Offshore Wind Science and Research:
Promoting Beneficial Colonization of Offshore Wind Infrastructure

Synthesis Report -
Nature-Inclusive Design of Multi-Purpose Offshore Wind Farms
Task 1: Workshop/Stakeholder Engagement and Literature Review

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Introduction

Offshore Wind (OW) development in the United States (U.S.) is currently primarily focused along the Atlantic Coastal Shelf stretching from the Carolinas to Maine. This region contains almost all the OW lease areas in the U.S. because strong wind resources paired with relatively shallow water depths allow well-established fixed foundation technologies to be used (see Figure 1), and close proximity to major city hubs with high energy demands.[1] Recent OW growth has already led to $36B of investments into port infrastructure across the U.S. according to an industry report.[2] However, as OW grows it is important to consider how it fits into the pre-existing economy and other ocean-uses.

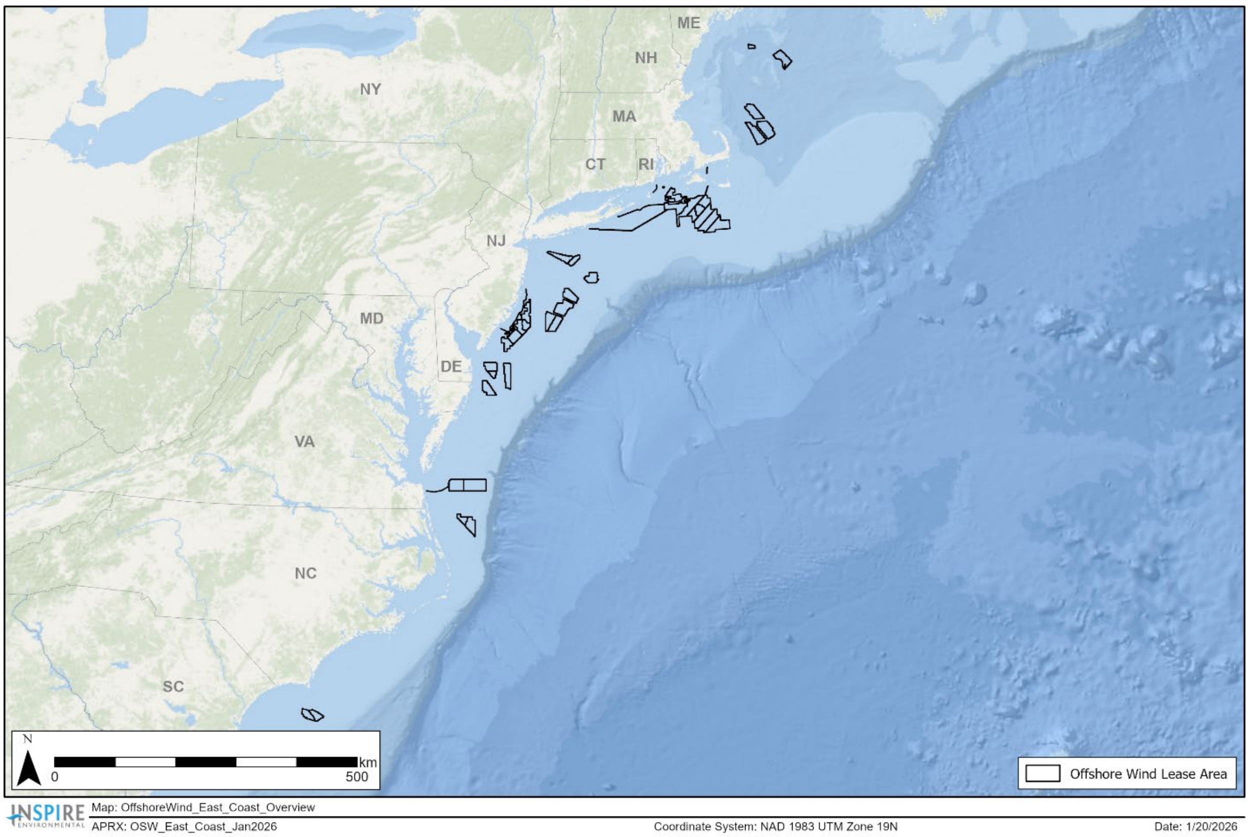

Figure 1. Map of East Coast Atlantic Shelf with OW Lease Areas

OW development along the East Coast must coexist alongside a major fishing industry with strong cultural and economic ties to coastal communities.[3] Commercial fisheries operating out of New England and mid-Atlantic ports generate $2B/year in landings revenues, or about 40% of the national total, and the seafood industry in this region is estimated to support, directly or indirectly, nearly 350,000 jobs with total sales impacts of over $45B/year.[4] Even before OW development started in this region, these fisheries were at risk due to the combined impacts of a changing climate and anthropogenic effects such as overfishing and local pollution.[5] Compared to the North Sea, which had an established oil and gas industry prior to the development of OW, the East Coast of the U.S. does not have a history of offshore structures. Creative thinking and proactive planning are needed to coordinate the coexistence of the commercial fishing industry and the new offshore energy industry.

In addition to specific conflicts with fisheries, local communities have been skeptical of OW. For example, Smythe et al. used an energy justice framework to investigate the perceptions of members of coastal communities in the Northeast to OW; they found that local "participants experienced the federal government-led planning and permitting process, in itself, as the problem" and that "the primacy of local communities was inadequately recognized".[6] This finding mirrors prior work from Susskind et al. that used a database of renewable energy project opposition to highlight how procedural complexity is a risk factor that affects public opposition to projects.[7] In addition to concerns about procedure and a general backlash to renewable energy, OW also faces a nascent network of opponents made up of a mix of local groups enabled by formal think tanks that provide an "information subsidy".[8] Engagement with local parties to build a positive vision about the role of OW in the ocean could counteract some concerns.

One key theme uniting the challenges with the fishing industry and general public is that OW energy in the U.S. needs to be incorporated into the larger blue economy that encompasses all ocean activity. In their 2016 article "The New Blue Economy: the Future of Sustainability," Spalding introduces the term the *New Blue Economy,* noting the importance of having a well-defined scope with specific sectors and metrics so that its growth can be tracked in a way that is "understandable and usable by decision-makers at varying scales".[9] Spalding's paper breaks the new blue economy into traditional sectors (i.e. Recreational Fishing, Commercial Fishing, Open Pen Aquaculture, Coastal Tourism, etc.), new industry sectors (i.e., Renewable Energy, Remediation/Restoration, Blue Technology, etc.), and a *New Blue Economy* subsector that synthesizes the traditional and new industry sectors and focuses on sustainability and biodiversity impacts. The *New Blue Economy* provides an excellent framework to balance OW energy development, sustainable fisheries, and ecosystem preservation.

Work has already begun in Europe to balance energy, seafood, and the environment. Over 25 GW of OW capacity has been connected to the European grid in the past decade.[10] Because of the massive scale of OW projects, subtle changes to design and planning can have major impacts downstream on many parties, and groups in Europe are working to maximize the positive impacts of OW projects beyond clean energy generation. With the right policies and knowledge, OW investment can be leveraged to build the *New Blue Economy*.

This work introduces a framework called Nature Inclusive Offshore Wind Farms (NIOWFs) to describe how OW development fits into the New Blue Economy in the context of the U.S. East Coast. Figure 2 illustrates how NIOWFs cut across three key pillars of the New Blue Economy: energy production (i.e. new industry sectors), economic development (i.e. traditional sectors) and the New Blue Economy subsector represented here as ecosystem management.

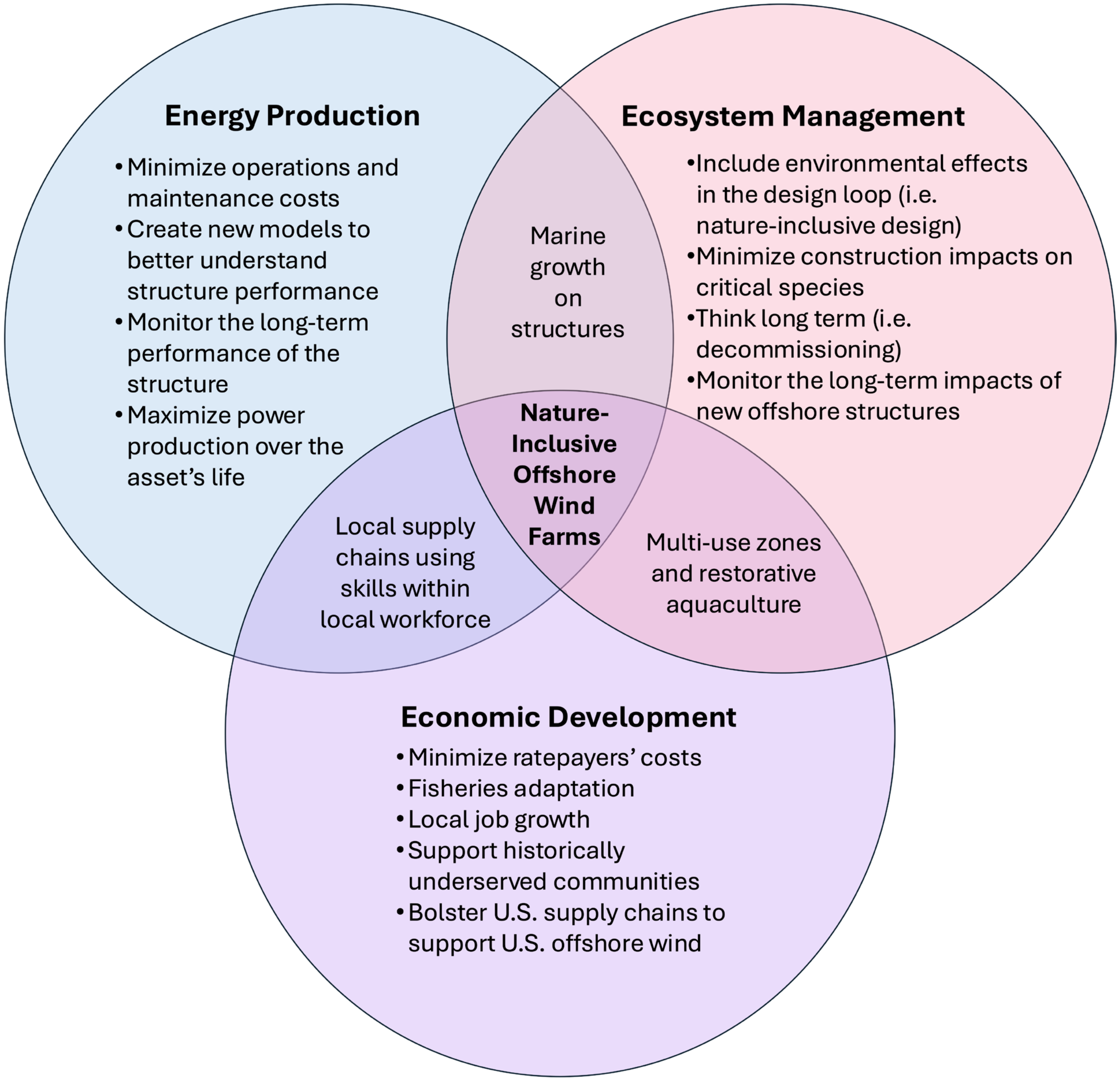

Figure 2. The 3 E's of the New Blue Economy and Nature Inclusive Offshore Wind Farms (NIOWFs)

Methodology

This review was supported by Massachusetts Clean Energy Center (MassCEC) through their Offshore Wind Science and Research program and an award (#2315558) from the U.S. National Science Foundation (NSF) on an Engine Development project titled "MOCEAN: Accelerating a Just Energy Transition while Nurturing Healthy Ocean and New Blue Economies through Innovative Offshore Wind Farms". MOCEAN (Mission is the OCEAN) is a broad-based group united in the view that the development of the U.S. OW energy resources present a large and critically important opportunity to the future prosperity and health of many coastal communities and ecosystems. This work includes a review of over 100 articles and reports and integrates thoughts, questions, and research gaps identified during discussions at several workshops (see Table 1). Workshop attendees included environmental and structural engineers, ocean scientists and marine biologists, fisheries management organizations, commercial fishers, and members of local and state governments, NGOs and others interested in marine and coastal environments, energy and/or blue tech.

Table 1. Workshops Informing this Report

Workshop Title	Format	Date
Supporting marine ecosystems through nature-inclusive design	*online*	May 16, 2022
MOCEAN: Accelerating a just energy transition while nurturing healthy oceans	*online*	January 6, 2023
Driving Opportunities for Diversity, Equity, and Excellence throughout the Offshore Wind Workforce Pipeline	*online*	May 22, 2023
MOCEAN kick-off	*in-person*	January 3, 2024
MOCEAN convening	*in-person*	May 20-21, 2025

The intent of this review is to provide a broad overview of an array of efforts ranging from marine spatial planning (MSP) policy, nature inclusive design (NID) features, and multi-use pilot projects to outline a vision for the NIOWF framework.

1 Work and Perspectives from Europe

Managing the ocean is complex, requiring cooperation between governments, developers, fisheries, marine scientists, NGOs, and coastal communities. While the U.S. does not have the same scale of OW development as does Europe, there are opportunities for the U.S. to learn from the European experience in navigating the balance of interests across ocean-user parties.

In Europe, conflict management can be broken into three broad categories: marine spatial planning (MSP), multi-use zones, and nature inclusive design (NID). All three fields of research and practice balance positive ocean stewardship with blue economy development. They are complementary fields but approach the problem from different perspectives. Marine spatial planning research is framed from the perspective of the government and focuses on policy and stakeholder engagement. Multi-use research focuses on developing early pilot projects and identifying partners to help commercialize new ideas. NID is at the nexus of marine science and engineering design to intentionally create features that are aimed at having a net positive impact on the environment. Figure 3 uses the common analogy of a three-legged stool to show how each field is critical to the development of NIOWFs.

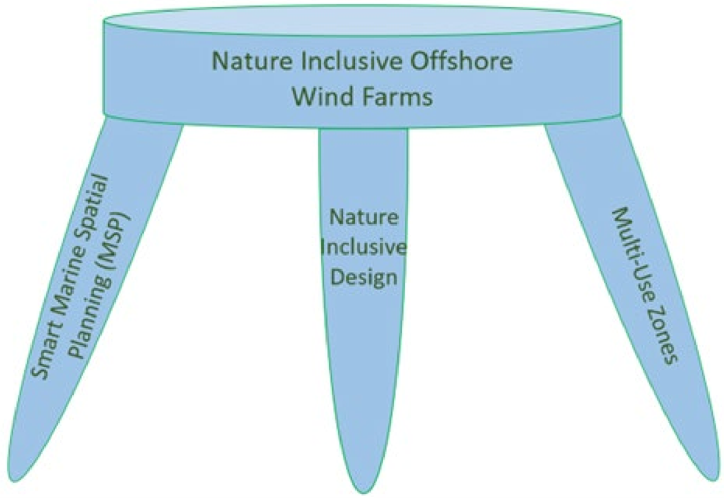

Figure 3. Stool Diagram for Nature Inclusive Offshore Wind Farms (NIOWFs)

1.1 Marine Spatial Planning

Marine Spatial Planning **(MSP)** is defined by the IOC-UNESCO as "A public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic and social objectives that have been specified through a political process".[11] MSP was initially used in the 1980s to describe efforts towards marine conservation, but recently the focus has shifted to conflicts among activities (e.g. among marine conservation, renewable energy, and fishing activities) in crowded ocean spaces such as the North Sea.[12] Academic publishing on MSP boomed after an IOC-UNESCO workshop on the topic in 2006, and the European Union (EU) has an MSP policy directive. A website was launched in 2016 to share relevant reports and government planning documents called the EU MSP Platform.[13]

MSP policies in Europe overlap with other EU goals focused on preserving biodiversity and deploying clean energy. In the North Sea, where there are many countries sharing limited offshore ocean space, there has been a lot of tension. According to a 2022 report focused on MSP policy interactions with the EU Green Deal the four most common conflicts related to MSP are: nature conservation versus fisheries, nature conservation versus extractive activities, nature conservation versus offshore renewable energy development, and offshore renewable energy development versus fisheries.[14] These relationships underscore the trade-offs inherent to MSP. Offshore renewable energy (ORE) is incorporated in two of the four most common conflicts. MSP is a critical part of managing these conflicts by allocating space for each activity.

