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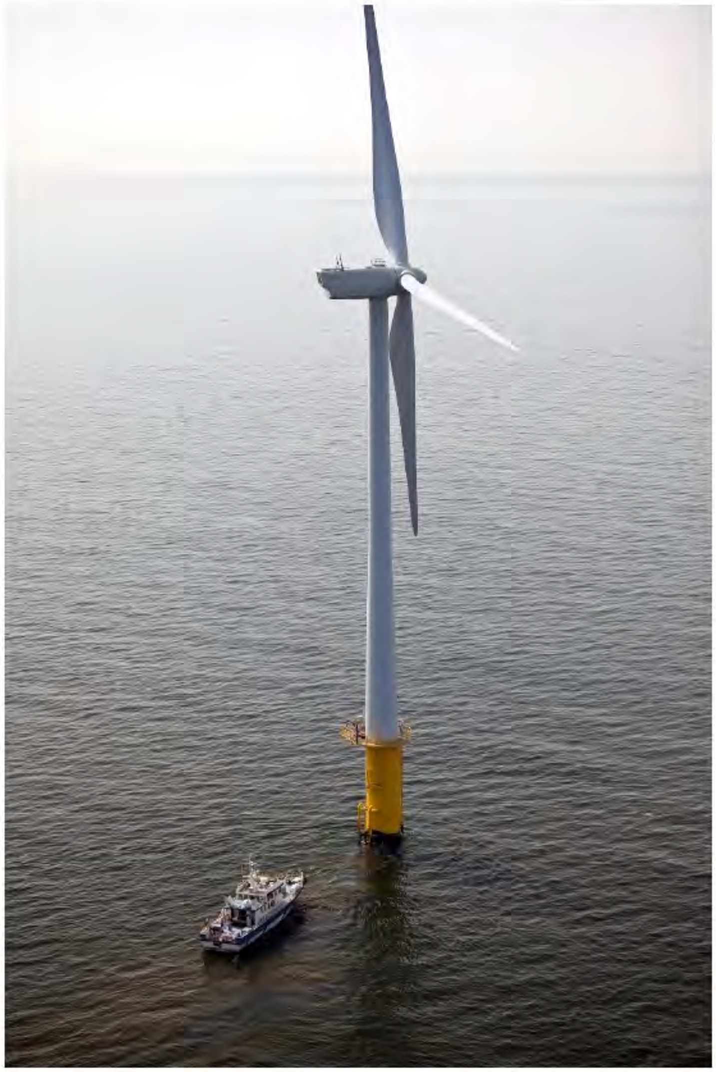
SUPPORTING NATIONAL ENVIRONMENTAL POLICY ACT DOCUMENTATION FOR OFFSHORE WIND ENERGY DEVELOPMENT RELATED TO NAVIGATION



U.S. Department of the Interior
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BOEM
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SUPPORTING NATIONAL ENVIRONMENTAL POLICY ACT DOCUMENTATION FOR OFFSHORE WIND ENERGY DEVELOPMENT RELATED TO NAVIGATION

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Table of Contents

EXECUTIVE SUMMARY

In the coming decade, the Bureau of Ocean Energy Management (BOEM) anticipates the development of offshore wind farms in federal waters on the U.S. Atlantic Outer Continental Shelf (OCS). BOEM is responsible for overseeing offshore renewable energy development on the OCS, including offshore wind energy development. BOEM supports responsible development of renewable energy through issuing leases and approving development plans. Under its National Environmental Policy Act (NEPA) responsibilities, BOEM uses the best available information within an environmental assessment to identify and mitigate potential space-use conflicts with other ocean uses.

This study utilized a literature review to evaluate the current documentation related to navigational concerns associated with offshore wind infrastructure, focusing on existing policy and guidance, navigational risk assessments, collisions and allisions, commercial fisheries, and recreational fisheries. Expert discussions were conducted with subject matter experts to gather supplemental information on concerns related to offshore wind energy development and marine vessel navigation. This report provides summaries of the major topics identified and areas of broad agreement among the literature sources and stakeholders, as well as areas of divergent views where additional research may be necessary.

For the five categories examined in this literature review—existing policy and guidance, navigational risk assessments, collisions and allisions, commercial fisheries, and recreational fisheries—several findings were identified. The following subsections provide an overview of these findings.

ES-1 Policy and Guidance

Several international regulations and agreements predate the commercial offshore wind energy industry but have provisions that are applicable to navigating in and around offshore wind farms. More recent policy and guidance (dating from 2016 to 2018) were developed based on lessons-learned from a mature European offshore wind industry and provide critical guidance for nascent U.S. offshore wind projects. These guidance documents include the United Kingdom Maritime and Coastguard Agency (UK MCA) Marine Guidance Note (MGN)-543, U.S. Coast Guard (USCG) Atlantic Coast Port Access Route Study (ACPARS), USCG Navigation and Vessel Inspection Circular (NVIC) No. 02-07, and the World Association for Waterborne Transport Infrastructure (PIANC) Maritime Navigation Commission (MarCom) Working Group Report no. 161-2018.

While representatives of the shipping industry and other marine vessel navigators suggest that the marine planning guidelines in ACPARS (2 nautical miles [nm] setback from Traffic Separation Schemes [TSS] and a 5 nm setback from the TSS entrance) be adopted widely as minimum planning standards, representatives of USCG and the offshore wind industry state that each offshore wind energy area is unique and should be evaluated on a case-by-case basis based on vessel type, size, and traffic density, among other site-specific considerations. The offshore wind industry suggested that the PIANC planning standards should be used to calculate the necessary width of vessel traffic routes (e.g., TSS) to reduce navigational risk to acceptable levels.

ES-2 Navigational Risk

Several reports noted that the highest risk to navigation typically occurs during the wind farm construction phase as this phase involves supply and support traffic, resulting in increased vessel traffic, activity, and noise. In discussions with the offshore wind industry, developers agreed that safety zones (an area in which vessels are excluded) are useful during construction, but not necessary during operations. Wind turbine generators (WTG) have the potential to serve as aids to navigation (ATON), which mark locations, routes, or obstructions in waterways. The USCG installs and maintains traditional ATON; private ATON will be required within wind farms thereby making the existing system more robust. Mariners rely on ATON at all times to navigate and avoid collisions and allisions.

ES-3 Collisions and Allisions

The underlying risk factors and probabilities for collisions and allisions are primarily based on incident case studies from European offshore wind farms and statistics from offshore oil and gas platforms. The major risk factors that could contribute to vessel allisions with offshore WTGs include human error, mechanical and technical equipment failure, and environmental factors such as wind and weather. During discussions with subject matter experts, marine vessel operators and offshore wind industry representatives agreed that the funneling of vessels into narrower areas and mixing of previously segregated vessel types can increase the risk of collision. The greatest risk of collisions or allisions is posed by potential loss of steering, power, or both vessel functions, which can be caused by human error.

ES-4 Commercial Fisheries

Commercial fishing vessels can face several risks when operating within offshore wind farms. The spacing and arrangement of WTGs is critical because they may constrain the maneuverability of fishing vessels with deployed gear or impede the transit of vessels during poor visibility. These constraints are affected by the orientation of and distance between WTGs, the size of fishing vessels, and the types of gear used. Offshore wind farms can create a conflict with commercial fishing, although the magnitude and mitigations for this risk are not well documented. Expert interviews revealed concerns among fishermen that insufficient research has been conducted to determine the cumulative impacts of offshore wind farms and potential for radar interference. Existing literature and experts interviewed identified that wind farms can be built in areas where commercial fishing historically occurs, or where commercial fishing vessels transit in unofficial, but heavily-used, vessel traffic routes. Informal exclusion zones may be created when fishermen choose to avoid wind farms for fear of incurring increased insurance costs or not being able to safely navigate the area.

