A comprehensive assessment of existing Gulf of Maine ecosystem data and identification of data gaps to inform future research

Conceptual Model & Workshop Synthesis Report
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1. Background

The Northeast Fisheries Science Center (NEFSC) provides scientific support to conserve and protect marine ecosystems and resources, including fisheries, protected species, and marine habitats. The NEFSC has an interest in understanding the impacts of the offshore wind industry on NOAA trust resources and fishing communities. The bathymetry of the GOM presents engineering challenges to offshore wind development, requiring the use of floating turbine technology designed for deep waters. The Gulf of Maine represents the first large-scale floating wind technology project, both in the US and across the globe. As such, there is an imminent need to improve the scientific understanding of the ecosystem impacts of floating offshore wind development and operation.

The Gulf of Maine (GOM) is a unique and diverse ecosystem with a long history of fishing. Implementing strategic policies and plans from research findings can ensure minimization of direct and indirect costs and maximization of both monetary and non-monetary benefits. Taken in isolation, the impacts from individual offshore wind projects on the environment and fishing activities may be minimal. However, when expanding the scope to include the numerous projects that have been proposed, the cumulative impacts could substantially affect the region (Berkenhagen et al. 2010), potentially at the ecosystem level, and specific locations or species will likely experience more extreme impacts than the system as a whole. It is, therefore, imperative to take into account the cumulative effects of the full network of offshore wind projects and explicitly account for tradeoffs between offshore wind and other ocean uses such as fishing.

To address these key knowledge gaps, we first developed a conceptual model of the Gulf of Maine ecosystem based off of public comments submitted as part of the BOEM public comment process. The conceptual model helps identify key linkages within the system as well as aspects of the system that are important to different user groups. Next, we held multiple in-person and virtual meetings with stakeholders in the Gulf of Maine to refine the conceptual model and began to identify potential data sources. These meetings helped us prioritize the data types and sources that we will pursue in the upcoming data inventory and analysis process.

2. Conceptual model

A conceptual model is a flexible representation of the system of interest that identifies relevant items, processes, linkages, locations, information, and outcomes. Conceptual models can help ensure a common understanding across stakeholders (Rosellon-Druker et al. 2019), and they can be developed within a participatory process where multiple stakeholders bring their understanding of the system together. This helps identify key linkages within the system as well as aspects of the system that are important to different user groups. Once created, a conceptual model can serve as the basis for additional analyses, whether those analyses are qualitative in nature or require the development of more quantitative models (Reum et al. 2021), all of which will provide decision makers with the ecosystem information they require.

2.1 Comment analysis

A qualitative analysis of public comments from fishing industry members was conducted in preparation for the workshops. Understanding the significant effort the fishing industry has taken to provide input into the existing BOEM process, we felt it was important to use this information to avoid duplicative conversations and develop a preliminary conceptual model. The Request for Information public comments were downloaded from regulations.gov (Docket No. BOEM-2022-0040) and categorized by stakeholder groups (e.g., fishing industry, wind industry, environmental groups, federal and state government entities). In addition to reviewing the public comments received, we attended public meetings hosted by BOEM, including all virtual meetings and one in-person meeting locally, taking extensive notes of public comments received at each. Fishing industry letters (N=20) were uploaded to MAXQDA, a software designed for qualitative, quantitative and mixed methods data and text analysis. BOEM's meeting summaries were also downloaded and used in the analysis. Using a grounded theory approach (Glaser and Strauss, 1967), we analyzed public comments through thematic analysis (Braun and Clarke 2006) methods. Through these methods, codes and themes were generated which were then used to develop a preliminary conceptual model. An output of an initial round of themes is provided in Table 1. Based on the comments provided in the letters, definitions were created to describe each of the themes. As themes were developed, notes were taken on possible codes and sub codes within each theme for an additional round of text analysis. The themes that appeared the most included Fisheries, Leasing Process and Research & Data Needs. For each of the themes, a set of codes and sub-codes were created. An example of such sub-codes is shown in Table 2.

2.2 Draft conceptual model

The themes in Table 1 were used to develop a draft conceptual model as a communication tool for the workshop (Figure 1, 2). The model represents the major themes and connections described by stakeholders through the BOEM public comment process, and identified in existing research efforts including a 2022 "Synthesis of the Science" effort (Hogan et al. 2023). The purpose of the conceptual model was twofold. First, it organized themes from public comments, drew connections between related elements, and added scientific understanding where possible to create a quasi-systems model of the physical, biological, and social elements and processes that encompass offshore wind development and fisheries. The intention was to represent the system and the elements of stakeholders' concerns without assigning a direction or magnitude of impact to relationships. This type of model allows us and others to identify pathways of cause and effect, elements that influence multiple other parts of the system, and, therefore, potential indicators and outcomes to monitor. Second, the model visualization was meant to be a tool for consolidating and easily communicating the vast breadth and depth of topics made in the public comments. This was intended to allow stakeholders to quickly see and react to the elements and relationships that were identified.The draft model was later refined following input from workshops with fishing industry community members and scientific researchers (Figure 3).

3. Workshops with Fishing Communities and Scientific Experts

After drafting the initial conceptual model, we facilitated a series of workshops with Gulf of Maine fishing community members and research scientists to discuss their perceptions and knowledge of potential interactions between offshore wind and fisheries, solicit feedback on the draft conceptual model and list of themes, identify priority concerns and areas of uncertainty, and discuss possible indicators and data types. These workshops provided an additional avenue of direct input from research experts and local communities beyond the public comments submitted to BOEM. They were designed to ground-truth our analysis and conceptual modeling process with participatory approaches to stakeholder input, and to modify a finalized conceptual model based on the input provided by workshop attendees.

3.1 Workshop Planning

3.1.1 Fisheries Workshops

Workshops were held in person at locations accessible to major fishing communities across the U.S. Gulf of Maine in order to facilitate participatory discussion (Figure 4). We reviewed key commercial fisheries landing sites in the Gulf of Maine using NEFSC data and determined that two locations in Maine, one in New Hampshire, and at least one in Massachusetts would provide comprehensive coverage of the region. The Responsible Offshore Development Alliance (RODA) contacted fishermen and representative fishing associations through their existing partnerships for guidance on suitable towns for outreach meetings. Multiple meeting locations were identified that accounted for the broad geographic range of homeports for various fisheries operating within the Gulf of Maine. Rhode Island Sea Grant team members also worked with the Sea Grant network to identify a potential location and date in New Hampshire, utilizing pre-existing stakeholder roundtables supported by NH Sea Grant. Finalized locations were Ellsworth, ME, Brunswick, ME, Portsmouth, NH, and Gloucester, MA. Workshops were initially planned for Fall 2023, and delayed to December in order to avoid overlapping with BOEM-hosted public engagement on the October 2023 draft Wind Energy Area (WEA).

We next developed a list of general questions representing the focal research areas to share during workshop advertisement, and an additional list of specific discussion prompts to guide workshop conversation within the general questions and workshop goals:

General questions framing workshops:

1. How will offshore wind development affect fishing activities?
2. How can we measure the impact of offshore wind on the fishing industry?
3. What data and knowledge is available to measure the impacts of offshore wind?

Specific discussion prompts for participants:

1. In your view, how might the development and operation of floating offshore wind change (positively or negatively) fisheries and fishing communities?

2. What uncertainties, risks, interactions, or impacts do you feel are missing from current assessments and management approaches?
3. What are your concerns or priorities regarding the planning, development, and operation of floating offshore wind in the Gulf of Maine?
4. How can we measure the impact of floating offshore wind development and operations on fisheries and fishing communities?
5. What data and knowledge is available or necessary to measure the social and ecological impacts of offshore wind?

Fisheries workshops focused on the first three of the five specific discussion questions, though all five were offered as discussion areas. We also created a presentation of the initial thematic analysis of public comments, draft conceptual model, and workshop objectives to share at the beginning of each workshop. Additional facilitation tools included posters and printed handouts of the presentation content, the draft conceptual model, and the draft WEA. Workshops were not recorded. We maintained detailed notes of each session, and kept any written comments provided by participants.

RODA utilized its membership (over 200 current members) to advertise and generate interest in the fisheries workshops. Registration links were made available in order to estimate the number of attendees in advance, however, individuals could attend without registering at all. All meeting information was posted on RODA's website including the registration links. Meeting information was shared via RODA's membership list and through over 65 individual invitations issued (60+ via email and 5 via telephone). The Portsmouth workshop was co-organized with New Hampshire Sea Grant (NHSG) in order to utilize a pre-existing fisheries "roundtable" meeting space hosted by NHSG.

3.1.2 Researcher Workshops

Workshops with research scientists were held virtually over Zoom in order to accommodate participants based across a broad geographic range, as researchers who conduct relevant work are not necessarily based at institutions in the Gulf of Maine. We scheduled three workshops to prioritize physical, natural, and social sciences fields of study to allow for more targeted discussions in each session. Participants were invited to attend more than one workshop, given that some researchers are engaged in interdisciplinary efforts spanning both social and natural or physical sciences.

An initial list of invitees was developed based on our network of colleagues and through soliciting recommendations from colleagues and searching faculty and research staff profiles and contact lists at research institutions and universities in the U.S. Northeast. Invited participants were initially contacted through a scoping email to gauge interest and availability, and to solicit suggestions for additional individuals to contact to invite to the workshops. Following the scoping email to expand the list of invitees and determine the best date availabilities, we sent an official invitation to participants, who RSVP'd via Google Forms. Meeting information was shared via this invitation email, and we encouraged recipients to share the invitation with colleagues.

To steer the discussion during the workshops, we used the same set of general framing questions and specific discussion prompts as listed above. Research workshops focused on the latter three of the five specific discussion questions, though all five were offered as discussion areas. We also developed a presentation of the initial thematic analysis of public comments, draft conceptual model, and workshop objectives to share at the beginning of each workshop. Additional facilitation tools included digital copies of the presentation content, a shared Google Document where participants could type suggested indicators and data types and sources, and a series of Google Jamboards with the draft conceptual model and sample submodels available for participants to post typed comments and questions to contribute to the discussion. Zoom meetings were not recorded in order to protect any discussion of proprietary data or preliminary research results. We maintained detailed notes of each discussion as well as copies of the facilitation tools with participants' comments, questions, and suggestions.

3.2 Fishing community workshops

3.2.1 Overview

Four in-person workshops were held in the U.S. Gulf of Maine in December 2023. Participants included fishermen and community members closely associated with the fishing industry. Workshop participants represented a variety of fisheries, species, and gear types, as well as fishing association representatives and consultants, one recreational fisher in Ellsworth, and in Gloucester one federal employee and one academic researcher. Workshops ranged from seven to 10 participants, with a total of 35 participants across all four workshops. The purpose of these workshops was to ground-truth the draft conceptual model and to inform the next stage of identifying key indicators and data needs. Participatory workshops helped identify missing and/or high priority concerns or uncertainties, resulting in adjustments to the interactions and pathways in the conceptual model.

At the beginning of each workshop, Dr. Bingham summarized the draft conceptual model and workshop objectives with a short presentation and posed a series of questions to attendees designed to solicit their feedback on the conceptual model, before opening the room to discussion. Workshop discussions lasted for approximately two hours, with the exception of Gloucester which extended to three hours upon the attendees' requests to continue discussion. Facilitation tools included poster sized versions of the BOEM draft Wind Energy Area (WEA) map, the draft conceptual model, and listed existing themes and subthemes represented by the model. Attendees were provided with printouts of the same content, along with printed copies of the goals and discussion topics of the workshop and resources for following up with additional questions and feedback. Dr. Bingham moderated the discussion for each workshop, and was supported by attending team members in answering participant questions.

All discussions touched upon the major theme of uncertainty regarding the technology, scale, timeline, and process of offshore wind development. A major area of concern was the impact of offshore wind development on vessel transit patterns, as transit through floating offshore wind farms may be unsafe even if legally permitted and the development of offshore wind could result in potential displacement from important fishing grounds. Concerns regarding impacts to fisheries stocks through habitat disruption were also common. Maintenance of key onshore fishing infrastructure and avoiding an increased cost to fishing were noted as important for avoiding detrimental effects to fishing communities. Participants suggested several priority indicators to use in future assessments, including landed catch value and metrics listed in NOAA

Fisheries' Community Social Vulnerability Indicators (NOAA, 2021). The following sections review the topics discussed in each of the four workshops in greater detail, and Tables 3 and 4 provide relevant summary information.

3.2.2 Ellsworth, ME

A total of 10 fishing industry members or representatives (5 in-person and 5 online) attended the workshop in Ellsworth, ME. Attendees represented the lobster fishery. Virtual attendees called in from Swan's Island as weather conditions impeded travel to the meeting location. The workshop was supported by Dr. Julia Bingham (URI/NOAA Fisheries), Dr. Sean Lucey (NOAA Fisheries), and Dr. Fiona Hogan (RODA).