The ability to maximize the positive impact of OW depends on a sturdy foundation of smart and intentional MSP. The growing role of ORE, particularly OW, has become a major theme in the MSP community globally as well. The UN Global Compact Ocean Stewardship Coalition recently published the "Roadmap to Integrate Clean Offshore Renewable Energy into Climate-Smart Marine Spatial Planning", in which two of their key recommendations relate to biodiversity and multi-use zones. In the Roadmap, one key recommendation identifies the need to "[s]trengthen the links between [Offshore Renewable Energy] ORE and biodiversity protection/restoration to maximize climate mitigation effects" while another key recommendation says that entities need to "[e]xplore synergistic multi-use combinations that can speed up the transition to low-carbon and climate-resilient economies".[15] This roadmap highlights the role of MSP.

Climate change is one of many risks to marine biodiversity that requires balancing. On one hand, deployment of ORE can reduce CO_2 emissions and help mitigate climate change effects. However, ORE deployment will affect the local marine environment and if these effects are not properly considered, they can have a net negative impact on marine biodiversity. MSP is a policy tool that can directly shape the environmental and economic tradeoffs at the government level. If it is designed well, it carefully considers input from all ocean stakeholders.

1.2 Multi-Use OW Energy Areas

The Multi-Use in European Seas (MUSES) project arose to support the European Union Marine Spatial Planning Directive and develop the Ocean Multi-Use Action Plan.[16] The MUSES project examined a total of nine opportunities for multi-use, four of which included offshore wind farms (OWFs): OWF & Tourism, OWF & Fisheries, OWF & Aquaculture, and OWF & Marine Renewable Energy. MUSES defined multi-use as the following:

> [Multi-use] is an umbrella term that covers a multitude of use combinations in the marine realm and represents a radical change from the concept of exclusive resource rights to the inclusive sharing of resources by one or more users.[17]

After the conclusion of the MUSES project in 2018, the Multi-**U**se offshore platforms demo**N**strators for boost**I**ng cost-effec**T**ive and Eco-friendly pro**D**uction in sustainable marine activities (aka UNITED) began in 2020. While MUSES focused on stakeholder engagement and paper studies, the UNITED project took the next step by deploying five pilots. The first pilot in Germany combined blue mussels, seaweed and offshore energy. The second pilot in the Netherlands combined seaweed and floating solar energy. The third pilot in Belgium combined OW, oyster restoration, and seaweed cultivation. The fourth pilot in Denmark combined OW and tourism. Finally, a fifth pilot in Greece combined aquaculture and tourism.[18, 19] This project ended and has been succeeded by the Circ**U**lar **L**ow **T**rophic o**F**fshore **A**quaculture in wind farms and **R**estoration of **M**arine **S**pace (ULTFARMS) project in 2023, with a focus on integrating seaweed and mollusc cultivation with OWFs.[20]

Outside of these two major projects, several research papers have been published on the topic of multi-use zones. Co-location of OWFs and fisheries activity were one of the multi-use opportunities examined as a part of the MUSES project. A stakeholder analysis for both German and Scottish OWFs examined the different barriers to multi-use.[21] Similar work was published using a SWOT (Strength, Weaknesses, Opportunities, & Threats) analysis for mariculture and OW.[21] Much of the early work done on the potential of multi-use zones is also summarized in the MUSES reports.[23, 24]

The most comprehensive synthesis of MSP and multi-use principles comes from the Symbiosis Inclusive Design (SID) work introduced in a roadmap published by a Dutch OW consortium called GROW (**G**rowth through **R**esearch, development and demonstration in **O**ffshore **W**ind). GROW published a report titled "Advancing Multi-Use in Offshore Wind Farms" that breaks up the synergetic opportunities of OWFs into three main pillars: food, nature, and energy.[25] This breakdown for SID recognizes food production, energy production, and protection of the natural world as three key drivers for ocean use and stewardship much like the three E's for MOCEAN listed in Figure 2.

In addition to these specific reports and projects actively piloting ideas, there is research available about the interactions between OWFs in Europe and other ocean industries. The North Sea is home to almost 80% of Europe's total OW capacity.[10] Consequently, much of the cutting-edge work on the interactions between OWFs and the environment has been conducted in the North Sea. For example, a report commissioned by the European Commission about the effects of OW on fishing and aquaculture summarizes the different strategies between Belgium, Denmark, Germany, Netherlands, Sweden, and the UK.[16] This report is referenced later to compare Europe with the U.S.

The definition of multi-use also opens the door for a very expansive view of an ocean "user". If one includes nature as an ocean "user", environmental protection and restoration becomes a part of the multi-use umbrella. The idea that the environment is an ocean stakeholder is already seen in the Nordic energy research report on coexistence.[26] If the idea of multi-use is expanded to include the environment as an ocean user, then nature inclusive design (NID) fits neatly into the same framework.

1.3 NID in Europe

NID in Europe focuses on a relatively narrow band of design decisions made within an OWF tied to environmental impact. According to a catalogue of NID features published by Wageningen University:

> NID refers to options that can be integrated in or added to the design of an OW infrastructure to create a suitable habitat for native species (or communities) whose natural habitat has been degraded or reduced.[27]

This definition of NID is commonly used in Europe and is also referenced by the Nordic Energy report on coexistence.[27] The broad definition of NIOWFs used by MOCEAN is different from this specific definition of NID in Europe. While MOCEAN views NID as a means to promote economic growth while in Europe NID is focused on environmental restoration.

In addition to this definition of NID, the private sector uses the phrase "net positive impact" to describe work focused on restoring ecosystems, for example by attracting and improving marine growth in OWFs. Orsted, Vattenfall, Equinor, and Iberdrola all have set ambitious goals that their projects will have a net positive impact on biodiversity by 2030.[28–31] These companies have taken a variety of approaches to achieve this goal. As examples, Iberdrola recently gave an award for a start-up competition focused on integrating nature into the design of OWFs and Orsted is piloting a project to use OW jacket structures in Taiwan to restore native corals.[32, 33]

NID and net positive impact research is additive and does not replace the existing mitigation hierarchy used for OW projects: avoidance, minimization, and restoration (mitigation) (Figure 4).[34] Additional conservation efforts cover the NID features that seek to make the project "net positive" on the local environment. While the definition of NID does not specifically account for the foundation of the mitigation hierarchy, it is inherently intertwined when stakeholders talk about OW and net positive impact. NID efforts need to be built on top of robust marine science and monitoring programs that form the basis of the mitigation hierarchy.

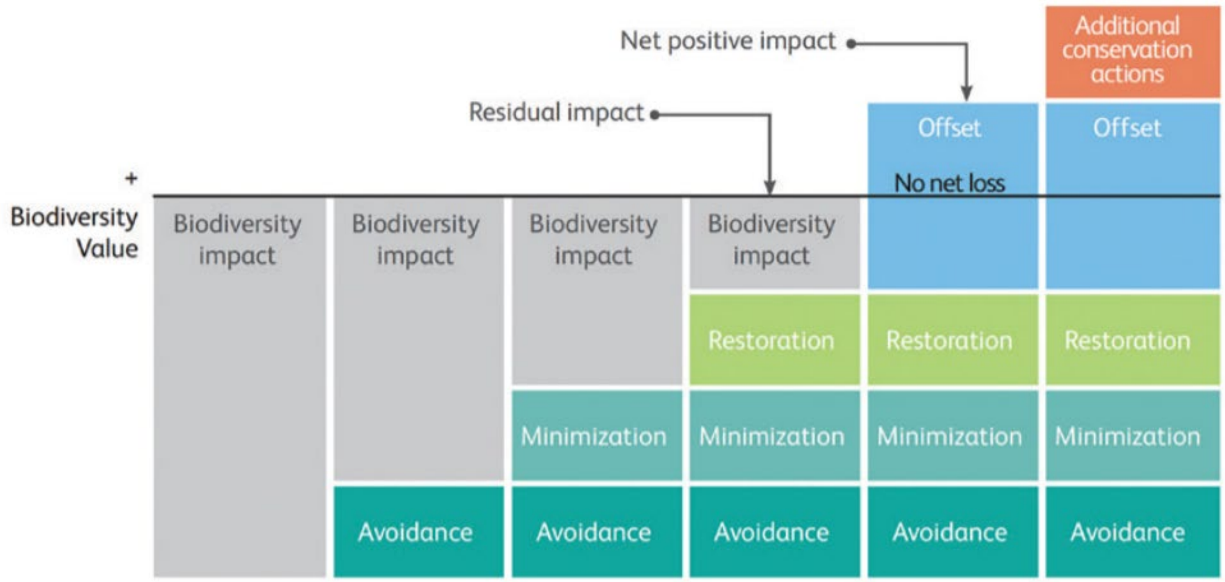

Figure 4. The Role of Net Positive Impact on Mitigation Hierarchy (from (Jedele et al., 2023))

Several NID projects have been piloted in the Netherlands. One example would be efforts to restore oyster reefs overlap with efforts to create new wind energy zones. In 2022, the Dutch Ministry for Agriculture, Nature, and Food Quality commissioned a report that examined the suitability for flat oyster (*Ostrea edulis*) restoration efforts within wind farm zones.[35] This report follows a previous pilot project in Dutch OWFs.[36] The Rich North Sea (de Rijke Noord zee), a private research organization, formed by Natuur & Milieu, and The North Sea Foundation (Stichting De Noordzee) has been a critical supporter of these efforts such as a project that supported artificial reef design within OWFs with Blauwwind.[37] Another NGO called the Offshore Coalition for Energy and Nature (OCEAN) combines the efforts of multiple organizations involved in OW to apply NID principles in the North Sea and Mediterranean Sea at regional levels.[38]

In addition to these specific studies and pilot projects, NID has been included in the OW procurement process. The Netherlands recently held a tender (OW auction) where NID criteria accounted for half of the total 200 points available for one of the OW zones (Netherlands Enterprise Agency, 2022). This is a critical development since prior to this there was not a precedent to have incentives within the OW procurement process to promote NID. Policy support for NID in the tender process is one of the recommendations made by the Nordic Energy Research report indicating additional interest in the subject.[39] Without supportive policy, the potential of NID will not be fulfilled.

2 OW Development in the U.S.

The first U.S. OW farm, Block Island Wind Farm (BIWF), was installed in 2016 with only five turbines constructed on jacket foundations. Unlike the North Sea, the eastern seaboard of the U.S. does not have a history of offshore infrastructure from oil and gas development that could be monitored and provide a record of data on interactions between the structures and the marine environment in the region. Despite the relative lack of direct experience and data in the U.S., environmental impacts of OW have been a focus of U.S. research programs. This research has focused on generating reports to identify research gaps and on active monitoring programs for the handful of U.S. OW installations.[40]

2.1 Introduction to U.S. System

Before comparing the OW ecosystems in the EU and the U.S., a brief overview of the U.S. system is provided here for context. In the U.S., all planned commercial OW projects are greater than three nautical miles off the U.S. coastline, placing them in federal waters, with most projects sited 20 to 30 miles off the U.S. east coast.

Projects in federal waters are regulated by the U.S. Department of the Interior (DOI), specifically the Bureau of Ocean Energy Management (BOEM) and the Bureau of Safety and Environmental Enforcement (BSEE). BOEM is the primary regulator for projects up until the completion of construction, while BSEE is the primary regulator for projects during operation through decommissioning. BOEM starts the process for OW by identifying lease areas as a part of the planning and analysis phase (the left side in Figure 5).[41]

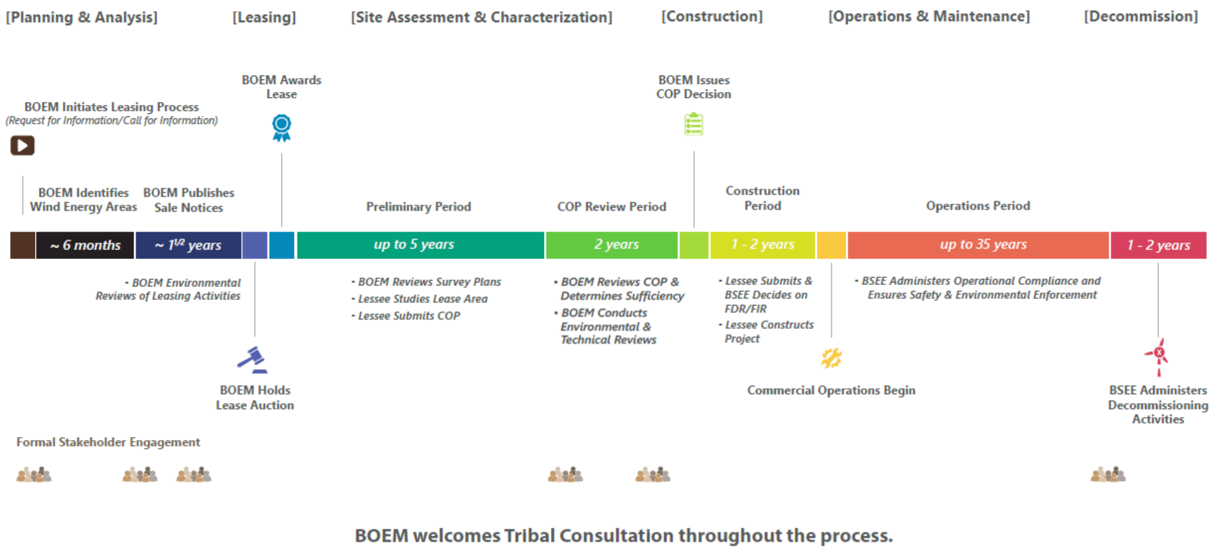

Figure 5. BOEM Regulatory Roadmap (from BOEM Website)

Figure 5 shows the steps required to get a wind farm built in federal waters, but for a project to be viable, developers also need to sell the power that the wind farm is expected to generate through a procurement process which varies by state. For example, in Massachusetts, the Department of Energy Resources, in concert with local Massachusetts utility companies, solicit proposals for long term OW energy contracts to follow state law Section 83c.[44] Connecticut, Rhode Island, New York, New Jersey, and Maryland each have their own competitive bid process followed by an award for power purchase with details varying from state to state. Projects also need to plug into the grid with cables that traverse state waters, so developers coordinate with state and local governments to get permits for the electrical transmission equipment. In Massachusetts, the electrical transmission equipment for Vineyard Wind 1 needed to be approved by the Massachusetts Energy Facilities Siting Board (EFSB).[43] Similarly, for projects bringing power to shore in Rhode Island, approval by the Rhode Island Energy Facilities Siting Board is required. In New York, the Public Service Commission, in collaboration with state agencies and local interested parties, reviews the need and environmental impact of major transmission facilities through the Article VII process, with approved projects being granted a Certificate of Environmental Compatibility and Public Need (CECPN).

There are exceptions to this process. For example, the first U.S. OW farm, BIWF, is unique because it was developed in Rhode Island state waters. In Virginia, Coastal Virginia Offshore Wind (CVOW commercial) is being built by the vertically integrated utility company (Dominion) instead of a competitive bid process.[44]

2.2 U.S. Marine Spatial Planning

In the U.S. there is no equivalent national program to the European MSP directive. The closest thing would be an executive order from 2010 that separated the EEZ (Exclusive Economic Zone) into nine different regions and created a framework for MSP, but this executive order was replaced by a different framework in 2018; only two of the nine ocean regions received federal approval for plans, the Northeast and mid-Atlantic regions.[45] The Northeast Regional Ocean Council (NROC) and Mid-Atlantic Regional Council on the Ocean (MARCO) formed to foster collaboration across state and disciplinary boundaries so that these plans could be developed.[46, 47] These councils still exist today and provide valuable services such as the northeast ocean data portal and mid-Atlantic data portal.

NROC and MARCO also support the Regional Wildlife Science Collaborative (RWSC) for OW, an entity focused on “regional monitoring and research of wildlife and marine ecosystems that supports the advancement of environmentally responsible and cost-efficient OW power development activities in U.S. Atlantic waters”.[48] In addition to these two regional councils, four states have MSP plans established by state law: Oregon, Washington, Rhode Island, and Massachusetts.[49–52] While these marine spatial plans for the Northeast are regionally relevant to fixed OW, they are also several years old. Some of their OW recommendations, such as coordinating with the Department of Defense, have already been implemented in databases maintained by NROC and MARCO.

The 2023 lease selection processes for new wind energy areas in the Gulf of Maine also considered MSP. A final report of this analysis was released for comment in October 2023.[53] To create a draft wind energy area in the Gulf of Maine, BOEM used a gridded relative suitability analysis as a part of a Multi Criteria Decision Analysis (MCDA), dividing their criteria into four main sub models given equal weights: (i) Natural & Cultural Resources, (ii) Industry & Operations, (iii) Fisheries, and (iv) Wind. The draft report itself has more details about how the sub models were built, but at a high level, it shows that identifying lease areas is an extensive mapping activity balancing the needs of varied stakeholders. While selection of U.S. OW sites may not be formally driven by MSP policy like in the EU, the mechanics of how OW lease areas are selected parallels the European MSP.

This lease identification process requires a combination of environmental, economic, and social data. The U.S. National Oceanographic and Atmospheric Administration (NOAA) is a key partner in this process. Specifically, the National Centers for Coastal Ocean Science (NCCOS) have helped build spatial models for the mid-Atlantic, Oregon, Gulf of Mexico, and Gulf of Maine ocean regions. Supporting sustainable development of ORE is one of the sub-categories of NOAA’s strategic goal to strengthen established sectors of the blue economy.[54] The NOAA strategic plan does not include procedures for multi-use zones, but it mentions that private companies will collect data during OW deployment that could support NOAA’s science mission. The plan suggests that partnerships with industry players could help advance NOAA’s mission.

2.3 Multi-Use Zones in the U.S.

The U.S. also does not have an equivalent to the MUSES project or the UNITED project. This is largely due to different regulatory environments and approaches to OW. Europe has stricter rules and regulations surrounding navigation within OWFs in Europe, motivating conversations around multi-use zones. In Belgium and the Netherlands, no navigation is allowed within 500 m of a wind farm area, and in Germany safety rules are established after a wind farm is constructed, but fishing is "de facto" banned.[16, 21] The UK is the only major country in Europe that allows fishing within OWFs.[16] Some of the interest in multi-use research in Europe likely comes from the very strict baseline a lot of countries have regarding navigation within OW wind energy areas.

In contrast to many countries in Europe, the U.S. has no planned restrictions on fishing activities inside of OWFs. Fishing is currently allowed at BIWF, and there are no plans to restrict access.[55] For the much larger Vineyard Wind 1 farm with 67 turbines, there are also no plans to restrict access for navigation or fishing activities.[56] In fact, for the southern New England wind energy area, encompassing seven lease areas, several years of discussions between developers, regulatory agencies, and fishing industry representatives resulted in the wind industry agreeing to a coordinated grid layout of turbine foundations each 1 nautical mile apart with an aim of providing sufficient space for navigation and fishing between the turbines positions. These discussions highlighted the fact that the commercial fishing industry in New England is diverse, and made up of several different stakeholder groups with varying concerns based on how they fish for each target species (i.e., fixed gear, mobile gear). However, being legally allowed to fish in an area does not necessarily fully maximize an area's utility or ensure fishermen will be willing to access the area. The coordinated grid layout in the southern New England wind energy area did not necessarily resolve the conflict for space between commercial fishermen and OW as many commercial fishermen expressed continued concern over safety while accessing the waters between the turbines within the grid.[57] Similarly, in the UK, surveys with fishermen found that although a small number returned to operate in OWFs, most did not, due to a perception of higher risk.[58] The recreational fishermen in the U.S. have expressed the opposite, for example, BIWF has become an attractive fishing destination for recreational fishermen.[59] The BIWF experience provides some reasons to be optimistic with the caveat that there are ongoing concerns about crowding and potential loss of access, particularly for commercial fleets, off the U.S. east coast. It could be argued that the U.S. is ahead of Europe in multi-use zones because the U.S. approach to access would be defined as inherently multi-use in countries where navigation and fishing is restricted. However, the U.S. does not have the same projects such as MUSES or UNITED H2020 designed to actively identify barriers to multi-use.

The experience from the UK shows that real multi-use zones will need to be supported by proactive measures. Merely opening the OW energy areas to fishing does not mean they will be multi-use zones in practice. Currently the Responsible Offshore Science Alliance (ROSA) is acting as an important convenor of stakeholders, in particular groups involved in the U.S. fishing industry. ROSA is a non-profit organization formed in 2019 to collaborate across a variety of stakeholders such as fisheries, OW developers, and experts in federal and state agencies to support research and decision making at the nexus of OWFs and fisheries.[60] ROSA is a critical organization for U.S. OW, but it does not have the level of resources of similar organizations in Europe.

In the U.S., there has been little discussion around co-locating aquaculture projects within OWFs. In 2022, the U.S. Department of Energy (DOE) Water Power Technologies Office (WPTO) and Pacific Northwest National Laboratory (PNNL) were involved in a report on ocean renewable energy and offshore aquaculture for the international energy agency (IEA).[61] This report included OW as well as other ocean energy technologies such as wave energy and floating solar. Rather than focusing on the synergies that come from co-locating ocean activities, the report focused mostly on the potential for offshore renewable energy to supply power for offshore aquaculture. Still, some researchers in the U.S. have examined the potential for blue mussel aquaculture in the U.S. Atlantic shelf.[62, 63]

The relative lack of interest in co-locating aquaculture with OWFs in the U.S. may be due to the nascent nature of the aquaculture industry in federal waters, and in particular the lack of a streamlined permitting process for these commercial operations, although progress in this area is ongoing at the national level. In their review of the global aquaculture industry, Garlock et al. found that the growth rates for aquaculture in North America and Europe were the lowest in the world and that aquaculture in the U.S. shrank in the last decade.[64] In a 2016 review of the U.S. aquaculture market, Knapp and Rubino mention there are efforts in the U.S. to reverse this negative trend for aquaculture. According to NOAA's most recent strategic plan, one of the key outcomes for strengthening established sectors of the blue economy is to "create a national framework for sustainable and productive aquaculture".[65] In addition to including aquaculture in their overall strategic plan, NOAA has published a strategic plan for aquaculture covering the years 2023-2028 and a guide to permitting aquaculture in the U.S.[66] NOAA is not the sole permitting authority for aquaculture, but it plays an important role in coordinating efforts at the federal level. In addition to these reports by NOAA, the National Science and Technology Council Subcommittee on Aquaculture has published a plan to enhance regulatory efficiency and coordination among the relevant federal and local agencies.[67] Compared to OW where much of the coordination for permitting is handled by one federal agency, BOEM, the process for offshore aquaculture in the U.S. is less streamlined. It is possible that the relatively new permitting process for marine aquaculture in federal waters makes it a less attractive option for multi-use zones due to a higher permitting risk, but a more detailed analysis of the barriers such as the ones done in Europe for the MUSES project are needed in the U.S.

2.4 NID in the U.S.

To-date, NID has been used in the U.S. more in coastal than offshore spaces. And while there has not been enough OW construction in the U.S. to have a broad experience with NID features there, there has been a significant focus on the potential environmental impact of OWFs. Much of the current research in the U.S. has been to start to populate baseline marine data, as the Northeast U.S. does not have a history of offshore energy infrastructure. The U.S. is further down the mitigation hierarchy with research focused on establishing the baselines and monitoring needed to support mitigation. As mentioned earlier, successful NID implementation requires a firm foundation of mitigation.

Recognizing that the U.S. is behind Europe in this regard, there have been several research projects in the U.S. to build this foundation. The U.S. Offshore Wind Synthesis of Environmental Effects Research (SEER) project, co-lead by the Pacific Northwest National Laboratory (PNNL) and National Renewable Energy Laboratory (NREL), is a large multi-year paper study of OW environmental effects in the U.S.[68] The SEER project has developed a database of relevant projects on Tethys as a part of their literature review, convened multiple workshops on specific environmental topics, and published a series of synthesis reports, and online materials.[69] These reports cover the following seven main topics:

1. Bird and Bat Collisions
2. Vessel Collisions
3. Floating OW Cable Systems
4. Underwater Noise Effects
5. Effects on Fish Ecology

6. Electromagnetic Field Effects
7. Benthic Disturbances

In addition to paper studies and reviews, field work has been done on the limited number of OW assets in U.S. waters. The BOEM Realtime Opportunity for Development Environmental Observations (RODEO) project has monitored the five turbines at BIWF and two turbines at CVOW since 2015 and 2021 respectively. The RODEO monitoring focuses on a variety of topics including underwater noise, benthic/epifaunal effects, and sediment suspension/turbidity.[40] One RODEO project is focusing on work off the coast of Virginia.[70] There is also some NYSERDA funded work off of the coast of Long Island supporting ECOncrete and a Vineyard Wind cable project by ECOncrete.[71]

The research into environmental effects of OWFs is only the start. Understanding this nexus of marine science, biology, and engineering creates a foundation for this knowledge to be put into practice. A technical report from The Nature Conservancy and INSPIRE Environmental was inspired by the Dutch NID catalogue and investigates opportunities for NID in OWFs off the U.S. East Coast rather than for the North Sea.[72] Although the U.S. eastern Atlantic coastal shelf is similar to the North Sea in Europe, the two regions differ according to the Marine Ecoregions of the World (MEOWs) model commonly used to define ocean regions.[73] While the lessons from Europe have significant value for U.S. OW technologies and features should be adapted to the U.S. market not applied one to one.

3 Key Questions for U.S. NIOWFs

The U.S. OW ecosystem has many of the pieces needed to develop NIOWFs. However, there are no active large-scale projects to coordinate stakeholders, support pilot projects, and understand the permitting requirements. Compared to European OWFs that have historically restricted access to their OW energy areas, the U.S. is in a good position to explore synergies between the fishing industry and OW. Aquaculture in U.S. federal waters is at an early stage of development but should also be explored as a multi-use opportunity. There have been major efforts from organizations such as NOAA to explore opportunities in aquaculture, but these have mostly occurred in parallel to discussions about OW deployment. Greater coordination is also needed in the U.S. to build NIOWFs with all three pillars of the *New Blue Economy*.

In addition to a general need for more resources and coordination, there are several key questions and barriers that need to be addressed. These questions cover a range of challenges including technical, environmental, social, and policy. Some can be partially answered using existing work in the U.S. or from projects in Europe. In many cases, the answers remain unknown and need to be developed in future work.

3.1 What incentives exist to promote NIOWFs in the U.S.?

Experience in Europe has displayed the importance of government policy and tender structures on the OW market. In the U.S., state governments have the most power over OW procurement. Table 2, adapted from research done by the Vermont Law and Graduate School, shows the breakdown of points for the most recent OW solicitation of each East Coast state.[74] One key takeaway from Table 2 is the lack of consensus in the state procurement process. Apart from Maine, which only recently published a roadmap for OW in 2023, and Maryland, which starts its review with a qualitative assessment of non-price criteria to see which bids will get to be reviewed on price, every other state has a split of roughly 70/30 for price/non-price criteria. Connecticut and Rhode Island have a slightly higher focus on price at 75/25 but also make up a relatively small proportion of the overall OW market on the U.S. East Coast.

The non-price criteria in state requirements tend to focus on some combination of project viability, economic benefit, and impact on the environment and fisheries. However, these top-level categories can be misleading. For example, in New York, "quiet installation" methods and management of installation noise fall under project viability rather than environmental impact. Many states also have some requirements for environmental monitoring built into their procurements. New York and Maryland both require public reporting on environmental monitoring efforts. New Jersey and Massachusetts have both added language in their recent solicitations incentivizing environmental monitoring and data transparency.[74]

One major barrier to incentivizing nature inclusive OW via state policy is coordination across state boundaries because OW is not bound by state borders. South Fork Wind and Vineyard Wind 1 are only 32 nautical miles apart, but Vineyard Wind 1 is procured by Massachusetts while South Fork wind is procured by New York. One example of state coordination would be a memo of understanding (MOU) between Massachusetts, Rhode Island, and Connecticut that allowed for multi-state bids in their 2024 procurement process.[75] OW transmission is a good example of a topic where the importance of regional coordination has been fully recognized. The recent DOE action plan for transmission in the Atlantic region is an example of the kind of regional perspective that is needed.[76] Similar levels of coordination need to extend to conflicts with the environment and fisheries.

In addition to incentives during the state procurement process, there are opportunities at the federal level to shape the future of U.S. OW via the lease process. In 2022, BOEM used a Multi Factor Auction (MFA) format for its Carolina, California, and Gulf of Mexico lease areas.[74] The MFA format incentivizes developers to invest money towards a certain policy goal in exchange for a non-cash credit that is added to their cash price during the auction. In previous auctions, BOEM has offered credit for domestic supply chain investments, workforce development, and money for a fisheries compensatory mitigation fund. Another credit was given for having a community benefits agreement (CBA) with local communities near the lease area. In a recent workshop on the potential for OW development to have a net positive effect on biodiversity, a panel of experts identified the MFA format as a potential avenue to incentivize net positive impacts.[34] The panel recommended including a biodiversity criteria in the most recent auction for the Gulf of Maine leases; however this bidding credit for biodiversity was not advanced in the October 2024 auction. Even if it is too late for existing fixed OW projects to benefit, the multi-factor auction format can influence future projects.

The potential for policy incentives was also discussed during the MOCEAN meeting and the key questions and perspectives were brought up beyond what was found in the literature review. For example, the internal incentives and motivations that exist within the private sector because of their net positive biodiversity goals were flagged as an important driver of NID work in the U.S. It was also discussed that adding complexity to the tender process for power procurement can raise the barrier of entry for new market participants. Participants stressed that any incentive structure for NIOWD should not inadvertently harm the existing OW market.

Table 2. Summary of State Procurement Policies

Non-Price Criteria							
East Coast States	**Key Procurement Organization**	**Price**	**Project Viability**	**Economic Benefits**	**Environment & Fisheries Impact**	**Required Monitoring Research**	**Notes**
New York	NYSERDA	70	10	20	N/A	Yes	Plans for "quiet" installations support Project Viability Score & all projects need an Environmental Mitigation Plan
New Jersey	NJBPU	70	N/A	15	15	Recommended	Demonstrate environmental net benefits & have Environmental Protection Plan (EPP)
Maryland	MDPSC	N/A	Qualitative assessment made before considering price			Reporting Required	Demonstrate environmental net benefits
Massachusetts	DOER & DPU	70	15	15		Recommended	Focus on Environmental Justice
Rhode Island	RIPUC	75	25			Part of EFMP	Requires an Environmental Impact and Fisheries Mitigation Plan (EFMP)
Connecticut	DEEP	75	25			No	Requires an Environmental Impact and Fisheries Mitigation Plan (EFMP)
Maine	MEPUC	N/A	N/A			N/A	Roadmap stresses importance of protecting natural resources and the fishing industry

3.2 How could a focus on NIOWFs affect the identification and layout of wind energy areas?

As described previously, BOEM's process includes opportunities to balance the needs of different ocean users and analyze trade-offs. Wind farm layout is one example of such a trade-off. OWFs in the U.S., such as Vineyard Wind 1, are laid out in a grid system with one nautical mile spacing to allow for navigation through the wind farm. This spacing allows for fishing activity inside of the OW area. However, this flexibility comes at a cost, as the layout cannot be fully optimized for power production. If fishers avoid navigating through OWFs, like in the UK, then U.S. policy is sacrificing optimal power production for an underutilized multi-use opportunity.

Distance to shore is another variable where there are trade-offs between visual impact and the potential for fishing utilization. In their survey of recreational fishermen, Smythe *et al*. noted that BIWF is unique because it is very close to shore and that the current trend for other U.S. OW projects, which are farther from shore to minimize visual impacts, may make them less attractive to recreational fishermen.[6] For these kinds of trade-offs to be effectively considered would require an MSP process designed to consider opportunities for multi-use of the OW lease areas.

3.3 How might NIOWFs affect the public acceptance of OW projects?

As described in the introduction, OW projects are facing an increased degree of public concern. These concerns are driven in part by frustration with the processes around OW deployment and a sense that the system is unfair. For example, quantitative work focused on survey data about BIWF was conducted to investigate how community members' underlying values and perception of the ocean affect public opinion of OW energy.[77, 78] Recently qualitative work from Smythe et al. used an environmental justice framework also identified fairness as a significant concern.[6] In addition to these research examples, the field of maritime and fisheries anthropology could be a helpful supplement to identify the needs of coastal communities. While maritime and fisheries anthropology have not been used extensively in OW related work, it has been used in the context of general marine management according to a recent review by Aswani.[79]

One goal of NIOWFs would be to allow OW industry members, other ocean users, and members of coastal communities to build a positive vision for the ocean together. One template for such a community would be recent work in the Netherlands focused on communities of practice [COPs].[80] In their paper, Steins *et al.* utilize a pre-existing definition for a COP with three distinct qualities:

> [First] the domain: the identity of the COP is defined by a shared interest, [Second] the community: members of the COP pursue their interest in the domain through joint activities and discussions, help each other and share information, and [Third] the practice: members are practitioners who develop a shared practice.

In their paper, Stein *et al*. recognize that the community of practice in the North Sea (COPNS) is not a perfect COP because it was formed by the government of the Netherlands as a part of their marine spatial planning efforts and North Sea 2030 planning. Nevertheless, it serves as an example of how varying stakeholders can be brought together to exchange information and learn from one another. While surveys and anthropological studies can help identify key stakeholders and values to shape NIOWFs, some organization is needed to put these ideas into practice. Because initial research suggests that public frustration with OW projects is partially driven by procedural issues, a U.S. Atlantic COP could help ocean stakeholders come together to define a vision of the future of OW that also assuages fears of ocean industrialization. Given the increasing importance of acceptability and justice for all communities, section 4 of this report presents additional consideration on this matter.

3.4 How can the NIOWF Lens affect economic development?

Every state solicitation also has a major focus on local economic development, see Table 2. These goals for economic development do not need to be mutually exclusive with goals for NIOWFs. The Nature Conservancy and INSPIRE report on turbine reefs and OW includes an appendix that lists eight different products that are produced in the U.S. and could be used for nature-based design.[72] NID features in particular may be a good option for providing local content in OW projects. Unlike other aspects of the OW system (e.g. monopile foundations, large offshore towers, blades, and nacelles) nature-based design features (e.g. NID scour protection) may not require the same highly specialized equipment and manufacturing facilities with direct port access.

In addition to producing components specifically for NID, NIOWFs could provide opportunities to support long-term jobs tied to the cumulative capacity of an OW build. One critique of OW as a tool for economic development is that many of the jobs are tied to the deployment rate rather than the cumulative capacity. In a 2022 workforce assessment, a team at NREL found that out of a total of 58,000 FTEs/year (jobs) by 2030 only about 2,300 FTEs/year would be in O&M, under 5% of total FTEs.[81] Figure 6 shows how non-O&M jobs (e.g. Manufacturing and Supply Chain, Ports and Staging, Maritime Construction and Development) are related to the annual deployment rate, assuming 100% domestic content. Over 80% of these jobs come from manufacturing and the supply chain. The supply chain workforce is not as elastic as other areas such as marine construction, so the relationship is not quite one-to-one, but the total FTEs appear to be somewhere between 50,000 and 70,000 jobs for an annual deployment pipeline between 4 GW and 6 GW. Figure 7 shows that cumulative installed capacity is closely tied to the total FTEs for operations and maintenance jobs in OW. These are the jobs that are expected for the 30-year life of the wind farm regardless of the deployment rate for new projects.

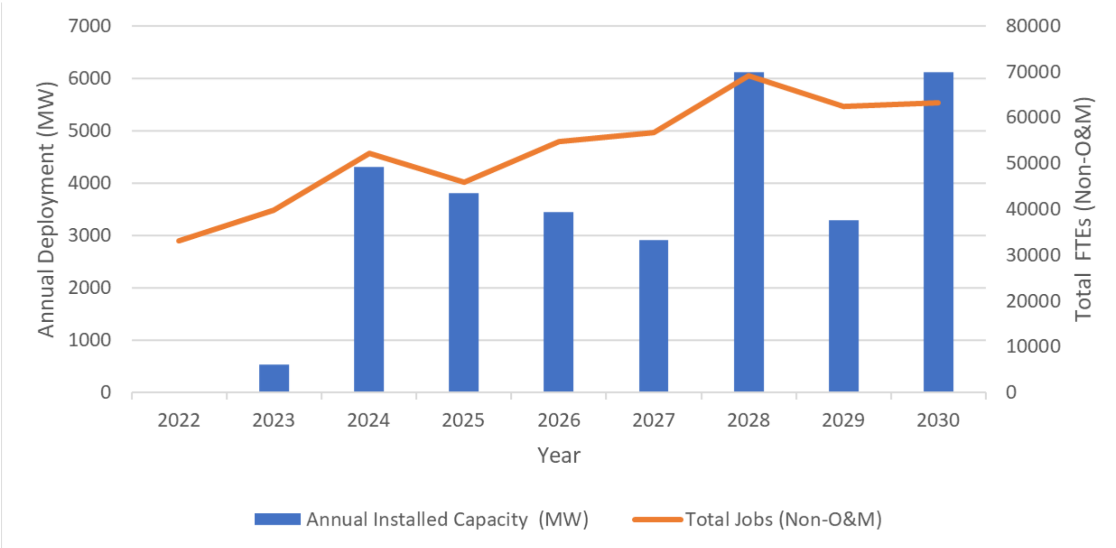

Figure 6. **Relationship Between non-O&M Jobs and Annual Deployment (Based on Stefek Data for 100% Domestic Content (Stefek et al., 2022))**

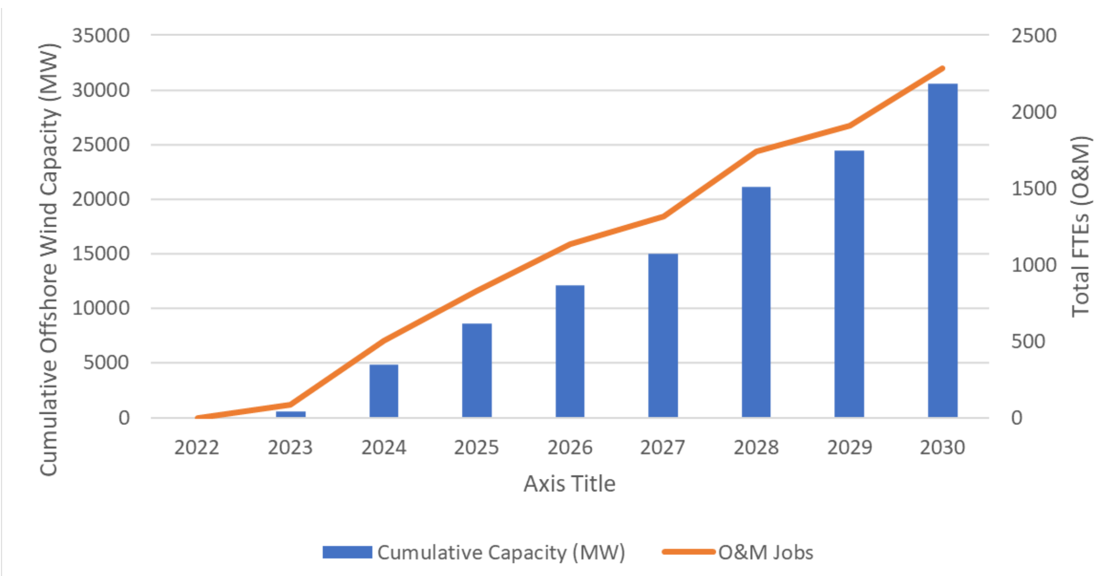

Figure 7. **Relationship Between non-O&M Jobs and Cumulative Capacity (Based on Stefek Data for 100% Domestic Content (Stefek et al., 2022))**

Proper project sequencing can create a robust pipeline of projects and ensure that the deployment jobs are stable, but job duration is a reasonable concern. From an equity standpoint, it is critical that OW provide sustainable work, not a cycle of booms and busts in coastal communities.

Multi-use zones and support for NID can align with economic development to support an expanded, sustainable blue economy around OW. For example, in a paper on the five golden principles for marine reef restoration, Hostede et al. state that the fifth principle is active stakeholder engagement beyond activation. Hostede et al. emphasize that a marine reef restoration project is a 15–20-year commitment.[82] The work to collect data, measure impacts of NID features, and maintain these structures can add to the “O&M jobs”. Beyond potential jobs for mariners and marine scientists in support of NID, a creative idea for multi-use zones would be to co-locate aquaculture within wind energy areas. This could provide an additional layer of economic activity for local coastal communities.

While it does not tie directly back into a specific sector, a major topic at the January 2024 MOCEAN workshop was the "workforce for the future blue economy". This phrase was used to describe the idea that the introduction of the OW sector to the Atlantic shelf creates opportunities for a vast amount of data to be collected. At this time, the utility of this data and how available it will be is not clear but as time goes on it could become a valuable resource. One could imagine a market for prediction products and tools that utilize this data to support other commercial activities, such as fishing, or conservation goals. While this is still a very speculative idea, it was flagged as one worthy of further discussion and investigation.

3.5 Lease Lengths & Decommissioning

During the discussions at the MOCEAN workshop, lease lengths and decommissioning challenges were also discussed. The lease lengths for OW are typically around 25-35 years and the lease duration is often attributed to a historical relic of the oil and gas industry. Obviously, the wind is an inexhaustible resource so participants pose the question of how a longer duration of lease activity may affect how projects are considered. This ties directly into NID features because seeing pieces of the infrastructure as beneficial to the local environment adds a layer of complexity to the decommissioning process. If an OW foundation is deemed to be useful as an artificial reef but is past its useful service life for harvesting wind resources, what is the appropriate action to take? Because the natural resource (wind) is inexhaustible, unlike oil and gas, it may be most ecologically responsible to recycle this ocean space at the end of the life of the infrastructure, which would require removing the old turbine and foundation and replacing it with new (likely larger and more efficient) infrastructure. This would ultimately disrupt the 25-35 year old artificial reef that had established in this space, however the community would be expected to recolonize following disturbance. These are the kinds of long-term questions that come up when OW structures are seen as an integral part of a new local marine seascape.

3.6 What research is needed to inform NIOWFs?

Multiple databases of research projects, research gaps, and existing technologies for environmental monitoring and mitigation have been identified to help identify gaps in the existing research. These databases are generated by a variety of institutions including national labs (e.g. NREL and PNNL) as well as private organizations focused on OW (e.g. RWSC and ROSA). The abundance of databases and research in this space are indicative of the interest in the environmental effects of OW. However, it also means that a comparison of these different projects, organizations, and recommendations is needed to better understand the space.

The SEER project published a database of 219 recommendations for future research based on a review of over 800 documents.[68] The SEER team created this database on behalf of the Regional Synthesis Working group. Figure 8 is made from a pivot table of the database and shows the number of recommendations for each receptor/taxon in the database. The total of the columns in Figure 8 is 607 because many research recommendations cut across multiple taxa. Recommendations related to fish and benthos are some of the most frequent with counts of 96 and 90 respectively. While the SEER research recommendations cover a wide range of taxa, the most relevant groups for underwater infrastructure associated with NID include fishes, benthos, and ecosystem/oceanographic processes.. The prevalence of these taxa in the database indicates that a greater fundamental understanding is needed to inform the design of NID features.

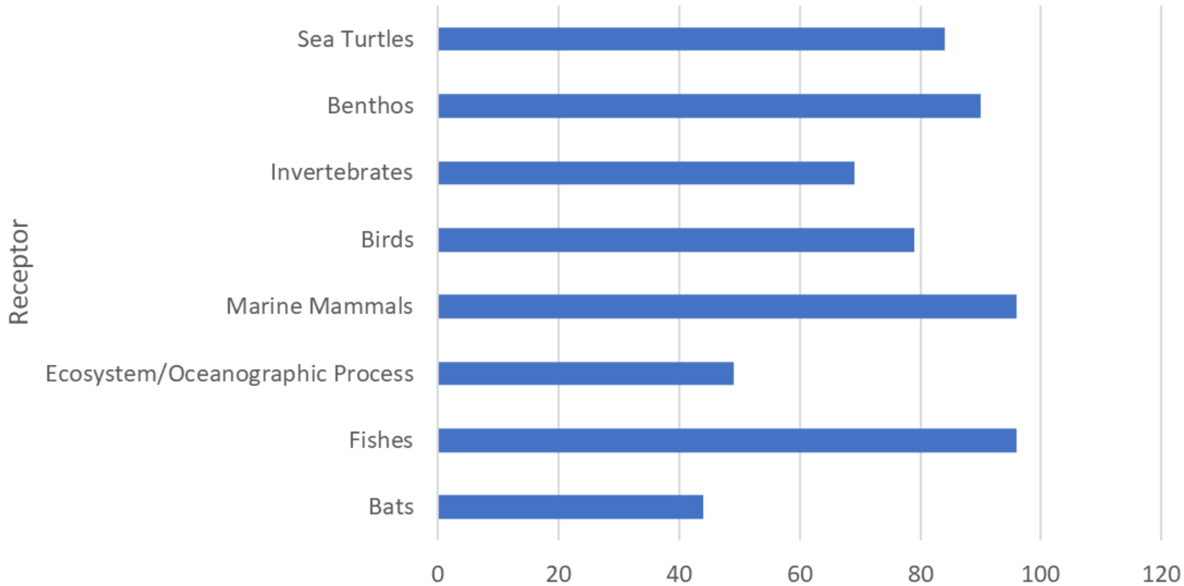

Figure 8. SEER Database Receptor Counts

Figure 9 breaks up the SEER recommendations into broad categories based on their stressor/topic and shows the totals for the receptors/taxa most relevant to NID features. The total of columns in Figure 9 is 349 not 219 because many research recommendations cut across multiple topics. Baselines, habitat change, noise, and technology/methods development stand out as the most common recommendation topics. Of these four baselines and habitat change are particularly important for the implementation of NID. Reliable baselines are needed to quantify the impact of NID features while habitat change is required to measure impacts and design NID features for intentional effects. Research on the impacts of noise are critical for mitigation, particularly pile driving noise, but it is generally less relevant for the kind of artificial reef effects examined as a part of NID. Finally, the technology/methods development topic cut across multiple categories because new technology and monitoring solutions will be needed for modern management of the oceans even beyond OW development.

