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CONSTRUCTING COOPERATION FROM THE SEABED
UP: ASSESSING COMMERCIAL FISHERS'
PREFERENCES ON THE DESIGN OF OFFSHORE WIND
FARMS
BY
MADELEINE FENDERSON

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS
IN
MARINE AFFAIRS

UNIVERSITY OF RHODE ISLAND

2020

MASTER OF ARTS
OF
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2020

ABSTRACT

There are more than a dozen lease sites designated for the implementation of offshore wind energy generation from Massachusetts to the coast of North Carolina, yet the long-term impacts of these large wind farms on the domestic commercial fishing industry are largely unknown. There has been opposition from commercial fishermen regarding offshore wind development in the United States, and design and configuration of turbines has been significant topic of concern. The purpose of this research is to understand commercial fishermen's views on the configuration of offshore wind farms. An anonymous online survey was used to assess commercial fishermen's preferences on grid type, layout, and footprint. Each design feature was coupled with a set of Likert scale questions addressing to what extent risk factors of safety concerns, gear entanglements, and loss of landings influenced their decisions. By making this data accessible and comprehensive, developers have the opportunity to learn more about the historical habits of their regional commercial fishing industry as well as other potential existing uses of the ocean space.

Descriptive statistics demonstrated that for the most part, the respondents of this survey preferred design features that were consistent with the current proposed layout from the New England developers (1nm grid going East/West). However, a major finding of this research demonstrated that the basis by which the five developers agreed on the standardized 1 nautical mile grid – to reduce gear conflicts by following the same pattern as the regional fixed gear/mobile gear agreement - was the reason why the grid was *dispreferred* by survey respondents. Additionally, this research indicated that for a single proposed design, different perceived risks can

simultaneously make the layout component more *and* less desirable depending on which risks the respondent values higher. This further demonstrates the incredibly complex nature of how design can impact perception of risk and should further stress the importance of cooperation and information sharing between the offshore wind and commercial fishing industry. This research is conducted in cooperation with the Rhode Island Department of Environmental Management, the Responsible Offshore Development Alliance (RODA), the New England Fisheries Management Council, as well as the Commercial Fishing Center of Rhode Island (CFCRI).

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future in one way or another. I appreciate your interest in this research and distribution of my survey to your various organizations.

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INTRODUCTION

Harnessing energy from offshore wind increases the risk of conflict over uses of the ocean. *Mare liberum* teaches us that the ocean is open to all, but how do you mitigate challenges when a portion of the ocean is designated to a new use and could exclude others? There are more than a dozen lease sites designated for the implementation of offshore wind energy generation from Massachusetts to the coast of North Carolina, but the long-term impacts of these large wind farms on the domestic commercial fishing industry are largely unknown. Individual states have pledged to create over 25,000 MW of electricity from offshore wind by 2035--a 846.6-fold increase in the amount being generated in the United States in 2020 (American Wind Energy Association 2020). The physical landscape of the ocean space is going to change, and this rapid development opens up the likelihood of conflict arising from many uses sharing one space. The commercial industry will face challenges if any of these fifteen leases off of the Atlantic coast are set in areas of high fishing activity or transit, and risks of reduced safety, gear conflicts, and reduced landings may increase with turbine presence. Gear conflicts may impose extra fishing costs, and reduced landings may negatively affect their livelihoods.

One set of decisions that can be made to promote cooperation between both industries is offshore wind design--the way the turbines are configured in the ocean space. Engineers must optimize the amount of energy extraction in a lease area by arranging turbines in a manner that promotes technical efficiency. However, developers must also take stakeholder safety and historic usage into account when

proposing a design layout. There are several key design components to offshore wind that will impact the fishing industry--orientation of turbines, the grid layout of turbines, and the total footprint of the project. Each design has the propensity to either increase risk or mitigate it, and this research sought to understand layout preferences from the commercial fishing industry.

Using an online survey, this study asked members of the Eastern U.S. commercial fishing industry to identify their preferences and indicate the factors driving those preferences. The findings of this research highlight the importance of information sharing, adding context to the complicated risks that are associated with fishing in a wind farm lease area and demonstrating that there are gaps of missing knowledge between the developers and the ocean users.

BACKGROUND

SECTION 1: OFFSHORE RENEWABLE ENERGY

Why Renewable Energy?

Globally, 24% of our power demand came from renewable energy sources in 2017, and this share is projected to hit 30% in 2023 (IEA Renewables on the Rise 2018). This shift from fossil fuels to naturally occurring and theoretically inexhaustible forms of energy is attributed to the finite nature of coal, oil, and natural gas, as well as their negative externalities on the environment.

The atmospheric levels of carbon dioxide has increased dramatically since the Industrial Revolution, and in 2019 surpassed 414 parts per million (NOAA ESRL) for the first time in recorded history. Once in the atmosphere, CO₂ acts as a blanket and traps heat close to the surface of the earth, coining the term “global warming”. This change in climate has a slew of negative side effects, such as sea level rise, extreme storm events, increased ocean acidity, and drops in global biodiversity.

CO₂ emissions aside, fossil fuels are a finite resource. It takes hundreds of millions of years for the earth to create them, and we are extracting oil/ coal/ natural gas far faster than can be replenished which is unsustainable. A 2009 study estimated that at the current rate of global consumption, global oil reserves will be empty in 2040, global natural gas reserves will be empty in 2042, and coal will be depleted by 2112 (Shaffiee 2009). Even if we extract fossil fuels to the very last drop, it will become very expensive to both find and harvest them once they’re at low global levels, and the cost will rise exponentially. As a society, we really won’t be able to

survive without energy, and allowing our most common sources to deplete without having a safety net of renewables would be incredibly detrimental to our economies and quality of life. Harvesting energy from wind, solar, biomass, geothermal, hydropower, and from ocean renewables are all ways the global energy system can switch to using more renewable and clean sources.

Offshore Wind

Garnering energy from offshore wind is a form of renewable energy that has been utilized globally. Although it is not the most commonly used renewable energy source, it has the opportunity to generate large amounts of electricity for communities along the coast. Compared to onshore wind, offshore wind energy generation has garnered lower levels of public awareness, results in different types of aesthetic impacts, has a marine context versus a terrestrial context, and involves completely different types of community and government stakeholders in the decision-making processes (Wiersma et al 2014). However, it has the capacity to generate a substantial amount of power in close proximity to the communities that demand it the most. Forty-one percent of the world lives within 62 miles of the coast (Martinez et al 2007) and being able to harness energy produced within a hundred miles of this population, versus oil rigs across the world, is a far more efficient way of managing the energy transfer process. Additionally, twenty-one of the thirty-three global “megacities” are situated directly on the coast, so the energy source would be very close to the communities that need it the most (Id). Currently, there are seventeen countries that are currently utilizing offshore wind power which in total generated 23,140 megawatts of electricity in 2018 (Global Wind Energy Council).

Compared to the more common onshore wind farms, offshore wind farms are more expensive to construct but generate more energy since wind resources are stronger off the coast. Some of the perceived benefits from offshore wind harvesting are reduced reliance on carbon dioxide emitting energy (Dvorak et al 2013), reduced air pollution (Delucci 2011), a surge in local job opportunities (Walker et al 2014), and community benefit funds (Id) such as compensatory payments, as well as improved infrastructure (Klain et al 2016).

Europe is leading the global offshore wind industry with a current offshore wind capacity of 22,072 megawatts (Wind Europe 2019). Several other countries are utilizing major European offshore wind companies and technology to expand it elsewhere. Plans for U.S. offshore wind farms are much more ambitious than the early plans built in Europe (Snyder et al 2009). The rate at which the United States is expanding this industry in our ocean space is exponential compared to the European early stages of development since large-scale offshore wind technologies are already available. The first European offshore wind farm was constructed 2 km off the coast of Denmark in 1991. The eleven-turbine, 9.61-gigawatt wind farm was active for 25 years. Following their first project, Europe had a steady growth by implementing projects that were only ten to fifty megawatts larger than the previous (Id), yet the next plans in the United States are well into the hundreds of megawatts.