ES-5 Recreational Fisheries and Other Recreational Activities

Artificial offshore structures, such as bottom-founded oil and gas platforms, wind energy platforms, and shipwrecks are popular destinations for recreational fishing and diving. These offshore structures provide hard, man-made (artificial) substrates that modify the habitat and attract recreational fish species. If the experience with offshore oil and gas platforms in the U.S. is extrapolated to planned offshore wind farms off the U.S. Atlantic coast, it can be expected that recreational fishermen and divers will travel to offshore wind installations to take advantage of additional fish habitat and greater recreational fishing stocks.

LIST OF ABBREVIATIONS AND ACRONYMS

ACPARS	Atlantic Coast Port Access Route Study
AIS	Automatic Identification System
AoA	Area of Analysis
ATON	Aids to Navigation
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
COLREGS	Convention on the International Regulations for Preventing Collisions at Sea
COP	Construction and Operations Plan
CPA	Closest Point of Approach
DTI	Department of Trade and Industry
DWSF	Deepwater Wind South Fork
EEZ	Exclusive Economic Zone
EU	European Union
FAA	Federal Aviation Administration
FSA	Formal Safety Assessment
ft	Feet
GIS	Geographic Information System
GPS	Global Positioning System
GPSR	General Provisions on Ships' Routeing
HSE	Health and Safety Executive
IMO	International Maritime Organization
km	kilometer
m	meter
MarCom	Maritime Navigation Commission
MCA	Maritime and Coastguard Agency
MGN	Marine Guidance Note
MW	Megawatt
NASCA	North American Submarine Cable Association
NEPA	National Environmental Policy Act
nm	nautical mile
NOAA	National Oceanic and Atmospheric Administration
NSRA	Navigation Safety Risk Assessment
NTSB	National Transportation Safety Board
NVIC	Navigation and Vessel Inspector Circular
NYSERDA	New York State Energy Research and Development Authority
OCS	Outer Continental Shelf
OREI	Offshore Renewable Energy Installation
OWF	Offshore Wind Farm
PARS	Port Access Route Study
PIANC	World Association for Waterborne Transport Infrastructure
RAMP	Resource Access Mapping Project

RODA	Responsible Offshore Development Alliance
SAR	Search and Rescue
TSS	Traffic Separation Scheme
UK	United Kingdom
UNCLOS	United Nations Convention on the Law of the Sea
U.S.	United States
USCG	U.S. Coast Guard
VHF	Very High Frequency
VMS	Vessel Monitoring Systems
WDA	Wind Development Area
WEA	Wind Energy Area
WTG	Wind Turbine Generator

1 INTRODUCTION

The first utility-scale offshore wind program was initiated in Denmark in 1991. Since then, offshore wind programs have opened across the world including in Europe, Asia, and most recently, in the United States (U.S.). The Block Island Wind Farm, the first utility-scale offshore wind farm in the U.S., became operational in December 2016 and consists of five wind turbine generators (WTG) with a total capacity of 30 megawatts (MW) in state waters off the coast of Rhode Island. Several additional offshore wind projects are currently in the planning phase on the Atlantic and Pacific coasts (BOEM, Undated).

The Bureau of Ocean Energy Management (BOEM) is responsible for overseeing offshore renewable energy development on the Outer Continental Shelf (OCS), including offshore wind development. BOEM supports responsible development of renewable energy through issuing leases and approving development plans. Under its National Environmental Policy Act (NEPA) responsibilities, BOEM uses the best available information within an environmental assessment to identify and mitigate potential space-use conflicts with other ocean uses.

The main goal of this study was to assess the potential impacts associated with the development of offshore wind energy facilities on marine vessel navigation. This report provides a summary of the potential concerns for navigational impacts for five different categories: policy and guidance, navigational risk, collisions and allisions, commercial fisheries, and recreational fishing and other activities. This information can be used by BOEM, and others, for environmental analyses under NEPA and for other compliance needs.

This report is organized as follows:

- The **Literature Review** (Chapter 2) describes the studies authored by international, federal, and state government agencies; peer-reviewed academic papers; and professional and trade organizations that were reviewed. **Appendix A** provides individual summaries of the literature reviewed for this study.
- The **Expert Discussions** (Chapter 3) provides an overview of the discussions held with identified experts on navigation and offshore wind farms including marine vessel operators, marine transportation trade associations, and representatives from the offshore wind industry, such as facility developers and consultants.
- The **Conclusion** (Chapter 4) provides a summary of the findings from the literature review and expert discussions.

2 LITERATURE REVIEW

2.1 METHODOLOGY

Working closely with BOEM and the U.S. Coast Guard (USCG), the Research Team initially identified potential literature sources to review for this report. The team created a list of major government, academic, and other professional organizations currently working with offshore wind energy facilities; studying navigational impacts related to shipping and commercial or recreational fishing; or having a maritime presence near offshore wind farms. The Research Team conducted a comprehensive internet search for U.S. and international sources covering navigational impacts of offshore wind farms. Navigational assessments for offshore wind farms planned for construction along the U.S. Atlantic Coast were included, as well as risk assessments conducted by the offshore wind industry in Europe. Literature sources reviewed were mostly published within the past 10 years (i.e., 2008 to present), although some older sources were reviewed that had relevant information. In addition, BOEM and USCG identified several literature sources for potential inclusion in the reviews. The Research Team created a preliminary bibliography of literature sources for concurrence from BOEM and USCG.

After approval of the identified literature sources, the Research Team reviewed and summarized the identified sources. Working closely with BOEM and USCG, a few literature sources were removed from consideration after their review because they were not sufficiently relevant to navigational impacts. With the literature review underway, several data gaps were uncovered requiring additional research. For example, literature sources describing recreational fishing and diving activities were limited and required inclusion of a research paper over 20 years old. The individual literature summaries are included as Appendix A.

Following the creation of the literature review summaries, findings were organized by category of risk and are provided below.

2.2 Findings

For the five categories considered in this literature review—policy and guidance, navigational risk assessments, collisions and allisions, commercial fisheries, and recreational fishing and other activities—several findings were identified. The following subsections provide an overview of the findings from the literature review for each category. A summary of each literature source is provided in Appendix A differentiated by category of risk.

2.2.1 Policy and Guidance

Several international regulations and agreements predate the commercial offshore wind industry but have provisions that are applicable to navigating in and around offshore wind farms. These include the Convention on the International Regulations for Preventing Collisions at Sea (COLREGS), 1972; United Nations Convention on the Law of the Sea (UNCLOS), 1982; and the International Maritime Organization (IMO) General Provisions on Ships' Routeing (GPSR), 1985. Applicable provisions from these regulations and agreements address safe distances between vessels and stationary objects, as well as standards for vessel traffic routes and establishment of safety zones (areas in which vessels are excluded) around offshore platforms. The Shipping Advisory Board North Sea has proposed the formula 0.3 nautical miles [nm] + 6 ship lengths + 1,640 feet [ft]/500 meters [m] on the starboard side and 6 ship lengths + 1,640 ft (500 m) on the port side for calculating buffer distances. (Shipping Advisory Board North Sea, 2013)

More recent policy and guidance (dating from 2016 to 2018) were developed based on lessons-learned from a mature European offshore wind industry and provide critical guidance for nascent U.S. offshore wind projects. These guidance documents include the United Kingdom Maritime and Coastguard Agency (UK MCA) Marine Guidance Note (MGN)-543 (2016), USCG Atlantic Coast Port Access Route Study (ACPARS) (2016), USCG Navigation and Vessel Inspection Circular (NVIC) 02-07[1] (USCG, 2007),[1] and the World Association for Waterborne Transport Infrastructure (PIANC) MarCom Working Group Report no. 161-2018 (2018). These documents address one or more aspects of risks to navigation posed by offshore wind farms and offer guidance

[1] At the time of publication of this report, USCG was developing an update to the 2007 NVIC -2007.

on safe distances between vessel traffic routes and wind farms, as well as information and guidance to evaluate site-specific assessments of navigational risk.

These guidance documents concur that offshore wind farms may prompt vessels to alter their historical routes of navigation, which may increase risks of collision and allision, interfere with electronic navigation equipment (e.g., radar), and limit visibility. These risks are especially acute where vessel traffic rerouting may prompt tug and tow vessels traveling in a coastwise direction to move farther out to sea. The likelihood of collisions increases as smaller vessels comingle with larger, faster, deep draft vessels. This may also result in the exposure of smaller vessels to heavier sea states at distances farther from safe harbors. The documents reviewed also suggest that offshore wind farms may reduce sea room in general and may create vessel congestion, potentially increasing the risk of collisions. (PIANC, 2018; UK MCA, 2016; USCG, 2007, 2016)

A variety of minimum safe distances or setbacks are offered by these guidance documents. Both the MGN-543 and ACPARS provide specific guidance on minimum distances between offshore wind farm boundaries and vessel routes, such as traffic separation schemes (TSS). MGN-543 presents a three-tiered framework for evaluating minimum distance between offshore wind farms and vessel traffic routes as follows. Setback distances of less than 0.5 nm are not considered acceptable. Distances of 0.5 to 3.5 nm may be appropriate depending upon site-specific factors (e.g., vessel size, S-band radar interference, and compliance with COLREGS). Distances greater than 3.5 nm are considered broadly acceptable. The USCG adopted the marine planning guidelines (i.e., suggested distance between a traffic lane and offshore wind farm boundary should be at least 2 nm, and distance between entry/exit of a TSS and offshore wind farm boundary should be at least 5 nm) based on the older MGN-371, which was the prevailing guidance during development of the study. UK MCA updated its MGN to be less prescriptive based on experience that each offshore wind area has different characteristics. (PIANC, 2018; UK MCA, 2016; USCG, 2007, 2016)

A factor in the buffer discussion relates to a sense by some in the offshore wind industry and USCG that the UK leasing process is more rigorous in removing potential contentious areas prior to leasing. In comparison, BOEM allows for developers to undertake navigational risk assessments after lease issuance and provide a more in-depth evaluation that factors in appropriate buffer distances with justification in the Construction and Operations Plan (COP). (Kearns & West, 2018)

2.2.2 Navigational Risk

Several reports—ESS Group (2006b), Deepwater Wind (2012), EMU (2012), Deepwater Wind South Fork (2018), and VanderMolen & Nordman (2014)—noted that the highest risk to navigation typically occurs during the offshore wind farm construction phase as this phase involves supply and support traffic resulting in increased vessel traffic, activity, and noise. Recommended mitigation measures for risks during this phase include establishing a temporary 1,640 ft (500 m) safety zone around specific turbines under construction. These safety zones recommended by EMU (2012) for the Neart na Gaoithe wind farm are transitional and cover only the specific area where construction is occurring at a given time. Turbines are assembled one at a time in a sequential fashion. This enables the safety zone surrounding one turbine to close as another opens and avoids closing off the entire offshore wind farm area. It was also noted that cable-laying vessels pose additional risks as these vessels have reduced maneuverability. (Deepwater Wind, 2012; Deepwater Wind South Fork, 2018; EMU, 2012; ESS Group, 2006b; VanderMolen & Nordman, 2014)

Nearly all sources noted that communication among the offshore wind industry and mariners is vital, and the lack of communication can lead to risky behavior. Notifying vessel operators through notices to mariners and coordinating with harbor masters, event sponsors, and other entities during times of maintenance and closures, and when safety zones are established or terminated, assists mariners in making better route decisions. Rawson and Rogers (2015) note that routes are determined using multiple factors, including travel distance, fuel needs, and time requirements. An important part of informing mariners consists of ensuring all WTGs and cables are marked individually and accurately on National Oceanic and Atmospheric Administration (NOAA) navigation charts and prescribe a consistent lighting scheme. All sources identified that good communication leads to better informed decision-making. (Deepwater Wind South Fork, 2018; ESS Group, 2006b; Kearns & West, 2018; NYSERDA, 2017a)

Lastly, WTGs have the potential to serve as aids to navigation (ATON), which mark locations, routes, or obstructions in waterways. The USCG installs and maintains traditional ATON; private ATON (see 33 Code of Federal Regulations [CFR] § 66 for associated regulations) will be required within offshore wind farms thereby making the existing system more robust as mariners rely on ATON at all times to avoid collisions and allisions. (Deepwater Wind, 2012; ESS Group, 2006b; PIANC, 2018; UK MCA, 2016; USCG, 2016; VanderMolen & Nordman, 2014)

2.2.3 Collisions and Allisions

Underlying risk factors and probabilities are primarily based on incident case studies from European offshore wind farms and statistics from offshore oil and gas platforms. The major risk factors contributing to vessel collisions with WTGs include human error, mechanical and technical equipment failure, and environmental factors such as wind and weather (Christensen, Andersen, & Pedersen, 2001; NYSERDA, 2017a; Oltedal, 2012; Orbicon, 2017). A study by the UK Health and Safety Executive (HSE) found that human error caused 45% of vessel collisions with offshore oil and gas platforms, 33% were caused by equipment failure, and 22% were attributed to external factors (Oltedal, 2012). A study by the Norwegian Petroleum Safety Authority found that the most important factors leading to collisions were caused by human error, including lack of an effective safety culture, poor understanding of training and use of advanced technical equipment, poor bridge team management, and crews not being sufficiently warned by installations when approaching due to a lack of notation on navigation charts or proper lighting and warning systems not being implemented (Oltedal, 2012). Since the commencement of the first major offshore wind energy project in 2003, only two allisions have been recorded for offshore wind farms in the UK (one was caused by a distracted fishing vessel captain, while the other resulted from a power steering failure on a container ship) (Kearns & West, 2018).

Collision damage to WTGs poses potential risk of crew member injury, expensive production outages, and increased maintenance and repair requirements. Collisions can also result in fuel spills (from any vessel) or oil or hazardous material spills from tanker vessels. Head-on collisions occur when a ship is pointed in the direction of an offshore wind energy structure (on a collision course) and the vessel operator fails to act to prevent the collision due to factors such as navigational error and absence of proper watch standing. Maneuvering collisions occur when a vessel hits a structure after the operator misjudges a maneuvering action, such as a turn. Drifting collisions occur when a vessel experiences steering or propulsion failure and is pushed into a structure by the force of wind and waves. (Christensen et al., 2001; Dai, Ehlers, Rausand, & Utne, 2013; NYSERDA, 2017a, 2017b; USCG, 2007)

Risk assessment models are commonly utilized by wind energy developers to determine the optimal placement of offshore WTGs. These risk assessment models simulate collision risks based on factors such as ship traffic and navigational routes in the vicinity of the proposed site, environmental conditions and bathymetry of the area, and geometry of the proposed wind farm. As wind farms are being planned and constructed further offshore to reduce safety concerns associated with shipping lanes and other maritime traffic, the risk of collision with transiting service vessels can increase. Deepwater areas are more exposed and require larger service vessels to withstand the more extreme environmental conditions. These larger vessels enhance collision risk through their reduced maneuverability and their magnitude of potential energy increases the severity of impact with WTGs. Although larger service vessels may be built to higher construction, equipment, and crewing standards, they may also have advanced features (e.g., dynamic positioning) that can help mitigate navigational risk and have fewer transits at slower speeds than smaller vessels. Between 2001 and 2010, service vessels were responsible for 24 of the 26 reported collisions with offshore oil and gas installations on the Norwegian Continental Shelf. The UK HSE reported that between 1975 and 2001, 514 of the 557 collision incidents between ships and oil and gas platforms involved service vessels. (Dai et al., 2013)

2.2.4 Commercial Fisheries

Commercial fishing vessels face a number of navigational risks when operating within offshore wind farms, chiefly from the wind turbines themselves and the inter-array and export cables. The spacing and arrangement of WTGs is critical because it may constrain the maneuvering of fishing vessels and fishing gear. These constraints are affected by the distance between turbines, the size of fishing vessels, and the types of fishing gear used.

A 2015 study conducted on the impacts of offshore wind energy development in Northern Ireland cited a minimum spacing of 0.54 nm between wind turbines to allow for commercial fishing. As offshore wind technology advances, new offshore WTGs are trending toward fewer turbines with higher generation capacity but greater between turbine spacing requirements in contrast to older offshore WTGs with more low-capacity turbines. (Poseidon Aquatic Resource Management Ltd., 2015)

Wind turbines can have a variety of foundation designs, most involving some type of scour protection such as rock armor. Scour protection measures can pose the risk of entangling fishing gear and further spatially constraining commercial fishing operations. Current discussions are focused on best practices (e.g., rock size) that would provide the least potential impact. The risk that cables pose to fishing operations is largely dependent upon whether cabling is buried at a sufficient depth and if additional protection by rock armor or concrete mattresses is needed. These features are typically necessary in areas where cables cross and increase the potential for fishing gear entanglement outside of the offshore wind farm area. Most offshore wind farms feature a single export cable, as well as numerous inter-array cables, that connect the wind turbines. If cable burial is not possible, inter-array cables can be placed in a manner that maintains cable-free “fishing corridors” between rows of turbines, but this can result in challenges by limiting fishing patterns to a narrow direction and sea space. Any loss of construction equipment on the sea floor can also introduce a risk of entangling fishing gear. Any such construction equipment losses must be reported to BOEM. (Poseidon Aquatic Resource Management Ltd., 2015)

Smaller vessels that tend to operate a variety of gear are better-suited to fishing within offshore wind farms. Larger vessels that tend to tow heavy gear are less suited due to limited sea space and room for maneuvering. Fishermen operating long strings of pots (i.e., fixed gear) have an increased risk of entanglement, but can reduce this risk by deploying shorter strings. Beam trawlers can reduce the weight of their beams which in turn reduces ground penetration and lessens the risk of entanglement. Demersal otter trawlers can reduce their gear spread and avoid twin trawls to lower their risk of entanglement. A study of Northern Ireland offshore wind farms concluded that trawlers, scallopers, and fishermen using strings of pots are likely able to operate within offshore wind farms with some constraints (e.g., twin and pair trawling is unlikely to be possible), while larger types of mobile gear such as seine and drift nets are less likely able to operate safely. (EMU, 2012; NYSERDA, 2017a; Poseidon Aquatic Resource Management Ltd., 2015)

For the Block Island Wind Farm, USCG approved safety zones were established around WTGs during construction but has not implemented any formal exclusionary zones during normal turbine operation. Safety zones are established for WTGs when the USCG deems it necessary for a specific situation. The USCG's authority for instituting safety zones currently does not extend beyond 12 nm from shore; regulations for this authority can be found at 33 CFR § 165. Informal exclusion zones may be created when fishermen choose to avoid offshore wind farms for fear of incurring increased insurance costs or being unable to safely navigate the area while transiting or fishing. (Deepwater Wind, 2012)

The configuration of WTGs within offshore wind farms may place constraints on which vessel sizes or gear types can fish or transit in or around them, or the directionality in which they may lay gear. Fishing vessel operators using mobile gear, including dredge and trawl equipment, have greater risk associated with navigation safety and gear damage than fixed gear vessels. (Deepwater Wind, 2012; W.F. Baird & Associates Coastal Engineers, 2019)

2.2.5 Recreational Fisheries and Other Recreational Activities

Artificial offshore structures, such as bottom-founded oil and gas platforms, wind energy platforms, and shipwrecks, are popular destinations for recreational fishing and diving. These offshore structures provide hard, man-made (artificial) substrates that modify the habitat and attract recreational fish species. Nearshore wind energy structures can function as fish aggregation devices for species that prefer complex, hard bottom habitats provided by the offshore wind infrastructure (Hooper, Hattam, & Austen, 2017). In the Gulf of Mexico, fishing and diving at offshore oil rigs was found to be popular with recreational users; one study referenced in Stanley (1989) found that 70% of recreational fishing trips in the Gulf of Mexico Exclusive Economic Zone (EEZ) target offshore platforms as fish congregation points.

Information on recreational fishing and diving on offshore oil and gas platforms is applicable to offshore infrastructure because the bottom-founded structures used in both types of platforms are similar. If the experience with offshore oil and gas platforms in the Gulf of Mexico are extrapolated to planned offshore wind farms off the U.S. Atlantic coast, it can be expected that recreational fishermen and divers will travel to offshore wind installations to take advantage of additional fish habitat and greater recreational fishing stocks. In Europe, some countries impose safety zones that prevent recreational fishing immediately around WTGs (e.g., Denmark, the UK, Germany, and Netherlands typically employ 1,640 ft [500 m] safety zones around WTGs[2]), but survey data indicated that fishermen expect a greater abundance of fish near offshore wind platforms and a greater variety of species (Vandendriessche, Persoon, Torreele, Reubens, & Hostens, 2017). A 1989 survey of recreational fishermen and divers in the Gulf of Mexico found that recreational fishermen were willing to travel up to 45 nm offshore and divers 77 nm offshore to visit abandoned platforms that had been reefed (Stanley, 1989). This suggests that, if wind farms are located within these distances off U.S. coastlines, these platforms could attract recreational fishing and diving activity. A survey of UK offshore recreational fishers by Hooper et al. (2017) found that respondents frequently fished at offshore wind farms with a mean distance from shore of 10 nm. About a quarter of the respondents reported having fished within or around the perimeter of offshore wind farms. The survey results suggest that recreational fishermen are willing to travel to offshore wind farms and fish within them, and concern about the safety of being near wind turbines is not a major deterrent to potential fishermen (Hooper et al., 2017).

3 EXPERT DISCUSSIONS

3.1 METHODOLOGY

To supplement the findings of the literature review, the Research Team held discussions with offshore wind industry and vessel navigation subject matter experts. Due to the compressed timeline and budgetary constraints of this effort, the Research Team was limited to conducting eight targeted discussions with subject matter experts over a four-week period in January and February 2019 to validate and complement the information gathered in the literature review (Section 2). Potential interview participants were selected from six major stakeholder categories to ensure a well-rounded and diverse set of perspectives were considered and captured. The Research Team held teleconference phone calls with representatives of the shipping industry, representatives of specific harbor stakeholder groups, offshore wind energy developers, foreign regulators, representatives of the commercial fishing industry, and consultants that support navigational risk studies for offshore wind energy.

Participants were contacted via email and invited to participate in a telephone interview regarding navigational risks associated with offshore wind development. Potential questions were distributed to interview participants prior to each telephone interview; however, these discussions were conducted as open-ended conversations with the Research Team focusing on areas of interest and novel ideas presented by interviewees. Each interview lasted approximately 60 minutes. Participants were encouraged to have a frank discussion and were instructed that the Research Team would not attribute specific statements to individuals or organizations. For all but one interview, no federal government representatives participated in the interview;[3] rather contractor staff, as part of the Research Team, conducted each interview. Information gathered from these discussions is attributed only to the stakeholder categories identified above.

[2] According to the Danish Maritime Authority Summary Report on North Sea Regulations and Standards (2015), the UNCLOS gives member states authority to establish up to 1,640 ft (500 m) safety zones around an offshore installation within its EEZ (Shipping Advisory Board North Sea, 2013).

[3] The interview with UK MCA included participation from BOEM and USCG representatives.

3.2 Findings

The views and concerns of the experts interviewed largely confirmed the information gathered in the literature review. While most subject matter experts interviewed largely agreed on major issues and concerns, there were some key areas of disagreement, primarily reflecting the need for further discussion between historical OCS users—vessel operators and their representatives—and the offshore wind industry.

3.2.1 Areas of Agreement

Experts interviewed broadly agreed on the types of impacts that offshore wind farms can have on marine vessel navigation. There was general agreement that routing measures, such as TSSs, are critical to allow vessels to safely navigate around and through offshore wind farm areas. The interviewees felt that these routing measures are particularly critical in high traffic areas such as ports and river mouths where many vessels, traveling from many directions (both transoceanic and coastwise) converge and navigate into a port. There was broad agreement that the presence of offshore wind farms can introduce risk to these high traffic environments by funneling traffic into smaller areas, mixing disparate vessel traffic that was previously segregated (e.g., forcing small, slow, tug and barge traffic offshore where it intermingles with large, fast, deep draft vessels), thus reducing distance between vessels, placing higher demands on vessel crews' situational awareness, and potentially increasing the risk of collision among vessels. Experts reported that the presence of many fixed platforms in an area of high traffic introduces a risk of allision, and that the greatest risk of allision arises from vessel malfunctions (which can be caused by human error) that result in a loss of steering, power, or both functions. In addition, the risk of collision and allision is exacerbated by poor weather conditions, poor visibility, and higher sea state.

3.2.2 Routing Measures and Setbacks

Experts from the offshore wind industry tended to disagree with marine vessel navigation experts in the magnitude of the risk posed by offshore wind farms, as well as the optimal setback distances between routing measures and wind farms. Representatives of the commercial shipping industry advocated for the 2 nm setback between TSSs and offshore wind farms, and the 5 nm setback between TSS entries and offshore wind farms presented in ACPARS as minimum planning guidelines. Representatives of the commercial shipping industry also stressed that TSSs are not the only important vessel traffic routes; heavily-used unofficial traffic routes (which can be identified using Automatic Identification System [AIS] heat maps) should be afforded the same setbacks as TSSs. On the other hand, offshore wind industry representatives noted that many setbacks applied to European wind farms are not as large as those proposed in ACPARS. They expressed that all setback distances should be calculated based on site-specific characteristics such as vessel size, type, and traffic density rather than an all-encompassing single minimum planning standard. To emphasize their point, marine vessel operators and representatives stressed that large distances may be required for the largest marine vessels (such as tankers or bulk cargo carriers) to stop, make evasive maneuvers, or safely anchor in the case of a loss of power. Vessel operators also stressed the challenges of safely navigating major international ports noting a concern for language barriers with international vessel crews and a lack of familiarity with U.S. navigation policies. Also noting the global nature of marine shipping, offshore wind industry representatives highlighted that many of the mariners who will soon be navigating near new offshore wind farms in the U.S. have already gained valuable experience safely navigating around offshore wind farms in Europe and will bring those skills to bear in U.S. waters.

3.2.3 Vessel-Fitted Radar Interference

The experts interviewed generally agreed that offshore wind farms can cause interference with vessel-fitted radar systems by generating radar shadows, scattering, and false radar signals, although these experts disagreed on the magnitude and potential risk mitigation. Representatives from the commercial shipping industry stressed that the effects of offshore wind farms on ship-based radar is not well-understood and a cause of concern for them. Other electronic navigational tools, such as AIS and global positioning systems (GPS), are used to complement and enhance radar capabilities, but none are as technologically simple or have as few potential failure points as radar. For example, collision/allision avoidance using AIS requires GPS, the transmission of an AIS signal (from a vessel or offshore structure), and the ability of a vessel to receive and view/display the signal. Further, GPS technology is susceptible to signal jamming from hostile actors. Another concern is that some vessels (e.g., small fishing vessels) are not equipped with AIS. These vessels could be lost on radar screens if their radar signature is invisible among cluttered wind farm signatures, or if radar operators adjust their gain to compensate for offshore wind farm clutter. Combined with low visibility, these potential risks could lead to a failure to recognize the presence of a nearby small vessel.

Offshore wind industry representatives disagreed and judged the risk of radar interference to be minor. They stressed that skilled radar operators can distinguish between true radar signals and scattering or false echoes. They shared that wind turbines would not be the only objects that cause radar interference; other shore-based structures, such as buildings, can result in interference. Marine radar operators should already be trained to properly address such challenges. The offshore wind industry also stressed that newer, next-generation radar systems can better process radar scattering thereby reducing this concern. Wind energy developers could assist in mitigating this conflict by providing funding to upgrade radar systems. The offshore wind industry representatives also noted that the commercial shipping industry in Europe has not reported significant negative impacts from offshore wind farm radar interference. During discussions with vessel operators, it became clear that they may be unfamiliar with existing studies on offshore wind vessel radar interference performed in Europe. Their concerns could potentially be addressed with outreach and education about the magnitude of the problem and potential mitigation options.

3.2.4 Safety Zones

Offshore wind industry representatives discussed the use of safety zones around WTGs; this topic did not appear to be an area of controversy. However, the USCG's uncertain authority to establish safety zones beyond 12 nm is becoming more of a concern for developers as planned offshore wind farms are nearing the construction phase. The USCG is currently attempting to resolve this jurisdictional question. Based on the European experience, wind developers recommended the use of safety zones around WTGs during the construction phase but did not believe safety zones were warranted during operations. The mariners interviewed did not express any concerns with the implementation of safety zones during construction.

3.2.5 Commercial Fisheries

Experts generally agreed that offshore wind farms create a conflict with commercial fishing, although there were disagreements over the magnitude and mitigation for this risk. Representatives of commercial fisheries expressed concerns that insufficient research has been conducted to satisfy uncertainties surrounding cumulative impacts and potential for radar interference. Commercial fishermen tend to stress that offshore wind farms may exclude them from their historical fishing grounds due to an inability to fish within the wind turbine arrays, and that offshore wind farms could force fishermen to navigate greater distances to route around the wind farm and access their fishing grounds. It was noted that fishing with fixed gear (e.g., pots) within offshore wind farms should not pose significant challenges and that commercial fishing (both with fixed and mobile gear) has successfully continued within offshore wind farms in the UK and Denmark. However, commercial fisheries representatives argued that it can be difficult to use the European experience to predict the effects of offshore wind farms on U.S. fisheries due to variations in fish species and the size and geographic expanse of fishing vessels.

The offshore wind industry stressed that several mitigation strategies are available to allow fishermen to fish (both with fixed and mobile gear) within offshore wind farms, such as adopting greater cable burial depths. Representatives of the offshore wind industry stated that factors such as seabed mobility influence whether the risk of cable fouling can be sufficiently reduced by increasing cable burial depth or whether concrete mattresses must be employed (which may pose a snagging risk to mobile fishing gear). Wind developers stressed that they have agreed, in a number of cases, to alter the layout of U.S. wind turbine arrays to accommodate historical fishing patterns (an accommodation that has not, according to the expert discussions, been commonly afforded in European wind farms). This often involves arranging the turbines in straight rows with adequate spacing between rows to allow for "fishing corridors" where fishing vessels can tow mobile gear and continue to transit and fish. However, fishermen disagree on the appropriate width of such lanes, a topic that was explored during workshops hosted by the Responsible Offshore Development Alliance (RODA) in 2018 (RODA, 2018).

Wind developers expressed that commercial fishing communities have been extensively canvassed for their concerns and input on issues, such as which cardinal direction the fishing corridors should be oriented to accommodate historical fishing tow patterns. However, commercial fisheries representatives noted disagreement from fishermen about the quality of outreach from offshore wind developers, including the level of appropriate context provided during the information gathering process and the willingness of developers to alter existing plans to accommodate fisheries concerns.

Finally, wind developers commented that a wind turbine layout that results in maximum energy production is often an irregular scattered layout, rather than a regular, grid-like layout; as a result, reconfiguring offshore wind farms to accommodate fishing corridors can cause a significant reduction in the net present value of wind energy installations. Wind developers felt that this fact demonstrated a good-faith effort on their part to compromise with commercial fishermen.

4 CONCLUSION

Based on the literature review and expert discussions conducted for this study, it is clear that there are many areas of general agreement among the literature cited and experts on the potential risks posed to marine vessel navigation by offshore wind farms. There appears to be broad agreement that offshore wind farms pose a risk to marine vessels, especially as vessels navigate around areas of dense traffic near major ports, and vessel traffic is funneled into areas of narrow sea room increasing the risk of collisions. Drifting allisions with WTGs pose a risk as well. Both commercial shipping industry and offshore wind industry representatives stressed the importance of embracing a holistic approach to siting and evaluating offshore wind farms along the U.S. Atlantic coast, and encouraged an assessment of cumulative navigational impacts, rather than viewing offshore wind farms as siloed, individual projects.

There are also areas of key disagreement, including the magnitude of the risk posed to commercial fishing and whether commercial fishermen can safely fish within and transit through offshore wind farms. The offshore wind industry and marine vessel operators disagreed on the magnitude of the risk posed by ship-based radar interference caused by offshore wind turbines and proper setback distances between vessel traffic routes and wind installations. While these disagreements and areas of uncertainty may be resolved with further experience as new offshore wind farms are installed along the U.S. Atlantic coast, the European experience with offshore wind energy suggests that marine vessel navigators have the ability to adapt to offshore wind farms and can safely navigate within and around them.

Ultimately, it appears that BOEM may most effectively fulfill its mission of balancing the needs of OCS users by closely coordinating with the many types of marine vessel operators and offshore wind industry representatives, and by leveraging lessons-learned from the European experience, while acknowledging the unique characteristics of the U.S. Atlantic OCS and marine vessel traffic conditions.

REFERENCES

BOEM. (Undated). Offshore Wind Energy. Retrieved from https://www.boem.gov/Renewable-Energy-Program/Renewable-Energy-Guide/Offshore-Wind-Energy.aspx

Christensen, C. F., Andersen, L. W., & Pedersen, P. H. (2001). Ship Collision Risk for an Offshore Wind Farm. Retrieved from https://dvikan.no/ntnu-studentserver/reports/Ship%20Collision%20Risk%20for%20an%20Offshore%20Wind%20Farm.pdf

Dai, L., Ehlers, S., Rausand, M., & Utne, I. B. (2013). Risk of Collision between Service Vessels and Offshore Wind Turbines *Reliability Engineering & System Safety, 109*, 18-31. doi:https://doi.org/10.1016/j.ress.2012.07.008

de La Vega, D., Matthews, J. C. G., Norin, L., & Angulo, I. (2013). *Mitigation Techniques to Reduce the Impact of Wind Turbines on Radar Services*. Retrieved from https://www.mdpi.com/1996-1073/6/6/2859/htm

Deepwater Wind. (2012). *Navigational Risk Assessment for Block Island Wind Farm and Block Island Transmissions System*. Retrieved from http://www.offshorewindhub.org/sites/default/files/resources/deepwater_9-27-2012_biwfbitserappendixu.pdf

Deepwater Wind South Fork. (2018). *Navigational Safety Risk Assessment*. Retrieved from https://www.boem.gov/Appendix-X/

Det Norske Veritas. (2010). *Interference Between Trawl Gear and Pipelines. Recommended Practice* (DNV-RP-F111). Retrieved from https://rules.dnvgl.com/docs/pdf/DNV/codes/docs/2010-10/RP-F111.pdf

DTI. (2005). *Guidance on the Assessment of the Impact of Offshore Wind Farms: Methodology for Assessing the Marine Navigational Safety Risks of Offshore Wind Farms*. Retrieved from https://webarchive.nationalarchives.gov.uk/+/http:/www.berr.gov.uk—/files/file22888.pdf

EMU. (2012). *Neart na Gaoithe Offshore Wind Farm Environmental Statement. Chapter 17, Shipping and Navigation*. Retrieved from https://nngoffshorewind.com/downloads/offshore-environmental-statement/

ESS Group. (2006a). *Methodology for Assessing Risks to Ship Traffic from Offshore Wind Farms*. Retrieved from https://corporate.vattenfall.se/globalassets/sverige/om-vattenfall/om-oss/var-verksamhet/vindkraft/kriegers-flak/5-kriegers-flak-risk-assessment_11335732.pdf

ESS Group. (2006b). *Revised Navigational Risk Assessment: Cape Wind Project Nantucket Sound. Project No. E159-501.16* Retrieved from https://www.boem.gov/Renewable-Energy-Program/Studies/CWfiles/FinalRevisedRiskNav11-16-06fullreport.aspx

Hooper, T., Hattam, C., & Austen, M. (2017). Recreational use of offshore wind farms: Experiences and opinions of sea anglers in the UK. *Marine Policy, 78*, 55-60.

Kearns & West. (2018). *BOEM's Offshore Wind and Maritime Industry Knowledge Exchange Summary Report*. Retrieved from https://www.boem.gov/BOEM-Maritime-Meeting-Summary/

Ling, H., Hamilton, M. F., Bhalla, R., Brown, W. E., Hay, T. A., Whitelonis, N. J., . . . Naqvi, A. R. (2013). *Final Report DE-EE0005380 Assessment of Offshore Wind Farm Effects on Sea Surface, Subsurface and Airborne Electronic Systems* Retrieved from https://www.energy.gov/sites/prod/files/2013/12/f5/assessment_offshore_wind_effects_on_electronic_systems.pdf

Mattera, F. (2018). *Affidavit Rationale for Commercial Fishing Industries Required East & West Turbine Layout for Wind Energy Areas for Rhode Island and Massachusetts Including Bureau of Ocean Energy Management OCS Lease Sites A-0486, A-0487, A-0500, A-0501*. Retrieved from

NYSERDA. (2017a). *New York State Offshore Wind Master Plan, Cables, Pipelines, and Other Infrastructure*. Retrieved from https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Biomass-Solar-Wind/Master-Plan/17-25f-Cables-Pipelines-and-Other-Infrastructure.pdf

NYSERDA. (2017b). *New York State Offshore Wind Master Plan, Shipping and Navigational Study*. Retrieved from https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Biomass-Solar-Wind/Master-Plan/17-25q-Shipping-and-Navigation.pdf

Oltedal, H. A. (2012). *Ship-Platform Collisions in the North Sea*. Paper presented at the The Annual European Safety and Reliability Conference (ESREL), Helsinki, Finland. https://core.ac.uk/download/pdf/52065219.pdf

Orbicon. (2017). *Horns Rev 3 Offshore Wind Farm Navigational Risk Analysis*. Retrieved from https://ens.dk/sites/ens.dk/files/Vindenergi/nav_risk_analysis_v3_final.pdf

PIANC. (2018). Interaction Between Offshore Wind Farms and Maritime Navigation: MarCom Working Group Report no. 161-2018.

Poseidon Aquatic Resource Management Ltd. (2015). *Fish Resource Access Mapping Project (RAMP) Economic Analysis and Literature Review*. Retrieved from https://www.seafish.org/media/1417509/fishramp_economic_analysis_and_literature_review_2015.pdf

Rawson, A., & Rogers, E. (2015). Assessing the Impacts to Vessel Traffic from Offshore Wind Farms in the Thames Estuary. *Scientific Journals of the Maritime University of Szczecin, 43*(115), 99-107.

RODA. (2018). December 3, 2018 Workshop Documents. Retrieved from https://www.rodafisheries.org/12318-workshop-documents

Scottish Power Renewables. (2018). *Navigational Risk Assessment for Vineyard Wind, Appendix G: ScottishPower Renewables Technical Note*. Retrieved from

Shipping Advisory Board North Sea. (2013). *The Shipping Industry and Marine Spatial Planning - a Professional Approach, Appendix A: Netherlands Summary of the International Regulations and Guidelines for Maritime Spatial Planning Related to Safe Distances to Multiple Offshore Structures (e.g. Wind Farms)*. Retrieved from https://www.nautinst.org/en/forums/msp/

Smythe, T., & Bidwell, D. (2018). Identifying Indicators of Offshore Wind Benefits: Focus Groups.

Stanley, W. (1989). Utilization of Offshore Platforms by Recreational Fishermen and Scuba Divers off the Louisiana Coast. *Bulletin of Marine Science, 44*, 767-776.

UK MCA. (2016). *Offshore Renewable Energy Installations (OREIs) - Guidance on UK Navigational Practice, Safety and Emergency Response*. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/502021/MGN_543.pdf

USCG. (2007). *Navigation and Vessel Inspection Draft Circular: Guidance on The Coast Guard's Roles and Responsibilities for Offshore Renewable Energy Installations (OREI)*. Retrieved from

USCG. (2016). *ACPARS Final Report*. Retrieved from https://www.regulations.gov/document?D=USCG-2011-0351-0144

Vandendriessche, S., Persoon, K., Torreele, E., Reubens, J., & Hostens, K. (2017). *"A wind of change" in recreational fisheries? Recreational fishermen and wind farms: current use and perception*. Paper presented at the North Sea Open Science Conference, Ostend, Belgium. https://www.researchgate.net/publication/321134354_Environmental_impacts_of_offshore_wind_farms_in_the_Belgian_part_of_the_North_Sea_Environmental_impact_monitoring_reloaded

VanderMolen, J., & Nordman, E. P. D. (2014). Wind Farms and Navigation: Potential Impacts for Radar, Air Traffic, and Marine Navigation. *Michigan Sea Grant*.

Vettenfall Wind Power Ltd. (2017). *Thanet Extension Offshore Wind Farm Preliminary Environmental Impact Report, Volume 2, Chapter 9: Commercial Fisheries*. Retrieved from

W.F. Baird & Associates Coastal Engineers. (2019). Vineyard Wind Supplementary Analysis for Navigational Risk Assessment.

Appendix A: Literature Summaries

The following section provides summaries of literature identified for the five categories—existing policy and guidance, navigational risk assessments, collisions and allisions, commercial fisheries, and recreational fisheries and other recreational activities. Each category includes a list of the literature sources with their corresponding page number within this Appendix. Several literature sources cover more than one category and are cross-referenced within the categories.

A.1 Policy and Guidance

Shipping Advisory Board North Sea, 2013. The Shipping Industry and Marine Spatial Planning - A Professional Approach, Appendix A: Netherlands Summary of the International Regulations and Guidelines for Maritime Spatial Planning Related to Safe Distances to Multiple Offshore Structures (e.g. Wind Farms)	
Summary	This publication provides a summary of the major international marine spatial planning regulations prescribing the minimum distance between the border of a maritime route and an area inhabited by multiple fixed objects that can be safely navigated by vessels. These regulations do not apply to shallow water areas with multiple objects, where vessel traffic is impossible. The provisions and regulations were drafted before offshore wind energy facilities existed but serve as a framework for determining a safe distance for maritime travel.
Analysis Methods	The following international vessel navigation and maritime spatial planning guidelines were reviewed to develop the recommendations and guidelines in this document: • GPSR: International Maritime Organization (IMO) Resolution A.572(14) - General Provisions on Ships' Routing, 1985 • UNCLOS: United Nations Convention on the Law of the Sea, 1982 • COLREGS: International Regulations for Preventing Collisions at Sea, 1972, as amended
Issues Addressed	Vessel Movement • COLREGS Rule 8 requires that vessel operators "take action" to avoid collisions with another vessel passing at a safe distance. Applicable provisions were used by the Shipping Advisory Board North Sea to derive equations for calculating safe distances for a ship to perform a full round turn over starboard to comply with COLREGS. The following equations were developed by the Shipping Advisory Board North Sea and endorsed by the Confederation of European Shipmasters' Associations: ▪ Distance between the starboard side of any route and a multi-object area = 0.3 nm + 6 ship lengths + 1,640 ft (500 m). ▪ Distance between the portside of any route and a multi-object area = 6 ship lengths + 1,640 ft (500 m). • According to GPSR 1.1, a Formal Safety Assessment (FSA) must be conducted to select maritime routes based on probabilistic risk assessments in order to improve navigational safety in areas of converging traffic or where the density of traffic is increased by restricted sea room, navigational obstructions, shallow depths, or meteorological conditions. Vessel operators must also perform their own deterministic risk assessments in real-time based on vessel size, main engine status, traffic conditions, and meteorological conditions to comply with COLREGS while navigating these routes. • GPSR 6.4 requires that structures be positioned along maritime routes in a manner that causes as few course alterations as possible and avoids approaches to convergence areas and route junctions that increase traffic volume. • GPSR 6.8 requires that TSS be designed to allow vessels to fully comply with COLREGS at all times. Therefore, a TSS should ensure sufficient distance between vessels and structures to allow the vessel operator to comply with COLREGS while navigating routes. • GPSR 6.10 states that traffic lanes should be designed to optimize the use of safe, navigable areas. These lanes should incorporate maximum water depths available with widths that account for traffic density, availability of sea room, and the lane's general usage. Below are guidelines for determining safe widths for routing measures based on annual traffic. These guidelines were derived from an AIS data study conducted by the Maritime Index of Open Datasets:

Shipping Advisory Board North Sea, 2013. The Shipping Industry and Marine Spatial Planning - A Professional Approach, Appendix A: Netherlands Summary of the International Regulations and Guidelines for Maritime Spatial Planning Related to Safe Distances to Multiple Offshore Structures (e.g. Wind Farms)	
	▪ Routes with less than 4,400 vessels per year should be wide enough to accommodate 2 vessels of the same size side-by-side. ▪ Routes with greater than 4,400 vessels but less than 18,000 vessels per year should be wide enough to accommodate 3 vessels of the same size side-by-side. ▪ Routes with more than 18,000 vessels per year should be wide enough to accommodate 4 vessels of the same size side-by-side. ▪ Each vessel should be given 2 ship lengths of room. • UNCLOS Article 60 describes the rights of coastal nations to authorize and regulate the construction, use, and operation of installations and structures for the purposes described in Article 56 (includes the production of wind energy). Article 60 imbues nations with the authority to establish reasonable safety zones around artificial offshore facilities and platforms to ensure the safety of both vessel navigation and the wind farm itself. • The state may determine the size of the safety zone, accounting for applicable international standards. Safety zones may not exceed a perimeter of 1,640 ft (500 m) (measured from each of the outer points), unless otherwise authorized or recommended by the competent international organization. The 1,640 ft (500 m) zone is intended for the protection of offshore wind structures and should not be used as guidelines for safe navigation in compliance with COLREGS. • Offshore wind facilities and their associated safety zones may not be established in areas that would interfere with the use of recognized sea lanes for international navigation. The room required to avoid interference is not stipulated in the COLREGS. However, shipbuilding guidelines for the maximum room required to perform full round turns provide a basis for determining a minimum distance. All vessels must adhere to these safety zones and comply with applicable international standards governing navigation in the vicinity of offshore wind facilities. • COLREGS Rules 10h and 10j state that vessels not using a TSS must avoid them by as wide a margin as possible, fishing vessels must not impede the passage of vessels following a TSS, and vessels with a length shorter than 66 ft (20 m) must not impede the passage of a power-driven vessel traveling in a TSS. Fishing vessels and recreational ships primarily travel in the area next to a traffic lane. Communications (Electronic Navigation, Communication Systems) • COLREGS 7c states that navigational assumptions must not be made on the basis of limited communications information (especially radar information). Wind farms can cause interference with ship-based radar that impairs the ability of ships to properly detect other vessels in the area and determine a closest point of approach (CPA). Moreover, the risk of collision must not be determined by a CPA derived from AIS data since the speed input is GPS-based and not sufficiently accurate. Deep sea pilots have determined that the distance for safely avoiding radar interference from wind farms is 0.8 nm.

United Kingdom (UK MCA) Maritime and Coastguard Agency (UK MCA), 2016. Safety of Navigation: Offshore Renewable Energy Installations (OREIs) - Guidance on UK Navigational Practice, Safety and Emergency Response	
Summary	This guidance was developed by the UK MCA to inform the design of offshore renewable energy installations (OREI), including wind farms, that minimizes risks to navigation, and best practices for navigating nearby and within offshore wind farms. This policy is heavily cited in navigational risk assessments for planned U.S. offshore wind farms (e.g., within Construction and Operations Plans [COPs]) and influenced the guidelines developed by the USCG in the ACPARS.
Analysis Methods	The guidelines were developed by navigational experts at the UK MCA.
Issues Addressed	OREI developers should evaluate the impacts of projects and follow the guidelines through the following phases of development: Planning, Construction, Operation, and Decommissioning. Considerations on Site Position, Structures and Safety Zones • A current vessel traffic survey should be conducted characterizing vessel types in the project area with a duration of at least 28 days. Traffic survey should take into account season variation in traffic and should not consist of only AIS data. • Air clearance of wind turbines should be at least 72 ft (22 m) but great enough to accommodate vessels found in the traffic survey. • It should be determined at what depth export cables are buried so that charted depths are not changed. If cable burial is not possible, then the cable should be protected by rocks or other suitable mattress placements. MCA will accept up to a 5% reduction in charted water depth to protect export cables. • It should be determined whether navigation within or near the OREI is feasible by assessing the following: ▪ Types of vessels that can safely operate within or near the OREI. ▪ Types of activities, weather conditions, or specified directions that are compatible with safe navigation within or near the OREI. ▪ Exclusion from the site can cause safety or routing problems for vessels. Navigation, Collision Avoidance, and Communications • Assess whether safe vessel operation in the project area is affected by tides, tidal streams, and weather and the extent to which this could interact with an OREI. • Wind turbine platforms should be aligned in multiple rows or columns to minimize risks to surface vessels and search and rescue (SAR) helicopters transiting through the OREI. • Adjacent wind farms should allow safe passage of surface vessels or SAR helicopters continuously through both sites. • Consider whether OREIs block the view of other vessels in the area or the coastline. • OREI can potentially interfere with radio, radar, sonar, can produce acoustic noise, and export cables can generate electromagnetic fields that can affect compasses and other navigation systems. • Consider how the site should be marked with lights, other electronic means such as Radio

United Kingdom (UK MCA) Maritime and Coastguard Agency (UK MCA), 2016. Safety of Navigation: Offshore Renewable Energy Installations (OREIs) - Guidance on UK Navigational Practice, Safety and Emergency Response

Beacons, AIS, transmitters, or audible hazard warnings.

- Template for assessing distances between OREI boundaries and shipping routes.
- The Electricity (Offshore Generating Stations) (Safety Zones) (Application Procedures and Control of Access) Regulations 2007 allows for offshore wind developers to apply for 1,640 ft (500 m) safety zones around wind turbines during construction, extension, maintenance, and decommissioning, and 164 ft (50 m) safety zones during operations. Applications for these safety zones must be sent by the developer to the Department of Energy and Climate Change, or other licensing authority.
- Navigation corridor widths between OREIs must be determined on a case-by-case basis and are calculated based on the assumption that vessel tracks can deviate as much as 20°.
- Where OREIs are located on either side of a navigational route, the width of the route should be calculated based on a potential 20° course deviation. The assessment of required route width should also take into account the following:
    - Whether the route is in a general sea passage location or near a harbor or river mouth (vessel crews will be more prepared to maneuver in areas of constrained operation).
    - Size and maneuvering abilities of the vessels expected to transit the route.
    - Standard turning radius of vessels, which should be based on six times the vessel's length.
    - Requirements for stopping in an emergency.
    - PIANC study suggests a 2 nm buffer between wind farms and shipping lanes.
    - Four ships should be able to safely pass each other traveling the same direction.
    - When a vessel overtakes another vessel, they should be separated by two ship lengths.
    - Engine failure may necessitate emergency or unplanned anchoring, restricting sea room for other vessels.
    - Heavy seas make navigating difficult and should be considered.
    - Concentration of fishing and leisure vessels can increase the risk of vessel to vessel conflict.
    - Displacement of traffic causing mixing of slow recreational traffic with large, faster traffic should be considered.
    - Presence of wind farms can result in false echoes on radar systems, which cause interfere with the identification of other vessels, and can cause radar operators to adjust the equipment, reducing overall target acquisition.
- The following template should be used to assess the tolerability of risk posed by vessel traffic lanes near OREIs:

United Kingdom (UK MCA) Maritime and Coastguard Agency (UK MCA), 2016. