| Multi-purpose use (MUII) | X | X | X | |
| Symbiotic use (MUI) | X | X | X | X |

#### 1.2.1. Multi-use in European wind energy areas

The concept of multi-use was formally introduced in Europe in response to rapidly developing Blue Growth, and in particular stemming from the development of the wind energy industry and the resultant competition for space with other uses including aquaculture, fishing, conservation, and tourism. Indeed, many offshore wind farms (OWF) have been operational for a decade or more in Europe [27,75]. Within Europe, there are a number of examples of multi-use policies in place, including several national or regional MSPs in Belgium, Germany, Poland, Portugal, Sweden and Denmark, as well as policies explicitly encouraging co-existence or multi-use of ocean spaces and activities (e.g., Portugal, Spain, France; [38]). The EU and European governments are formally encouraging multi-use through policies such as the EU Marine Spatial Planning Directive [25] while promoting and encouraging multi-use on a European scale [25,23,24], and investing in pilots and technological advancements to accelerate multi-use success (e.g., the MUSES [Multi-Use in European Seas] and UNITED projects) ([36,38]; https://www.h2020united.eu/; https://muses-project.com/).

Many European OWF areas are engaged in advanced multi-use, with co-occurring activities including recreational fishing [32], eco-tourism (https://muses-project.com/), and wind-farm tourism (https://www.h2020united.eu/pilots-denmark) happening adjacent to or within the wind farm areas. For example, the UNITED project has piloted integrating aquaculture including seaweed and bivalve aquaculture with offshore wind farms at multiple sites in Germany and Belgium (https://www.h2020united.eu/pilots), and in Denmark, tourists can visit an offshore wind farm, including climbing the turbines to an observation platform at the top (https://www.h2020united.eu/pilots-denmark). Combining these uses can allow for more efficient use of marine space, and potentially provide ecosystem benefits by reducing the amount of overall space required for anthropogenic activities [55,63,9].

As competition for space increases, commercial fishers and other historical users are increasingly concerned about losing access to spaces they have traditionally used for their livelihoods [29,64]. OWF constrain the movement of vessels transiting into or through an area during both construction and operation periods, and in some cases have restricted fishing access for commercial fishing vessels, either through legal measures [59,7] or as fishing activities have become too risky or impractical [30,64]. In Europe, navigation and commercial fishing are restricted from OWF during construction, and most OWF maintain a safety buffer zone around turbines during operation, effectively limiting commercial fishing within the wind farm, leading to reduced effort and catch, and to negative outcomes for fishers and fishing communities [7,20,59,70,74], although potentially positive incomes for biodiversity and fish recovery through reducing fishing activity and catches [42,16]. There are limited examples of co-location of both mobile and fixed gear fisheries, some of which are subject to individual agreements with energy developers [59,7].

#### 1.2.2. Existing precedent for multi-use in the U.S

In the U.S., where OWE remains in a nascent stage, the concept of multi-use in OWF has been synonymous with co-location. More advanced multi-use, encompassing synergistic and multi-purpose multi-use (MUI and MUII) is still theoretical, and the U.S. lags behind European countries in terms of multi-use policy [38]. However, as large-scale OWE developments are erected, a more advanced multi-use strategy becomes increasingly important to facilitate co-existence of uses, at a minimum, and ideally to promote thoughtful and synergistic sharing of ocean space. At present, many interested parties, including regulators, have an interest in developing a more complex multi-use goal, but there is no coherent strategy or regulatory requirement, minimal funding to support this discussion, and a lack of agreement on what multi-use will look like in the U.S. context [38]. Despite these barriers, ocean multi-use in the United States is not without precedent.

*1.2.2.1. Oil rigs in the Gulf of Mexico.* While most examples of multi-use come from Europe, the United States has experience with multi-use around oil drilling platforms in the Gulf of Mexico, which have taken on qualities of artificial reefs [11,60,61]. Recreational fishers routinely fish around the platforms to take advantage of aggregated fish. A successful Rigs-to-Reefs program has converted nearly 600 oil rigs into artificial reefs in the decommissioning process [12], an example of how a multi-use framework can consider new ocean technology beyond the life of the project.

*1.2.2.2. Block Island wind farm.* In the U.S., only two demonstration-scale wind farms, the Block Island Wind Farm in Rhode Island (BIWF) and the Coastal Virginia Offshore Wind-Dominion Energy in Virginia have been in existence long enough (since 2016 and 2020, respectively) for multi-use operations.[2] Development of the BIWF was guided by the Rhode Island Ocean Special Area Management Plan (Ocean SAMP), which was an MSP process leading to the creation of a plan for ocean uses in Rhode Island and its adjacent federal waters. Importantly, the Ocean SAMP process entailed significant participation of ocean users and community members [45]. One of the guiding principles of MSP is the participatory approach [37,56], as the engagement of key user groups is fundamental to the formulation of common solutions for a framework of shared use.

Studies of the BIWF have documented several cases of multi-use, most of which developed extemporaneously during and following the construction of the wind farm. For example, recreational fishing is a popular activity within the wind farm. Recreational anglers perceive improved catches in the vicinity of the BIWF [5], and specifically target fishing around the turbines [67,72] because of the aggregation of certain targeted species including black sea bass, fluke, and scup [19,66]. While recreational fishing was not specifically developed as a multi-use case, the accessibility of the wind farm area and the reported success of anglers at catching fish has made this an example of synergistic multi-use (specifically MUII).

### 1.3. A need for advancing multi-use in the United States

Enacting multi-use policies may be the only way to ensure equitable and efficient sharing of ocean space by various users. However, many gaps exist in advanced multi-use implementation, the above examples notwithstanding. Needs include an understanding of the concept by policy makers and affected communities, a common vision of how to share ocean space, the necessary policies and regulatory frameworks to operationalize multi-use, and the requisite trust between communities, policy makers, and users to come to agreement about how to use ocean space [27,47]. Thus, there is a need to identify the barriers and opportunities for multi-use in the U.S., where OWE development is quickly becoming a reality, as well as understanding how affected communities understand and perceive the concept and its implications. Accordingly, the specific objectives of this paper are to:

1. Identify the perspectives of engaged constituents in Southern New England about the concept of multi-use, including which activities and sectors they believe to be compatible with OWF development;
2. Identify barriers to and opportunities for multi-use in this region and beyond;
3. Share lessons about perceptions and the possibilities of multi-use as the development of OWE moves forward in the United States.

[2] Note: At the time of writing, two more offshore wind farms have come online, but have not been in operation sufficiently long for multi-use plans to be operational.

## 2. Methods

### 2.1. Multi-Frame project

This research was conducted as part of the Multi-Frame project, a collaborative project conducted under the auspices of the Belmont Forum with U.S. support from the National Science Foundation and the Bureau of Ocean Energy Management, which was designed to provide an assessment of the possibilities of multi-use for ocean systems.

### 2.2. Study area - Southern New England

This study is focused on the Southern New England region of the Northeastern United States, spanning the offshore waters of the states of Rhode Island and Massachusetts. This region is the location of the first operational OWF (BIWF) and the first commercial-scale OWFs in the U. S. At the time of this research, nine offshore lease areas had been leased to offshore wind developers in the region, and multiple offshore wind farms had been permitted, and construction began after the interviews were completed (Fig. 1). The current lease plans include more than 500 wind turbines providing power to Southern New England by 2030.

This region has deep cultural, historical, and economic ties to commercial fishing. It is home to New Bedford, Massachusetts, the most valuable commercial fishing port in the United States, with landings worth $451 million in 2020 [43]. Southern New England also supports robust recreational fisheries, including many for-hire recreational fishing vessels (charter and head boats).

### 2.3. Key informant interviews

Between June and September, 2022, 11 in-depth semi-structured interviews were held with key informants in several sectors who are highly engaged in or impacted by the development of OWE in Southern New England. These sectors included the OWE industry, commercial fishing, recreational fishing, research, and state and federal government. The commercial fisheries advocate represented a broad range of local fisheries relevant for the study site, including demersal mobile gear (e.g., groundfish [cod, haddock, flounders], squid, scallops), and fixed gear (e. g., lobster) fisheries. Key informants were initially selected using purposive sampling [8] to identify representative interviewees from each sector. A list of the sectors for the interviewees is shown in Table 2.

The list of interview questions was developed as part of a broader research project on multi-use (Multi-Frame project) conducted across five countries (Brazil, France, Norway, Sweden and United States), to elicit an understanding of some of the barriers and opportunities for multi-use in these regions, including similarities and differences transferable to different projects around the world. Factors influencing MU development were categorised using the PESTEL framework into political, economic, social, technological, environmental, and legal aspects [35]. This thematic analysis thereafter guided the creation of a semi-structured interview guide used across each case study in the five countries.

Interviewees were first asked for their understanding of the term multi-use, then were asked to share perceptions of how they understand the concept, as well as identifying types of multi-use in Southern New England and barriers and opportunities for multi-use. Interviewees also provided additional perspectives and information about multi-use in the course of the discussions that were further analyzed here.

Additionally, two workshops were held with a focus on multi-use of offshore wind developments involving the commercial and recreational fishing industries, offshore wind developers, state and federal agencies, and other experts. The workshops focused on steps towards multi-use between the offshore wind industry and the two fishing sectors. The commercial fishing sector was primarily represented at the workshops through commercial fishing organizations, bringing perspectives from a range of different commercial fisheries in the region. The workshop

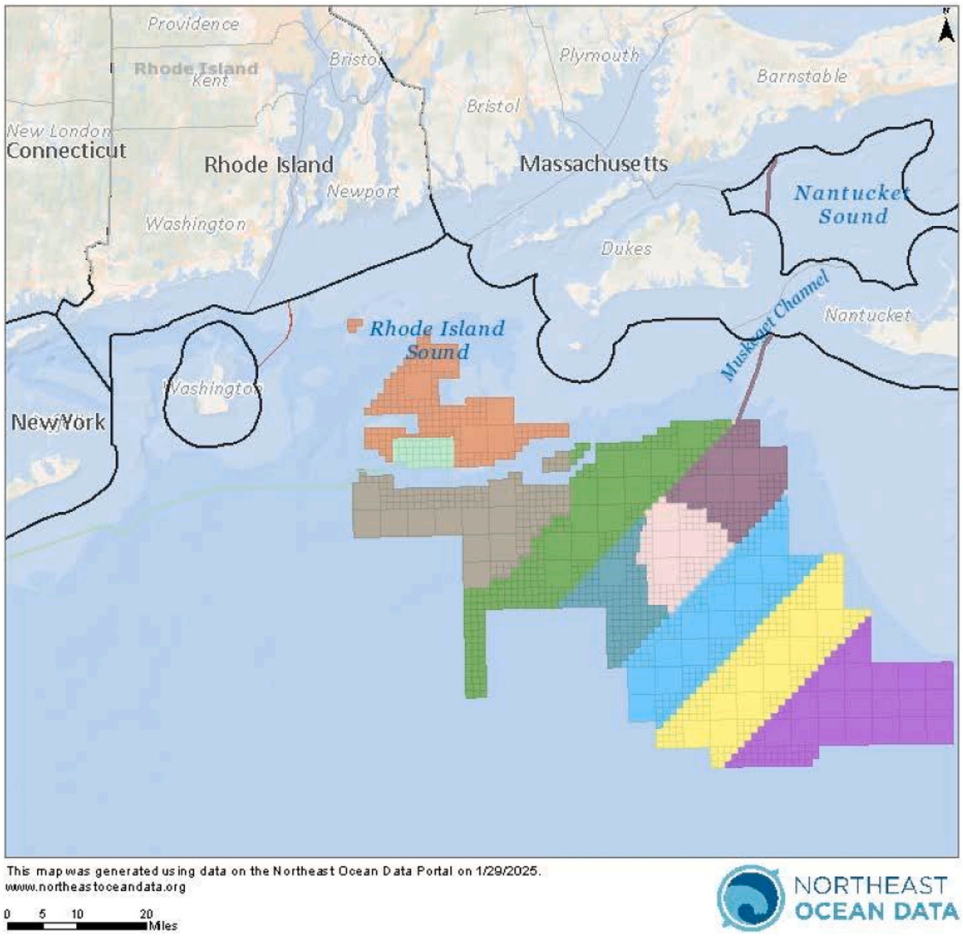


**Fig. 1.** Existing wind energy lease areas in Southern New England as of January 2025. Generated on the Northeast Ocean Data Portal, January 29, 2025.

**Table 2**
List of sectors for the interviewees.

| Interviewee Type | Number |
|---|---|
| Commercial fisheries advocates | 1 |
| Recreational fisheries advocates | 2 |
| State government agency staff | 2 |
| Federal government agency staff | 1 |
| Fisheries and offshore wind research organizations | 2 |
| Offshore wind and conservation advocates | 1 |
| Offshore wind energy industry representatives | 2 |

discussions are drawn on here to provide further context for the interview data.

### 2.4. Thematic analysis using Atlas.ti

A thematic analysis of the interview data was conducted using inductive coding in the Atlas.ti software package (Version 23.2.1) [3] to identify recurring themes and patterns in the interview response data. Interviews were analyzed qualitatively to understand how interviewees perceived the concept of multi-use and what kinds of uses they described as being compatible with OWE. Inductive coding was used to identify and group themes as they emerged from the data [6,17]. Interview codes were developed around use types and perceptions of their compatibility with offshore wind, and categorized and analyzed to identify common themes as well as opportunities and barriers to multi-use. Identification of barriers and opportunities is a critical step for promoting future multi-use, as identified in the Multi-Use Assessment Approach [40].

## 3. Results

### 3.1. Types of multi-use identified by key informants, and related considerations

The types of multi-use identified fall at different points along the spectrum of multi-use as defined by Schupp et al. [63], and as described by the interviewees. Perceptions of the possibility for and challenges of multi-use between different use types, along with where they were interpreted to sit on the multi-use spectrum, are summarized below.

#### 3.1.1. Commercial fishing and offshore wind

Each of the key informants interviewed mentioned commercial fishing when asked about multi-use, and described it as an activity that can both be compatible or in conflict with offshore wind development. Perceptions varied among key informants about the compatibility of OWF and commercial fishing. Conflicts with commercial fishing have dominated the discussion about offshore wind development in the Southern New England area, so, unsurprisingly, the majority of interviewees expressed more negative statements about the compatibility of mobile gear commercial fishing with OWE compared with other uses. The chief concern of most informants was whether fishers will be able to fish and transit safely between the turbines within the wind farms. State and federal regulators and offshore wind industry representatives pointed to concessions that had been made in the spacing of wind turbines during the permitting process to create navigational channels, for vessel passage, However, representatives and advocates for the commercial fishing industry expressed skepticism that these transit lanes would be sufficient to ensure the safety of commercial fishing vessels

within a OWF.

Interviewees expressed anticipation that commercial fishing would continue in the wind farm areas to some extent once the OWF were constructed, consistent with "co-location". Some key informants even hypothesized that commercial fishing could improve within the OWF if the introduction of hard structures and substrate into what had been mainly sandy areas could result in the aggregation or increased production of some commercially harvested fish species, such as black sea bass.

Most key informants made a distinction between mobile fishing gear (e.g., trawling) and fixed fishing gear (e.g., pots, gillnets, traps). The latter will be easier to conduct safely within an OWF. Fishing with fixed gear, by definition, does not require the fishing vessel to navigate while fishing, reducing the likelihood of gear getting caught up on a turbine, cable, or scour protection, all of which could be a safety hazard. For this obvious reason, fixed-gear use is more compatible with OWF. Simultaneously, key informants expressed the need for spatial and operational adaptations on the part of commercial fishers, including fishing in other areas outside of the OWFs, switching target species, adopting gear modifications or new gear types would facilitate fishing within the OWFs, switching target species, and diversifying livelihoods through working in offshore wind support services. While each of these adaptations may allow commercial fishing to continue, and these adaptations are not mutually exclusive (i.e., a commercial fisher could employ one or all of these strategies), it is worth noting that not all of these imply multi-use or coexistence. Moving fishing areas to avoid conflict with an OWF (displacement) is not, on its own, a multi-use strategy.

#### 3.1.2. Recreational fishing and offshore wind

The majority of participants explicitly listed recreational fishing (n = 8) as an activity suitable for multi-use, and indeed recreational fishing takes place within the BIWF today [66,72]. Nine of eleven key informants described neutral to positive effects of OWF on fish habitat for some species, particularly demersal species preferring hard substrate, including the placement of large structures offshore, creating an artificial reef effect or enhancing recreational fishing opportunities by introducing additional fish habitat structure in the ocean environment [21]. Multi-use of recreational fishing and offshore wind in the way interviewees described would be classified as either co-existence or co-location (MUIII, cf., [63]); recreational fishers will potentially take advantage of the fish aggregation characteristics of wind turbines and target their fishing in and around the turbines.

#### 3.1.3. Aquaculture and offshore wind

Nearly all the key informants (n = 10) cited aquaculture as an example of a use that could be compatible with offshore wind, and in particular, aquaculture of bivalves or kelp. Nevertheless, many described existing regulatory and other barriers to offshore aquaculture, which has not yet been permitted in this part of the U.S., as potentially inhibiting the multi-use between aquaculture and offshore wind energy. While they had a generally positive perception of the compatibility of these uses, the discussion remains hypothetical because of the lack of existing offshore aquaculture facilities. Aquaculture in offshore wind areas would be considered an example of symbiotic multi-use (MUII -[63]), where aquaculture farmers are likely to use the OWF or perhaps the turbines themselves to anchor cages or other farm equipment. This would inevitably require agreement and coordination between aquaculture farmers and offshore wind farm operators, perhaps even sharing crews, vessels, or monitoring data between them [15,39].

#### 3.1.4. Tourism and offshore wind

Tourism was also cited as a use type compatible with the multi-use of offshore wind farms. Whale watching, diving, and wind farm tours were all mentioned as potential multi-use cases. Indeed, wind farm sightseeing tours already exist around the BIWF, as do recreational fishing charters that focus on fishing around the wind turbines as a destination, both because of their perceived benefits in aggregating fish and because of the novelty of viewing the turbines up close [67]. Wind farm tourism could also be considered an example of synergistic multi-use (MUII) according to Schupp et al. [63], as the tourism is entirely dependent on the existence of the OWF.

#### 3.1.5. Future uses

Some interviewees described potential future uses of wind farm areas, including, for example, the development of green hydrogen along with wind power at offshore platforms. Others mentioned the need to think beyond current uses of the area to emerging technologies that could coexist or exist symbiotically with offshore wind, such as green hydrogen or solar energy, and discussion of future uses included a recognition that multi-use approaches should extend beyond a focus on existing uses of ocean spaces.

### 3.2. Identification of barriers and opportunities

An inductive analysis of the interviewees answers was conducted to identify barriers and opportunities to multi-use with OWFs in Southern New England, as well as some of the enabling conditions that should exist ahead of implementing multi-use.

#### 3.2.1. Barriers

1. Lack of federal policy on multi-use

   At present, no federal policy exists in the United States to guide or to promote multi-use in OWE development [38]. In fact, as reported by key informants, multiple federal and state agencies are responsible for managing various ocean uses, leading to a compartmentalized approach. The lack of a guiding or coordinating policy for multi-use has meant that any overtures toward multi-use by developers are done on an entirely voluntary or informal basis, and they could also easily decide to move away from multi-use activities at any point during wind farm operations. Multi-use concessions are also negotiated piecemeal for each federal lease rather than following a consistent, transparent policy. For example, in the first two commercial OWF in Southern New England, a one nautical mile grid spacing between turbines was recommended based on navigational safety considerations from the U.S. Coast Guard and discussions with commercial fishers, to enable transit through the wind farms. Interviewees expressed an expectation that this design would be a permitting requirement for other proposed OWFs, but as this is not an official policy, there is uncertainty among both developers and commercial fishers about whether this will be required of all OWF permits moving forward. While some key informants noted that developers are likely to prefer the lack of an overarching federal policy, giving them more flexibility in negotiating with user groups, this may disincentivize multi-use in the long run, and disadvantage user groups who are not at the table to negotiate with developers. Further, it should be noted that multi-use can create additional financial costs and logistical hurdles to OWE, so offshore wind energy developers may not implement it willingly. Some interviewees concluded that multi-use is not enforceable without a federal policy in place.
2. Lack of cooperation between federal agencies

   Many interviewees described a lack of cooperation between the relevant federal agencies responsible for managing natural resources and human uses in ocean space as a significant barrier to multi-use. In the U.S., offshore wind energy siting, permitting, and regulation within federal waters (outside of 3NM) is led by the Bureau of Ocean Energy Management (BOEM). NOAA, as the agency responsible for managing the ocean natural resources of the U.S., including fisheries, serves a consulting role, providing data and analysis on ocean conditions and affected marine resources and consulting with BOEM to meet the requirements of national policies. Several interviewees

noted that these two agencies do not have effective protocols for communication and coordination related to offshore wind development, in part due to the imbalance of authority. This poses a barrier to multi-use because there is a need for effective federal guidance from these agencies to advance multi-use strategies.

3. Federal agencies are not always open to innovation without evidence to support it

   Furthermore, while many interviewees described the need for innovation to foster multi-use practices, most multi-use scenarios that are more than just achieving "subsequent use" (MUIV) will require multiple permits for various activities, falling under the jurisdiction of multiple federal and often state agencies. For example, allowing experimental commercial fishing gear that can more easily be fished within a OWF footprint to be deployed within a OWF will require the gear to be permitted by NOAA, and may require approval from BOEM for multi-use of the lease area. Offshore aquaculture based around offshore wind turbines would require permitting from the U.S. Army Corps of Engineers, the Environmental Protection Agency (EPA), and in some cases from NOAA as well. Designing scour protection to maximize habitat value for fish species may entail using materials or technology that are not yet approved by BOEM.

   Despite the *status quo* (MUIV), which requires individuals and businesses to acquire permits for each of these activities, interviewees pointed out that federal agencies are slow to permit new uses and often skeptical of new innovations without sufficient research to support their benefit or to demonstrate a lack of environmental impact. Thus the permitting process, or even the uncertain path to permitting, may stifle the innovation needed for successful advanced multi-use.

4. Insufficient engagement of affected communities and user groups

   Many interviewees listed insufficient engagement of affected communities among the barriers to multi-use in Southern New England. While there have been efforts by the offshore wind developers to engage affected user groups, including both commercial and recreational fishers, many interviewees expressed that these have been both insufficient and ineffective, and that many affected groups feel their input was not taken into consideration in the planning and siting processes for OWE in the region. Relatedly, some interviewees expressed a perceived lack of transparency in the approval and siting processes that have led to construction of the first OWFs in Southern New England. These factors have yielded a disintegration of trust between developers, ocean users and communities. The Ocean SAMP was an initial example of a community engagement process for ocean planning, which ultimately led to the development of the BIWF [45, 65]. With the expanded growth of OWF, an inclusive and transparent engagement process that results in implementation of agreed upon decisions is critical to successful advanced multi-use planning, both for ensuring an equitable and fair process, and for fostering long-term acceptance and sustainability ocean planning.

5. Conflict between commercial fishing industry and offshore wind

   One of the most significant challenges to promoting advanced multi-use in Southern New England is the ongoing, significant distrust between the commercial fishing and offshore wind industries. Broadly, the two industries do not share a common vision of the future, or of what advanced multi-use could look like between these two uses. Interviewees from several sectors reported that many commercial fishers are convinced development of OWF will be detrimental to their industry and livelihoods by excluding access, either through regulatory or practical means, to wind farm areas which sit within traditional fishing grounds, and potentially by causing adverse impacts to fish habitat that could be deleterious to fish populations. As reported by interviewees, many commercial fishers have disengaged from formal discussions around multi-use planning, believing their concerns were not being heard. Furthermore, the offshore wind developers (2) interviewed did not share the perception that wind farm development would result in detrimental impacts to the livelihoods of fishers, and thus the two sides lack a common understanding about what the impacts might be. OWE developers have made attempts at engagement with the commercial fishing industry, but some have been more successfully received than others. Two interviewees noted that the few attempts to engage the commercial fishing industry were meant solely to check a box (or at least that was the perception of the fishers), rather than meaningfully consider additional perspectives and opportunities for collaboration. The result has been an impasse where mistrust persists on both sides.

6. Not all uses are compatible

   Some interviewees pointed out the limits of advanced multi-use in that some ocean uses may be inherently incompatible, and thus, may not be able to successfully coexist. For example, a few (3) key informants expressed concern that developing aquaculture within OWFs would be incompatible with commercial fishing in the same space, as implementing mariculture operations around the base of wind turbines would further restrict the space needed for commercial fishing vessels to fish or transit safely within wind farm areas. Likewise, it was noted that aquaculture operations could reduce the opportunities for recreational fishing around wind turbines, depending on the configuration of the aquaculture farms.

7. Safety considerations

   Several interviewees pointed to important safety concerns for commercial fishing vessels navigating through wind farm areas. At present there are no legal restrictions on commercial fishing vessels accessing wind farms in the U.S. However, commercial fishers and industry advocates expressed concerns about the dangers of fishing vessels trying to fish in or transit through OWFs, particularly in times of adverse weather conditions or low visibility. The OWFs also present a navigation barrier in that if vessels choose to navigate around the wind farms while steaming to or from fishing grounds, they may add travel time and fuel consumption. An additional concern expressed was that Coast Guard helicopters may not be able to fly between turbines as needed to conduct a rescue, but no effort to validate this concern was made. The required 1 nautical mile spacing between turbines of the two OWF built to date is meant to allow access to commercial fishing within the OWF. This layout, which potentially introduces additional costs to the wind farm design by reducing efficiency, was intended as a concession to the commercial fishing industry through consultation with fishers, the Coast Guard, and federal and state regulators, recognizing the need to allow for the commercial fishing industry to continue to use these areas. It was reported in some interviews that many fishers are nonetheless concerned that this spacing is insufficient for navigational safety, particularly in the event of adverse weather conditions including storms or fog, and do not agree mobile gear fishing could take place within the footprint of the wind farms. Bonsu et al. [7] likewise found safety concerns, including uncertainty about insurance considerations, and notes that these probably pose a barrier to co-location and multi-use of commercial fisheries and offshore wind in Europe. The perception or the reality of safety challenges presents a persistent barrier to multi-use with the commercial fishing industry.

#### 3.2.2. *Opportunities*

1. OWE developers incorporating commercial fishing access into design

   To promote co-existence (MUIII), multiple wind energy developers in Southern New England have been designing access for commercial fishing vessels into the OWF layout by increasing spacing between wind turbines to one nautical mile. This spacing to ensure safe transit and enable the continuation of commercial fishing activity, as a means of enabling co-existence between the industries. While many fishers are concerned that this spacing is

insufficient for navigational safety, it nonetheless represents an attempt by developers to enable cross-sectoral multi-use.

2. Considerations for multi-use have informally been part of the federal bidding process

   Beyond voluntary alterations to wind farm layouts to promote co-existence with the commercial fishing industry, some key informants noted that considerations for commercial fishing access have informally become part of the federal bidding process for offshore wind areas and for permitting of OWFs. While not an official policy, some key informants believed OWF plans that include concessions to the commercial fishing industry in terms of access and transit may be more likely to be awarded to developers and approved by BOEM.

3. Federal decision-making process does not currently restrict any sort of multi-use

   One key opportunity for advanced multi-use is that BOEM, the U.S. federal agency responsible for permitting offshore wind projects, has no existing policy on multi-use as of the time of publication. This can be viewed as an opportunity (as well as a barrier) in the sense that federal policies currently contain no restrictions on multi-use activities of any kind. Interviewees contrasted this with the European context where commercial fishing near OWFs is restricted in many countries.

4. Successful incorporation of recreational fishing and OWE in Block Island

   Southern New England is home to the first pilot-scale offshore wind farm in the U.S., and this region has experience with advanced multi-use that has moved beyond co-existence to a more synergistic relationship. Recreational fishing regularly takes place within the BIWF, as do tourism activities including wind farm tours. Recreational fishers have described the wind farm as a destination for fishing because of the aggregation of some fish species in the area of the turbines [66]. Thus, several (5) key informants discussed the BIWF as a positive example of multi-use and a model for moving forward. Further, as described by interviewees, recreational fishers have identified the wind turbines as a visual navigational aid, and like the fact that they now have mobile phone service in the vicinity of the OWF, both which promote safety for boating activities. These factors are illustrative of how advanced multi-use is already happening in this area, albeit in a mostly ad hoc, unplanned manner.