The east coast of the United States has the potential to dominate the domestic offshore renewable energy sector based on regional wind patterns and bathymetric data. A study published in 2013 suggests that utilizing offshore wind technology in its full capacity off of the east coast has the ability to provide either the full annual energy

demand of coastal communities from Maine to Florida *or* about a third of the total demand for the United States (Dvorak et al 2013). Although this data is very promising, it might not be socially feasible. With all of the preexisting uses on the ocean, such as transportation, fishing, commercial shipping, and navigation, it would be near impossible to include the scale of offshore wind power Dvorak et al. suggest.

The only active offshore wind farm in the United States is the Block Island Wind Farm, a small five turbine 30-megawatt project. The U.S. domestic offshore wind industry is expected to expand rapidly in the coming years, with fifteen active federal leases along the east coast that will be home to offshore wind farms (BOEM 2019). These lease areas are in the federal waters off the coast of Massachusetts, Rhode Island, New York, New Jersey, Delaware, Maryland, North Carolina, and Virginia. By 2019, developers had successfully bid \$473 million for over 1.7 million acres of federal ocean space for the development of offshore wind energy (BOEM 2019). The next major project likely to be installed in the United States is the Vineyard Wind project, a lease site covering 132,370 acres of ocean space off Massachusetts and Rhode Island and is projected to produce around 800 megawatts of energy (Vineyard Wind).

In the current New England lease areas, the five largest developers in the area (Vineyard Wind, Equinor, Ørsted, Eversource Energy and Mayflower Wind) have agreed to standardize grid spacing in all of their separate lease sites to accommodate both the commercial fishing industry as well as navigational safety (Proposal submitted by 5 Offshore Wind Companies 2019). More details on this specific design framework will be outlined further in the coming sections, but this mutual agreement

was created in the hopes to increase consistency and maritime safety in the lease areas.

Figure 1: Map of current BOEM offshore wind leases off the coast of Massachusetts (BOEM 2019)

Engineering Basics

Technical efficiency, profit maximization, and working with preexisting ocean uses are all factors that need to be taken into consideration when designing an offshore wind farm. Hashemi and Neill (2019) provide a useful summary of the technology. Each project is different based on the wind supply and bathymetric components of the ocean space they are trying to utilize. Wind speed and consistency varies at every site based on the climate of the region, the Coriolis force, and the physical geography of the area. One of the limitations on constructing an offshore wind farm is water depth. The deeper the water in which you're trying to construct a wind farm, the more complex the technology is that's required to stabilize the individual turbines on the ocean floor. The physical turbines themselves range in size

depending on how modern their technology is and how much electricity they generate. In shallow water, developers may use a simple monopile to “ground” the turbine to the ocean floor, where the single base of the turbine is driven into the seafloor with no other structural support. Between thirty meters and sixty meters of depth, turbines require a jacket or tripod structure to anchor them down, and deeper than sixty meters, floating turbines are utilized. Thus far in offshore wind development, monopiles and jacket/tripod structures have been the most common mechanisms in large scale farms, and floating turbines are still in the research stage of application. Turbines generate energy by allowing the wind to move the blades. The movement of the blades spins the rotor within the turbine, and that kinetic energy is transformed into utilizable electricity.

Additionally, since there can be changes in energy extraction optimization from noise and visual impacts, engineers use micrositing to configure a wind farm to obtain the most amount of energy possible in a given area (Bathelmie et al 2011). Microsited turbines are set in a manner that takes advantage of topographic channeling and reduces power losses from wind turbine wakes (Id). Micrositing is often driven by maximizing power output and minimizing cost of energy—a process known as optimization. Coupled with optimization as a major constraint in the early stage farm development, engineers should also consider the priorities of other ocean users in terms of risk as part of design criteria.

Layout and wind farm design has been a source of conflict within the commercial fishing industry leading to installation delays and lawsuits (Faulkner, EcoRI News, 2019). Within just a couple of years, the Vineyard Wind project had to

change its grid pattern, transit lanes, and orientation several times to accommodate both the commercial fishing industry and maritime commerce (Vineyard Wind webpage). This conflict has pushed construction more than a year past their proposed start date and cost the company millions in compensatory packages (Faulkner, EcoRI News, 2019).

Three design factors that are particularly important to both developers as well as stakeholders are turbine orientation, grid layout, and total footprint of offshore wind farms. Orientation is a design element that is very important to the commercial fishing industry because the way turbines are oriented may interfere with historical fixed gear drop-off patterns (MA DMF). This potential for conflict over configuration was made evident during the early and middle stages of the Vineyard Wind project. Within the New England lease area, there is a decades-old “gentleman’s agreement” between trawlers and fixed gear users to lay out lobster traps and gill nets in rows from east to west and spaced one nautical mile apart to avoid gear entanglements (Providence Journal, Kuffner 2018). During the time of the negotiations between the Fishers Advisory Board (FAB), discussions over orientation of the project’s turbines were central because there was concern over the (then) proposed orientation of Northwest/Southeast and how that would impact the set East / West fixed gear layout plan already existing in the area. Gear entanglements between fixed gear and mobile gear users are common but are costly because it damages both the fishing gear, the fishing vessels, and takes a long time to untangle which is why gentlemen's agreements are incredibly important to the industry to limit the likelihood of conflict from happening. By constructing a wind farm that does not follow the same grid

pattern of gear agreements, it is a concern that “trawlers would not only snag their nets on traps and other fixed gear but would also run the risk of colliding with a turbine” (Providence Journal, Kuffner 2018). Similar to orientation, grid layout and footprint of offshore wind farms have the propensity to either follow or disrupt historical ocean uses and transit routes. The pattern by which turbines are set in the ocean space can either promote or inhibit navigation, and the layout of wind farms can create or eliminate zones in the ocean space non-transitable because of the spacing between the turbines.

Developers make decisions regarding these three factors based on what will maximize the total efficiency of the offshore wind farm. These design elements will vary from project to project since the wind resources, weather, and seabed bathymetry differ by location. For this study, turbine orientation is how the turbines are related to each other in reference to true North. Grid layout is defined by how the turbines are aligned with each other relative to the lease space. Lastly, the total footprint refers to how densely clustered or spread apart the turbines across the lease area.

SECTION 2: THE FISHING INDUSTRY

Culturally and socio-economically, the commercial fishing industry has a large presence in the North Atlantic region of the U.S. In 2017, commercial landings in domestic ports within the United States were valued at \$5.4 billion, and landings from the Atlantic coast accounted for 37% of that value (Fisheries of the United States 2017, NOAA). With close to \$2 billion in bargaining weight - which doesn't include

revenue made from processing, distribution, and consumption - being cognizant of this large and historic industry when opening up our coastlines to new uses will benefit both the commercial fishermen and economy of our Atlantic shore.

Based on the 1976 Magnuson Stevens Act (MSA), the primary responsibility of the management and planning for the regulation of fisheries lies within the eight fisheries management councils. The two councils that currently have the most “at stake” in regards to offshore wind development in the United States are the New England Fisheries Management Council (Maine, New Hampshire, Massachusetts, Rhode Island, and Connecticut) and the Mid-Atlantic Fisheries Management Council (New York, New Jersey, Delaware, Pennsylvania, Maryland, Virginia, and North Carolina) because they’re managing the waters that have current offshore wind leases. In regard to these council’s views on offshore wind development, their goal is to “support policies for U.S. energy development and operations that will sustain the health of marine ecosystems and fisheries resources while minimizing risks to the marine environment and fisheries” (Council Policy on Wind Energy 2018). Although this is a very idealistic approach to cooperation since there is no model in place to guarantee minimized risks, they address that steps need to be taken to minimize potential negative consequences of offshore wind development to the domestic commercial fishing industry.

Opposition

Some major concerns commercial fishermen have over the development of offshore wind farms in their fishing grounds are fear of displacement, loss of livelihood, and confusion regarding potential benefits (Alexander 2013). This data

came from face-to-face interviews with commercial fishermen in Scotland and may not fully represent attitudes of the industry in the United States, but fears of displacement and loss of job security have been themes of opposition over here as well (Commercial Fisheries Center of Rhode Island). Although there is limited peer-reviewed data in the United States on perceived impacts of offshore wind farms on the commercial fishing industry, the research of ten Brink and Dalton (2018) highlight that both recreational and commercial fishermen fear both ecological and human impacts. Some of these impacts include commercial fishermen being crowded out by recreational fishermen, navigational concerns, lost/damaged fishing gear, and unknown future impacts from decommission (Ten Brink et al 2018). Throughout the Northeast offshore wind lease citing and planning process, there has been a strong call for developers to work fairly, take sufficient time studying the environmental effects, mitigate the impacts of their projects to the commercial fishery, and compensate fully for their damages (Harrington 2019).

The Massachusetts Department of Marine Fisheries stated that the main concerns from the fishing industry include wind farms and cables being off limits to mobile gear, safety concerns, and increased cost of fishing (MA DMF 2019). Mobile fishing gear may traverse over and come into contact with cables and turbines which may cause damage to either the offshore wind gear or fishing gear but closing the area to commercial fishing would be very detrimental to the industry with large-scale wind projects. Commercial fishing is a very dangerous job to begin with, and economist Dr. Tom Sproul reported in an interview that radar interference from the turbines while travelling in and around wind farms may have the possibility to add more hazards,

especially in poor weather and limited visibility (Sebai 2019). He also shared that it is very possible that the current risk estimates of fishing within offshore energy areas are less than the actual risk, and concerns over both navigational hazards and crowding of displaced vessels outside of the project should be taken into account when reviewing potential safety implications (Sebai 2019).

In regard to increased cost of fishing, there is fear that insurance costs will rise due to increased risk of accidents, the farms will have negative effects on the targeted fish stocks, and there will be increased fuel costs navigating around wind farms to travel to fishing areas (MA DMF 2019). Massachusetts is the state on the east coast that has the highest value of landings coming from areas of wind farm leases followed by Rhode Island and New Jersey (Livermore 2017). Based off of vessel monitoring system data (VMS), Massachusetts had over \$19 million worth of landings in the offshore wind lease sites through six years (2011-2016), Rhode Island had over \$10 million worth of landings, and New Jersey had over \$8 million worth of landings (Livermore 2017). Although it is highly unlikely that commercial vessels will not be able to fish at all in the wind area sites and face full exclusion, there is a chance that their total landings will be reduced due to the shared space, and the states listed above would have the most to lose. Offshore wind developers have given compensatory packages for landing losses to the commercial fishing industry in the past, but there are other sources of potential loss that have not been taken into account when calculating the current industry loss estimates (Sebai 2019). These include inflation effects, the issues with using VTR data to estimate fishing revenue density, the lack of

scientific consensus, and the economic benefits of shore-side stakeholders such as processors, distributors, and local restaurants (Sebai 2019).

There is also high scientific uncertainty on the long-term effect the turbines will have on the ecosystems they are placed in, and although that it is agreed upon by regulators and stakeholders alike that there will be impacts, the type and scale of them are widely unknown (BOEM 2015). This amount of uncertainty sparks concern within the fishing industry because it is unknown to what extent offshore wind development will impact both the commercially caught species as well as the ecologically important ones, and assessment protocols based off of previous projects in the United States are very lacking because we don't have any large-scale wind farms present in this area yet (BOEM 2015).

The Bureau of Offshore Energy Management is responsible for enforcing the laws and regulations that govern offshore leasing and regulations. The “best management practices” regarding the overlapping nature of the commercial fishing and offshore wind industries adopted by the Bureau of Ocean Energy Management (BOEM) include fisheries community outreach and communication programs, project siting, design, navigation, and access, safety, environmental monitoring plans, and financial compensation (BOEM Final Report on the Best Management Practices and Mitigation measures 2014).

Some of the Mid-Atlantic Fisheries Management Council policies (which have been adopted by the New England Council) expand on BOEM's framework of mitigation of offshore wind conflicts which include following BOEM's “best management practices,” early developer engagement in the fishing industry, cables not

being places in sensitive fish habitat, installing transmission cables with the purpose to reduce impacts on the ecosystem and buried deep enough to avoid gear conflict, proposals should evaluate how scour/sedimentation will impact the ecosystem outside of the lease area, and wind service platforms should implement adequate fuel spill response plans for support vessels and platforms (MAFMC Council Policy on Wind Energy 2018). These frameworks are the foundation for mitigating conflict with the new upcoming wind leases off of the Atlantic coast, but there are still some concerns from the fishing industry based on issues not satisfactorily addressed.

Vineyard Wind is expected to be the first large-scale project developed in the United States. Plans for this project created a lot of controversy because the lease area is in the middle of valuable fishing grounds for the ports of New Bedford (MA), Galilee (RI), and beyond (Livermore 2017), and there were many fears of unknown impacts to the commercial fishing industry. Although the farm is in federal waters, the state of RI was able to file for compensatory payments because of the adverse effects the project would have on the state's commercial fishing industry under the Coastal Zone Management Act to maintain federal consistency. The CZMA states that:

“After final approval by the Secretary of a state's management program, any applicant for a required federal license or permit to conduct an activity, in or outside of the coastal zone, affecting any land or water use or natural resource of the coastal zone of that state shall provide in the application to the licensing or permitting agency a certification that the proposed activity complies with the enforceable policies of the state's approved program and that such activity

will be conducted in a manner consistent with the program” (16 U.S.C § 1456, Coastal Zone Management Act 1972)

This law is very important to the development of offshore wind farms in federal waters because it requires that they must comply with all the state laws the project “directly affects”. In the case of Vineyard Wind, the state of Rhode Island felt that the upcoming project would harm the local commercial fishing industry and did not comply with the state’s marine spatial planning program, so they filed suit. The Vineyard Wind Project settled a \$16.7 million compensatory package to the commercial fishermen which included a series of payments over the next thirty years as well as a trust to compensate fishermen for losses in the first five years of project development (RI CRMC 2019). Although that is a large payment package, many people within the industry feel the amount owed has been downgraded and the amount given out in compensation does not reflect true potential losses (EcoRI Faulkner 2019).

Executives representing the five big players in the New England offshore wind energy industry (Vineyard Wind, Equinor, Ørsted, Eversource Energy and Mayflower Wind) agreed to propose a standardized grid layout for the upcoming farm layouts off of Massachusetts and Rhode Island (Proposal submitted by 5 Offshore Wind Companies 2019). The grid would have turbines spaced one nautical mile - 1.15 miles - apart in an east/west orientation. The proposed design would look like this:

Figure 2: Uniform Grid Layout in New England proposed by five offshore wind lease holders (Proposal for a uniform 1 X 1 nm wind turbine layout for New England Offshore Wind 2019)

This specific orientation was chosen because it allows for “safe navigation of fishing, tanker, and cargo vessels without the need for designated transit corridors, increases navigational safety, responsive to fishermen’s requests for 1nm turbine spacing and east-west rows, and facilitates search and rescue operations” (Proposal for a uniform 1 X 1 nm wind turbine layout for New England Offshore Wind). The announcement of this proposed layout came at the end of data collection for this study, and the findings from this survey will be compared to this agreement. A major component for deciding on this grid orientation was based on a “gentleman’s agreement” between fixed and mobile gear users to avoid gear entanglements. This agreement establishes that fixed gear will be spaced 1 nautical mile apart in areas where both gear types coexist (Providence Journal, Kuffner 2018).

Research Purpose and Design

The purpose of this research is to understand commercial fishermen's views on the configuration of offshore wind farms. The responses for preference of grid type, layout, and footprint were each coupled with Likert scale questions addressing to what extent risk factors of safety concerns, gear entanglements, and loss of landings influenced their decisions. These three specific risk factors were chosen due to patterns in literature (Alexander 2013, MA DMF 2019) as well as direct quotes from commercial fishermen as big potential negative impacts as concern.

Findings from this study can be used to promote cooperation between the two industries as well as facilitate information sharing and communication. By doing so, developers learn more about the historical habits of their regional commercial fishing industry as well as other potential existing uses of the ocean space they wouldn't have known without this data. This research was conducted in cooperation with the Rhode Island Department of Environmental Management, the Responsible Offshore Development Alliance (RODA) as well as the Commercial Fishing Center of Rhode Island (CFCRI).

Research Questions

Since there has been conflict between the offshore wind industry and the commercial fishing industry, this research assessed fishermen's preferences for configuration and why they hold those preferences. Does safety, gear conflict, and fear of reduced landings influence some design features- such as orientation, grid type, or footprint- over others? Do fishermen of certain regions have consistency in

preferences over others? Overall, what were the preferred design features and are they consistent with the proposed design from the five offshore wind developers in New England?

METHODS

SURVEY

Data for this survey was collected using an anonymous Qualtrics link sent out to various industry list-servs. This sampling method was convenience sampling and not random. Convenience sampling occurs when the researcher chooses the nearest and most convenient people to act as respondents and it is very widely used (Robson 2011). This was tactical because due to the nature of this research and schedule conflicts, using ListServs was the best way to reach as many members of this population as possible during the short timeframe of data collection. The data was collected from August to October, which is a popular fishing time due to weather, and scheduling time to individually meet with commercial fishermen face-to-face was not feasible. Therefore, it made the most sense given the time constraints to collect data using a ten-minute online survey versus an extended interview. Additionally, there was no way to get the contact information for all of my respondents without relying on industry ListServs. The data collected began the middle of August of 2019 and ended at the end of October 2019. The survey's anonymous link was sent out with an explanatory email across the ListServs of the Responsible Offshore Development Alliance, the Commercial Fishing Center of Rhode Island, the New England Fisheries Management Council, and the Massachusetts Lobstermen's Alliance.

Before taking the survey, respondents were asked to read consent information, which included the purpose of the survey, assurances of their anonymity, the research integrity approval, and the contact information to go to with questions. By proceeding to the rest of the survey, they indicated that they have read and understood the consent document and volunteered to participate in this study.

The survey included four sections:

Background: The questions asked in the background section included whether they identify as a commercial fisherman or not, their port state, their role on the boat, the type of vessel they currently use, their fishing permits, their knowledge on offshore wind development (using the Likert scale 1-5), and how often they talk about offshore wind development in their daily lives (never-most of the time). The choices for role on the boat included owner, captain, deckhand, engineer, or other, and respondents could only choose one. The type of vessel choices included pots and traps, longline, gillnet, trawler, dredger, hook and line/harpoon/greenstick, factory trawler, and aquaculture. The options for fishing permits were picked based on NOAA Fisheries regional fishing permits commonly utilized off the Atlantic coast, and respondents could check off as many of them as they need. All questions were in multiple choice format and there were no open responses. They could not proceed to the rest of the survey without giving a response to every question.

Section 1 Grid Types: This is the first section where data on the preferences of engineering practices was collected. Respondents ranked their preference (1-4) on four different grid designs: a) random alignment of turbines, b) one straight line of tightly clustered turbines, c) four parallel lanes, and d) a grid of turbines spaced 1 nautical mile apart in all directions (Figure 1). The respondent was asked to rank their preferences being 1 most-favorable and 4- least favorable.

Figure 3: Graphics A, B, C (Hashemi et al 2018)

These options were the specific four chosen for this study because they are technically viable options (Hashemi 2018) and include suggestions from the developers for a uniform layout (Proposal for a uniform 1 by 1 nm wind turbine layout for New England Offshore Wind, 2019).

Following each of the ranking questions (grid type, grid orientation, and total footprint), respondents revealed why they chose the grid they chose by being asked “how important was **safety & navigation** when ranking your preferences for grid types?”, “how important was reducing **conflict with other fishers/gear entanglements** when ranking your preferences for grid types?”, and “how important was considering **reductions in fish landings** when ranking your preferences for grid types?”. They answered each of these questions by responding with *extremely important, very important, moderately important, slightly important, or not at all important*. For all of the risk values, the rank of importance was coded into numerical values to allow for later regression analysis:

1= extremely important

2=very important

3=moderately important

4=slightly important

5=not at all important

At the end of the section they were able to leave an open response to elaborate on their choices if they wanted to share, but doing so was not required to pass on to the next section.

Section 2 Grid Orientation: The following section assesses respondent’s preferences on the grid orientation of offshore wind projects. The graphics provided were wind

farms of a) North/South orientation, b) East/West orientation, c) Northeast/ Southwest orientation, and d) Northwest/Southeast orientation (Figure 4).

Figure 4: Orientation choices

All of the graphics were created using PowerPoint. The respondent was asked to rank their preferences in grid orientation 1-4, 4 being the most favorable and 1 being the least.

Section 3 Overall Footprint: The final set of questions from the survey asked respondents to choose between wind farms that have “turbines that are tightly clustered together with maneuverable space around the rest of the leased area” or

“turbines are spread out across the entire lease area with room to maneuver between them” (Figure 5).

Turbines tightly **clustered together** with maneuverable space around the rest of the lease area

Turbines **spread out** across the entire lease area with room to maneuver between them

Figure 5: Layout choices

STATISTICAL ANALYSIS

The responses for the survey were uploaded into IBM SPSS (Statistical Package for Social Sciences). Most of the responses were coded into categorical numerical values to allow for analysis (See Appendix for key). More detailed methods will be provided in the following section, but this analysis primarily relied on descriptive statistics as well as linear regressions. Descriptive statistics were calculated by creating frequency tables and bar charts to numerically and graphically show the distribution of respondents and linear regressions were used to calculate the relationships between the ranked grid type or grid orientation choices and the extent to which each risk factor (reduced safety, gear conflict, reduced landings) played a role in their decisions.

RESULTS

Descriptive statistics, linear regressions, and a linear probability model were the primary statistical tests used in this research. Since respondents were not required to answer every question of the survey, the sample size varies at different points of the study. The following figures show the sample population dynamics as well as the regressions that report the relationships between design choices and risk factors.

Sample Population Demographics:

Descriptive statistics were calculated by creating frequency tables and bar charts to numerically and graphically show the distribution of respondents (n=56). Many of the background questions on the survey offered a lot of possible choices, and many responses were coded together to demonstrate more broad trends. For example, all 14 states included in this survey were grouped as 1 or 2 representing New England or Mid-Atlantic. Coding this large multinomial variable into a simple binary variable aided in analysis since there weren't enough subpopulations within every state to perform accurate statistical tests.

Seventy percent of the respondents' port states were in New England (Maine, New Hampshire, Massachusetts, Rhode Island, and Connecticut) and the other thirty percent were in mid-Atlantic port states (New York, New Jersey, Maryland, Virginia, and North Carolina). The three most abundant port states in this survey were Massachusetts, Rhode Island, and New Jersey which accounted for 76.8% of the respondent's fishing

regions.

Figure 6: Distribution of respondents by port state

Respondents were able to identify their role on the boat and could select multiple options with the majority self-associating as boat owners. The majority of respondents self-identified as being vessel owners followed by “other.” Respondents in the “other” category, which may account for people who took the survey that have a stake within the commercial fishing industry since they were on those specific listservs, but they could be retired or work for processing plants, non-profit groups, or other fishing-related organizations.

Figure 7: Distribution of respondent's role on the boat

There were fifteen permits the respondents could claim registry for, and they were able to select as many as they carry. Most respondents selected more than one permit. The permits carried by the highest number of respondents were for squid, Atlantic mackerel, and butterfish, followed by black sea bass, scup, and then Atlantic bluefish.

Figure 8: Frequency of registered permits by type

There were two questions in the background section of the survey geared to assess the respondent's background knowledge on offshore wind.

Figure 9: Distribution of respondent's previous knowledge on offshore wind development in the United States

78.6 percent of the respondents identified as having strong knowledge of offshore wind development in the United States (rating of 4 or 5). Another way this survey gained information on the respondents was by asking how often offshore wind development came up in conversation and discussion in their lives:

Figure 10: Distribution of self-assessed personal discussion level of offshore wind in the past year

Respondents were able to pick between “never, rarely, several times, and most of the time” for this question. As shown above, no respondents believed that they *rarely* discussed offshore wind development in the United States in the past year, and the majority of the respondents have integrated the topic into conversation.

Design Preferences:

The following figures show the distribution of respondents' first choice grid type, orientation, and footprint preferences and do not take into account how they ranked the rest of the options. There were very distinct preferences for some of the design features and varied preferences for others.

Figure 11: Distribution of Preferred Grid Type, n=32

As shown above, the distribution of responses favored both the multiple lane and the 1nm grid type and did not show high preference for the random grid type or single lane grid type. The preference between the multiple lane layout and the one nautical mile grid is hardly discernable based on responses from this survey.

Figure 12: Distribution of preferred grid orientation, n=37

Based on the Figure 12, the East/West grid orientation was favored over the rest of the choices. Although there was a clear “preferred” orientation, there was little difference in preference of the remaining three options.

Figure 13: Distribution of preferred footprint, n=35

Figure 13 demonstrates a preference of having spread out turbines across the entire lease area over having turbines that are clustered together in zones throughout the lease space.

Regression Models:

A linear regression was used to calculate the relationships between the ranked grid type or grid orientation choices and the extent to which each risk factor (reduced safety, gear conflict, reduced landings) played a role in their decisions. Linear regressions can determine if the preferences for both grid type and orientation can be captured by their risk responses, and the coefficients can be interpreted with ease.

When calculating a linear regression with the ranking of each choice as the dependent variable, one must assume that the respondents prefer the first choice over the second choice by the same amount that one prefers the third choice and last choice, and that may not be the case in reality. Some respondents may prefer the first choice over the rest of the choices by a really large margin, or they may dislike the last choice far more than they dislike the second choice compared to their first choice, and linear regression models do not capture that behavior. Due to this hidden underlying information, the data was coded into favorite and not favorite as well as least favorite and not least favorite, and the regressions were run from there. It is expected that respondents may have an easier time determining their favorite and least favorite grids or orientations from the four options instead of ranking them against each other. The ranked data sets were re-coded into 2 groups- the first where the “favorite” orientation or grid type was coded as 1 and everything else was 0, and the second group the “least favorite” orientation or grid type was coded as 1 and everything else was 0.

A linear probability model was used to calculate the relationships between preferred footprint and the four risk factors. The binary nature of respondents choosing their preferred footprint out of two choices allows for the use of this model. This method of analysis was also used to keep this regression consistent with the other linear regressions and to create coefficients that are easier to interpret.

Coefficients ^a						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	-.158	.147		-1.069	.287
	Random Safety	.083	.111	.134	.747	.457
	Random Gear	.091	.077	.177	1.190	.237
	Random Landings	.003	.080	.007	.039	.969
	Line Safety	.139	.111	.223	1.248	.215
	Line Gear	.026	.077	.049	.333	.740
	Line Landings	-.056	.080	-.118	-.695	.489
	Straight Safety	.025	.111	.041	.229	.819
	Straight Gear	-.014	.077	-.027	-.183	.855
	Straight Landings	-.152	.080	-.321	-1.895	.061
	Grid Safety	-.236	.112	-.381	-2.119	.036
	Grid Gear	-.101	.077	-.196	-1.316	.191
	Gear Landings	.185	.080	.386	2.298	.023
	Option=Grid	.746	.208	.746	3.593	.000
	Option=Line	.095	.209	.095	.457	.649
	Option=Straight	.812	.209	.812	3.894	.000

a. Dependent Variable: Favorite

Table 1: Linear Regression Coefficients for “Favorite” Grid Type

This linear regression had an adjusted R Square of .201, so 20.1% of the variability in whether the grid option was the favorite or not was explained by the four risk factors. The regression had a significant ANOVA (p-value=.000) so the regression model statistically significantly predicts the favorite grid. The straight grid was preferred in this model based on the three risk choices, but since the standard error was .209, there was not a true significant different in preference between the straight grid and the 1 nautical mile grid. Because the grid was the favorite based on descriptive statistics and not this model, there were underlying factors not captured by the three risk types presented in the survey that made respondents favor the grid. Based on the coefficients table, valuing landings was a reason the respondents picked

the grid layout (p-value=.023) whereas valuing safety was a reason that the grid was not their favorite (p-value=.036). Following the regressions of favorite/ least favorite grid type, linear regressions of the raw rankings 1nm grid and straight lines based on the risk factors were conducted to see if there was any more explanatory power from the risks, but there was not (Appendix 2). There were no additional revelations of the risks being significant predictors of choice when organized using a different type of regression.

Coefficients ^a						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.927	.120		7.724	.000
	Random Safety	-.212	.091	-.342	-2.346	.021
	Random Gear	.003	.062	.005	.042	.967
	Random Landings	.057	.065	.120	.870	.386
	Line Safety	.143	.091	.230	1.577	.118
	Line Gear	.036	.062	.070	.580	.563
	Line Landings	.013	.065	.027	.195	.846
	Straight Safety	-.023	.091	-.037	-.254	.800
	Straight Gear	-.015	.062	-.030	-.246	.806
	Straight Landings	.024	.065	.051	.372	.711
	Grid Safety	.088	.091	.142	.974	.332
	Grid Gear	-.024	.063	-.046	-.383	.702
	Gear Landings	-.086	.065	-.180	-1.313	.192
	Option=Grid	-.675	.169	-.675	-3.994	.000
	Option=Line	-1.160	.170	-1.160	-6.829	.000
	Option=Straight	-.884	.170	-.884	-5.209	.000

a. Dependent Variable: Least_Favorite

Table 2: Linear Regression Coefficients for “Least Favorite” grid type

This regression had an adjusted R Square value of .47; 47% of the variation in whether a grid option was the least desirable or not is accounted for by the risk factors.

Since the coefficient on safety interacted with random last the least favorite choice was negative, valuing safety was a reason that the random turbine grid pattern was not the least favorite (p-value=.021).

Coefficients ^a						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	.770	.139		5.534	.000
	NS Safety	.120	.094	.214	1.279	.203
	NS Gear	.075	.082	.147	.904	.368
	NS Landings	-.070	.070	-.157	-.997	.320
	EW Safety	.002	.094	.004	.022	.983
	EW Gear	-.247	.082	-.486	-2.997	.003
	EW Landings	.075	.070	.169	1.078	.283
	NESW Safety	-.071	.094	-.126	-.756	.451
	NESW Gear	.026	.082	.052	.318	.751
	NESW Landings	-.053	.070	-.120	-.764	.446
	NWSE Safety	-.051	.094	-.091	-.545	.587
	NWSE Gear	.146	.082	.288	1.774	.078
	NWSE Landings	.048	.070	.107	.684	.495
	Option=NESW	-.451	.197	-.451	-2.293	.023
	Option=NS	-.724	.197	-.724	-3.677	.000
	Option=NWSE	-.906	.197	-.906	-4.603	.000

a. Dependent Variable: First_Choice

Table 3: Linear Regression Coefficients for “Favorite” Orientation

The linear regression on first choice of orientation has an adjusted R Square of .175, meaning that 17.5% of the variation in whether an orientation is the favorite of the four choices or not is due to the risk factors. The ANOVA for this regression had a p-value of .000 which means that the model statistically significantly predicts the favorite orientation. Based on the intercepts, East/West was the favorite since it was positive (.770, p-value=.000). Respondents who were more concerned with gear entanglements favored the East/West grid less and were less likely to pick it as their

first choice (p-value=.003). Following the regressions of favorite/ least favorite orientation, linear regressions of the raw rankings of the East/West orientation based on the risk factors were conducted to see if there was any more explanatory power from the risks, but there was not. There were no additional revelations of the risks being significant predictors of choice when organized using a different type regression, and gear conflict was still the only significant predictor for East/West orientation (Appendix 2)

Coefficients^a						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	.047	.142		.330	.742
	NS Safety	-.004	.096	-.008	-.046	.963
	NS Gear	.100	.084	.197	1.189	.237
	NS Landings	-.083	.071	-.187	-1.163	.247
	EW Safety	-.074	.096	-.133	-.777	.439
	EW Gear	.102	.084	.201	1.212	.228
	EW Landings	-.026	.071	-.059	-.370	.712
	NESW Safety	-.010	.096	-.018	-.106	.916
	NESW Gear	-.114	.084	-.225	-1.355	.178
	NESW Landings	.119	.071	.268	1.670	.097
	NWSE Safety	.089	.096	.159	.929	.354
	NWSE Gear	-.088	.084	-.173	-1.045	.298
	NWSE Landings	-.010	.071	-.022	-.138	.891
	Option=NESW	.100	.201	.100	.495	.622
	Option=NS	.191	.201	.191	.949	.344
	Option=NWSE	.522	.201	.522	2.592	.011

a. Dependent Variable: Least_Favorite

Table 4: Linear Regression model for least favorite orientation option

This linear model had an adjusted R Square value of .137, meaning that 13.7% of the variation in least favorite orientation is accounted for by the risk factors. Based on the table, the NWSE orientation was the least favorite of the four options because it had the highest intercept (.522, p-value=.011), but there is no significant information provided by the regression as to why. It is assumed that the reasons why the respondents disliked the NWSE orientation is captured by intangible behaviors not captured by the three risk factors.

Coefficients ^a						
Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	1.220	.369		3.301	.002
	footprint_safety_coded	-.501	.282	-.391	-1.778	.085
	footprint_gear_coded	-.285	.316	-.280	-.900	.375
	footprint_landings_code d	.270	.334	.274	.807	.426

a. Dependent Variable: Footpring Choice

Table 5: Binary Regression for footprint type

This binary regression model of layout type and footprint shows which risk factor (safety, gear conflict, or loss of landings) is the best predictor for footprint type. Although none of the coefficients are statistically significant at the 5% level, the largest exponent is for perceived safety risks. In this model, the respondent's perceived risk of reduced safety in the given layout options had the largest impact on their decision on preferred offshore wind design, followed by risks of gear entanglements and then risks of reduced landings.

DISCUSSION

This research sought to understand:

- What are fishermen's preferences for configuration?
- Does safety, gear conflict, and fear of reduced landings influence some design features- such as orientation, grid type, or footprint- over others?
- Were the reported preferences consistent with the proposed design features from the five offshore wind developers in New England?

I: WHAT ARE FISHERMEN'S PREFERENCES FOR CONFIGURATION?

When developing an offshore wind farm, developers and engineers must make their designs with overall technical efficiency and profit maximization in mind, on top of taking into account existing ocean uses. There are certain design attributes engineers must meet, but they also should consider the priorities of the commercial fishing industry in terms of risk in design and maximizing energy. Adding safety and potential conflicts with ocean users should be added as part of this design criteria, and both the preferences and risk assessments generated from this research could supplement those constraints.

Orientation

The *most favored* orientation among respondents was East/West. 48.6% of the respondents preferred EW orientation, 21.6% preferred North/South, 16.2% preferred Northeast/Southwest, and 13.5% preferred Northwest/Southeast. The distinct

preference of an East/West orientation over the other choices is consistent with the preferences of the Fisheries Advisory Board during the Vineyard Wind negotiations. This makes sense because the majority of my respondents were from the same port states that fish in the area of the gentlemen's agreement (Massachusetts and Rhode Island) and may already be abiding by the East/West fishing pattern.

Grid Type

43.8% of respondents preferred the one nautical mile grid, 40.6% preferred the multiple parallel line layout, 9.3% favor the randomly scattered turbines, and 6.3% prefer the single line of turbines. The type of grid that the turbines are arranged in is both important to the technical efficiency of the wind farm but is also important to stakeholders in regards to navigational safety. Based on the Gentlemen's Agreement highlighted above, the plurality's preferences were consistent with a one nautical mile fixed gear grid, but it was the majority only by 3.2% which is negligible.

Figure 14: Top two grid type choices

The differences between the top two preferred grid types was that one had a grid type where there is a wider corridor between rows and the other has turbines that are all equidistant from each other. However, both of these two grid types are similar because

they both offer uniformity on configuration. Both may facilitate navigation within the offshore wind farm, but perhaps to different extents.

Layout

62.6% of respondents reported that they prefer to fish in a wind farm with turbines that are spread out across the entire lease area with room to maneuver between them *compared to* turbines that are tightly clustered together with maneuverable space around the rest of the leased area. With the preferred footprint, it is possible to navigate between the turbines throughout the entire lease area whereas the latter had “zones” within the lease area that would effectively be closed off to fishing since they were not navigable. A big fear from the commercial fishing industry is that the offshore wind areas will become closed to fishing and become pseudo marine protected areas (Commercial Fisheries Center of Rhode Island). Therefore, it’s not surprising that the majority of respondents prefer the design that- albeit potentially with some challenges in poor weather and poor visibility- allows them to be able to fish throughout the entire lease area.

It is important to note that all of these design components also have impacts on the overall technical efficiency of the wind farm, and developers make decisions on how to lay out the turbines to maximize the amount of energy the farm creates while keeping the levelized cost of energy as low as possible. Following the suggestions of the commercial fishing industry is great in regard to improving transit safety but may not be technically or economically feasible.

II: DOES SAFETY, GEAR CONFLICT, AND FEAR OF REDUCED LANDINGS INFLUENCE SOME DESIGN FEATURES- SUCH AS ORIENTATION, GRID TYPE, OR FOOTPRINT- OVER OTHERS?

A linear regression was used to calculate the relationships between the ranked grid type or grid orientation choices and the extent to which each risk factor (reduced safety, gear conflict, reduced landings) played a role in their decisions.

Grid Type

Valuing landings and fears of reduced fishing output was a reason why respondents' favored the grid layout (p-value=0.023) of the four options whereas valuing their safety at sea was a reason that the grid layout was *not* their favorite (p-value=0.036). This is particularly notable because it demonstrates that there may be opposing factors that commercial fishermen take into account when stating their design preferences for offshore wind farms. There may be underlying checks and balances present where one design feature may improve one concern but worsen another. This further demonstrates the incredibly complex nature of this issue and how there must be intensive research conducted to truly find the associated risks offshore wind development will pose on the commercial fishing industry. This also demonstrates the need for further productive information sharing between stakeholders and developers since the risks may be far more complicated than they've been appearing in the early stages of research and development in the United States.

Orientation

An interesting finding of this linear regression model method is for orientation; valuing the ability to avoid gear entanglements was a reason why the East/West orientation was *dispreferred* in the model. This is particularly notable because the five major developers proposed the East/West grid to reduce the risk gear entanglements by being consistent with the gentlemen's agreement in the area. The fact that risk of gear entanglements was a reason why the East West grid was *not* the favorite choice for grid type contradicts this agreement, and this opens up the question "who really cares about the E/W gentleman's agreement" to discussion. Is it the fixed gear fisherman that really values that agreement? How important is the gentleman's agreement to the entire fishing fleet in the New England lease area? Since this gentleman's agreement was part of the core basis for developing this standardized grid pattern, it is important to further research the importance and validity of this gear pattern and if it benefits members of the entire commercial fishing industry.

Layout

Although none of the coefficients were statistically significant, respondent's perceived risk of reduced safety in the given layout options had the largest impact on their decision on preferred offshore wind design. Since the coefficient was negative, impacts on safety was the primary reason they disliked the tightly clustered layout. This makes sense because tightly clustered turbines would be harder to maneuver around, thus increasing risks at sea if fishermen choose to transit between them.

III: WERE THE REPORTED PREFERENCES CONSISTENT WITH THE PROPOSED DESIGN FEATURES FROM THE FIVE OFFSHORE WIND DEVELOPERS IN NEW ENGLAND?

In November of 2019, the five developers that control the seven major lease areas off of Massachusetts agreed to standardize the design of their farms. This decision was made to “accommodate long-standing practices designed to minimize conflict between fixed and mobile fishing gear” (Proposal for a uniform 1 X 1 nm wind turbine layout for New England Offshore Wind). A grid type of 1 nautical mile by 1 nautical mile going East/West relative to true north was proposed with no additional transit lanes. This announcement came shortly after the data collection for this research closed. Although the data collected for this thesis is not a true representative of the entire commercial fishing population off of the east coast, some of the responses were consistent with the proposed layout and others were not.

Based on the survey, the choices that are consistent with the developer’s proposed layout are the *East/West orientation*, the *1 by 1 nautical mile grid*, and the footprint that displayed turbines that were *spread out across the entire lease area with room to maneuver between them*. Referring back to the preferred choices, 48.6% of the respondents preferred EW orientation, 43.8% of the respondents preferred the one nautical mile grid, and 62.6% of the respondents reported that they prefer to fish in a wind farm with turbines that are spread out across the entire lease area with room to maneuver between them.

Design Element			
	Grid Type	Orientation	Footprint
Agreement	1 nautical mile grid	East/West	Spread out, no transit lane
Findings	44% preferred grid	49% preferred East/West	63% preferred spread out turbines
Consistent?	Showed preference for a grid but not significantly the 1nm option over the offset grid	Yes	Yes

Table 6: Distribution of first choice design choice and all other choices that represent options laid forth in the November 2019 standardized agreement for wind farm configurations among New England lease holders.

IV: BIG PICTURE

The findings of this research can be applied into a broader management context in regard to marine spatial planning and stakeholder engagement. Meaningful stakeholder engagement coupled with interagency/ inter-organizational cooperation is essential for successful ocean governance (Smythe and McCann 2018), and lessons learned from this research can be applied to existing methods of marine spatial planning and communication. This research relied on direct stakeholder engagement in the commercial fishing industry, and its purpose was to facilitate cooperation and communication between two industries with interest in utilizing the same ocean space. The conflicting values regarding why respondents preferred some aspects of design but disliked others highlight the importance of information sharing. The manner by which state and federal agencies work with developers to designate a portion of the ocean space for offshore wind development generates conflicts that are fairly consistent with planning marine space to other uses, such as aquaculture, oil rigging, or even a marine protected area (MPA). Even though the types or values may be

different from one marine spatial planning project to another, there will always be associated risks or impacts it might have to other users. By acknowledging that risks exist and getting more information on what they are and how they might be affected, it may be easier to mitigate potential conflicts by having the information to avoid them in the first place. Additionally, since there are so many consistencies between the challenges and processes of marine spatial planning and leasing a wind farm, agencies can learn from the lessons and challenges of MSP to help resolve conflicts between developers and commercial fishermen. The Ocean SAMP – Rhode Island’s marine spatial planning process for 1,467 square miles of both state and federal ocean space – was a crucial step in regard to developing the first wind farm in the United States off of Block Island. This immense marine spatial management project was led by the state’s Coastal Regional Management Council and created several levels of stakeholder and interorganizational advisory committees and advisory boards (Smythe and McCann 2018). By creating a regulatory plan that involved many different sectors and involved constituents of different interests, the Ocean SAMP works as an excellent example of early and often stakeholder engagement and thorough communication and dialogue between different parties.

V: RESEARCH LIMITATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

The data for this research was collected by using a convenience sampling method by sending out the survey to industry listservs. Convenience sampling is a subset of non-probability sampling in which it is impossible to specify the probability

that any person will be included in the sample (Robson 2011). Given the time constraints and limited access to survey participants this research had, purposefully sending out the survey to certain listservs that have many members from the targeted population aided in collecting data but may have led to some research bias. Based on the technological nature of this research, the only members of the commercial fishing industry that were able to partake in this research must have had working email addresses and were members of one of the four listservs this survey was sent out from. There is a very large population of the commercial fishing industry that did not meet those qualifications and did not get their opinions and preferences shared. Additionally, the respondents were not selected randomly- there was bias in who was able to gain access to this survey but there was not a better alternative method of data collection at the time.

If this topic is researched further, getting the survey out by a triangulation of online distribution, mail distribution, as well as meeting with commercial fishermen face to face would greatly reduce the bias in convenience sampling and would get data from individuals that may not be as present online. Another suggestion for further research would be to both move the season the data is to be collected and earmark a longer period of time to collect data. A major limitation of this study was the low survey population and a high drop-out rate of respondents taking the survey. Over half of the respondents that started the survey actually completed it and working to cut down the length and time requirement of the survey would be incredibly beneficial. Another way to get maximum responses is to tailor the survey distribution to when commercial fishermen have more time in their schedules. The data for this survey was

collected from the middle of August to the end of October which contributed to a very large limitation in this study. Summer and early fall is part of peak commercial fishing season, and my respondents may have been checking their emails less during this busy time. If this survey were to have been sent out during the late Fall or winter, there may have been room for increased response rates and reach. Additionally, analyzing these research questions adhering to a more qualitative methods approach versus a quantitative approach might reveal missing information that might now have been captured in a ten-minute online survey. Performing regressions on Likert scale responses can only reveal so much about why the respondents were making the decisions they made and including dialogue from in-person interview would have added a lot of context and additional information to the results of this online survey.

CONCLUSION

With fifteen active leases in the United States and more to come, offshore wind development and its relationship to existing ocean uses is going to be a topic of discussion and conflict in years to come. The commercial fishing industry has close to two million dollars in revenue (NOAA 2018) and drives local economies and trade. Offshore wind farm leases can be zoned in fishing areas or common transit routes, and it is unclear what ecological, social, and economic impacts the projects will incur on the fishing industry. Besides micro-siting and maximizing technical efficiency of projects, engineers should also consider the priorities and safety of the commercial fishing community in terms of risk in design and maximizing efficiency. The physical design of the offshore windfarm has potential to positively or negatively impact the co-sharing of the ocean space between the two industries. Therefore, perceived risks from offshore wind design preferences from the commercial fishing industry requires extensive research and information sharing. The purpose of this research was to assess 1) what the fishermen's preferences for configuration are; 2) determine if safety, gear conflict, and fear of reduced landings influence some design features over others, and 3) to evaluate if the reported preferences are consistent with the proposed design features from the five offshore wind developers in New England.

Descriptive statistics demonstrated that for the most part, the respondents of this survey preferred design features that were consistent with the proposed layout from the New England developers. 48.6% of the respondents preferred EW orientation, 43.8% of respondents preferred the one nautical mile grid, and 62.6% of

my respondents reported that they prefer to fish in a wind farm with turbines that are spread out across the entire lease area with room to maneuver between them.

One major finding of this research is that the basis by which the five developers agreed on the standardized 1 nautical mile grid - reduce gear conflicts by following the same pattern as the regional fixed gear/mobile gear agreement - was the reason why the grid was *dispreferred* by survey respondents. This juxtaposition questions both the validity of the gentlemen's agreement in the area as well as the extent to which the developers consulted the commercial fishing industry outside of fixed gear users. This research also revealed that for a single proposed design, different perceived risks may simultaneously make the layout component more *and* less desirable depending on how much each respondent values each risk factor. This conflict in risk assessment demonstrates that there are many factors at play when trying to design a wind farm that promotes cooperation between the offshore wind and commercial fishing industry.

Research on offshore wind design will become increasingly important as leases continue to sell and more farms occupy the ocean space off of the Atlantic coast. This research suggests that although setting standardized offshore wind designs may facilitate consistency and iteration, there is no guarantee it satisfies the preferences of all stakeholders in the entire area. Contrastingly, it is unclear if a single design proposal that is favored by every stakeholder exists, and perhaps the best layout proposed by developers is the design that reached pareto efficiency. Either way, shifting protocols in cooperation to a more adaptive approach versus a rigid set of design elements may promote inclusion in the development process in the future. This

type of technological progress must adhere to slower developmental timelines in order to coexist with historical ocean uses and policies, and this research further justifies the need for further research. Making purposeful decisions on the layout of the farms can promote cooperation between the two major industries and improve the sustainability of expanding offshore wind development in the future.

APPENDICES

Appendix 1: SPSS Coding of Survey Variables

is_fisherman:

- Does respondent identify as a commercial fisherman
- 1=yes, 2=no

port_state:

- What port state are they from?
- 1=Maine
- 2=New Hampshire
- 3=MA
- 4=Rhode Island
- 5=Connecticut
- 6=New York
- 7=New Jersey
- 8=Deleware
- 9=Maryland
- 10=Virginia
- 11=North Carolina
- 12=South Carolina
- 13=Georgia
- 14=Florida

role_boat

- What is their role on the boat (choose most relevant)
- 1=owner
- 2=captain
- 3=deckhand
- 4=engineer
- 5=other

vessel_type:

- What type of vessel does the respondent currently work on (select all that apply)
- 1=Pots and traps
- 2=Long line
- 3=Gillnet
- 4=Trawler
- 5=Dredger
- 6=Hook and line / harpoon / greenstick
- 7= Factory Trawler
- 8=Aquaculture

permits:

-Which permits do they currently possess? (check all that apply)

1= Mid-Atlantic Forage Fish

2= Squid, Atlantic Mackerel, and Butterfish

3=Incidental Highly Migratory Species (HMS) Squid Trawl

4=Spiny Dogfish

5=Atlantic Bluefish

6=Atlantic Herring

7=Tilefish

8=Skate

9=Atlantic Deep-Sea Red Crab

10=American Lobster

11=Scup (Porgy)

12=Summer Flounder (Fluke)

13=Surfclam / Ocean Quahog / Maine Mahogany Quahog

14=Monkfish

15=Black Sea Bass

knowledge_ranking:

-How would you rank your knowledge on offshore wind development in the United States? (1 is no knowledge, 5 is thorough knowledge)

offshorewind_discussion:

-how often has respondent discussed offshore wind development in the past year

1=never

2=rarely

3=several times

4=most of the time

gridtype_1

-What ranking out of 4 did the respondent rank the random grid type?

-1 being most favorite

gridtype_2

-What ranking out of 4 did the respondent rank the lined grid grid type?

-1 being most favorite

gridtype_3

-What ranking out of 4 did the respondent rank straight line grid type?

-1 being most favorite

gridtype_4

-What ranking out of 4 did the respondent rank the 1nm by 1 nm grid type?

-1 being most favorite

gridtype_ranking_safety

-How important was safety and navigation when ranking your preferences for grid types?

1= extremely important

2=very important

3=moderately important

4=slightly important

5=not at all important

gridtype_ranking_gear

-How important was reducing conflict with other fishers/gear entanglements when ranking your preferences for grid types?

1= extremely important

2=very important

3=moderately important

4=slightly important

5=not at all important

gridtype_ranking_landings

-How important was considering reductions in fish landings when ranking your preferences for grid types?

1= extremely important

2=very important

3=moderately important

4=slightly important

5=not at all important

gridtype_comments

-any comments, optional

orientation_NS

-ranked preference for the first orientation, North/South

orientation_EW

-ranked preference for the second orientation, East/West

orientation_NESW

-ranked preference for the third orientation, NESW

orientation_NWSE

-ranked preference for the fourth orientation, NWSE

orientation_ranking_safety

-How important was safety and navigation when ranking your preferences for orientation?

1= extremely important

2=very important

3=moderately important
4=slightly important
5=not at all important

orientation_ranking_gear

-How important was reducing conflict with other fishers/gear entanglements when ranking your preferences for orientation?

1= extremely important
2=very important
3=moderately important
4=slightly important
5=not at all important

orientation_ranking_landings

-How important was considering reductions in fish landings when ranking your preferences for orientation?

1= extremely important
2=very important
3=moderately important
4=slightly important
5=not at all important

orientation_comments

-optional comments

footprint

-which do you prefer for the footprint of offshore wind farms?

1=clustered
2=spread out

footprint_ranking_safety

-How important was safety and navigation when ranking your preferences for footprint?

1= extremely important
2=very important
3=moderately important
4=slightly important
5=not at all important

footprint_ranking_gear

-How important was reducing conflict with other fishers/gear entanglements when ranking your preferences for footprint?

1= extremely important
2=very important
3=moderately important
4=slightly important

5=not at all important

footprint_ranking_landings

-How important was considering reductions in fish landings when ranking your preferences for footprint?

1= extremely important

2=very important

3=moderately important

4=slightly important

5=not at all important

footprint_comments

-optional comments

final_comments

Appendix 2: Additional regressions on favorite design element

Coefficients ^a					
		Unstandardized Coefficients		Standardized Coefficients	
Model		B	Std. Error	Beta	t
1	(Constant)	2.357	.455		5.185
	Safety & navigation	.302	.343	.206	.881
	Reducing gear conflict with other fishers/gear entanglements	.128	.237	.115	.540
	Reduced fish landings	-.441	.247	-.397	-1.786

a. Dependent Variable: 1 nm grid

Table 7: Regression table for 1nm grid and risk types

Coefficients ^a					
		Unstandardized Coefficients		Standardized Coefficients	
Model		B	Std. Error	Beta	t
1	(Constant)	1.596	.379		4.213
	Safety & navigation	-.082	.286	-.066	-.286
	Reducing gear conflict with other fishers/gear entanglements	.028	.197	.030	.142
	Reduced fish landings	.364	.206	.387	1.769

a. Dependent Variable: Straight lines

Table 8: Regression table for Straight line grid

Coefficients ^a					
		Unstandardized Coefficients		Standardized Coefficients	
Model		B	Std. Error	Beta	t
1	(Constant)	1.457	.296		4.922
	Safety & navigation	-.171	.199	-.171	-.860
	Reducing gear conflict with other fishers/gear entanglements	.513	.175	.576	2.926
	Reduced fish landings	-.165	.148	-.221	-1.112

a. Dependent Variable: EW Orientation

Table 9: Regression table for EW orientation

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