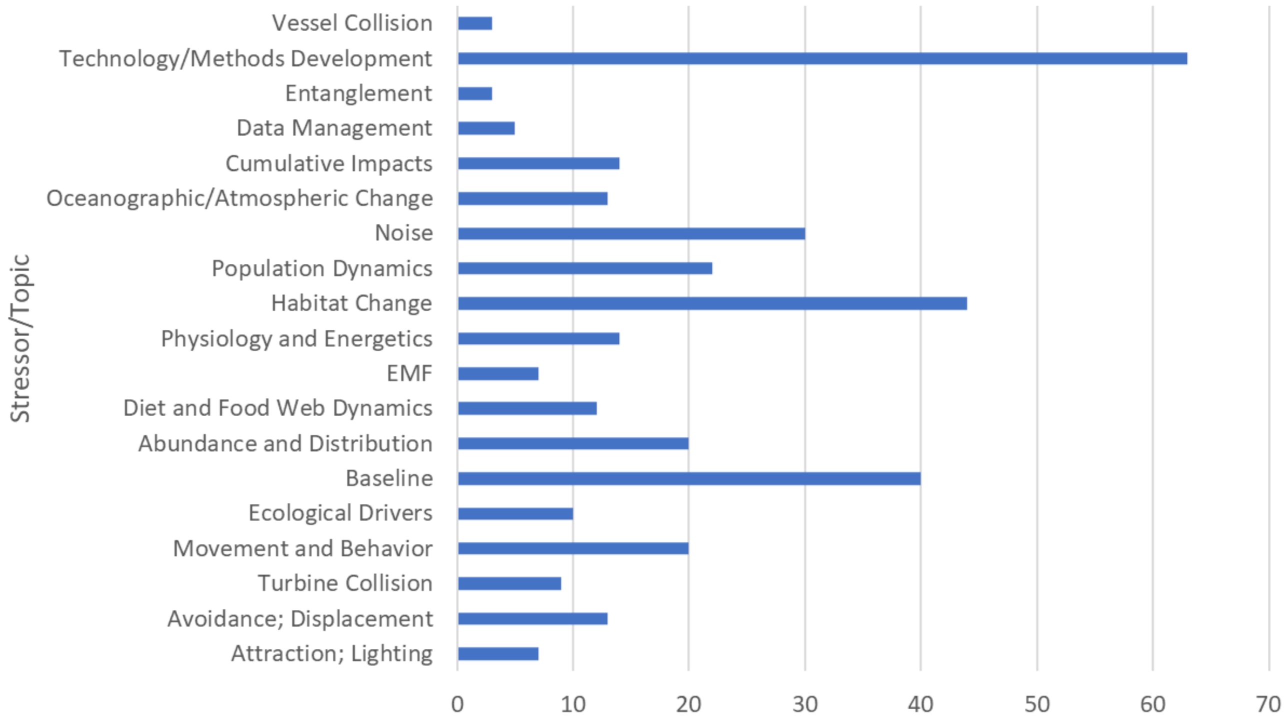

Figure 9. **Synthesized Research by Topic for all Receptors**

While the SEER Database is broadly concerned about environmental effects, it does not have a specific focus on fisheries. ROSA, the non-profit organization focused on the nexus of OW and fisheries, recently commissioned a database of relevant existing research programs and gaps that need to be addressed. The first draft of this database, named FishFORWRD, was released alongside a user manual in 2022.[85] Figure 10 shows the number of times that each research need appears in the database of 234 research recommendations as of November 28th, 2023.

These two figures show that many of the research recommendations highlighted by FishFORWRD broadly match the same Topics as the SEER database. While the specific wording may differ, "Species Distribution/Composition" is closely related to establishing "Baselines" and "Habitat Fragmentation/Modification" tie into "Habitat Change". One major difference between the databases is that FishFORWRD does not emphasize "sound/vibration impacts" nearly as much as the SEER database mentions "noise". Part of this may be because FishFORWRD only looks at Fish, Fisheries, and Other as research focuses. While noise is an important topic for all marine life, it is particularly relevant to marine mammals and BOEM released draft guidance for noise abatement in 2022.[86] Another interesting difference between the SEER database and FishFORWRD is the prevalence of electromagnetic forces (EMFs) in FishFORWRD. In FishFORWRD, EMFs are more prevalent than noise for their research recommendations. This is a significant difference compared to the SEER database that does not even have EMFs in the top 5 most common topics for research recommendations. This may be due to a difference of opinion by experts in the field or due to FishFORWRD's focus on fisheries.

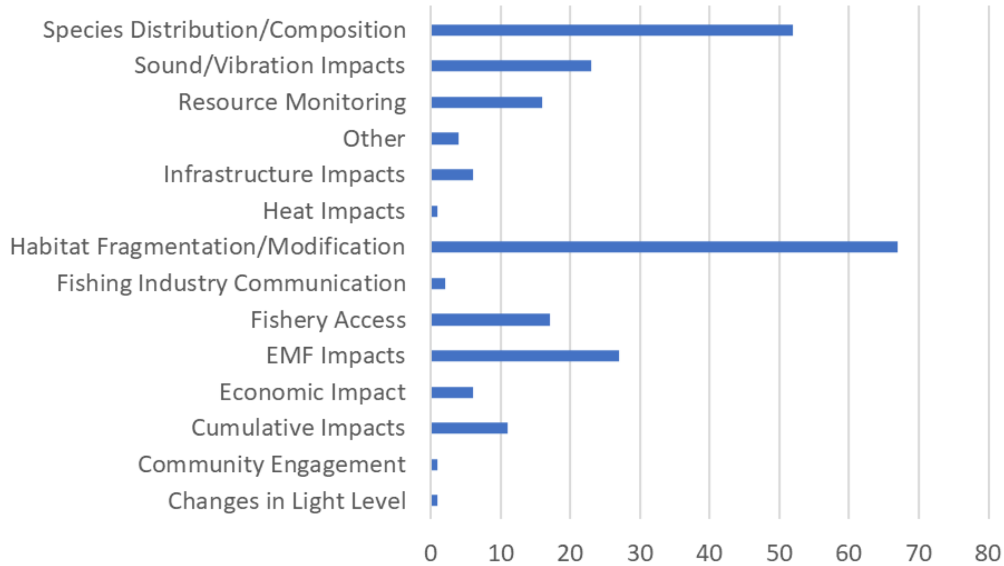

Figure 10. FishFORWRD's Research Needs

Finally, the RWSC has created a database tracking ongoing/past projects related to environmental impact. In addition to this database, the RWSC published an integrated science plan in 2023.[87] This science plan was published to be a living document and uses many of the same recommendations that are published in the SEER database. In addition to the direct research recommendations, a significant portion of the science plan is dedicated to the importance of collecting, standardizing, and sharing data. While it may not be a specific research recommendation focused on a technology or a species, data standardization and availability are a key part of NIOWFs. This information will be needed to measure the success of different features and monitor the impacts of this new sector.

3.7 What should the goals for a nature inclusive wind farm be?

First, the goals for any net positive biodiversity increase will depend on the local ecology of a region. The Dutch report discussed earlier about the potential for flat oyster restoration in different potential OW sites is a good example of this opportunity.[35] Another example of a location specific NID feature would be the ReCoral trial by Orsted at the Greater Changhua OW farm that looks to combine OW jacket foundations with coral restoration efforts.[33] In a panel discussion, experts stated that the U.S. Fish and Wildlife Service (USFWS) consults with BOEM early in the lease identification process using a no net loss policy for their mitigation hierarchy.[34] At this stage, the actual impact of a net positive framework being used in addition to the conventional no net loss policy can only be theorized.

This specific challenge was also discussed at the MOCEAN meeting. Participants discussed that the commonly used phrase "net-positive impact on biodiversity" is difficult to define because biodiversity can be a loaded term. This led to a discussion about what metrics would be useful to measure for biodiversity including: focusing on impacts to charismatic megafauna, focusing on species under the Endangered Species Act (ESA), focusing on a few key commercial species, and the potential for other techniques such as eDNA to play a role. The discussion at MOCEAN was a preliminary exploration of the topic but it highlighted the need to create specific metrics to define biodiversity and targeted and measurable goals associated with various NID features.

4 Equitable OW Development

4.1 Introduction

As the OW sector scales rapidly to meet global climate goals, it also presents a series of socio-ecological challenges. OW development disrupts the livelihoods of traditional ocean users as it can spatially overlap with existing marine industries and transform ecosystems, raising concerns about its environmental impact. Consequently, it forces coastal communities to alter their cultural connections to the ocean and adapt to reshaped ecosystems.

These realities raise a critical question: How can OW development simultaneously advance climate goals, steward marine ecosystems, and protect the cultural and economic resilience of coastal communities? Addressing this question demands an inclusive governance framework that considers tradeoffs through the lenses of all participating community members. Without such an approach, conflicts over our shared marine space could turn OW development into a source of division rather than a catalyst for sustainable transformation.

This paper considers equitable decarbonization as a process that advances climate goals while safeguarding and even improving the economic, environmental, and cultural well-being of the coastal communities. Coastal communities, particularly those composed of minority, Indigenous, and low-income residents, at times, are categorized as marginalized due to their reliance on livelihoods such as small-scale fishing, which are increasingly threatened by climate change.[88–90] Coupled with limited political influence that often leads to exclusion from decision-making, their cultural ties to the ocean are often overlooked and are left disproportionately affected by external developments.[91–93] To forge a path towards equitable decarbonization, specifically in the context of OW development, there is a need to first identify the three key community groups whose participation is essential to an inclusive decision-making process:

- **Energy Sector Actors**: These include utility companies, engineering firms, infrastructure investors, ratepayers, and developers who hold the technical expertise and capital to build and operate OWFs. Their priorities often focus on project efficiency, regulatory certainty, and financial viability.

- **Marine-Dependent Communities**: These include fishers, coastal residents, and Indigenous peoples whose economic, cultural, and social well-being are tied to continued access to marine space. Many of these communities have historically stewarded the ocean through traditional ecological knowledge and rely on it for subsistence, livelihood, and identity. Their priorities include maintaining access to ocean space, preserving cultural connections, and securing sustainable livelihoods for future generations.

- **Environmental Stewards**: These include scientists, conservation organizations, and environmental regulators who are key advocates for biodiversity, healthy ecosystem function, and climate adaptation. They push for OW development that accounts for habitat restoration, species protection, and broader ecological resilience. In doing so, they help ensure that the transition away from fossil fuels does not replicate past patterns of environmental harm.

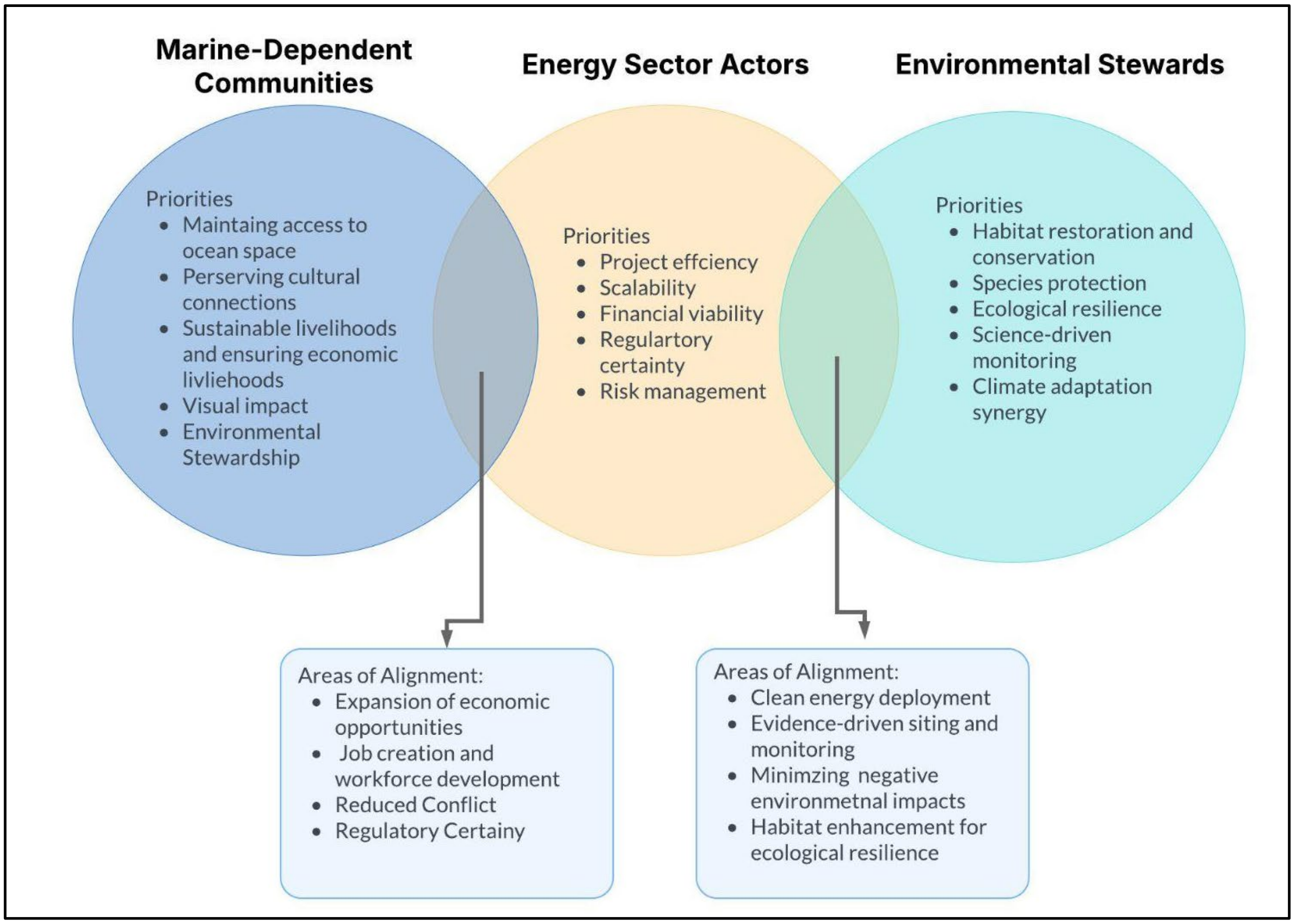

Figure 11. The community member categorization presented here is context-sensitive and relative to how groups identify themselves. In reality, boundaries between categories are fluid. For example, many fishers also see themselves as environmental stewards, and conservation scientists may have ties to coastal communities. However, for the purposes of this paper, members are grouped into three broad categories based on their primary roles and priorities in relation to OW development, with the aim of highlighting areas of alignment and informing more collaborative decision-making.

Understanding the priorities of these community groups reveals areas of alignment and sources of tension with OW development. Addressing these dynamics sets the stage for deeper questions about how decisions can be made, whose knowledge and experiences are valued, and how benefits and burdens are distributed fairly. For OW to advance in a way that is both equitable and just, three dimensions must be considered:

- **Distributive justice** focuses on how benefits (e.g., jobs, clean energy) and burdens (e.g., restricted marine access, ecological disruption) of OW development are shared across different groups.[94–96]
- **Procedural justice** considers who gets to participate in decision-making, whose knowledge is valued, and how conflicts are resolved.[97, 98]

- **Recognitional justice** emphasizes the importance of acknowledging and respecting the identities, rights, and knowledge systems—particularly of historically marginalized coastal and Indigenous communities—that are often overlooked in energy development processes.

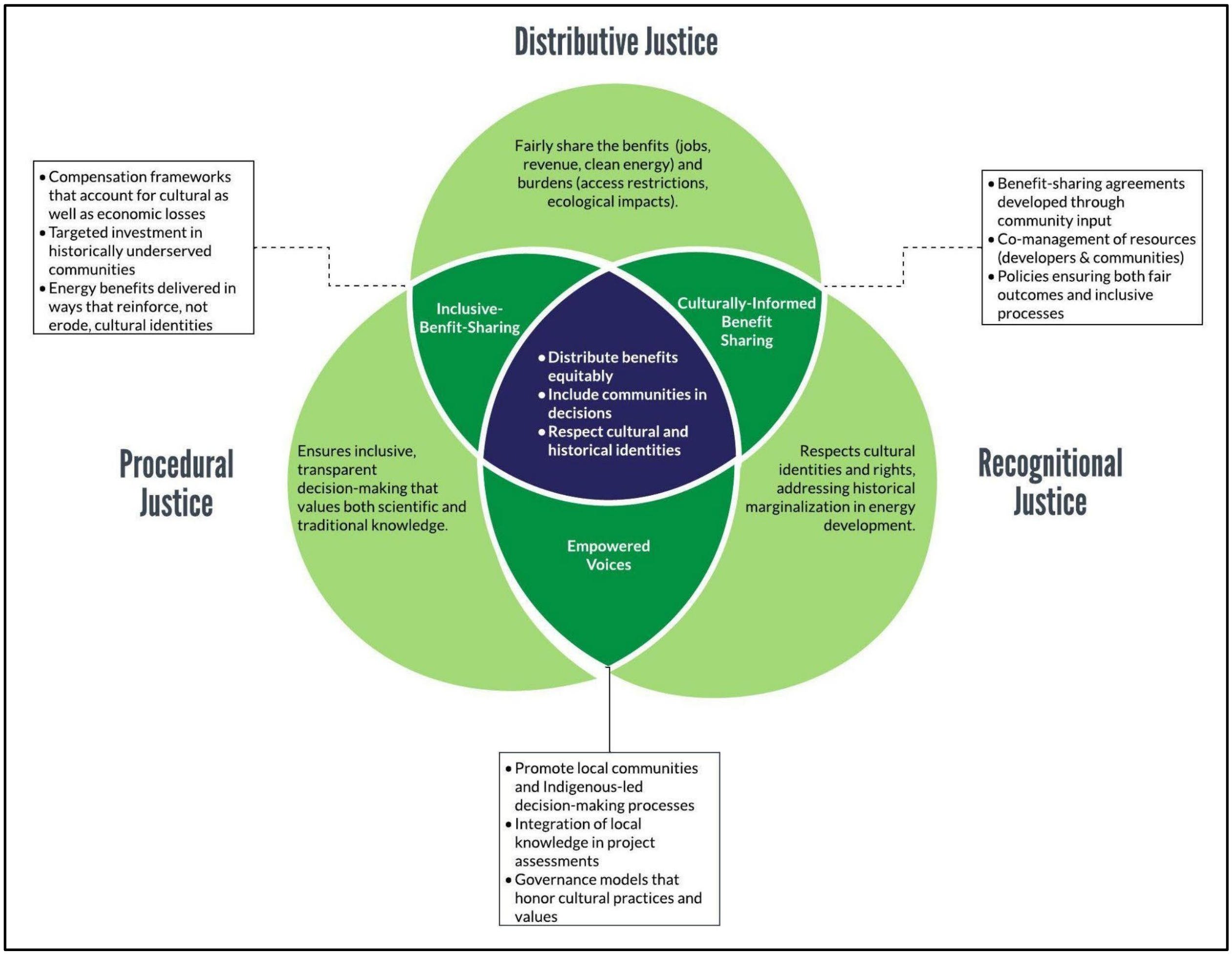

Figure 12. The three dimensions of justice overlap and reinforce one another. Together, they form a framework for evaluating tradeoffs and determining which approaches are most appropriate for specific regional contexts.

Without consideration of the three dimensions of justice, OW development risks undermining the cultural identity and economic livelihoods of local communities, deepening existing inequalities, and ultimately creating barriers to future progress of OW development. Although current community engagement practices in the OW industry attempt to incorporate local input, they often remain insufficient.[99] This is evident in the ongoing struggle to balance the interests of energy sector actors, marine-dependent communities, and environmental stewards.[100–102] In this context, the success of OW development must be evaluated not only by how quickly it reduces carbon emissions, but how the three key community members can collectively shape decision-making and ensure that the benefits and burdens are shared justly.

This perspective proposes two interconnected strategies to achieve equitable OW development:, outlined in detail later in the paper, that can help navigate the tradeoffs of OW development. The first is a policy strategy, Multi-Use governance that can help manage spatial conflicts between ocean users.[103] The second is a technological strategy, Nature-Inclusive Design (NID), that can help manage environmental outcomes.[27]

This perspective complements existing literature on multi-use governance and NID implementation by distilling key lessons from previous demonstrations and engaging with the environmental ethics of fundamentally altering marine ecosystems—whether to conserve, restore, or enhance them. Finally, it provides key considerations for adoption of these strategies to scale OW in ways that encourage social inclusivity and environmental stewardship, offering insights that can be applied globally.

4.2 Tradeoffs in OW Development

At a global level, the benefits of decarbonizing through OW development is undeniable. However, developing OW infrastructure inevitably brings local consequences. These impacts must be thoroughly analyzed to negotiate acceptable tradeoffs.

At a local level, OW energy development can provide several benefits. It can enhance energy security, help meet high energy demands of coastal regions, reduce long-term electricity costs, and lead to generation of clean electricity–that is electricity with virtually no operational emissions.[104–108] OW development stimulates economic growth by creating jobs across construction, maintenance, supply chains, and port operations, offering new opportunities for coastal economies.[109] Ecologically, the foundations of the OW turbines can act as artificial reefs, providing new habitat for benthic organisms and increasing local biodiversity.[110–112]

However, while OW development may support certain species, it may also shift community composition and alter ecosystem dynamics in ways that may help or hurt different species differently.[110] OW turbine foundations can negatively impact benthic ecosystems and marine mammals via sediment disturbance and noise pollution.[113–115] Beyond environmental impacts, OW development can have a visual impact on coastal views, giving rise to concerns over tourism and the authenticity of historic and cultural sites. It can also impact local economic activity when it spatially overlaps with the footprint of existing traditional ocean users. For example, OW development limits access to or displaces preexisting fisheries, which puts further strains on fishing communities facing economic hardship from climate change. This can deepen their social marginalization by reinforcing their underrepresentation in the decision-making process.[116, 117]

The need to decarbonize our energy sector to meet climate goals is more urgent than ever; however, these communities are often asked to sacrifice parts of their livelihood and cultural connection to the ocean in the process. Current policies designed to speed up decarbonization focus mainly on ramping up clean energy production, which unintentionally puts the burdens on local communities. A more equitable approach to OW development requires empowering the voices of all marine-dependent communities and environmental stewards. A shift toward multi-use governance through inclusive decision-making can promote shared access to our ocean and create synergistic economic opportunities.

4.3 Summary of Considerations and Approaches for Multi-Use and NID Adoption

Building on the preceding review, we present key considerations to overcome the various technical, social, and environmental barriers blocking the integration of multi-use strategies and Nature-Inclusive Design (NID) into just and equitable OW development. These considerations are organized around three core objectives grounded in the three justice dimensions (Fig. 2) aimed at equitably scaling OW and are consistent with existing knowledge and established best practices for NID (See references 116–119).

1. **Early and Visible Community Engagement**
   Engagement is essential to ensure that development reflects the principles of procedural justice and recognitional justice. This engagement process needs to achieve the following items:
   - ❖ Ensure early and continuous involvement of Energy Sector Actors, Ocean-Dependent Communities, and Environmental Stewards:
     - ➢ Build upon existing community engagement practices to empower locals with greater shared decision-making power. Use place-based expertise to define acceptable tradeoffs, preferred outcomes, and risk thresholds.
   - ❖ Prioritize spatial equity in planning decisions:
     - ➢ Consider how benefits and burdens are distributed spatially—who has access to restored areas, who loses access, and how those tradeoffs are addressed.
   - ❖ Co-develop clear ecological and social targets:
     - ➢ Identify which target species and habitats of cultural importance NID should prioritize, and define clear metrics to evaluate ecological success
   - ❖ Clarify economic and livelihood interests by region:
     - ➢ Map which industries (e.g., fisheries, tourism, aquaculture) are active in the area and how the economic viability of multi-use opportunities vary regionally.
   - ❖ Establish mechanisms for transparency and accountability:
     - ➢ Set clear timelines, communication channels, and feedback loops to ensure communities are kept informed throughout the project lifecycle.

2. **Build Knowledge Through Research, Case Studies, and Pilot Projects**
   To demonstrate the feasibility of Nature-Inclusive Design (NID) and multi-use strategies on a region-by-region basis, we need evidence-based design, adaptive learning, and long-term observation grounded in recognitional justice of diverse ecological and cultural knowledge is acknowledged. This can be done via the following:
   - ❖ Support region-specific ecological and social research:
     - ➢ Study habitat preferences, seasonal dynamics, and cumulative impacts across different offshore contexts to avoid one-size-fits-all designs.
   - ❖ Fund pilot projects and demonstration sites:
     - ➢ Test NID features (e.g., scour protection modifications, artificial reefs, sediment sanctuaries) and multi-use configurations (e.g., co-location with fisheries or aquaculture) under real-world conditions.
   - ❖ Standardize monitoring procedures and data sharing across neighboring regions:
     - ➢ Track ecological functioning, species succession, habitat use, and social outcomes over time—beyond short-term biodiversity snapshots.
   - ❖ Create open-access data platforms:
     - ➢ Share findings from pilot projects, monitoring results, and design blueprints to accelerate learning across regions and sectors.
   - ❖ Integrate adaptive management frameworks:

  - ➢ Design systems that allow iterative adjustments in response to monitoring data, community feedback, or unforeseen ecological changes.
- ❖ Encourage interdisciplinary collaboration and innovation:
  - ➢ Bring together environmental scientists, social scientists, engineers, and local practitioners to co-develop methods, tools, and indicators for success.

3. **Develop a Supportive Policy and Legal Framework**

To effectively scale NID and multi-use strategies, governance systems must embed integrated planning, clarifying legal responsibilities, and minimizing risks and uncertainties to ensure the fair distribution of benefits and burdens in line with distributive justice. These include the following:

- ❖ Mandate community inclusion and equity considerations in governance frameworks:
  - ➢ Embed procedural and recognitional justice requirements into planning statutes and regulatory guidelines to ensure meaningful participation and fair outcomes.
- ❖ Integrate NID and multi-use into MSP and offshore permitting processes:
  - ➢ Ensure that site selection, impact assessment, and licensing frameworks explicitly consider opportunities for ecological enhancement and co-use.
- ❖ Define legal responsibility and shared-risk insurance mechanisms for clear financing models, long-term monitoring, maintenance, and adaptive management:
  - ➢ Clarify which entities (e.g., developers, governments, third-party stewards) are responsible for ecological outcomes over time, and explore the use of insurance or financial assurance instruments to guarantee funding for post-construction monitoring, habitat maintenance, and adaptive measures.
- ❖ Create regulatory incentives for nature-positive and socially inclusive designs:
  - ➢ Reward developers who incorporate NID and multi-use features through streamlined permitting, public funding eligibility, or preferential terms.
- ❖ Address jurisdictional and policy fragmentation:
  - ➢ Harmonize offshore energy, fisheries, and conservation policies to reduce conflict and foster integrated decision-making.
- ❖ Mandate periodic review and reassessment of ecological and social outcomes:
  - ➢ Establish requirements for regular, independent evaluations of NID and multi-use performance over time. These reviews should assess whether ecological goals are being met, identify emerging risks or tradeoffs, and trigger adjustments to design, operations, or governance structures as needed.

5 Conclusion

The NIOWF framework sees new OW development as a unique opportunity to be a cornerstone to a *New Blue Economy* centered on environmental stewardship, equitable economic development, and energy generation. Europe’s OW industry offers imperfect, but effective insights into a starting framework for building socially equitable and environmentally responsible OW wind farms. As the U.S. OW industry grows, it can apply lessons from Europe and improve on NIOWFs by focusing on marine spatial planning, multi-use, and nature inclusive design. To build NIOWFs, the U.S. will need to set some additional groundwork and establish some additional partnerships, including the following:

1. Paper studies identifying key barriers and opportunities for multi-use OW zones similar to the MUSES project in the EU.
2. Baseline studies monitoring key species off the U.S. East Coast to establish the baselines needed to determine future impacts of OW farms.
3. Outreach to key coastal communities involved in the seafood industry to identify techniques for coexistence including the potential for multi-use.
4. Additional studies on key coastal communities to determine key concerns.
5. Monitoring of wind farms that are already built and are currently under construction in order to measure environmental effects.
6. Pilot projects inside of OW farms to test the viability of co-locating other economic activity (i.e. tourism, aquaculture, etc.).
7. Development of metrics to define success.

5.1 General Conclusions & Key Findings

The European OW started building some of the first generation monopiles as early as 2002. It was not until around 2016 with the MUSES project that Europe started to look at OW as a part of the larger blue economy and ocean ecology. The U.S. should not have to wait over ten years to plan how OWFs will fit into our ocean environment and economy. The NIOWF framework expands the lens from an industry focused only on power production into an industry that is a primary pillar of a *New Blue Economy* centered on environmental stewardship, equitable economic development, and efficient clean power generation. While NIOWFs are the vision, there is a lot of groundwork needed in the U.S. to get there including:

- Paper studies that identify key barriers and opportunities for multi-use OW zones similar to the MUSES project in the EU. This article starts by identifying the lack of a holistic MSP system for U.S. federal waters, but more work is needed talking to stakeholders from coastal communities as well as other ocean users.
    - As a part of this outreach to the seafood industry will be critical. The goal should be to identify techniques for coexistence including the potential for multi-use. Mutli-use here refers to either the combination of OWFs with restorative aquaculture or intentional adaptation strategies for fishing within OWFs. Research from the UK has shown that merely opening the wind energy areas is not enough.
    - More work is needed to understand the concerns of coastal communities.
- A review of research databases from critical U.S. organizations confirms that more baseline studies monitoring key species off the U.S. East Coast are needed. This is more relevant to the mitigation hierarchy, but nature inclusive design is impossible to build without a solid foundation in the marine sciences.
- In addition to baseline testing there should be active monitoring of OWFs that are being built and are currently operating in order to measure environmental effects. The beginning of offshore wind construction in the U.S. creates an exciting opportunity to test different NID features such as scour protection or fish hotels.

- Metrics need to begin to be developed now in order to measure the success of different frameworks. Right now, even if the U.S. wanted to financially support NIOWFs the metrics and goals are not in place to measure success.
    - Nature inclusive or net positive impact are generally quite vague terms. For example, if a wind turbine foundation forms an artificial reef and concentrates marine life in a location is that a success? Now is the time to have conversations with marine biologists, the seafood industry, coastal community members, Indigenous tribes, and other ocean stakeholders to visualize what success would be for a wind energy area.
- After the paper studies are completed, basic marine science is established, and goals/metrics are defined, projects need to be tested at OWFs. Multi-use in particular is an exciting opportunity to test the viability of co-locating other economic activity (i.e. tourism, aquaculture, etc.) within OWFs. This could be a win-win for projects and communities in two ways.
    - A key phrase that comes up when individuals are worried about the environmental impacts of OWFs is "industrialization of the ocean." If a positive shared vision for the role of OW energy areas in the ocean can be established, it could assuage these concerns. For example, in the Netherlands the efforts to establish seafood production in and around OWFs allows them to set aside more of their ocean for marine conservation.
    - Another way this can be a win-win is to help with economic concerns. Many coastal communities rely heavily on tourism and fishing, two industries that often worry about the impact of offshore wind.
- The way OW works in the U.S. and the way the U.S. is broken up more generally does pose some additional challenges for planning and coordinating NIOWFs.
    - Unlike in Europe where the lease sales and procurement are typically handled by the federal government, in the U.S. lease sales and permitting are controlled at the federal level while procurement is controlled at the state level. This can pose a challenge for coordination.
        - Each state can be incentivized to ask companies for "local content," supply chain development, and marine research related to their own state projects. More coordination is needed between states when they procure OW.
    - The federal government has recently gotten more creative by adding bid credits to the leases for things like community benefits agreements, supply chain development, and fisheries management. However, on the east coast many of the lease areas were sold before the implementation of the multi-factor auctions so these credits do not affect projects being built right now.
    - The U.S. does not have the same laws and goals as the European Union requiring regional marine spatial planning. Some states have MSP, but offshore wind is not being developed in state waters. Instead BOEM in their lease identification process is

essentially having to play the role of MSP coordination. There should be an effort to support MSP in the U.S. to build a comprehensive vision and strategy for the ocean.

- For successful implementation, we must embrace inclusive planning that integrates local knowledge with scientific research, guided by the three dimensions of justice—recognitional, procedural, and distributive. These strategies are not a one-size-fits-all solution. It is a context-sensitive approach that must reflect the ecological conditions, cultural identities, and economic realities of the communities it affects. A bottom-up approach invites critical conversations about how local communities envision the energy transition while maintaining cultural identity and connection to the ocean. Embedding these principles into offshore wind policy and planning is essential not only for minimizing harm but for building enduring public support.

5.2 Conclusions and Key Findings from May 2025 Convening

Supported by the U.S. National Science Foundation and hosted at Tufts University in Medford Massachusetts, the May 2025 convening of MOCEAN ("Mission is the OCEAN") aimed at championing and catalyzing nature-inclusive underwater infrastructure by exploring metrics and practical pathways for real-world testing and demonstration projects; promoting innovation that creates good jobs and business opportunities, including for local communities; and advancing supportive policy and regulatory frameworks.

Over 100 individuals, with interest, responsibility, and/or business in the stewardship and use of the oceans, gathered over two days, for this invitation-only event. Participants included leaders from a range of sectors – offshore energy development, fishing, heavy marine industry, federal government, state governments, entrepreneurship, and unions – and included professors and graduate student researchers as well as professional practitioners in design engineering, marine biology, ocean science, environmental science, and public policy.

The attached Proceedings present the conclusions and key findings from the May 2025 convening. One of the plenary sessions and one of the breakout sessions was dedicated to discussing topics related to this specific project. The conclusions and key findings of particular relevance to the MassCEC project are listed below. Additional information about the meeting, including information about the other plenary sessions and breakout sessions which were not as relevant to this specific project are available in the attached recap.

Plenary 1 - Showcase of Pilot Projects - Integrating marine science, engineering, and new ocean technology

- Pilot projects are a necessary step in understanding the complex processes at the interface of subsea infrastructure, the marine environment and human use.
- Goals for nature inclusive design will vary from region to region based on local ecology, uses and community/cultural values and require input from technical experts (in ecology, engineering, fisheries management, and fishing) and other community members. examples: restoration of naturally occurring habitat, or new types of habitat to support commercially important species, or carbon sequestration.

Breakout 1 - Advancing Nature-Enhancing Design & Ocean Science

- Metrics are needed for a given NID structure according to its ecological/engineering/societal goals. examples: species richness, biodiversity, and impacts to critical ecosystem functions (e.g., foraging grounds, nursery habitat)
- Possible species of societal value in New England include: lobster, cod, blue mussels, kelp, but consider warming waters when selecting a target species.

For information about the other plenary and breakout sessions of less relevance to this project, please see the attached meeting recap.

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Attachment

Proceedings from the MOCEAN May 2025 Convening

Proceedings from the May 2025 Convening

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Introduction

Overall Key Takeaways

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- **Plenary 2 - Policy Drivers Panel & Open Discussion** - How can we make innovative co-use & nature-enhancing design strategies buildable, bankable, permitable, and effective as a priority in U.S. offshore energy infrastructure development?
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INTRODUCTION

MOCEAN (Mission is the OCEAN) hosted a multi-day convening in May 2025, bringing together key players in the future of our ocean spaces. The event gathered leaders from science, industry, government, and communities to explore how underwater infrastructure can be designed and deployed in ways that support ocean health and the economies of communities on the coast and beyond.

This convening, supported by the National Science Foundation, aimed to advance the policy and regulatory frameworks needed to support nature-inclusive infrastructure, foster innovation ecosystems that include community-based economic opportunity, and set the stage for real-world testing and demonstration projects. Activities included a showcase of ongoing pilot initiatives, a policy panel and open discussion, a fireside chat, breakout working sessions, and an “Open Space” marketplace of ideas proposed by participants.

Participants came from a variety of fields, reflecting the cross-sector nature of the work. Invitations went out to ecosystem actors up and down the Atlantic Coast, with a focus on Massachusetts due to the Commonwealth's leadership in this space. We were also joined by a European expert who helped us benchmark against international progress and thinking on these issues. Attendees included offshore energy developers, fisheries advocates, representatives from heavy marine industry, staff from state and federal agencies, ocean technology entrepreneurs, educators, engineers, marine biologists, climate scientists, community advocates, graduate students, and NGO leaders.

Participants engaged actively throughout the event – sharing insights in plenary sessions, leading breakout groups, and proposing new ideas and discussing them in Open Space conversations. Topics included ideas for pilot projects, materials innovation, co-location of energy development with aquaculture, restoration of the seafloor and other habitats, the need for better policy tools, and how to execute this work in true partnership with communities on the coast and beyond. Participants pointed to opportunities for better measurement and monitoring, data sharing, and approaches incorporating social and economic good through cross-sector communication and collaboration and through consideration of the dynamics – and needs – of our oceans.

This convening is part of MOCEAN's broader effort to help overcome key barriers to development of ocean-based energy in the Mid- to North-Atlantic – particularly those around community acceptance, environmental impact, and fragmented infrastructure planning. MOCEAN, which stands for *Mission is the OCEAN*, is a network of individuals from more than 100 organizations in research, industry, education, and regulation. We are working together to build a Regional Innovation Engine that supports a regenerative ocean economy – connecting the offshore energy, seafood, and ocean technology sectors in ways that strengthen ocean ecosystems and human livelihoods alike.

MOCEAN's approach is to convene people across the ocean economy to co-design regenerative infrastructure. This convening is a key example of that work: bringing together people who often don't find themselves in the same room, surfacing both challenges and shared priorities, and laying the groundwork for continued progress. As we move forward, we are building on the ideas and relationships that emerged from this event to inform new projects, partnerships, and funding proposals.

We are grateful to all who participated, and we are excited for what comes next.

Below you will find a list of key takeaways from the event, possible next steps for MOCEAN, and summaries of the various sessions.

OVERALL KEY TAKEAWAYS

Here are some overall takeaways from what was presented across the panels, breakouts, and open space discussions.

1. There is multi-sector, statewide and cross-state interest in advancing the design of underwater infrastructure to strengthen marine ecosystems.
2. Given the complex and varied nature of marine ecosystems, region- and site-specific learning is needed to determine how to advance Nature-Inclusive Design (NID) in any particular environment and which specific objectives should be set for each environment.
3. This learning can be achieved by executing pilot projects, considering global experience to date, and creating a regional innovation ecosystem around NID that leverages the exceptional marine science assets, mechanisms for advancing innovation, and engaged and experienced communities in our region.
4. Data standardization and sharing can contribute to effective and efficient NID by advancing scientific and engineering models and policy.
5. The Mid- to North-Atlantic – and Massachusetts in particular – is well positioned to be a global leader in NID, given state commitments to offshore wind development, the strength of our marine science communities, the scale and importance of our seafood industry, and the capacity of our innovation ecosystem.
6. Policy innovation will be needed to catalyze the effective, systematic integration of NID as standard design practice for offshore infrastructure.
7. We should not wait for others to take the lead; MOCEAN connects ecosystem actors who together can take on several key responsibilities.

ABOUT MOCEAN, AND NEXT STEPS

NSF award and associated deliverables

Funded through a two-year development award through the U.S. National Science Foundation's Regional Innovation Engines program, MOCEAN (Mission is the OCEAN) is committed to developing a strategic plan and growing an innovation ecosystem around nature-inclusive design of underwater infrastructure in the Mid- to North-Atlantic region of the U.S. for the benefit of local maritime economies and ocean health.

MOCEAN is a Tufts-led initiative that has about a dozen "core-partners" organizations, including UMass Boston, the New England Aquarium, Hampton University, Marine Biological Laboratory, Woods Hole Oceanographic Institution, and Responsible Offshore Science Alliance (ROSA). MOCEAN's work is roughly organized into six focus areas: nature-enhancing offshore infrastructure; advancing ocean science; future fisheries; education, workforce development, and outreach; and ocean technology innovation.

We presently advance the initiative by organizing and supporting workshops and the participation of individuals at conferences and other events to learn and make others aware of MOCEAN's objectives. Here are a few examples of MOCEAN's past and ongoing activities: convening researchers from disparate fields and coordinating test site access for a Massachusetts Clean Energy Center (MassCEC) joint-industry funded project "Promoting beneficial colonization of offshore wind infrastructure" focused on the development of nutrient-infused coatings for underwater infrastructure to support growth of desirable organisms; supporting workshops around the seeding of atlantic surf clams as mitigation that offshore wind developers could execute, an idea developed through collaboration between fishers and marine scientists. A website https://mocean.us is being developed to share information about MOCEAN-associated projects and general information about nature-inclusive design of underwater infrastructure.

We are considering several possible deliverables for the NSF grant period. Ideas include journal articles, white papers, workshop reports, web resources, pilot projects, and created communities. We will be reaching out to relevant communities for input and feedback on these products, and we invite the perspectives of all who are interested.

We thank the participants of the present convening for their presence, questions, and ideas about how underwater infrastructure can be designed and deployed in ways that support ocean health and the economies of communities on the coast and beyond, and we look forward to integrating these contributions into the deliverables to advance policy and regulatory frameworks, promote innovation ecosystems and community-based economic opportunity, and create testbed frameworks and initiate pilot projects in advance of our award end date of February 2026.

Growing the MOCEAN initiative

We intend to leverage our convening power and experience around Nature-Inclusive Design (NID) of underwater infrastructure to serve – for the long-term – in a convening role around this topic and to lead or co-lead pilot projects and other focused initiatives. As "connective tissue" among innovators, universities, laboratories, industry, accelerators, investors, and others, MOCEAN strengthens and coordinates the already exceptional individual assets in the Commonwealth, supporting a nationally leading Ocean Innovation Network that delivers economic opportunities to the most deserving communities across the entire state and beyond.

We are always looking for others who are interested in our mission: to convene partners across the ocean economy to *co-design and champion regenerative ocean infrastructure* to revive oceans and help communities – on the coast and beyond – prosper through traditional and new opportunities. We are considering various models for funding and welcome suggestions about funding models, possible funding sources, and collaborations.

Should you wish to learn more – and/or potentially contribute to the near-term deliverables or the planning and running of future activities – please contact us at mocean.contact@gmail.com

SESSION SUMMARIES

Plenary 1 - Showcase of Pilot Projects - Integrating marine science, engineering, and new ocean technology

The first plenary shared background and findings from a range of pilot projects, each exploring innovative possibilities for catalyzing positive outcomes from an intervention associated with offshore wind infrastructure. Speakers described a range of approaches, including testing coatings that attract kelp and small animals; surf clam seeding outside offshore wind lease areas to mitigate for lost fishing access within wind farms; 3-D printed reefs and "cod pipes" that shelter fish; and co-locating low-trophic level aquaculture with offshore energy infrastructure.

Structures in the water change the ecological function of a particular site through colonization and also impact the use of the location for other human activity. Pilot projects are a necessary step in understanding the complex processes at the interface of subsea infrastructure, the marine environment and human use – uncovering opportunities to make the related changes beneficial to ocean health and economies on the coast and beyond.

Speakers suggested that we develop a framework for where, when and why to pursue particular interventions and how to assess their effects. Goals for nature inclusive design will vary from region to region based on local ecology, uses and community/cultural values. Determining goals for Nature-Inclusive Design (NID) requires input – from technical experts (in ecology, engineering, fisheries management, and fishing) and other community members – to determine which ecosystem services to prioritize in particular locations.

Well-designed monitoring programs are critical for learning from pilot projects. The pilot projects discussed employ different 'metrics of success', including species richness, biodiversity, and impacts to critical ecosystem functions (*e.g.*, foraging grounds, nursery habitat). Data sharing across projects could accelerate learning.

Key Takeaways

- MOCEAN's broad definition of nature positive design can include management and mitigation measures, as in the surf clam example, not just manipulation of structural features. We need to develop a common language: What do we mean by "NID"?
- We need to be clear about what we want to achieve: restore naturally occurring assets, optimize necessary infrastructure to achieve NID goals, or include add-on structures to achieve even greater ecosystem change? Are we focusing on, for example, restoration of naturally occurring habitat, or new types of habitat to support commercially important species, or carbon sequestration?

- We need to consider the time horizon for NID: permanent (leave in after project is decommissioned) or temporary (remove after project life)?
- Comparative eDNA monitoring nearby and distant from the new structures may help address the question of whether observed changes in species presence are due to aggregation or new biomass.
- To create a systematic, long-term approach to advancing NID and understanding micro and macro scale (cumulative) ecological interactions with what we put in the water will require new approaches to financing, possibly including diversification of funding sources.
- Mitigation to create certain habitats or species can look more like farming than creating a balanced ecosystem. How should we account for both environmental impacts and socioeconomic considerations?
- There are great opportunities for ocean technology innovation to support NID in offshore infrastructure. Connecting scientists and existing ocean industries with the start-up community to explore challenges and solutions will be beneficial.
- When we talk about tradeoffs, we have to remember that decarbonization is part of the picture, offering a socioeconomic and environmental rationale for offshore renewables.
- How does what we're doing with NID overlay with efforts to protect existing habitat? Let's consider the importance of sand plains and gravel beds in concert with hard-substrates.

Plenary 2 - Policy Drivers Panel & Open Discussion - How can we make innovative co-use & nature-enhancing design strategies buildable, bankable, permitable, and effective as a priority in U.S. offshore energy infrastructure development?

The second plenary turned to policy. Panelists said developers designing and constructing offshore infrastructure should aim for a net-positive impact on nature that goes beyond current regulations that require them to avoid, minimize and mitigate negative ecosystem impacts. They compared European approaches, where biodiversity enhancement is incentivized and valued in the procurement process, to the U.S. system that is much less strategic. They emphasized how, in the U.S., state offshore wind initiatives have driven some of the fundamental support structures – like data sharing, required investment in ecosystem research, and collaboration with fisheries – necessary to promote nature inclusive design. However, they noted that clearer signals, like those embedded in the Netherlands, Belgium and German procurement processes, could be adapted to the U.S. context – specifically through state procurement processes – to systematically advance nature inclusive design domestically.

Key Takeaways

- In addition to advances in technology and scientific analysis, innovation in policy and regulation will be essential to support the systematic adoption of nature inclusive design and multi-use in the U.S. offshore wind enterprise.
- People and local economies – as well as nature – will benefit from a policy framework that operates across Economic, Social, Technological and Ecosystem functions and engages with community values in offshore infrastructure development, moving us towards a *Restoration Economy.*
- Offshore wind has been a major driver of advancements in marine data collection, hardware and analytics, also revealing gaps that call for ocean technology innovation to support ecosystem functions.
- Barriers to commercialization of innovative technologies include overly-burdensome, unclear regulatory requirements for pilot projects, difficulty accessing testing infrastructure, and lack of clear pathways to acceptance – by regulators – of new technologies.

Breakout 1 - Advancing Nature-Enhancing Design & Ocean Science

In this breakout, engineers and ecologists from several academic institutions, environmental NGOs, offshore wind developers, and consultants discussed what Nature Inclusive Design (NID) may look like within the context of offshore wind projects off the U.S. east coast. To start the conversation, two brief presentations were given. An overview of different design concepts being employed in the North Sea was presented along with some factors that may influence the goals of intentional engineering, including of concrete and nature-based designs: environmental, engineering, and societal considerations.

During the subsequent open discussion, some key themes emerged:

Building social license to develop offshore wind

The health of the ocean and quality of marine habitats is poor and deteriorating, in part due to changing climate and the way we've interacted with the ocean to-date. Offshore wind development can be leveraged to improve the health of the ocean and the human communities who depend on it. But public concerns about offshore wind development exist and differ depending on the nearby coastal communities and include disruption to fisheries access and production – this looks different in New England versus Mid-Atlantic depending on the primary fisheries in the region – threats to tribal lands, and the well-being of particular kinds of organisms.

NID as an approach to the design of marine structures

NID is, in its most mild form, consideration of the likely effect of design options in the overall decision-making process. Using engineering and economic criteria to govern essentially all design decisions – with the requirement to avoid the use of certain materials such as a specific type of galvanic anode, as well as the requirement to remove offshore wind installations after the end of the "operational period" of the wind farm (typically 20-30 years) – affects the type of material used (i.e. steel vs. concrete), the geometry of that material, and the types of coatings applied to that material, and this in turn affects the types of marine growth that occurs and the habitats which are supported. The greater benefits of the use of concrete, gravity-based designs over steel structures were discussed.

Managing the space

We discussed how offshore wind farms should be managed from an ecological perspective. There was much discussion about what to focus on in managing the outer continental shelf Marine Protected Areas (MPAs): optimizing production or conserving the natural environment. Some participants were for offshore wind farms being managed with the goal of maximizing production, while others thought conservation (and preservation) was a better priority, and still others questioned why both objectives could not be met.

Metrics of success

This was a continuation of a discussion started during the first panel: regulators are looking for a metric – and a threshold of this metric – which can indicate success of a design. Participants discussed how this is more complicated than simply identifying a number – this metric or metrics should be determined based on the goal of the structure (see above), which is shaped by the environmental and ecological conditions, the societal values, and the engineering constraints.

Identifying key iconic species for each region

Several participants pointed to the value of identifying particular species whose health and abundance the intentional engineering could enhance. These species would be of particular societal (*e.g.*, economic and/or cultural) value. If we can select regionally appropriate and valuable charismatic species to target, this could help with the above points (identifying metrics of success, obtaining social license, designing the space, and managing the space). Potential species of interest are region-specific, and, in New England, include lobster, cod, blue mussels, and kelp.

The group broke out into smaller subgroups to discuss which species would be on the list for the U.S. east coast. There was some hesitation from researchers in definitively identifying particular species that would be promoted given the unknown trajectory of outside stressors that are driving the decline in species such as lobsters and cod. These species are not necessarily declining due to lack of habitat (although that may be contributing to the dynamic), but rather warming waters and fishing pressure.

Breakout 2 - Future Fisheries

The objective of this breakout session was to develop a shared understanding of what we mean by supporting *Future Fisheries* in the context of the multiple challenges confronting the sector, the values the sector represents in terms of food production, local culture and community economics – and MOCEAN's overall objectives.

We began by defining a future fisheries that thrives given increasing conflicting uses of the ocean space, discussed current conditions within the sector, and then considered influences and barriers to innovation in order to understand the range of actions that could be prioritized to move towards the desired future.

We used ongoing work in two specific commercial sectors – surfclam and squid fisheries – as case examples to highlight general principles and types of research and innovation that would ensure the vitality of the fishery. The conversation was wide-ranging, providing rich material for a deeper-dive.

Envisioning Future Fisheries

Participants identified a range of indicators of a sustainable, robust domestic fisheries sector, including:

- Fresh wild seafood is available in the US; *local* seafood is available locally.
- The fishing industry is economically profitable.
    - There is financial stability, with a predictable market share in relation to imports, over time.
    - Fish stocks are managed so the resource is viable and flexibility for the industry to adapt to changing conditions.
    - There are mentorship and training opportunities for the next generation of fishers.
- There is community support for the fishing industry and a clear connection between net and plate; people understand the economic impact of the industry on the community.
- Fishers, scientists and fisheries managers are working collaboratively to solve problems and innovate to support a healthy fishing resource and a sustainable industry.
- The management process considers ocean variability and effectively incorporates industry knowledge and experience.

What is the current reality?

Participants highlighted troubling **trends** including limited flexibility in the management process and the move from small business operators to corporate ownership. While the total revenue may be the same industry-wide, the number of participants is down while the median age of commercial fishers is going up. It is **extremely expensive** for new market entrants. There's a significant risk of losing essential operational knowledge without apprenticeship opportunities for a **next generation**.

Many different **stressors** on the fishing industry were discussed, as well as the interactions among them. Climate change impacts, the need to now coexist with a new offshore wind industry, multiple market factors; limited access to fishing grounds, to quotas/permits and to shoreside facilities were identified as key concerns.

Challenges and opportunities:

More and better data is needed to manage and to catch fish. The good news is that commercial fishers are collecting the data and using it. Data sharing is one important way to invest in coexistence between fisheries and other offshore human activities. We should continue to cooperatively expand the types of sensors that are going on commercial fishing vessels (*e.g.*, collecting the bottom temperatures through EMOLT). We should better leverage the huge investment in data collection by using the data for a broader range of purposes. For example, multiple offshore industries, academic research, and government entities are collecting similar environmental and ecological data, often in different formats. Looking forward we should move towards **standardization** so that the data can be aggregated and serve multiple decision-making processes. ROSA and Regional Wildlife Science Collaborative (RWSC) have made great progress in making data sharable and accessible, and exploring the best options for managing large volumes of data. BSEE and BOEM are also working on a data sharing pilot project. Finally, fishing vessels are platforms of opportunity for data collection: we need to continue integrating technology like sensors in fishing gear. **Collaborative research is the key**.

It was noted that there are limitations to the data available for stock assessments. Fishing fleets collect catch data – **fishing-dependent data,** but NOAA may have a hard time maintaining long-term datasets for **fisheries-independent data** if surveys change due to offshore wind development. There is concern that the limited funds available for data collection will be channeled away from physical sampling and towards investment in AI, which means we won't be able to validate statistical or assessment models. The relocation of the Pioneer Array will also add to uncertainty in climate models. But it's important to remember that AI needs data to learn. If federal funding for data collection is cut, could we instead harness private sector resources like Amazon or Google?

How do we drive innovation in fisheries?

To thrive in a rapidly changing world, the **way we fish** and the **way we monitor fish populations** may have to change. Developers and states must partner with fishers to fund innovation. Fishers need to be supported and compensated for their innovation to expand the reach of their impact through partnerships with the private sector and their markets. For example, fishers transformed a costly $25,000 tool into an affordable $600 version attracting interest from private sector providers.

Through these partnerships, the **cost** of innovative gear can be maintained within reason and/or accompanied with financial incentive for wider adoption across fishing fleets.

Another big barrier to innovation is the inflexible, **non-adaptive management system**. Scientists do effective innovative gear development, but the fishermen may not be able to use it due to restrictions in the management systems. It puts the fishers in a box. Programs in place to **exempt fishermen from gear requirements are needed to encourage innovation.**

Synergy with offshore wind: The conversation touched on the idea of aquaculture in windfarms. Any new structures creates competition for limited space with commercial fisheries. "**Aquaculture" needs to be defined**: finfish aquaculture has a different risk profile than a kelp farm. If we are considering seeding to enhance scallop or surf clam stocks, is it aquaculture? What regulations and management-body would it fall under? Another consideration is **liability**: the scale of value for an aquaculture operation compared to an offshore wind farm is small – if something goes wrong, who will be prioritized. Two other possible targets were suggested for co-investment by the offshore wind industry in fisheries: **electrifying fishing vessels to** make up for increased steaming time and expanded co-investing in **safety-related infrastructure**.

Future fisheries innovation and tool development for pelagics: *(This conversation focused on squid as an example.)* Gear innovation often targets improving **fish quality vs. quantity,** resulting in a higher price point per fish (*e.g.*, jigging for squid) but sometimes the market doesn't respond to quality. Some markets are very responsive to local sourcing, whereas others are more price sensitive. Asian communities consume more seafood than other demographics – how can we get more populations consuming seafood?

The **seasonality and dynamics of pelagic fisheries** raise different research questions. For example, there's an interest in mapping egg patches, called *squid mops,* on the bottom – do these show up in offshore wind surveys? We don't know because we aren't asking the question. There may be an opportunity using already-collected visual data to uncover important life history information. What other questions should we be asking? The MTS (Marine Technology Society) is having a tech surge focusing on fisheries and benthic innovation – this is an opportunity to raise these issues and connect with tech innovators.

All of our discussions are about *right now*, but managers are already talking about 2027; squid quotas are being set based on their 'great-great grandparents data'. Can we develop a predictive model for warm core rings – we know they influence squid movement and abundance – and **can we use such a model to make better, more time-scale appropriate management decisions**? What other questions should we be asking?

We need oceanographic data to show phenology and life-stage data. We need to get environmental data into stock assessments. We need to flip the questions we ask in fisheries management governance. Everything assumes an equilibrium condition based on the Great Lakes, but these laws are based on a framework that doesn't exist in the ocean. Setting up a control in the ocean isn't possible. We need to be much more flexible. The question is **how do we align the time scales into how the system is actually varying?**

Look at more dynamic management examples from other parts of the world – *e.g.*, The Faulklands. Globally, U.S. fisheries are considered to be very well managed, but are there regions or countries we can learn from? Much of the discussion centered on the improvement in observing and modeling dynamic ocean conditions relevant to squid distribution. Collaborative research that delivers this more timely and dynamic understanding could inform a more dynamic management decision-making process. Additionally new analysis techniques could address questions over longer time scales.

Can we use **genomics** to increase the hardiness of wild stock fish to combat climate change?

And finally, how do we balance trying to solve everything all at once for all fisheries? Fishermen want to fish; they need to be at the table but there is extreme meeting-fatigue "and they all tell me I have to change how I'm fishing". Successful cooperative research is **efficiently** engaging all the right community members, focusing on **priority issues** and structuring the process to meet their needs.

This discussion will help inform the development of a **MOCEAN white paper** that explores the definition of future fisheries through the lens of two case studies, examining both common challenges and differing strategies to addressing them.

Breakout 3 - Communicating the Case for Offshore Wind Energy and Nature-Enhancing Underwater Infrastructure

In this breakout, participants considered the current status of offshore wind (OSW) development in the U.S. and what might be achievable in federal government, state government, business, education and other community spaces through strategic (albeit time-intensive) relationship-building, listening, and messaging by trusted messengers. There was a sense that MOCEAN could serve as a bridge across communities (*e.g.*, for coalition building) and help counter misinformation about OSW by producing simple, positive messages that allow people to see themselves as part of it, through examples and stories.

Some specific ideas are listed below:

- Join and/or form coalitions
- Reconsider current Time-to-Decommission (*e.g.*, to increase ROI)
- Frame OSW as meeting the tremendous (and growing) electricity demand of AI
- Connect across companies, outside of the constraints of project timelines
- Include – in the conversation – union reps as well as utilities like National Grid
- Broadcast the broader map of economic-benefits
- Discover and respond to people's concerns
- Educate youth and others re: financial benefits of union OSW jobs
- Make lesson plans for schools
- Calculate and broadcast the comparative societal cost of OSW vs. some alternatives

Open Space Discussions

In Open Space, participants had the opportunity to create and manage their own agenda of parallel working sessions, diving into topics of personal interest towards advancing our shared purpose. Everyone had the chance to propose topics and actively engage in multiple conversations. Nineteen topics were raised, ranging from "What marine science questions do we still need to answer?" to "How to use art to tell a Nature-Inclusive Design story". Four examples are summarized below to illustrate the thinking and connections the discussions inspired.

Can Nature Inclusive Design contribute to achieving social license for offshore wind?

Offshore wind (OSW) development across the US continental shelf presents an opportunity to scale decarbonization efforts like never before. However, concerns towards environmental impact, visual impact, and disruption to the local coastal economy (*e.g.*, fisheries) act as significant barriers to widespread social acceptance. Much of the current dialogue has focused on increasing acceptance through cross-sector collaboration, particularly by integrating Nature-Inclusive Design (NID) features that could support fish stocks and benefit the fishing industry.

However, as discussions progressed, it became clear that even well-designed NID solutions cannot eliminate all negative impacts. For instance, approximately 70 clammers operating out of New Bedford will be displaced within the wind lease areas due to the spatial requirements of bottom trawling, which demands at least 3.5 miles of unobstructed seabed. To address such challenges, supplementary measures such as establishing artificial seeding zones for clams outside wind lease areas have been proposed.

This example underscores a broader reality: the negative impacts of OSW development will vary depending on which communities are consulted. As such, there is a pressing need to extend and deepen these conversations to fully understand and address localized, demographic-specific impacts.

Key Takeaways

- NID offers an avenue to mediate some of the concerns on OSW development, potentially leading to accumulation of greater social license.
- How to communicate the benefits must be experimented with, and refined.
- NID is not a silver bullet that solves all problems.
- Greater community engagement efforts must be made to address issues from every demographic.
- Addressing negative impacts must be explicit and negotiated transparently.

- Gaining social license is not a “one-stop shop”. It must be continuously addressed through iterative dialogue to maintain trusting relationships.

During this pause, draft guidance to develop offshore wind projects responsibly

This group discussed using this time effectively to identify gaps in existing guidance, in particular for benthic and fisheries monitoring, to improve consistency (balanced with flexibility) and certainty for developers in terms of acceptance and costs.

ROSA or RWSC could be possible conveners for this collaborative effort.

This group also discussed how this time could be used to gather best practices and a potential menu of pre-vetted acceptable NID for developers to consider. MOCEAN could take the lead in developing these deliverables, and if states include incentives for using NID in power purchase agreements that could help increase the use of NID.

What scientific research to inform setting biodiversity goals, and how can I help?

This group had a diverse representation in the group that included perspectives for agencies, NGOs, consultancies and developers.

This group talked about various scientific research and guidance information that would assist in defining how Nature-Inclusive Designs (NID) may benefit marine projects and setting biodiversity goals. This group discussed research topics that may help identify NID concepts applicable to specific environments in the U.S., including New England, New York Bight, and Mid-Atlantic regions. Initial desk-based studies could help identify NID specific concepts and benefits for the respective environments. Those concepts could then further be evaluated through research studies. Goals of research studies would also include evaluation of best practices for monitoring and quantifying the effects of the NID concepts.

This group discussed potentially developing a list of the NID concepts, conceptual designs, benefits (which could be used to assist developing biodiversity goals), and monitoring methods. This information could benefit states or others awarding PPAs / OSW development projects by identifying NID concepts. If such concepts are validated by subject-matter experts via research, then this would help reduce the burden of states defining beneficial NID concepts.

This would also provide potential benefit to developers by completing some level of NID design or providing valid concepts that could be readily incorporated into the project. This group noted that by the time a PPA is awarded, the project designs are already fairly developed, and it may not be efficient or feasible to incorporate NID concepts at that point if they had not already been implemented. Having NID concepts (or best practices) defined, may help get those concepts implemented at early stages of the project.

This group also explored areas where research could support or augment existing guidance. For example, research could be performed to evaluate best practices for benthic and fisheries monitoring of wind projects after they are constructed. At this time, little information exists in guidance documents from BOEM or NMFS regarding frequency and amount of benthic monitoring, how long monitoring occurs, and methods for monitoring, and what will be acceptable to agencies. This creates – for a project – unknown financial efforts and potential risk that is challenging for developers and their consultants to plan for.

OSW as a tech platform

Opportunities

- Opportunities are immense, and there is much interest from the science community. The offshore wind (OSW) infrastructure (turbines/substations) allow for hardline connections to internet and power, and shelter from the weather, which is a unique opportunity for ocean science. Further, the cables and vessels can collect data over wide ranges.

Challenges

- Incentives: We need to find ways to incentivize developers to offer this (*e.g.*, through state offtakes, reduction in other regulatory requirements, etc.).
- Contractors: We need to get contractors to cooperate. The supply chain is small and contractors are hesitant to add any scope that can add risk.
- Timing: These additions would need to be integrated early into project designs, which is many years before construction and many projects are well advanced.
- Design: To integrate into project designs, the monitoring systems need to be designed and provided to the main OSW design teams.
- Sustainability: We need to find long term funding for supporting the work.
- Health and Safety: Health and safety of increasing activities offshore
    - Cybersecurity: Cybersecurity issues

Potential paths forward

- Leverage work funded by NJ Research Monitoring Initiative, led by Rutgers.
- Integrate into state offtake solicitations (*e.g.*, extra points in evaluation).
- Create standard designs that are open access.
- Convene turbine OEMs (turbine, transition piece, and offshore substation) and fabricators.