Attendees expressed concern and general opposition over offshore wind development (OSW) in the Gulf of Maine (GOM) because they want to maintain their fishing practices and viewed offshore wind development and operation as fundamentally incompatible with a successful fishing industry. Attendees anticipated that OSW would threaten their livelihoods. Some attendees stated that they expect direct conflict between OSW and fishing operations, such as exclusion of fishing from OSW areas because of risk to safety. The entire GOM was considered to be utilized by various fisheries to some degree, and attendees generally agreed that the fishing industry in this region could not afford to be excluded from key areas. It was suggested that socioeconomic impacts could be measured by looking for changes in year-round communities on Maine’s islands, such as Swan's Island. Participants commented that 85% of the tax base on Swan's Island comes from lobstering. We have not been able to verify that exact amount; however, Swan's Island is among the Maine communities with the highest proportion of total community earnings attributed to the lobster industry (Island Institute, 2018).

Impacts to lobster populations were also of shared concern. A fisherman stated that more sub-legal sized female lobsters that were “berried up” (having visible eggs) were being seen in the region over the last couple of years. Discussion speculated that this could imply the population is already under stress to reproduce at an earlier age, and so may be more vulnerable to other sources of negative impact. Discussion also noted that this could alternately have positive implications if it simply reflected an improved population-wide fecundity rate. This was noted as an example of needed research to understand existing dynamics in advance of OSW development, given the concerns regarding impact to lobster reproduction rates and juvenile survivorship.

Attendees expressed broader concerns about general negative impacts to the ecosystem. Ecosystem concerns included warming of waters from the electrical cables, cable burial dredging up contaminants in the sediments, damage to corals and coral habitat, and overall disruption to the ecosystem. There was a general consensus among participants that baseline studies and impact risk analyses (both environmental and socioeconomic) needed to be conducted before OSW leasing occurred so that ecosystem impacts could be more fully considered before the leasing process begins. There was concern that studies that indicated negative impacts were being ignored; the example provided was a publication from Scotland Marine that found deformities and attraction of lobster to electromagnetic fields after which lobster stopped eating (Harsanyi et al., 2022). OSW as a national security concern was also briefly mentioned, with questions regarding possible foreign access to wind energy areas presenting a threat to the national energy grid. Attendees consistently expressed that they felt they had very little information regarding the process of OSW development and the technology and materials required overall, and suggested that impacts of OSW development may not be well enough understood by scientists and management agencies to responsibly pursue it at this point in time.

One fisherman expressed concern that recent maps of potential offshore wind development areas shared by BOEM contained heavily fished areas, despite previous conversations between the fishing industry and BOEM suggesting that these areas might be excluded from consideration for offshore wind development. Attendees also stated that Secondary Area B was key lobster habitat; participants stated that it was dominated by mud but was a good lobstering area in the winter. A fisherman said it was essential to exclude this area from consideration for leasing and was disappointed that BOEM described in a recent meeting that they chose their sites based on shipping lanes as opposed to fishing usage. In line with this discussion, attendees expressed general distrust in government institutions, including NOAA Fisheries and BOEM.

Participants were concerned about the impacts of OSW on marine mammals, especially because they anticipated that the fishing industry might need to bear the brunt of any mitigation measures if there are negative impacts of OSW on marine mammals, as the turbines will not be able to be moved after installation. Participants felt that it was important for marine mammal monitoring to continue so that OSW impacts on marine mammals can be better understood. It was unclear at the time of the meeting whether NOAA Fisheries was still conducting its aerial marine mammal survey in the GOM. It was suggested that NOAA Fisheries could request that BOEM include marine mammal information collected by developers, such as number and location of sightings, in their reports to improve available data.

3.2.3 Brunswick, ME

A total of 9 fishing industry members or representatives attended the workshop in Brunswick, ME. Attendees represented the lobster, groundfish, herring, and scallop fisheries. The workshop was supported by Dr. Julia Bingham (URI/NOAA Fisheries), Dr. Sean Lucey (NOAA Fisheries), Dr. Fiona Hogan (RODA), Angela Silva (NOAA Fisheries) and Dr. Tyler Pavlowich (URI).

Attendees discussed multiple areas of concern regarding potential negative impacts of OSW, and especially emphasized areas of uncertainty where they felt they had too little information to accurately anticipate impacts. Specific concerns shared by most or all participants included de-facto exclusion of fishing in turbine arrays, gear entanglement in OSW cables preventing fishing near cables, and negative impacts from cooling stations that are a necessary component of DC to AC electricity conversion if DC cables are used. Participants expect that turbine arrays will be functional exclusion zones to fishing, and likely to transit; even if vessels are legally allowed near the turbines, fishermen anticipate that they will be de facto excluded because insurance companies will not cover activities in a turbine array due to navigational risks and the risk of gear entanglement with OSW infrastructure. Participants thus expected a high amount of displacement of fishing vessels from any turbine area overlapping existing fishing grounds, which would create various costs to fishermen including lost opportunity, increased gas for longer trips to different fishing grounds or to navigate around arrays, and increased costs of supplies and crew payments for longer trips. Cost was a major concern, as several attendees indicated they do not feel they can afford any increased costs. One groundfisherman attendee noted that he had a relatively successful 2023 fishing season in terms of pounds caught, yet ended with a deficit after subtracting all fixed and operational costs from the revenue of his landed catch. Participants also anticipated that displaced fishermen would move to other fishing areas already in use by other vessels, which could create social conflict, gear conflicts between mobile bottom tending gear and fixed gear - especially ropeless gear, and reduced catch revenue both overall and on a per vessel basis.

Three groundfishermen demonstrated areas of concern on a map of the Draft WEA. They pointed towards areas included in grids 3E, 3F, 3G, 4E, 4F, and 4G as important summer fishing grounds and areas in grids 5A, 5B, 6A, 6B, 7A, 7B, 8A, and 8B as their most important winter fishing grounds.[1] They were most concerned with likely exclusion from the winter grounds, and explained the most likely result would be moving north to fish near Platts Bank and in Lobster Management Area 1, which is already heavily used by the lobster industry and so presents a potential conflict between sectors. They noted they could not move south or east if displaced since it would increase the duration of transit, amount of fuel, and overall safety risks to move farther out to sea to fish.

Attendees expected that scientific research and monitoring vessels would also be de facto excluded from accessing the turbine array areas. Participants expressed concern that scientific surveys, such as the Northeast Bottom Trawl Survey, would not be able to continue in OSW areas, resulting in more uncertainty in stock assessments that could lead to lower quotas and lower revenues. Attendees felt that the current data used by NOAA Fisheries is already inadequate, and anything that could reduce data quality is not good for the fishing industry. Edge opportunities from closed areas were considered to be limited by a fisherman, and participants felt that existing closed areas do not result in spillover effects at present. A participant suggested that wind developers could expand the overall footprint of the offshore wind development but create lanes through the arrays, while other participants believed this would not sufficiently reduce gear entanglement risks because the turbines would still be linked with underwater cables, so fishing would still be de facto excluded in these areas. Participants felt there is no potential location where OSW wouldn't negatively affect one or multiple fisheries through issues of exclusion and displacement.

Individuals also raised specific concerns based on uncertainty regarding development plans, technology, and existing available data. One fisherman expressed concern over the ability of the existing electricity grid to handle this new source of energy. Another expressed frustration at the lack of information provided by BOEM on the technology to be used for floating turbines as the technology continues to evolve, and felt that fishing impacts could not be adequately anticipated without more information. Attendees also felt that there could be unknown impacts to ocean currents that would impact key fisheries species. In order to address these uncertainties, attendees expressed a desire to see more ecosystem research and consideration of fishing industry data in the OSW development process. Attendees felt that an economic comparison of the OSW and fishing industries does not adequately capture the value of the social and food production benefits of the fishing industry, and attendees perceived that regions that have been fished for generations were now being "sold" to OSW without equal consideration for both industries. Attendees also highlighted the importance of research specific to floating turbine

[1] The referenced grid areas are those presented in a BOEM map of the Draft WEA, available at https://www.boem.gov/sites/default/files/images/GulfofMaine_draft_WEA_outline_with_index_nauticalchart.png

technology to confirm whether impacts are similar to fixed turbine technology because there are few existing floating offshore wind turbines currently operating in the world. Information on the anchoring systems to be used was considered essential to discuss the impacts to fisheries. Attendees also suggested that species-specific impacts should be considered; as an example, participants mentioned that herring are sensitive to heat, light, and noise.

OSW planning and siting processes were also a major area of discussion, as these were considered important areas for making adjustments in order to avoid or minimize negative impacts. Participants felt that the current process had not adequately considered the socioeconomic impacts of offshore wind on existing fisheries. Participants felt that environmental impact statements would need to consider cumulative analysis of all OSW impacts to be fully adequate. Attendees suggested that there are ways that the OSW development process could be better balanced with fisheries and environmental needs; some participants suggested that essential ecosystem information could be provided sooner. A participant stated that the current NEPA approach results in essential information getting to developers too late in the process, which could increase the likelihood of failing to anticipate avoidable challenges in the construction and maintenance of turbines, resulting in outsized negative effects to the fishing industry, navigation hazards and accidents at sea, or increased conflict. Participants believed that essential information should be provided to bidding developers as quickly as possible, which would allow site design to potentially mitigate some issues. An attendee suggested working directly with the developers to help mitigate OSW impacts on fisheries and provided an example of the surf clam fishery helping an OSW engineering team to find the softest bottom possible for fixed turbine wind energy areas farther south. A fisherman suggested protecting migration patterns of marine mammals, target fish species, and species of concern. It was also suggested that micrositing using knowledge of larval transport should be incorporated as quickly as possible. Micrositing based on productive and non-productive habitat was suggested, however, a fisherman considered that to be already occurring because BOEM has considered vessel monitoring system (VMS) data for groundfish. Others believed that VMS data was not the best approach because it excludes GOM fisheries such as lobster, herring, scallop, and monkfish.

Attendees proposed tracking economic data to better understand OSW impacts on fishing communities. It was thought that OSW development may also affect the housing market in local communities where construction activities are concentrated. Tracking the price of electricity produced by OSW was suggested as a potential indicator for socioeconomic impacts to fishing communities; this might be in the form of what the ratepayer pays in the future as more OSW produced electricity is supplied to the grid. Insurance rates were also noted to have skyrocketed recently and companies have not indicated what will happen to prices after OSW installations are complete, or if vessels would be banned from operating within wind arrays as a condition of insurability. Insurance rates were thus posed as a potential indicator. Attendees noted that fishing is dynamic, and any methods to assess the impacts of OSW on fisheries would need to account for this dynamism. Attendees felt strongly that a static model would not adequately capture fisheries impacts, as fishing operations need flexibility to adjust when biological resources shift from one area to another. An attendee suggested that the inclusion of displacement of fisheries could be a good start. However, participants also expressed that shifting to fish in other areas might be difficult and they do not yet know how species will respond to the change in habitat caused by OSW development.

3.2.4 Portsmouth, NH

This workshop was hosted in Portsmouth, NH by New Hampshire Sea Grant (NHSG) during a recurring NHSG Fisheries Roundtable. A total of 7 fishing industry members or representatives attended the workshop. This workshop was supported by Dr. Julia Bingham (URI/NOAA Fisheries) and Angela Silva (NOAA Fisheries) who co-facilitated targeted discussion, and two members of NHSG who led in opening, closing, and moderating the meeting.

As a whole, attendees expressed negative sentiments towards offshore wind development, and seemed less willing than other communities to believe that plans for OSW development are confirmed in the Gulf of Maine. Attendees expressed dissatisfaction with the perceived imbalance in power between the fishing and OSW industries during the OSW siting process. Attendees felt that the value of New England fisheries was not being adequately represented in the current methods and expressed doubt that their participation in this workshop would result in impacts to the OSW decision making process (facilitators acknowledged that this workshop is not intended to impact OSW siting decisions).

Attendees felt that additional ecosystem research and improved understanding of OSW technology would be necessary to prepare the fishing industry for OSW development. Participants raised concerns about environmental impacts including heat released by OSW cables and converter stations, EMF, and impacts on population processes such as migration and spawning. As in other sessions, EMF and heat impacts were specifically of concern due to potential implications for larval and juvenile survivorship of important species such as lobster, crab, scallop, and baitfish. Two attendees were adamant that more research on potential EMF impacts to migratory species and elasmobranchs is necessary to fully understand ecosystem impacts before OSW development proceeds. Benthic habitat disturbance was briefly discussed, but attendees felt they needed more information about OSW technology before they could fully discuss risks associated with seafloor disruption.