5. Habitat enhancement creates opportunities for multi-use

   Interviewees pointed to the creation of hard substrate by the introduction of the wind turbine towers and the scour protection necessary around the turbines and over cables as an opportunity for fish species which prefer hard substrate, such as black sea bass, tautog, and cod [67], all species prioritized by recreational fishers, to colonize the wind farm areas. Indeed, some research has pointed to OWFs as creating an artificial reef effect [21,31,48] as has been observed on offshore oil rigs [11]. Recreational fishers using the BIWF as a fishing ground have attested to the creation of habitat here as attracting fish species to the area [5,67]. Interviewees pointed to this as a positive feature of OWFs, and developers have touted the habitat creation potential of OWFs as a way to offset the loss of natural benthic habitat during the construction process. Indeed, the artificial reef aspect of OWFs creates advanced multi-use opportunities for the recreational fishing industry, enhancing fishing within the OWF. Some interviewees also speculated that the habitat and fish aggregation aspects of OWFs could benefit the commercial fishing industry as well, specifically fishers who might target those species using fixed gear, but this opportunity has yet to be demonstrated. Furthermore, while most key informants described the creation of artificial reef in terms of its benefits to fisheries and commercial/recreational fishing, a few (n = 3) described it in broader terms for its benefits to biodiversity and conservation. Whereas in Europe, biodiversity impacts and benefits have been a more significant part of the research and discussion around offshore wind energy development, including restricting fishing from OWF to promote fish recovery and biodiversity enhancement [42,48,18,16], the focus from the interviewees was largely around the relationship between habitat enhancement and fisheries opportunities.

6. Attempts at community engagement

   Many interviewees agreed that successful engagement with communities and user groups is a key component of multi-use, both for designing OWFs in a way that accommodates the needs of other users, and for building trust between developers and user groups. OWF developers have made attempts to engage with user groups in the region with varying degrees of success. Several offshore wind developers have a fisheries liaison whose job is to engage with the commercial fishing industry and learn about their needs and assuage concerns where possible. While outreach has not always been successful from the perspective of interviewees (see more under Barriers), mainly due to their experience of developers not taking actions on responding to their concerns, there are frameworks in place for developers to engage with commercial and recreational fishers, as well as other ocean users. For example, some interviewees pointed to the one-nautical-mile spacing between turbines incorporated into current design plans for several OWFs as an example of developers listening to the needs of the commercial fishing industry. However, this is still viewed as inadequate by most commercial fishers.

7. Alternative gear types

   Commercial fishers are famously adaptive, as their livelihood requires operating with constant uncertainty and change even under the best circumstances, to which they often respond by switching between target species or gear types, or engaging in livelihood diversification [1,71]. To capitalize on this adaptability and to promote advanced multi-use that incorporates safe and efficient commercial fishing activity within the OWFs, some commercial fishing advocates are conducting research into alternative gear types that can be more easily used within OWFs. For example, fishing for squid (an important commercially targeted species) using automatic squid jigs instead of an otter trawl is being explored by the Commercial Fishing Research Foundation. Promoting multi-use by appealing to commercial fishers may involve reimagining the gears being used and how fishing is operationalized within these areas. However, doing so will require funding to promote research into fishing gear that can be compatible with OWFs. Also, a change to the permitting structure for state and federal commercial fishing is needed to enable affected fishers to easily acquire new permits for new or alternative gear types, a process that is sometimes restricted and frequently difficult to navigate, and was raised multiple times during the workshops.

8. Diversification of livelihoods

   Some interviewees (3 of 11) described the development of offshore wind farms as an opportunity for area residents, and commercial fishers in particular, to diversify or supplement their livelihoods. Some offshore wind developers have hired commercial fishing vessels and captains as support vessels during construction, or for monitoring, although interviewees also described logistical and legal challenges with doing so. Interviewees described OWFs as an opportunity for commercial fishers to diversify their incomes by using their skills as mariners and mechanics, continuing to work on the water while working for offshore wind developers, either supplementing or replacing their fishing income. The interchange of the commercial fishing and offshore wind industries through employment of fishers and fishing vessels as support for offshore wind farms could enhance

multi-use between these two industries, moving the relationship more towards symbiotic use (MUI). It must, however, be noted that commercial fishers do not necessarily view the creation of livelihoods to replace fishing as a positive outcome, as most would prefer to be fishing and view it as a way of life [51].

9. Turbines as observation platforms

   One potential example of multi-use that many interviewees perceived positively was the opportunity to use offshore wind turbine platforms as an opportunity to collect and share oceanographic data. As large, static structures in the ocean, turbine platforms could be fitted with many types of sensors and other equipment for collecting oceanographic, biological, or user data, serving as ocean observing platforms. This would enhance their multi-use benefits, and provide direct or indirect benefits to user groups, including commercial and recreational fishers, who could rely on access to real-time data to assess current oceanographic conditions in the vicinity of a wind farm and use this information in decision making about fishing. Platforms can also be used to collect time-series data to assess atmospheric and oceanic change over time, whether due to the construction of offshore wind farms, climate change, or other factors. Presently, some researchers are making measurements in and around the BIWF and future OWF. However, this recommendation is not wholeheartedly supported by the developers for many reasons, such as potentially affecting the structure of the turbine, reducing efficiency, the financial and human capital required to maintain such systems.

10. Charging stations for electric vessels

    One potential future opportunity for multi-use within wind farm areas which was mentioned by multiple interviewees is the opportunity for providing charging stations for electrified commercial and recreational fishing vessels, as well as other vessels. As some fishing advocates look to reduce carbon emissions and "green the fleet" by electrifying motors, the energy created by the wind turbines and the structure in the ocean provides an opportunity to equip them with charging stations for vessels. Electric or hybrid engines are still mainly at a pilot stage within the fishing industry, and remain prohibitively expensive for most commercial fishers, but could be a potential future, synergistic use, increasing multi-use between offshore wind and other industries and moving these industries to a symbiotic relationship. Once again, interviewees acknowledged this opportunity would require the support of developers.

## 4. Discussion

### 4.1. Multi-use is the next iteration of sustainable ocean planning beyond MSP

Key informants described the conditions that enable implementation of advanced multi-use within the context of the accelerated growth of offshore wind development in the United States as currently weak. However, this research has underscored the opportunity to advance multi-use as one of the most pragmatic solutions towards achieving sustainable ocean planning. Interviews with key informants illuminated several examples of possible opportunities for a more evolved multi-use, integrating OWE with recreational fishing, tourism, and research as offshore observation platforms. The current approach toward multi-use in the U.S. is largely to first avoid conflict by directing development toward areas that are not heavily used by other industries through traditional MSP, in an attempt to negate the need for multi-use, and then secondly to promote coexistence between uses. Through commitment and investment, Southern New England could move beyond coexistence (MUIII) to consider how to create synergies between uses, moving further along the Schupp et al. [63] spectrum of multi-use toward MUII and MUI, a necessary step for enhancing societal benefits of offshore wind energy and existing ocean uses.

### 4.2. There is a need for clear federal guidance to enable multi-use in the U.S

At present, advanced multi-use with OWF development is a mostly untested concept in the U.S. A key barrier to fully realizing multi-use in the U.S., and particularly to moving multi-use from co-existence to synergistic use, include a lack of any federal policy or clear federal guidance to direct or encourage multi-use or identify multi-use objectives. Rather than a consistent policy, multi-use in the U.S. has emerged as the result of case-by-case negotiations between offshore wind developers and users for each new OWF development. This approach can be contrasted with the embrace of multi-use in Europe, with national and EU-level policies that explicitly encourage multi-use along with available funding to implement pilot projects. Multi-use approaches in the U.S. are neither explicitly encouraged nor explicitly discouraged, leading to uncertainty and confusion among both offshore wind energy developers and users of ocean space about what types of uses may be allowed, along with creating socially and economically inefficient outcomes. This uncertainty also creates inertia moving forward, as multi-use may require the investment of time and/or money on the part of developers, federal and state agencies, and other users, each of whom may be unwilling to make such an investment in an uncertain environment.

Furthermore, the lack of integration or coordination across agencies, as described in the interviews, has presented at least a perceived barrier to developing, regulating, and managing a multi-use approach to developing offshore wind in Southern New England. A clear federal policy around multi-use would additionally compel further coordination between the multiple federal agencies who must be engaged in permitting various uses involved in multi-use.

### 4.3. Multi-use needs to be built in at the outset

In order to effectively reduce conflict, identify synergies and efficiencies, and promote equitable outcomes for engaged communities, a multi-use strategy (ideally federal) needs to be advanced as early as possible in an offshore wind planning process. Incorporating multi-use objectives and guidelines into an offshore wind development policy, and into federal agency objectives, could facilitate consideration of advanced multi-use at the outset of a project, allowing for more deliberate and creative synergies between uses. For example, a focus on accommodating fishing activity, driven by ongoing conflicts described herein, has meant that consideration of how to promote biodiversity within wind farms has not been as much of a focus, as evidenced by its lack of emphasis in the interviews. To date, the approach taken in the U.S. has been to avoid and minimize conflicts with users where possible during the leasing process by removing certain high-use areas from consideration, and to mitigate losses, including through compensation to fishers, when avoiding conflicts is not possible [13], without prioritizing the possibility of more synergistic multi-use. Bringing together the relevant ocean sectors and users in a process of designing multi-use before a project has begun, to identify multi-use objectives and assess the necessary enabling conditions including governmental commitment, institutional capacity, and a sufficient level of support, would allow offshore wind development to follow best practices for sustainable coastal development [44,46]. As interviewees described, considering advanced multi-use early in the design process, where wind farm layout and micrositing of turbines, including spacing, is being done, can facilitate transit and continued use of the area by the commercial fishing industry, among promoting synergies with other uses.

### 4.4. Multi-use requires the continued participation of user groups from the outset

To be effective, multi-use actions require an authentic, inclusive participatory process that brings together affected users and other interested parties from the outset of the planning process, in order to achieve multi-use outcomes that benefit user groups, are agreed upon, and can be sustained over time. Bringing together interested and affected parties can help to define the vision, objectives, and guiding principles for multi-use for various projects and areas, based on what they view as opportunities [38]. Critically, as one key informant described, multi-use should give everyone fair and equal access to ocean spaces. As the interviews have demonstrated, many user groups in the Northeast U.S., especially members of the commercial fishing industry sector, feel they have not been able to effectively or sufficiently engage in discussions about multi-use in offshore wind planning processes in Southern New England. This perspective is due in part to decisions being made regarding leasing ocean space before the commercial fishing industry was engaged. Furthermore, many believe the processes have not been sufficiently transparent. This lack of transparency and unclear commitment towards advancing multi-use has resulted in a lack of trust (and understanding) to promote multi-use. In this respect the U.S. approach to multi-use will likely differ from the approach taken in most European countries, where access to OWF by fishing vessels is generally restricted. As described above, maintaining access to OWF for the fishing industry in the U.S. has been prioritized as a multi-use objective by many actors, which has also created a hurdle to actualizing multi-use in this context.

While it may not be possible to arrive at a solution that maximizes benefits for all users, engaging communities and user groups early and often in the process means arriving at a solution that is more likely to be understood and accepted by all of those affected, can better identify synergies between uses, and increases the likelihood of a more optimal outcome [45,52,56,58]. Addressing multi-use from the outset of a development process, prior to the leasing stage, would allow users to see their interests included in future plans. Furthermore, authentically engaging users at the outset and throughout the planning, development, and operation phases, and allowing their perspectives to be heard will increase the legitimacy of the entire process from their perspective [28]. This requires moving beyond an informative process characterized by public meetings and input sessions to one that includes proactive, collective, and iterative and sustained communication [33].

### 4.5. Rhode Island Ocean SAMP experience provides a model in the region for furthering multi-use

Multi-use represents an evolution from many of the MSP initiatives of the last two decades. Whereas MSP carves out areas of ocean space to separate particular human uses, multi-use imagines these uses to coexist in the same ocean space and time, and to benefit from each other's existence. While the Rhode Island Ocean SAMP applied an MSP approach towards identifying a site for the nation's first wind farm that would have the least disruption to existing uses of ocean space, it has helped enable some multi-use activity. Through a participatory process with user groups, goals that prioritized both honoring traditional uses and providing access to new compatible uses encouraged the introduction of offshore wind energy [45]. The presence of an OWF has increased recreational fishing activity and tourism in the same area and timeframe [66], providing an example of how MSP ultimately led to multi-use. The introduction however, of other maritime activities including aquaculture within the wind farm area, has not been successful, not for lack of interest, but rather due to a combination of economic and regulatory factors along with a lack of political will.

### 4.6. As ocean uses and technologies proliferate, the need for comprehensive multi-use policies and approaches grows

This paper is focused on key informant perceptions of multi-use in Southern New England, where OWFs are already in place, and more turbines are being installed as this manuscript is written. Here, the opportunity to implement an effective, inclusive multi-use design process ahead of the design and construction phases has already passed for those OWFs already in progress. However, a coherent multi-use policy and robust processes for multi-use design are needed moving forward in particular for other regions of the United States where offshore wind development is in a nascent stage. For example, as of writing, lease areas had been granted to developers in the Gulf of Maine region, off the U.S. West Coast, and in the Gulf of Mexico [14]. For these areas, the opportunity for integrating a multi-use process in the design and construction phases still exists, and ideally future multi-use processes will begin before the leasing phase through a consistent national policy. Drawing lessons from the first commercial-scale offshore wind developments in the U.S. can advance multi-use for these and other future offshore wind energy projects yet to be considered, including how to expand opportunities for synergies between uses. Moreover, as offshore aquaculture policies and technologies advance, a multi-use framework will be needed to think not only about how to create synergies between aquaculture and offshore wind, but also how to ensure coexistence between offshore aquaculture and commercial fisheries [10,34], as well as other ocean uses. It is critical for federal and state agencies, research institutions, and private enterprises to invest in multi-use research and multi-use engagement processes to facilitate innovation and to maximize the benefits of ocean space.

### 4.7. Research and Innovation will be important for advancing multi-use

More research and pilot projects are needed to test the possible synergies between offshore wind and other industries in the U.S. This includes piloting new uses or technologies, such as fishing gear modifications, engaging in cooperative research between industries, and providing funding for innovation. Again the U.S. approach to multi-use can be compared with Europe's, where there have been a number of pilot projects funded to identify and develop synergies between uses. Monitoring and research should be a collaborative and transparent effort, involving commercial and recreational fishers and other user groups to both develop and implement these monitoring and research programs [49]. In addition, it is important to identify and better understand net-positive opportunities and actions – including restorative measures, alternative siting and operations – that can offset negative change from an ecological and social perspective and promote marine biodiversity [48,16]. Finally, funding is needed to develop research and innovative technologies that support the coexistence of offshore wind development and other ocean users, including, but not limited to, fishing gear and vessel modifications, and greening or electrifying the fleet - possibly in the future offering energy charging at the wind farms.

## 5. Conclusion and recommendations for moving forward

As new uses of ocean space begin to compete with traditional and culturally important uses of space, such as commercial and recreational fishing, there is a need to develop advanced multi-use approaches and policies to maximize the environmental and sociocultural benefits of the oceans, while facilitating their support of an emerging blue economy. As offshore wind energy developments are being rapidly constructed, multi-use strategies can provide a way to increase synergies and reduce conflicts, enhanced by a participatory process to promote an equitable and efficient use of ocean space. Multi-use further provides opportunities to enhance socio-economic value of existing and new industries, including through job creation, income diversification, energy synergy with offshore wind sources, and local economic development.

Practically, multi-use involves tradeoffs and concessions between industries and users. A win-win scenario may not always be attained. The outcomes of multi-use will be dictated by existing priorities and the role of current users in proposing new uses, as well as the existing or projected social and economic benefits of each. At the same time, multi-use can and should be about more than uses accommodating one another, and specifically, existing users accommodating new ocean uses such as offshore wind energy development. If done effectively and equitably, multi-use can also bring benefits to existing uses including aquaculture, commercial and recreational fisheries, and tourism, as well as creating opportunities for new uses.

Promoting multi-use as an integral part of offshore wind energy development, including considering the full spectrum of multi-use, from multi-functional infrastructure to subsequent use of offshore wind platforms by other industries, will allow all involved to maximize societal benefits of offshore wind energy development. Effective planning processes that seek to engage users for equitable outcomes, maximize the possible synergies between uses, and that are backed by comprehensive policies will support an inclusive blue economy into the future.

## CRediT authorship contribution statement

**Sarah Lindley Smith:** Writing – original draft, Methodology, Conceptualization. **Jennifer McCann:** Writing – review & editing, Writing – original draft, Supervision, Investigation, Conceptualization. **Julia A. Bingham:** Writing – review & editing. **Sereno DuPrey Diederichsen:** Writing – review & editing. **Fredrik Gröndahl:** Writing – review & editing. **Josselin Guyot:** Writing – review & editing. **Céline Rebours:** Writing – review & editing. **Jean-Baptiste E. Thomas:** Writing – review & editing. **Carlos Vinicius da Cruz Weiss:** Writing – review & editing. **John P. Walsh:** Writing – review & editing, Supervision.

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## Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2025.106851.

## Data availability

The data that has been used is confidential.

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