While safety risks including navigational hazards and gear damage or entanglement were brought up, attendees felt that they needed more information on OSW technology, such as cable burial, to better understand and anticipate how their own fishing practices would be specifically impacted should turbines or cable routes and landings overlap with their preferred fishing areas. Attendees raised concerns about increased fleet conflict if the displacement of fishing from OSW areas results in more fishing operations overlapping with each other. Attendees anticipated that issues of displacement are more likely to directly affect fishers from Maine or Massachusetts, but that displacement of their “neighbors” could lead to increased fishing activity competition in their own preferred fishing areas. This would be an issue as it could risk unsustainable fishing pressure on target species, social conflict, reduced catch and revenue, and increased economic uncertainty.

Attendees expressed skepticism about the quality of the data used to make OSW decisions and especially felt that impacts to whales were not being appropriately monitored or shared with the public. Participants were particularly concerned about OSW impacts on marine mammals because they felt that the fishing industry may be negatively impacted by any mitigation measures implemented to offset negative impacts of OSW on marine mammals. Attendees were skeptical of all government research, and suggested that transparency in funding sources would be necessary to improve legitimacy. Though the degree of distrust expressed varied across participants, collectively they expressed doubt in federal or state agencies' intent to engage in good faith with fishing industries as a whole. This was noted in other workshops as well, but discussion at the Portsmouth event more frequently returned to this issue. This discussion overlapped with sentiments that sufficient environmental reviews of OSW projects are lacking based on participants' knowledge of other OSW projects underway in southern New England, and that the current approach to leasing, siting, and construction is thus environmentally irresponsible. Attendees questioned whether research conducted in Europe was available and the extent to which it was being used in this project.

3.2.5 Gloucester, MA

A total of 9 fishing industry members or representatives attended the workshop in Gloucester, MA. This workshop was supported by Dr. Julia Bingham (URI/NOAA Fisheries), Dr. Sean Lucey (NOAA Fisheries), Dr. Fiona Hogan (RODA), Angela Silva (NOAA Fisheries) and Dr. Tyler Pavlowich (URI). Participants primarily represented the groundfish fishery, as well as herring and squid fishers.

Attendees expressed concern about a perceived lack of knowledge about the impacts of OSW on fisheries and the environment. Attendees suggested that potential impacts could be turbines contributing to the heating of water in the GOM and causing fish to move out of the region. Attendees felt that a comprehensive impact assessment is necessary and that impacts to the ecosystem cannot be fully anticipated at present. Attendees were concerned that negative impacts to the environment would cause fishermen to go out of business, and that potential fisheries mitigation would not occur in time to save the fishing industry. Additionally, attendees were concerned that OSW impacts on federal scientific surveys would result in more conservative fisheries management, which would further harm the fishing industry. Participants were also concerned that the dynamic aspect of the fishing industry was not being adequately captured in existing analyses. Fishermen noted that spatial management measures imposed by fisheries regulations restrict where and when they can operate in each fishery. Within approved areas of operation, where fishing is occurring now may not be an indication of future activity; working closely with the fishing industry to better understand vessel trip reports and vessel monitoring system data was recommended.

Attendees expressed discouragement with their experiences with OSW developers. An attendee noted that working with a developer hadn't gone well because of lack of interest on the developer's side. Participants felt that any agreements made with developers might be challenging as the leases could be sold to other multinational corporations, who might not honor the original agreements. Attendees suggested that revisions to BOEM's permit approval process could ensure that these conditions transfer between lease holders.

Participants also felt that port competition between the OSW and the fishing industry, as well as generally high interest in waterfront development, is a major issue. Attendees commented that degraded infrastructure is already a regional issue for commercial fisheries, and that the state has not historically prioritized port maintenance. Fishermen at this workshop noted that working waterfronts are a core of the local culture and provide a major draw for tourism, another economically important local industry. There is fear that if the state places a higher priority on OSW shoreside infrastructure, or if active commercial fishing and processing industries are reduced due to OSW impacts, fisheries-supporting infrastructure will further degrade and working waterfronts may be permanently lost.

Attendees were generally concerned about safety and the ability to secure insurance to operate within an OSW array. Attendees were concerned that the wind turbines will be too close together to allow for helicopter search and rescue efforts, which would result in the de facto exclusion of fishing. Attendees also expressed a desire to ensure that fish habitat is not destroyed, money is made available for fishers who target certain species or use certain gear types to help mitigate impacts, and that there are thorough environmental assessments and monitoring of the waters surrounding the turbines.

Participants suggested that indicator time series would need to be at least 20 years long for credible analyses, and the annual NMFS vessel survey was given as an example of a time series that is currently too short. Many participants suggested indicators that were economic or sociocultural in nature, such as calculating a multiplier for revenues generated from a processing plant versus condominium taxes. It was also suggested that fishermen and their operations could be used to generate real time data to improve analyses. Tracking sale or lease prices for fisheries quotas as proxies for barriers to entry and costs to participate in the fishery was suggested as an indicator of OSW impacts to the fishing industry. Attendees suggested that fishing permit value, revenues, and lease prices could be important to track, although they acknowledged that fishing permit valuation is not well understood and difficult to analyze at present. This is a major challenge to addressing decreased valuation of fishing permits resulting from OSW. Additionally, participants suggested that OSW could increase operational costs (e.g., increased fuel costs required to steam around the arrays), which would further stress fisheries.

Attendees also suggested some economic measures to help the fishing industry. Buybacks of fishing permits and vessels was raised as an option, which would protect fishermen from potential decreases in permit and vessel value, and suggested dedicated funding for young fishermen should be made available in the event there was an opportunity to fish the wind energy areas in the future. On the environmental side, outstanding questions included changes to ocean currents (before, during, and after) as well as impacts to warm core rings.

3.2.6 Key Takeaways

Across all fishing community workshops, attendees expressed a range of sentiments regarding OSW, with the majority being moderately to largely negative or apprehensive. This sentiment draws from concerns and perceptions regarding potential negative impacts to fisheries and fishing communities, from discomfort with the extent of real or perceived uncertainty regarding technologies involved with OSW and existing environmental assessments, and from the decision-making, siting, and construction processes involved with OSW development. Fishermen do not generally trust that federal agencies consider their input or value risks to their livelihood or to the environment. While all conversations called for additional necessary environmental reviews and risk assessments before the leasing, siting, or construction stages of OSW, a significant portion of discussions revealed a distrust in the sources, quality, and/or application of data used by federal agencies in these processes. As a whole, the dominant opinion is that OSW is fundamentally incompatible with fisheries and poses a threat to the Gulf of Maine ecosystem, though it is worth noting that some individuals expressed their opinion could change with a better understanding of OSW technology and more evidence that environmental reviews and mitigation efforts meet the requirements they perceive as necessary.

With regards to specific potential interactions between fisheries and OSW in the Gulf of Maine, the most consistently named concerns are areas of uncertainty and areas of anticipated or perceived likely negative impact. Table 3 highlights a condensed list of the most frequently discussed topics within each major theme and subnode of the base conceptual model. Table 4 provides additional context regarding fishermens' perceptions of key issues, including areas of concern and areas of uncertainty, as well as how these discussions informed adjustments and additions to the conceptual model.

Fishermen are concerned especially with impacts to the health, distribution, and populations of target fish species, and to benthic habitats important to lobster. Uncertainties regarding technology contribute to concern that electromagnetic fields (EMF), heat, or effluent affiliated with cables and cooling stations could harm larval populations of target species or negatively impact migratory species. Fishermen expect that turbine arrays will be de facto exclusion zones and that transit through or use of mobile gear within turbine arrays will be infeasible due to either spatial constrictions, safety risks, regulatory restrictions, insurance barriers, or a combination thereof. They therefore assume that all OSW arrays overlapping fishing areas will cause displacement of commercial fisheries. In all discussions, this perception of OSW causing de facto fisheries exclusion prompted a discussion of multiple cascading socioeconomic effects. Economic and qualitative social impacts were highlighted in all discussions, especially with regards to perceived negative impacts to fishing livelihoods, to fishing community culture and heritage, to mental health, and to the role of commercial fishing industry in local and national seafood markets. Economic vulnerabilities of fishing communities were thus frequently noted as an area necessitating indicator development and tracking.

As a whole, the workshops echoed many of the key themes extracted in the initial review of public comments and major pathways of interaction and potential effect illustrated in the draft conceptual model and sample submodels. Notable gaps and adjustments identified by workshop discussions with fishermen included:

(1) the role of infrastructure as its own node with feedback loops between fisheries, OSW, and various community and economic nodes,

(2) the potential for impacts to research and monitoring through potential overlap of turbine arrays with long term survey areas and transect routes to influence fisheries regulation through a change or reduction of available monitoring data, and

(3) consideration of social vulnerability indicators and particularly economic vulnerability of fishermen and fishing communities in assessing OSW impacts.

Other notable topics discussed at these workshops included system dynamism, cultural values and qualitative socioeconomic concerns, the perception and experience of impacts, and environmental justice and equity. Long term impacts of OSW on fishing communities are influenced by fishermen's perceptions of potential impacts, as fishermen appear likely to exit the fishery (viewed as a loss of livelihood) if they anticipate further reduction of economic viability of their profession, regardless of data-based modeling efforts by research institutions or federal agencies to understand how OSW may or may not influence economic dynamics in the commercial fishing industry.

In all discussions, participants appreciated that the conceptual modeling approach supports the ability to consider and eventually assess a variety of indirect and potential cumulative impacts, which attendees consistently view as a gap in their understanding of existing OSW planning and environmental assessment. Attendees responded positively to the ability to create submodels that consider specific sets of interactions, specific impact types, or specific factors of OSW that may interact with or impact fisheries and fishing communities. Some expressed that seeing more integrative approaches and attention towards indirect and cumulative impacts would help make them more hopeful about responsible development of OSW with appropriate mitigation of impacts. This reception supported the ability to discuss potential impacts, indicators, and data needs for understanding interactions between fisheries and OSW, despite the otherwise dominant negative or apprehensive sentiments among participants.

3.3 Researcher workshops

3.3.1 Overview

We conducted three virtual workshops with research scientists in January 2024. Each virtual workshop focused on one of three generalized themes: physical oceanography, biology and ecology, and socio-economics and human dimensions. Some participants joined multiple workshops, and discussions occasionally overlapped in specific topics given system interconnectivity. Workshops ranged from 8 to 15 participants, with a total of 28 participants representing 14 different institutions across all three workshops. All workshops were two hours in length.

The physical oceanography workshop discussion noted a need for understanding how turbine and cable effects might impact the GOM at a larger scale, because the total scale of the leases could potentially cover millions of acres. The biology and ecology workshop discussed trophic interactions of interest and potential behaviors of fished species in response to floating offshore wind structures. The socioeconomics workshop highlighted a need for understanding how community macroeconomics (larger scale economic dimensions influencing community well-being and not specific to a single industry) influenced by offshore wind development will also influence fishermen's livelihoods through, for example, possible changes to cost of living. Each workshop highlighted the challenge of differentiating between changes due to offshore wind development versus other drivers, such as climate change, and that this challenge should influence the selection of indicators for assessing offshore wind impacts. As a whole, participants expressed a need for data sharing and integrative, cross-disciplinary research to better address uncertainties. The following sections review the topics discussed in each of the three workshops in greater detail, and Tables 5 and 6 provide relevant summary information.

3.3.2 Oceanography & Atmospheric Science

The first virtual workshop focused on oceanographic and atmospheric dimensions of the Gulf of Maine and potential impacts from OSW. The workshop participants included eight researchers representing five institutions including the Woods Hole Oceanographic Institute (WHOI), Massachusetts office of Coastal Zone Management (MA-CZM), MIT Sea Grant, Maine Department of Marine Resources (ME-DMR) and the Gulf of Maine Research Institute (GMRI). Dr. Bingham presented the draft conceptual model, the workshop objectives, and the discussion prompts before facilitating the workshop discussion. Dr. Pavlowich supported discussion facilitation and provided technological support to manage the virtual setting. Note taking was coordinated by Dr. Hogan and Dr. Tyrell. Angela Silva and Jennifer McCann also joined for portions of the workshop to observe the discussion and provide input and support as necessary.

A major focus of discussion was the need to understand climate change influences in the Gulf of Maine to be able to accurately understand how OSW would impact an already-changing system. Participants noted that it could be difficult to determine if some changes to the system were caused by climate change, OSW, or some synergistic interaction of the two. Recent extreme temperature anomalies in Nantucket Shoals and unexpected variations in the Gulf Stream off of southern New England were provided as examples of processes or events that would likely impact species behavior, distributions, and population dynamics as well as localized current cycling and stratification patterns. In an area with wind turbines, it is necessary to be able to differentiate when ecosystem changes are attributed to OSW as opposed to major weather or climate events. Participants shared concern at the difficulty that this poses, and at the likelihood that such challenges will continue to occur given a shared expectation that climate anomalies will increase in frequency and magnitude.

One researcher based out of the Woods Hole Oceanographic Institution noted that 2023 was the most unusual year on record in terms of ocean processes in the Gulf of Maine. Warming in the Atlantic is associated with climate change and with periodic regime shifts such as El Niño, but no existing models had predicted the magnitude of the temperature anomalies recorded in 2023, which according to the participant were up to 4.5 standard deviations above normal. Similarly, according to this participant, the anomalously high amount of rain in New England in 2023 was attributable to a heat dome in the midwest driven by abnormal high-pressure systems, and this unusual amount of rain was not predicted in existing models but held implications for coastal stratification patterns. Participants agreed that changes to freshwater runoff influence the GOM Coastal Current and impact stratification patterns and larval fish transport. Others noted patterns demonstrating recent and ongoing climate-related system change included a 70% increase in frequency of saltwater intrusion in the Northeast US compared to 20 years ago and shifts in the timing of seasonal weather patterns which influence current dynamics important to migratory and feeding behaviors of various species.

Participants suggested that it is important to understand the cumulative or at-scale dynamics of turbine flow fields and potential wake effects, particularly with large structures, high numbers of turbines in a given area, and variability associated with large and extreme wind events. Participants noted that individual turbines create localized eddies and can at least locally shift patterns of upwelling or downwelling, and so it is reasonable to speculate that multiple turbines in an array may collectively have a larger impact to water flow. Participants varied with regards to what extent they anticipate the wake effects of a full turbine array to influence current dynamics, stratification, and other physical processes beyond an extremely localized scope, though there was a shared perspective that there is not yet enough existing or available data to accurately predict these dynamics, and any possibility for cumulative effects to influence processes important to the broader GOM oceanographic regime is a concern and so should be a research priority.

Participants also identified other potential local impacts of OSW turbines. The movement of the anchoring chains is likely to cause benthic disturbance, and the structures themselves may attract species that prefer complex habitat, while deterring species like scallop that prefer sandy, unstructured bottom. Participants also highlighted potential biogeochemical changes that could be caused by the OSW turbines, for example, everything that grows on or near the turbines would eventually become part of the detrital loop in the benthos near the turbines. A participant noted that, on the west coast, organic matter accumulated at the base of the turbines has been found to create an acidic environment, which results in corrosion of the OSW structures.

Participants generally felt that concerns around water heating caused by offshore transformer stations were unwarranted. A participant noted that these cooling stations would have a smaller intake than other existing power plant cooling stations. Additionally, the heat from cooling stations generally dissipates within dozens of meters from the point source. Given the size of the ocean, these effects were not considered a substantial source of concern, and siting decisions around the location of the intake structure and the speed of the intake flow could minimize the environmental impacts. Similarly, participants generally agreed that EMFs would not extend more than a few meters from the OSW cables and therefore would not be a substantial concern for the ecosystem; however, they felt that measurements should still be taken in during Gulf of Maine OSW development and operation to confirm this. Participants also raised the issue of increased vessel traffic due to OSW development and operations potentially impacting protected species via vessel strikes or noise disturbances.

Participants noted that OSW impacts on scientific surveys would also affect physical oceanography data collection, as many surveys take CTD (conductivity, temperature, depth), wind, and other physical measurements. Participants acknowledged that some surveys might be able to continue to operate in OSW areas, depending on the turbine siting design, and suggested that Autonomous Underwater Vehicles could take some measurements if survey vessels were excluded from an area. The discussion highlighted the importance of existing buoy systems for long term data collection. Participants gave the specific recommendation of reinstating the NERACOOS Northeast Channel buoy, which historically took physical oceanography measurements but has been recently removed. Participants agreed that this dataset is extremely valuable and it is important to continue to collect the same data.

Although this workshop targeted physical oceanography experts, participants also highlighted several biological and ecological concerns, due to the interconnectedness of marine systems. Various participants noted concern regarding implications of observed changes to migratory patterns or unusual sighting locations of specific species indicating warming waters in the Gulf of Maine or, in one participant's words, the "tropicalization of the New England shelf"; examples from three different participants included monkfish, black seabass, lobster, tautog, fluke, and mahi mahi. Biological dynamics potentially influenced by changes to the water column included copepod populations and the distribution of larval settlement. Based on collaborative work with fishermen, one participant noted a potential for larval settlement to move farther south, depending on possible shifts in currents and downwelling patterns. Another participant noted that decreases in copepod populations have important trophic implications, as copepods and sand lance are important for many other Gulf of Maine species, and limited food availability is among the stressors of concern for North Atlantic Right Whale (NARW) populations. Participants agreed that differentiating drivers of water column changes will be important, given these cascading ecological impacts. Another participant suggested that an increase in vessel traffic associated with OSW may be an important indicator that could help identify if impacts are being caused by OWS or by climate change.

Participants also noted several socioeconomic and human dimensions concerns. They highlighted spatial conflicts that could arise in ports, where limited space could lead to conflict between OSW power stations, fishing infrastructure, and housing. Participants also emphasized the nuance in physical oceanography data; when such data is collected on fisheries vessels (such as VMS and VTR data), researchers need to consult with fishermen to fully understand the data and determine appropriate data usage; this reflected comments made at the in-person workshops. Participants felt that involving the fishing community in physical oceanography research provides a net benefit to the sustainability and resilience of the social-ecological system.

3.3.3 Biology and Ecology

The second virtual workshop focused on biological and ecological dimensions of the Gulf of Maine, especially fisheries ecology, and potential impacts from OSW. The workshop participants included 15 researchers representing 12 institutions including MA-CZM, MIT Sea Grant, ME-DMR, GMRI, NEFSC, University of Maine, University of Massachusetts School for Marine Science and Technology (SMAST), the Bigelow Laboratory for Ocean Sciences, the Responsible Offshore Science Alliance (ROSA), and the Nature Conservancy (TNC). Dr. Bingham presented the draft conceptual model, the workshop objectives, and the discussion prompts before facilitating the workshop discussion. Dr. Pavlowich supported discussion facilitation and provided technological support to manage the virtual setting. Note taking was coordinated by Angela Silva and Dr. Hogan. Dr. Tyrell and Jen McCann also joined the workshop to observe the discussion and provide input and support as necessary.

The workshop discussion first focused on potential species-specific implications of OSW interactions with fisheries through the lens of fishing gear type. For example, while many gear types are used in bluefin fisheries, rod and reel fisheries could anticipate a higher risk of entanglement with anchoring cables, especially if hooked fish swim through cable arrays. Since such species are highly migratory, fishing activities are more spatially variable as they follow fish distributions, so if these species' distributions overlap wind arrays they may experience decreased fishing pressure due to de facto fishing exclusion. A similar set of interactions was proposed for harpoon fisheries, which would also be compromised by additional underwater structures, and for target species which are known to exhibit schooling behavior around structures. Alternatively, greater fishing effort may target wind energy areas if they are expected to act as fish aggregating devices (FAD) to schooling fish. Participants noted that this discussion relied heavily on speculation given uncertainties regarding gear interactions with and fish response to floating technology as compared to fixed turbines, and there is a major lack of fine scale data for highly migratory species in the Gulf of Maine. One researcher shared some preliminary work contributing to an effort to address this gap with regards to tuna using fishers' knowledge combined with existing catch data, and the discussion highlighted additional recent and ongoing work by workshop participants (Davis & Kneebone, 2023).

Participants noted that fishery interactions from OSW infrastructure also extends beyond turbine arrays; cables were noted as a major entanglement risk, especially to trawl fisheries. Participants suggested that impacts would extend outside of turbine arrays because there could be multiple lines crossing areas beyond the turbine arrays, prompting fishermen to need to further adjust navigational routes and target fishing areas. Changes to fishing behavior, effort, target area or species, and gear can have implications for stock dynamics, especially if large portions of the fishing industry have to make such adjustments in response to OSW. How OSW development might influence fishing activities with attention to implications for stock dynamics was therefore noted as an important area of focus.

Participants felt that scientific surveys would be able to adapt to OSW and were optimistic that the scale of the impact of changing surveys on fisheries stock assessments would be manageable. Uncertainty about continuity of sufficient funding for scientific surveys were of great current concern to participants.

When prompted with the potential issue of EMFs from cables, which was expressed as a concern in the fishery workshops, a shark expert noted that he expected EMFs to have negligible impacts to elasmobranchs, particularly highly mobile species that can transit over 100km per day, though they acknowledged that there is little data regarding elasmobranchs' response to structures in the water. The discussion did reflect possibilities for EMFs and heat to affect larvae, though there is uncertainty regarding whether potential negative localized impacts to survivorship would have any large-scale impacts; participants agreed that more research is needed. Similarly, participants viewed any temperature increases from cables or cooling stations to be unlikely to have an effect beyond a localized scale as heat should dissipate after a few meters. Not all researchers were confident on this subject and there was a shared interest in better understanding at-scale effects. Participants also referenced a recent study in the United Kingdom showing changes in recruitment and biodiversity of benthic populations on hard substrate habitats in offshore wind areas (Karlsson et al. 2022). Potential implications of this work include the possibility of recruitment of lobster populations to anchoring structures, moved boulders, and scouring protections, which may influence migratory patterns. Participants mentioned an ongoing study out of Long Island that is intended to address this question, as well as work by Dr. David Fields conducting lobster larval sampling for the Maine Research Array.

Participants suggested that trophic dynamics could be affected by OSW. Given that there is a possibility of floating structures to attract various species, it is possible that turbines could serve as preferred foraging locations of various species, including black sea bass and larger pelagic fish and migratory species such as tuna and sharks. It was speculated by some participants that this may influence distribution of scallops if turbine arrays overlap sandy bottom areas that don't usually have as many sharks or other species which forage on surf clams and other benthic organisms. Ongoing work supported by the University of Maine and GMRI is using various approaches to track the feeding patterns of sharks and tuna, which may be used to look for changes over time potentially affiliated with OSW. Other ongoing work out of GMRI is tracking seabird and small pelagic fish species to improve understanding of and monitor migration and feeding patterns. One participant noted that pollock have been observed schooling at the floating turbines in Scotland.

Participants suggested priority areas of focus should include migratory species and species protected under the Endangered Species Act (ESA), as impacts to these species have regulatory implications. It was also generally agreed upon that species highly vulnerable to climate change are also of high interest for monitoring, due to risk of exacerbated impact from OSW; Runnebaum et al. (2023) provides additional context for this concern. A potential strategy for monitoring to differentiate between climate change-related impacts, OSW-related impacts, and synergistic effects is to track multiple species with differing levels of vulnerability to climate impacts through various stages of OSW development as indicators of change. It was noted that the comments provided to BOEM by TNC through regulations.gov in response to the draft WEA in November expand on this discussion and articulates a strategy for identifying indicators to monitor based on hypotheses about how individual species might be impacted. This would be more likely to detect changes actually attributable to wind structures and operation than general observations about abundance in an area over time.

3.3.4 Socioeconomics and Human Dimensions

The third virtual workshop focused on socioeconomic and human dimensions of the Gulf of Maine, especially fisheries communities, and potential impacts from OSW. The workshop participants included 8 researchers representing 9 institutions including ROSA, NEFSC, NOAA Fisheries Greater Atlantic Fisheries Office (NMFS GARFO), ME DMR, GMRI, SMAST, University of Massachusetts Amherst, and URI. Dr. Bingham presented the draft conceptual model, the workshop objectives, and the discussion prompts before facilitating the workshop discussion. Dr. Pavlowich supported discussion facilitation, taking lead when Dr. Bingham's internet connection was disrupted. Note taking was coordinated by Angela Silva and Jen McCann. Dr. Tyrell also joined the workshop to observe the discussion and provide input and support as necessary.

Researchers discussed the difficulty in understanding direct OSW impacts when communities have cumulative stressors, including lobster and ropeless gear management, aging of the fleet and infrastructure, port redevelopment, markets and production, gentrification. This was discussed in the context of selecting indicators, as well as the vulnerability of communities to these multiple stressors and the concern that O would be the final impact that causes fishermen to leave the industry. The uncertainty of impacts, including impacts to target species, could lead to fishermen selling their permits and future generations being deterred from entering fisheries or continuing to fish. Uncertainty regarding the technology used in OSW, the potential restrictions or compatibility issues regarding fishing gear types in or near turbine arrays, whether wind areas would be functionally treated as Marine Protected Areas (MPAs) with regulated exclusion zones, and the implications for navigation and operational costs collectively increase the risks and uncertainties fishermen have to consider in planning future fishing seasons, adding to deterrents from participating in fishing. The question of how fishermen will react to OSW, and how that may influence other system-level interactions and impacts was a key theme throughout the discussion.

Participants noted that OSW appears to be deeply offensive to coastal and especially fishing communities, with communities viewing OSW as a privatization of the ocean or an inappropriate static use in a dynamic system. This is an example of a fundamental and value-based conflict, which participants noted should be addressed differently than resource use conflict, and may be a part of why some mitigation efforts fall short, and why changing careers or place of living is not accepted as a viable solution by some groups. While difficult to measure, sense of place is critically important for coastal communities, and especially culturally important for fishing and tribal communities. Community members often feel that the availability of other spaces does not adequately mitigate displacement from historic areas.

Participants discussed economic factors, including both fishing industry economics, as well as community macroeconomics. Participants viewed the economic stability or vulnerability of fisheries as being directly tied to the wellbeing of fisheries communities. Participants noted that there are a limited number of skilled individuals wanting to enter the fishing industry, especially in younger generations. The cost to entry is high, and inherent risk and uncertainty make it difficult to maintain an economically viable, much less profitable, fishing career compared to other career prospects. Workshop participants agreed that fishermen generally anticipate the wind areas to be de-facto fishing closures and expect that both the operational and fixed costs of fishing will increase due to OSW, adding to the difficulty to maintain economic viability, especially for small vessel operators. The discussion highlighted that the pressure to diversify income could be viewed positively or negatively; while OSW may offer additional career opportunities, external pressure to switch careers is viewed negatively. Furthermore, those who switch professions may risk ostracization from their communities, especially if they choose to work for the OSW industry. Participants also noted that the potential rise of energy cost to ratepayers is a socioeconomic concern, and would intersect with other factors influencing cost of living, such as gentrification, development, or revenue loss which may also be associated with OSW development. Community macroeconomics was therefore noted as an important node lacking in the base conceptual model.

The discussion of social conflict and community impacts also noted that different fisheries may be differentially impacted by various potential avenues of conflict. For example, lobster fisheries may be less impacted by de facto exclusion from OSW areas gear conflicts but may experience onshore impacts such as community demographic changes and space use conflicts. Floating OSW will require large areas onshore for staging, trucking, additional construction, among other considerations. It is currently unknown whether onshore OSW development will prioritize building new or upgrading old infrastructure, which have differing implications for shoreside development and seafood industries.

Participants identified Indigenous fishing as an important component that is missing from current assessments of OSW impacts. Indigenous shellfish harvest is completely outside of the market sphere, and impacts to Indigenous fisheries and to Indigenous heritage sites will be difficult to identify and assess with existing approaches. Participants noted other dimensions missing from current assessment approaches, such as recreational and subsistence fishing in the GOM. Based on some initial work done near Block Island Wind Farm to the south, participants suggested that any benefits to recreational fisheries to come from GOM OSW will primarily go towards big game fisheries targeting species far from shore. Charter businesses may benefit from turbine arrays that could attract novel species. Other comments included speculation that any autonomous underwater vehicle for turbine maintenance or monitoring could offer a technological spillover that could benefit fisheries, for example through tools useful acoustic survey methods.

Participants discussed several potential indicators and data sources. One suggestion was to measure people's attitudes over time (e.g., social conflict, relationships, how people adapt, expectations compared to experience, willingness to change occupation). Similarly, tracking intentions as well as actions in response to OSW is useful for anticipating changes to community dynamics and macroeconomics which may not be clear from overall economic tracking of fishing industries. Participants encouraged a spatially stratified approach to such work, given these dynamics likely differ across GOM communities and fisheries.

As noted in fisheries discussions, existing metrics of community vulnerability were suggested as an important starting point in considering both geographic variations and community macroeconomics such as gentrification pressure. Insurance rates for fishing vessels were also suggested as an indicator; insurance rates can be prohibitive expenses in fishing and it is unknown how they will be affected by OSW development. Tracking permit value and fishing history would help for understanding other dimensions of cost of fishing. Recreational fisheries data was also recommended; methods similar to DePiper (2023) would supplement Marine Recreational Information Program (MRIP) data to understand areas of recreational fishing activity.

3.3.5 Key Takeaways

Expertise from research participants was particularly insightful for addressing a selection of the concerns and questions raised by fishers in the fishing industry workshops. For example, scientific expertise regarding EMFs, heat, effluent, wake effects, and sound suggests all of these factors are likely to be less detrimental to species health and habitat than was perceived by the fishing industry. However, researchers agreed that these areas still require further research to affirm that these factors would continue to be of minimal concern at the scale of OSW development and operation planned for the GOM, as cumulative impacts could emerge.

Scientific experts emphasized that climate change impacts on ecosystem dynamics are already present and will likely only get stronger in the GOM. It will be important to develop indicators that can be clearly attributed to OSW or differentiated from climate drivers, and Environmental Impact Assessments need to consider how long term impacts and ecosystem interactions may change with time as climate related system changes occur. Researchers agreed upon the need for rigorous post installation monitoring of OSW operations.

Ecologists are generally more confident than members of the fishing community that floating OSW infrastructure has potential to provide artificial reef functions or act as fish aggregating devices. They are interested in understanding how this might facilitate changes to migratory and foraging behaviors, and influence the shift or expansion of species ranges. Participants identified many potential implications for trophic dynamics within turbine arrays and around anchoring systems and cables. Researchers share some concern with fishers regarding the potential for scientific surveys to lose access to turbine array sites.

Socioeconomic discussions emphasized the multidimensionality and variability of community vulnerability, and highlighted the importance of monitoring macroeconomics, community well-being, and social dimensions to understand the community-level effects of OSW.

Discussions with researchers provided several useful references and data sources that will be informative for understanding socioecological interactions in the GOM relative to OSW development.

4. Overall summary of workshop takeaways and conceptual model adjustments

4.1 Key workshop takeaways

The two workshop series provided substantial information important to understanding the key concerns and interests of both the fishing and scientific communities, modifying the draft conceptual model, identifying potential indicators and sources of data for assessment, and identifying data gaps and areas of uncertainty. As a whole, fishing communities are generally apprehensive and often pessimistic about the potential impacts to come from interactions between OSW and fisheries in the GOM. Research scientists are much more mixed in their perspectives, and generally do not express a primarily positive or negative sentiment regarding OSW. There were several areas of overlap between the major topics, themes, and areas of interest or concern discussed in both workshop series (Table 7).

Both the fisheries workshops and the socioeconomic-focused discussion with researchers highlighted a necessary inclusion of social, cultural, and economic factors into impact assessments and mitigation strategies. Shared priorities included considering equitable distribution of costs and benefits, identification of community vulnerabilities, and incorporation of qualitative and non-monetary approaches to indicator assessment alongside economic markers like fisheries revenue. The fishing industry is concerned about the ways in which OSW will directly or indirectly add to the safety risks and monetary cost of fishing as a livelihood, and are especially concerned that fishermen may soon decide to exit the industry entirely. Participants also suggested that OSW could affect other socioeconomic components such as shoreside infrastructure and community macroeconomics.

While both the fishing industry and ecologists and environmental scientists share overlapping concerns regarding the difficulty of anticipating environmental and ecological impacts without more knowledge of floating OSW technology and the scale and location of OSW development, the fishing industry pointed out these concerns have little bearing on them if they ultimately cannot afford to continue fishing. Hydrodynamic impacts from OSW are a major area of interest, especially to researchers. Researchers were also interested in ecological dynamics such as the response of animals to OSW infrastructure, modified larval settlement and survivorship patterns, modified foraging behavior, and the impacts of EMFs on various species.

Participants overwhelmingly agreed upon the need for more research on environmental, ecological, and socioeconomic implications of OSW development with specific attention to indirect and cumulative impacts, as well as more clarity regarding the technology used in OSW development. Additionally, participants suggested that indicator assessment and long term OSW monitoring will both need to consider community macroeconomics and climate impacts as concurrent drivers of system change.

4.2 Summary of updates to conceptual model

Based on the workshop discussions, we updated the base conceptual model and shifted the organization of subthemes represented by the various primary nodes. Fisheries infrastructure is more directly linked to seafood markets and production, and feeds back to fishing activities. Community macroeconomics is a new node in the base model to better illustrate processes by which OSW and other non-fishing industries influence fishing communities, livelihoods, and industry through non-fishing market dynamics, development, cost of living, among other factors. The nodes representing research and management/monitoring and the ecological and environmental dynamics of the system were rearranged to more clearly illustrate directional relationships between surveyable area and management decisions, ecological processes and stock dynamics, and management decisions and various fishing activities.

Two important processes that were frequently raised by stakeholders but were underrepresented in our original models were:

1) the impacts of oceanographic and physical drivers of ecological dynamics that impact fish stocks and the broader ecosystem, and

2) the follow-on effects of fisher displacement beyond lost fishing opportunities.

Scientists and fishermen spoke about the importance of physical environmental drivers for the functioning of the Gulf of Maine ecosystem and the productivity of its fisheries. Wind development could alter the hydrodynamics of the GOM, which could then alter temperature and stratification cycles, with cascading effects on phytoplankton and zooplankton blooms. Small prey fish and larvae or small individuals of target species would be affected, thereby affecting target species' stocks. The physical and oceanographic processes could affect biological productivity through two main mechanisms: by affecting the physiological processes of organisms (e.g., temperature effects on metabolism), and habitat availability. Indicators are needed to assess how these relationships may be influenced by OSW and how to differentiate such processes from concurrent large scale oceanographic drivers such as climate change. Figure 5 provides an example of a submodel that considers how impacts to fishing gear has cascading socioeconomic implications. Figure 6 illustrates how basic submodels focused on IPFs can communicate a need to consider additional environmental and socioeconomic dimensions in Environmental Impact Assessments.

5. Next steps

5.1 Priority Indicators

The major environmental data topics of conversation at the workshops were split between biological (organism and population-level) data and physical/chemical data. Participants raised questions about migration and seasonality, trophic interactions and potential trophic cascades, benthic habitat disruptions, species behavioral responses, and possible oceanographic shifts to the large-scale circulation and nutrient cycling of the region due to the cumulative impacts of turbine installation. Impacts to larval distribution, survivorship, and settlement for key species were suggested as high priorities to consider in future monitoring and research plans.

The impacts to fishing activities and response by fishing communities was of shared concern across different stakeholders. Participants suggested that stock size, fish population dynamics, and fisheries-dependent data collection might be all implicated by changes to fishing activities. The cost to fish, fishermens' choice to leave the industry, fishing displacement or redistribution of fishing effort, risks to safety, rates of catch, among other dynamics, might be influenced by offshore wind development and could result in ecological as well as socioeconomic implications.

Participants were concerned that the dual stressors of climate change and offshore wind development could make it difficult to identify the true cause of any observed ecosystem changes. Participants suggested that indicators that could help measure natural variability in ecosystem data would be useful for successfully attributing ecosystem impacts to either climate change or offshore wind.

5.1.1 Biological Indicators

Participants identified several biological and population-scale indicators that could be used to track the health of the organisms living in the Gulf of Maine. In addition, participants highlighted that these indicators should be tracked over a variety of representative species, as there will be some "winners and losers" in terms of impacts from offshore wind development. Proposed indicators and characteristics to monitor were migration and seasonality, fish aggregation, recruitment of young to fish populations, trophic interactions and changes to predator-prey relationships, fish condition, and the distribution, mortality, migration of protected species including turtles and marine mammals.

Participants also made suggestions regarding the collection and interpretation of these data. Biological data, particularly protected species data, requires a long time period for accurate interpretation, and participants suggested that time series of at least 10-20 years would be necessary to truly characterize any ecosystem-level impact of offshore wind. Additionally, participants suggested that biological data collection could help improve scientific survey mitigation strategies, as several of the long-running Northeast Fisheries Science Center surveys will not be able to continue within offshore wind areas. Finally, although fishing data is not directly reflective of population distributions and abundances, participants suggested that both commercial and recreational fisheries data could be used to better understand fish distributions, space use, and seasonal migration patterns.

Cumulative Indicators

Participants highlighted the need for cumulative and comprehensive indicators to provide information on ecosystem-level impacts of offshore wind development. Although a single project may not have an appreciable impact, the scale of the proposed build-out of offshore wind could ultimately result in population-level impacts beyond what would be anticipated for a single project. Because some species may be better able to adapt to offshore wind development than others, it is also important to monitor a suite of species to ensure that the full ecosystem effect is being documented. Additionally, the large scale of offshore wind build-out may result in trophic cascades or other ecosystem-level impacts that need to be assessed with the synthesis of comprehensive ecosystem information.

5.1.2 Physical & Chemical Indicators

Participants suggested that physical impacts such as electromagnetic fields, noise, and physical disturbance of the benthos should be monitored. Additionally, participants recommended that chemical changes should be monitored as well, as fish aggregation could affect nutrient cycling and sedimentation. Upwelling and downwelling were also thought to be of local importance.

Cumulative Indicators

Participants emphasized that cumulative impacts on currents and circulation would be extremely important to track. With two million acres in the Final Wind Energy Area in the Gulf of Maine, participants felt that large-scale impacts to the currents and circulation could occur.

Participants also raised the possibility of larvae being impacted by any changes to ocean currents because larvae usually depend on currents to bring them to nursery grounds.

5.2 Data plans

We developed a structured data gathering strategy that incorporates the conceptual model nodes and notes from the workshops to guide data collection and ensure that the data inventory adequately addresses the informational needs of the conceptual model. Our data inventory will build off of the established ecosystem data programs at the Northeast Fisheries Science Center, including the annual State of the Ecosystem report, which aggregates and assesses environmental, biological, and fisheries data over the Gulf of Maine ecoregion.

To aid the data inventory step, we plan to attend a collaboration workshop hosted by State of Maine researchers this summer, where we will be able to present our data inventory progress and solicit feedback to help identify additional data sources.

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Tables

Table 1: Primary coding results for major themes in thematic analysis of public comments submitted by members of the fishing industry and associated communities to BOEM (Docket No. BOEM-2022-0040). 20 total letters were reviewed; some letters contained multiple mentions of the themes.

Primary Theme	Number of mentions in comment letters
Siting Location & Design	18
Mitigation	30
IPFs	9
Marine mammals	6
Fisheries ecology	8
Habitat	15
Oceanographic Impacts	8
Fisheries	76
Complex/unique ecosystem	6
Leasing Process	62
Research & Data Needs	58

Table 2. A selection of example common sub-codes within frequently coded primary themes, based on comment review. Finalized list and organization of major themes and subthemes following workshop-informed conceptual model revisions is included in section 4.1.

Primary Theme (coding frequency)	Example sub-codes
Fisheries (76)	Lobster Industry
	Economic Impacts
	Social Impacts
	Management Restrictions
Leasing Processes (62)	Timeline
	Engagement
	Environmental Review
Research and Data Needs (58)	Ecological Data
	Fisheries-dependent Data
	Local Ecological Knowledge (LEK) / Fishers Ecological Knowledge (FEK)
Mitigation (18)	Compensation
	Safety

Table 3: Discussion topics of greatest overall interest or concern emphasized in fisheries workshops. Discussion focused on potential interactions or impacts and areas of uncertainty. Colors are thematically organized by primary system dynamic, and align with nodes in the conceptual model and submodels.

System dynamic	General theme	Specific topic
Safety	Safety at Sea	Navigation
		Accidents at Sea affiliated with OSW infrastructure
Fishing activities	Accessible Area	Transit Lanes
		Area functionally open/closed to fisheries (de facto exclusion)
	Gear Concerns	Gear Compatibility
		Damaged Gear
		Gear Entanglement
	Onshore / Shoreside Infrastructure	Fishing Infrastructure
	Location, Type, & Size of Fisheries	Fishing location (s)
		Gear type (s)
		Target species
		Trip duration
	Changes to fishing activities	Displacement from preferred fishing area
		Exiting the industry
	Catch	Target species
		Landed amount*
		Landed value
	Cost to Fish	Opportunity costs
		Fixed costs, eg insurance
		Operational costs, eg fuel
Fisheries Research, Monitoring, and Management	Research & Monitoring	Surveyable Area for Fisheries Independent Scientific Surveys
		Stock Assessments
		Biological and fisheries data
		Commercial vessel tracking/ observation
		Fisheries Dependent Data
	Management Decisions	Accounting for changes in FID and FDD data collections
		Area Closures
		Seasonal Closures
Environment and Ecology	Habitat	Habitat for early life stages
		Benthic habitat
	Species	Fish distribution
		Recruitment
		Migration

		Protected Species
	Ecological interactions	Change in life history patterns
Socioeconomics	Fishing Livelihoods & Culture	Identity and Culture
		Sustainable livelihood
		Fishing Industry Jobs
		Cultural value
		Fishing Identity & Sense of Place (Indiv. & comm)
	Coastal communities	Community Dependence on Fisheries
		Environmental Justice, Equity
		Fishing Material Culture & Tourism
	Seafood Industry & Markets	Seafood Production
OSW: processes of development and Impact-producing factors (IPFs)	Noise	Noise - Sound Pressure
	Cables	Cable Burial depth/covering
		EMFs or heat from cables
	Electromagnetic Fields (EMFs)	EMFs, generalized concerns or uncertainty
	Cooling Water Intake Systems (CWIS)	Heat
		effluent
		larval / plankton mortality
	HVDC Converter Stations	heat
	Entanglement	Gear entanglement
	Species movement	Invasive Species Establishment and Range Expansion (IPF)
	Contamination	Chemical Contaminants
	Hydrodynamic effects	Water at foundations / current effects
	Turbidity	Turbidity, generalized concerns or uncertainty
	Benthic habitat modification	Boulder relocation
		Reduced soft bottom habitat
	Mitigation	Communication & Outreach
		Project Siting, design, navigation and access
		Safety
		Environmental review and monitoring

Table 4: Summary information from fishing community workshops informing conceptual modeling process (four locations, 35 total participants).

Discussion areas	Socioeconomics	Environment and Ecology	Research, Monitoring, and Management	Fishing Activities	Safety at Sea
Possible (known or perceived) impacts of highest concern or interest	Loss of fishing culture and economy. Loss of livelihood viability. Impacts to community revenue and vulnerability from degradation or loss of fishing industry. Negative impacts to mental health.	Benthic habitat disruption, migratory species impacts, larval survivorship impacts, protected species impacts, change in fish stock distribution. Potential species impacts from electromagnetic fields, vibrations, water temperature increase, and effluent.	Changes to monitoring or data availability due to offshore wind development resulting in greater stock assessment uncertainty and more restrictive fishery regulations.	Closure (de jure and de facto) of fishing areas within lease sites. Displacement from historical fishing grounds. Increased cost to fish. Increased distance of transit to fishing grounds. Space use conflict. Loss of infrastructure.	Risks of collision if transiting near turbines. Risk of entanglement or damage through gear conflict with anchoring systems or cables - especially mobile gear. Cost of repairs.
Interactions or potential impacts with greatest uncertainty or lack of knowledge	Cost of development to ratepayers, responsibility for cost of maintenance and repair, location and scale of shoreside offshore wind energy infrastructure development. Non-monetary forms of mitigation.	Effects of cables and substations on larval distribution and survivorship (through EMF, heat, effluent). Potential wake effects at the intended scale of development. Ability to attribute changes or impacts to cause given multiple drivers (e.g. fishing vs climate change vs wind development).	Ability for research and fisheries monitoring necessary for management to continue within research arrays. Addressing lack of trust in data sources.	Ability to transit through/near wind energy areas. Uncertainty regarding gear incompatibility. Ability to know where submerged cables are when transiting.	Ability of Coast Guard to rescue/assist vessels in wind areas. Ability to acquire insurance if fishing or transiting in/near wind energy areas. Regulatory responsibility for accidents and damage in wind energy area.

Suggested adjustments to conceptual model themes and relationships	Emphasize cultural value and mental wellbeing. Include vulnerability indicators in assessment (multiple types). Incorporate justice and equity through distribution of impacts and ability to participate in or influence offshore wind related development decision-making.	Include physical oceanographic drivers of biological processes. Consider inherent system dynamism and non-wind drivers. Include movement of larval distribution in ecosystem dynamics. Include species migratory patterns as potential area of impact.	Role of monitoring as a potential mitigation tool. Connection between data availability or quality and management decisions. Emphasize effect of access for offshore surveys as an issue.	Feedback from fishing activity to onshore infrastructure. Fishermen's choice to exit the industry is based on cumulative stressors, not just economic viability or regulatory restrictions.	Perceptions as a mechanism of interactions. Example: even perceived safety risk will influence ability to get insurance (de facto displacement) and impact fishers' decision-making regarding where, when, and whether to fish.

Table 5: Discussion topics of greatest overall interest or concern emphasized in researcher workshops. Discussions focused on potential interactions or impacts and areas of uncertainty. Colors are thematically organized by primary system dynamic, and align with nodes in the conceptual model and submodels.

System dynamic	General theme	Specific topic
Safety	Safety at Sea	Navigation
Fishing Activities	Accessible Area (Fishing)	Area functionally open/closed to fisheries (de facto exclusion)
	Onshore / Shoreside Infrastructure	Fishing Infrastructure
	Fishing activity - Location, Type, & Size of Fisheries	Target location (s)
		Gear type (s)
		Target species
		Fleet size
	Changes to fishing activities	Displacement
		Exiting the industry
	Catch	Target species
	Cost to Fish	Operational costs
Fisheries Research, Monitoring, and Management	Research & Monitoring	Surveyable Area- Fisheries Independent Scientific Surveys
		Stock Assessments
		Biological and fisheries data
		Commercial vessel tracking/ observation
		Fisheries Dependent Data
	Management Decisions	Accounting for changes in FID and FDD data collections
		Catch Limits, Quotas
		Area Closures
Environment and Ecology	Oceanographic conditions	Currents
		stratification
	Habitat	Benthic habitat
	Species	Fish distribution
		Stock abundance
		Lobster

		Protected Species
		NARW
	Ecological interactions	Foraging Behavior
		Trophic interactions
	Climate change	Climate drivers
Socioeconomics	Fishing Livelihoods & Culture	Fishing Industry Jobs
	Coastal communities	Port space use
		Community macroeconomics
OSW: processes of development and Impact-producing factors	Cables	Cable Burial depth/covering
		heat
	Electromagnetic Fields (EMFs)	Electromagnetic Fields (EMFs)
	Cooling Water Intake Systems (CWIS)	heat
		larval / plankton mortality
	Species movement	Fish Attraction Device Effects
		Invasive Species Establishment and Range Expansion
	Hydrodynamic effects	Wind wake effect
	Turbidity	Turbidity - from construction activities
	Benthic habitat modification	Benthic habitat modification, general
	Mitigation	Communication & Outreach
		Project Siting, design, navigation and access
		Safety
		Environmental monitoring

Table 6: Summary information from researcher workshops informing conceptual modeling process (three events, 28 total participants).

Discussion areas	Socioeconomics	Environment and Ecology	Research, Monitoring, and Management	Fishing Activities	Safety at Sea
Possible (known or perceived) impacts of highest concern or interest	Loss of fishing culture and economy. Loss of livelihood viability. Changes (positive or negative)to employment opportunities. Intersection with and potential amplification or mitigation of community vulnerabilities. Risk of increased conflict.	Possibility for structures to act as fish aggregators, including for target fishery species. Possibility for wind energy areas to act as protected area if closed to fishing. Risks (or lack of risks) to protected and migratory species. Possibility for changes in oceanographic processes that impact lower trophic level prey species to then affect fisheries target species.	Amplified issues of distrust in regulatory agencies and research. If turbine arrays are inaccessible or require change in monitoring technology / tools for stock assessment surveys in wind energy, possible data implications for management strategies and regulatory actions. Communicating areas of likely low risk but high social concern (noise, EMF).	Displacement of fishers causing increased fishing pressure on remaining fishing grounds. Disproportionate impact to mobile gear fisheries.	Cables and anchoring structures causing navigational hazards.
Interactions or potential impacts with greatest uncertainty or gap in data	Intersection with and potential amplification or mitigation of community vulnerabilities. Role of community macroeconomics not necessarily specific to fisheries but with potential impacts to fisheries if influenced by offshore wind energy development, such as changes to cost of living.	Possible changes to trophic dynamics. Ability to attribute changes or impacts to a cause given multiple drivers (e.g. fishing vs climate change vs wind development). Lack of data for scaling up oceanographic interactions to that of the intended plans for Gulf of Maine. Risk of at-scale EMF impacts to elasmobranchs, forage fish,	Ability to communicate research and monitoring conducted by or in collaboration with regulatory agencies or offshore wind developers. Technology needs for in-turbine array research. Addressing lack of trust in data sources.	Difficulty to anticipate interactions until having more knowledge regarding scale and location of lease areas, mitigation strategies, and technology and layout of wind energy areas and cable landing sites. Possibility for an 'edge effect' if wind energy areas do function as protected areas.	Ability to safely access and transit through turbine arrays for monitoring, research, or fishing.

		migratory species - migratory and foraging behaviors (expected minimal).			
Suggested adjustments to conceptual model themes and relationships	Add a node for community macroeconomics, which will connect more of the fishing activity and socioeconomic nodes. Distinction between conflict types (daily vs deep - e.g. space use vs belief and trust). Perceptions as a factor influencing socioeconomic dynamics. Existing values and perceptions work and long history of socio-cultural research in ME can help fill in those relationships even if not wind-related.	Climate change is an inherent factor in most relationships. Indicator development and impact prioritization needs to consider ability to differentiate between multiple drivers. Expand types of specific potential impacts to habitat, trophic interactions, and larval distribution. Assessment clarifying lower than (socially) perceived risks, eg noise and EMF, valuable alongside addressing uncertainties. Hydrodynamic influences on sedimentation and larval movement and settling along shelf.	Effect of new onshore and offshore infrastructure and potential offshore access issues on historic trawl survey transects. Clarification of at-scale dynamics and impacts needed, but a difficult to address gap without active floating arrays (models limited). Need for data and knowledge sharing strategies. Suggestions re: data sources and reference to existing / upcoming research.	Fishing-related shoreside infrastructure changes have strong relationship to community culture and macroeconomics. Perceptions and expectations as a factor influencing fishing activity through fishers' responses to offshore wind.	Stronger socioeconomic implications, including and beyond fishing industry specific concerns.

Table 7: Selected major areas of discussion from each workshop series, highlighting areas of overlap.

	Fishing industry	Research scientists	Both workshop series
Socioeconomics	Infrastructure Community dependence on fisheries revenue	Community macroeconomics Demographics Gentrification	Culture and heritage Fisheries livelihoods Well-being e.g. mental health and social networks Equity; distribution of impacts
Environment	Heat EMFs Effluent, pollution Key habitat for target species	Climate impacts Stratification and sedimentation Differentiating different drivers of environmental dynamics	Benthic habitat disruption 'At - scale' impacts Hydrodynamics (high uncertainty) Public communication of environmental impacts
Ecology	Marine mammal impacts Lobster life history	stocks trophic dynamics climate impacts wind infrastructure serving as habitat / fish aggregating device	Distribution of species Larval survivorship and settlement migratory patterns Uncertainty in indirect and cumulative effects on ecosystem dynamics
Fisheries operations	Fixed and operational costs of fishing Safety concerns Access to fishing areas	Shifts in fishing effort of target species Location and scale of fisheries	Fishing displacement User conflict Monitoring and management Gear incompatibility between fisheries and wind industries

Figures

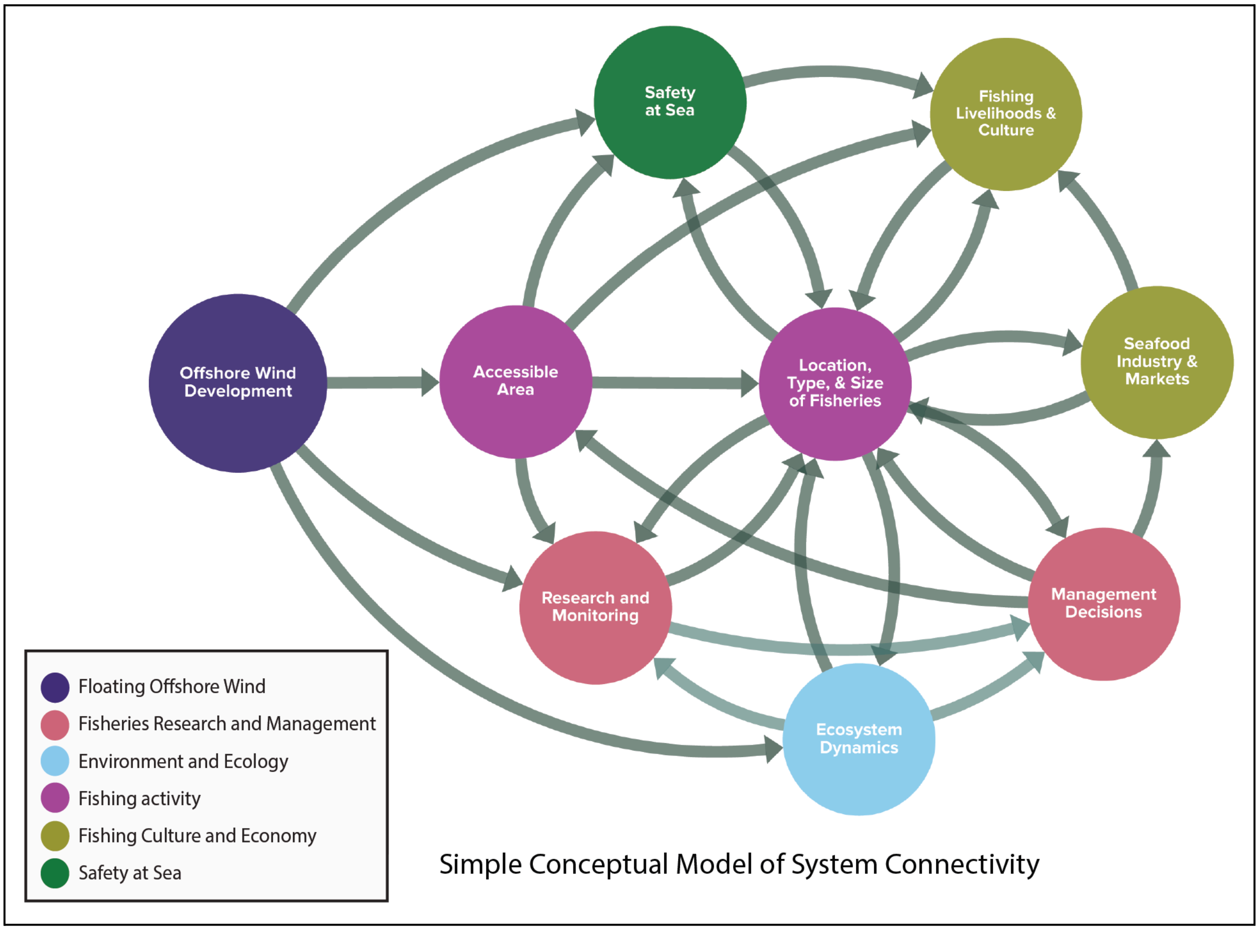

Figure 1: Simplified conceptual model of interconnectivity in the full Gulf of Maine system, and primary areas of direct potential interaction and impact by floating offshore wind development.

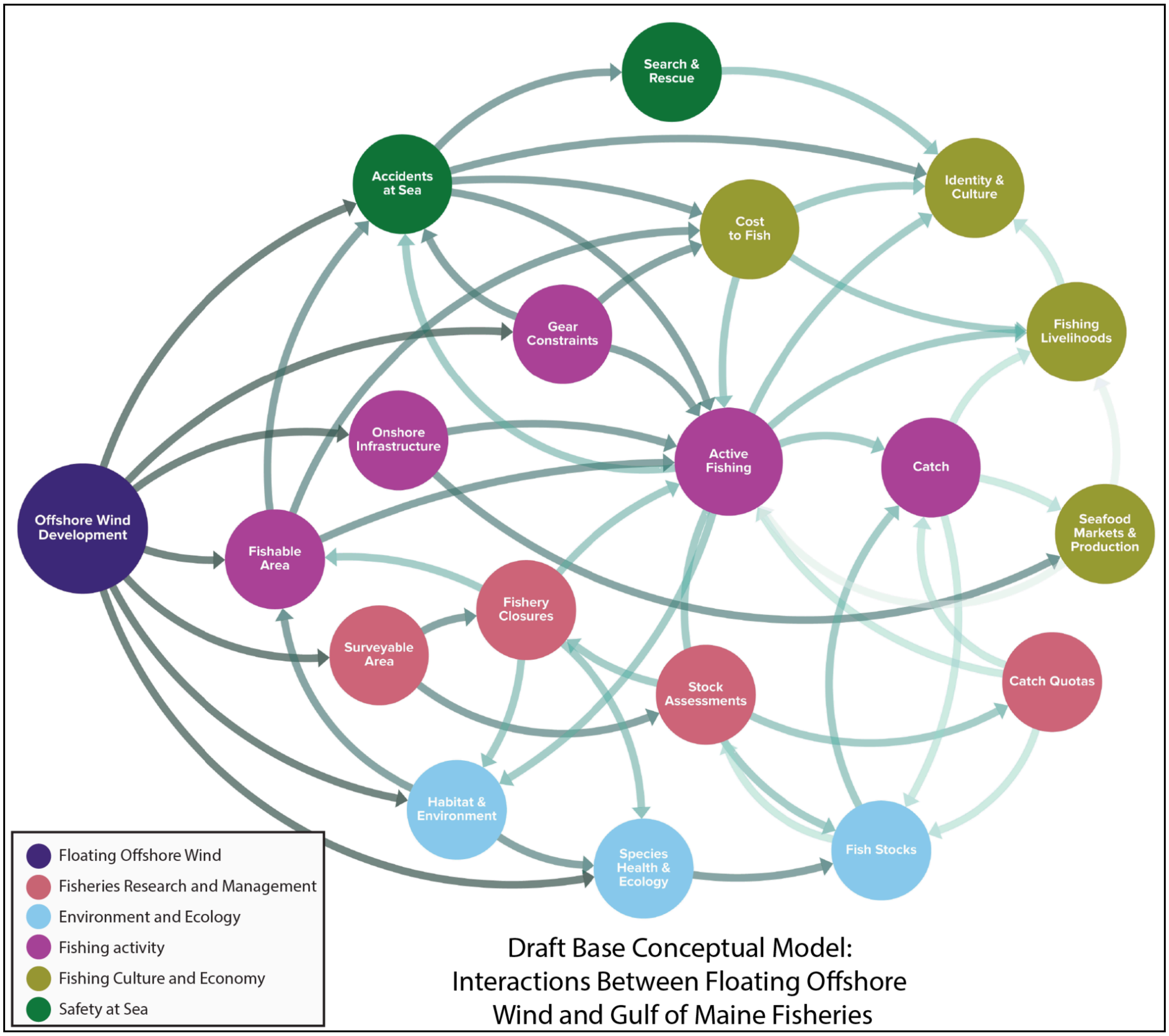

Figure 2: Draft full conceptual model for primary thematic groups potentially interacting with and directly or indirectly affected by floating offshore wind development.

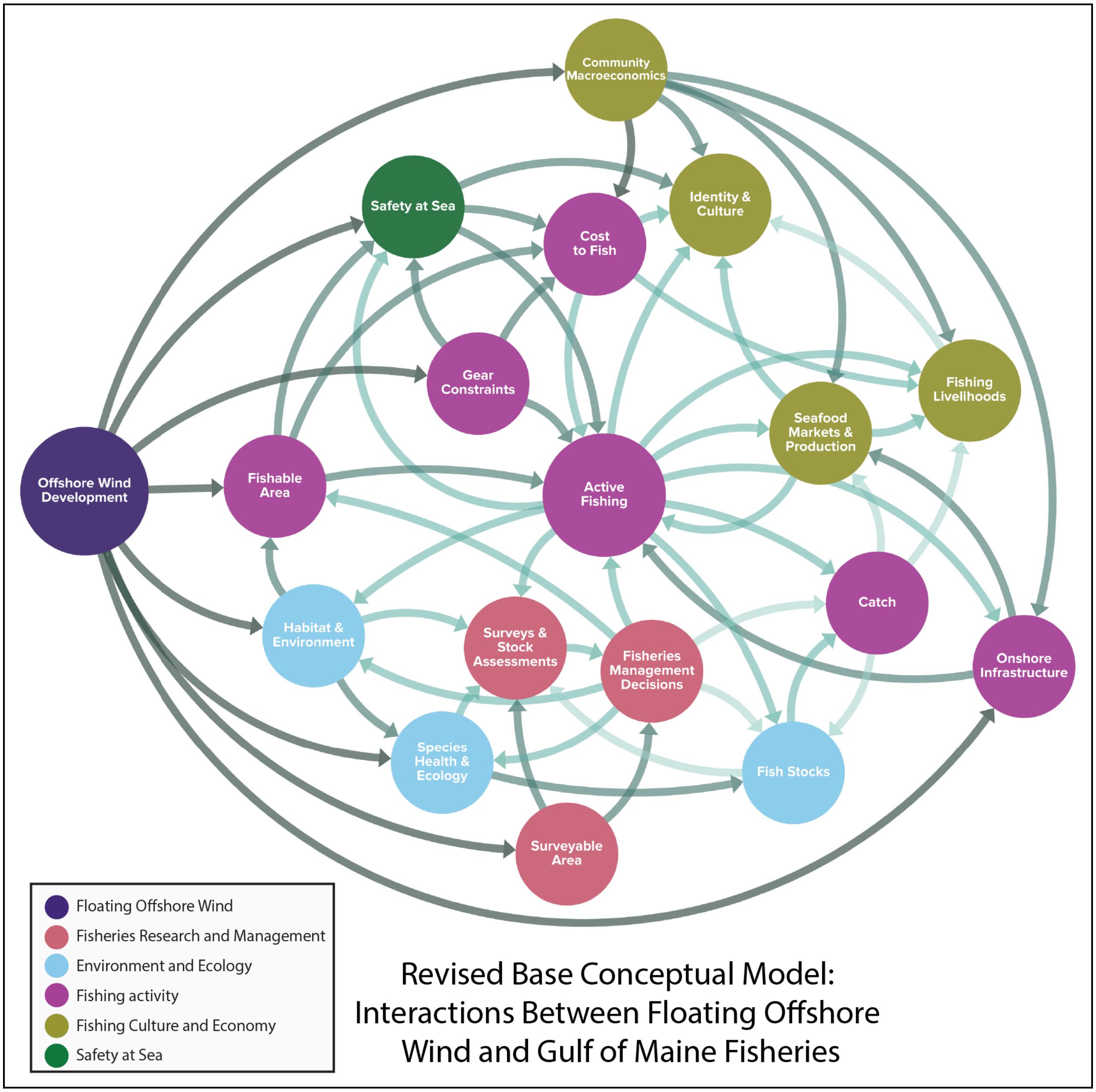

Figure 3: Revised base full conceptual model, following input from workshops with fishing industry and research scientists.

Figure 4: Locations of December 2023 fisheries community workshops, and the finalized Gulf of Maine Wind Energy Area.

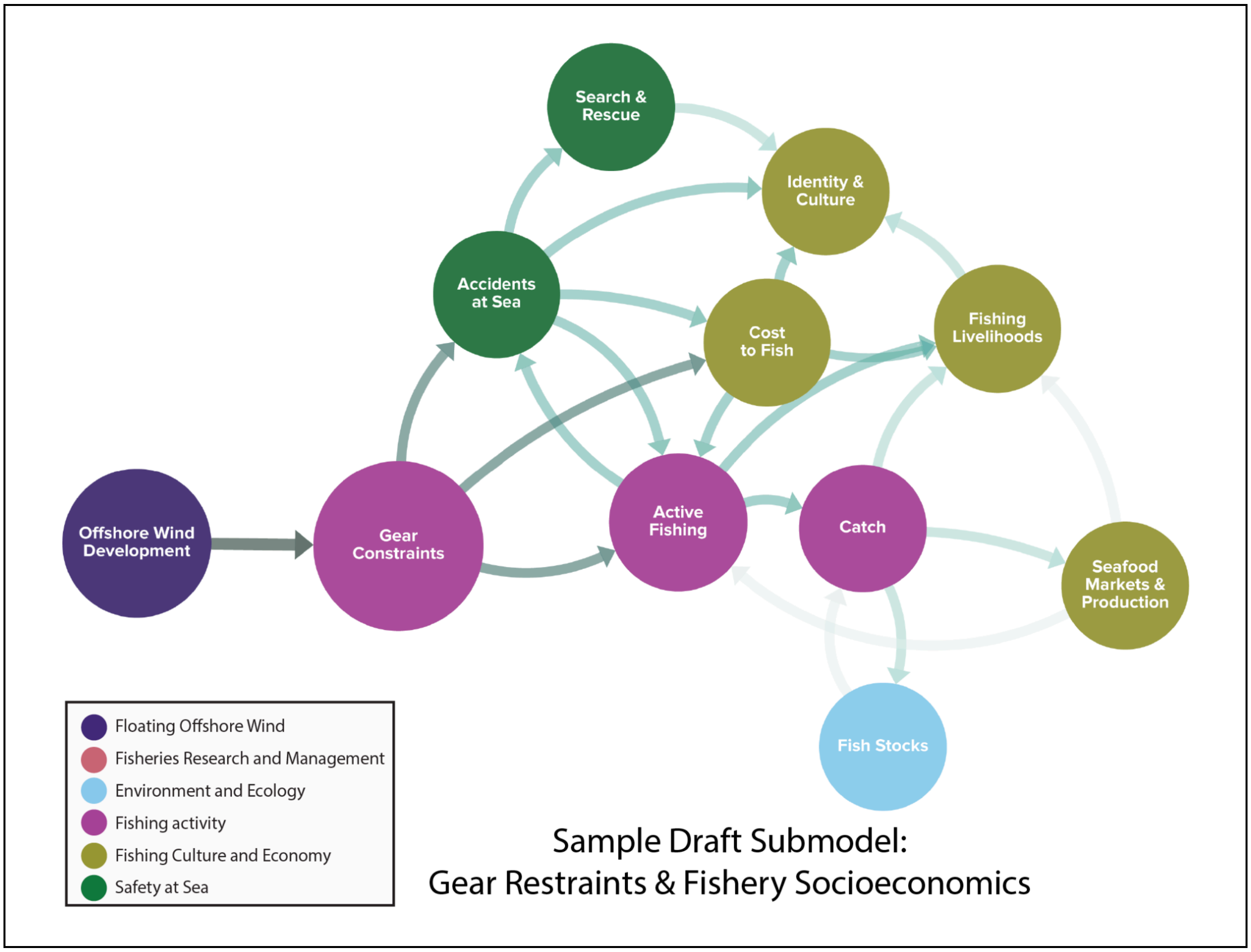

Figure 5: Example submodel demonstrating how interactions between OSW and fisheries in the Gulf of Maine specifically influencing restrictions on fishing gear (through regulation, safety risks, or other dynamics) influence socioeconomic dimensions of Gulf of Maine coastal communities.

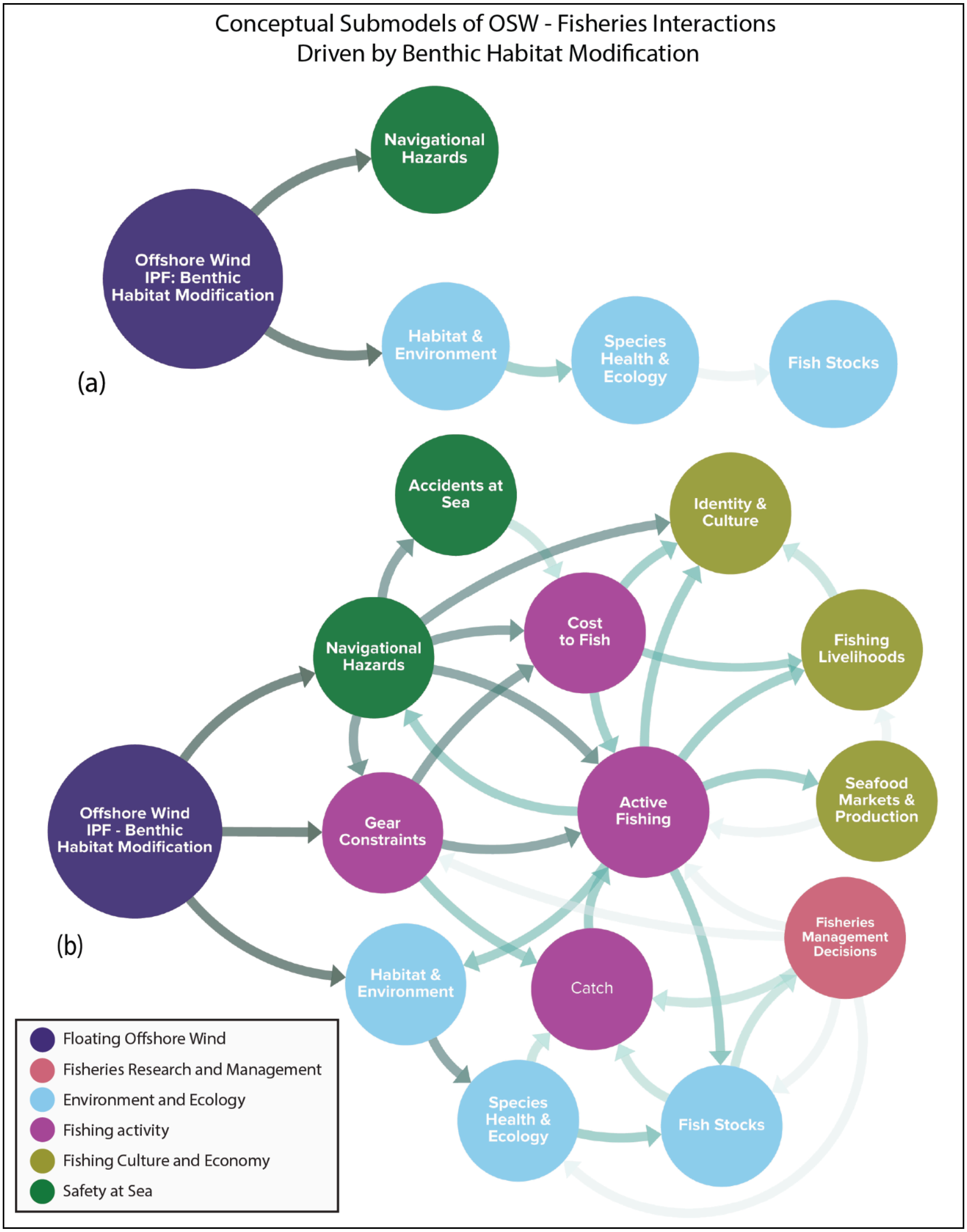

Figure 6: Example basic submodels of potential impacts from benthic habitat modification, an offshore wind Impact Producing Factor (IPF), based on (a) descriptions in existing developer - produced environmental impact reports for proposed offshore wind projects in New England and on (b) our conceptual modeling process.

Appendices

List of acronyms

BOEM	Bureau of Ocean Energy Management
CTD	conductivity, temperature, depth
EMF	Electromagnetic fields
GARFO	NOAA Fisheries Greater Atlantic Fisheries Office
GMRI	Gulf of Maine Research Institute
GOM	Gulf of Maine
IEA	Integrated Ecosystem Assessment
IPFs	Impact Producing Factors
MA-CZM	Massachusetts office of Coastal Zone Management
ME-DMR	Maine Department of Marine Resources
MPA	Marine Protected Area
MRIP	Marine Recreational Information Program
NARW	North Atlantic Right Whale
NEFSC	Northeast Fisheries Science Center
NERACOOS	Northeastern Regional Association of Coastal Ocean Observing Systems
NEPA	National Environmental Protection Act
NHSG	New Hampshire Sea Grant
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Association
OSW	Offshore wind
RODA	Responsible Offshore Development Alliance
ROSA	Responsible Offshore Science Alliance

SMAST	University of Massachusetts School for Marine Science and Technology
TNC	The Nature Conservancy
VMS	Vessel Monitoring System
VTR	Vessel Trip Reporting
WEA	Wind Energy Area
WHOI	Woods Hole Oceanographic Institute
URI	University of Rhode Island

Referenced studies

Published studies

Davis, M.M., & Kneebone, J. (2023). Characterization of fishing efforts for highly migratory species in the Gulf of Maine and how this relates to areas considered for offshore wind development. *Report to the Gulf of Maine Mapping Project for Highly Migratory Species.*

DePiper, G., Corvi, D., Steinbeck, S., Arrington, D.A., Blalock, B., & Roman, N. Leveraging data from a private recreational fishing application to begin to understand potential impacts from offshore wind development. *ICES Journal of Marine Science,* fsad154. https://doi.org/10.1093/icesjms/fsad154

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In progress or unpublished studies

- Work off Long Island to look at tagged species may or may not be affected by the Sunrise Wind project. Study species include horseshoe crab, lobster, and multiple elasmobranch species (smooth and spiny dogfish, winter skate, sandbar shark, dusky shark, and sand tiger sharks)

- Appears to be the first project described here: https://you.stonybrook.edu/theawesomepeterson/offshore-telemetry/
- Matt Sclafani (ms322@cornell.edu) was identified as a project lead

- The Hywind, Scotland project was mentioned as a resource with video and trawl data that could be used to study how the anchor systems may be affecting the seabed and species around the turbines.

- A participant stated that SeaGrant will be funding a second research fleet out of Chatham to conduct CFRF– 900 CPD profiles and study oceanographic variability.

- A participant suggested that data from ECOMON cruises could be assessed to study extreme seasonality, variability, and a breakdown in stratification in the Gulf of Maine.

- A participant provided the following link to the Sunrise Wind draft offshore converter station permit for reference: https://www.epa.gov/ma/public-notice-draft-permit-sunrise-wind-farm-offshore-converter-station-boem-renewable-energy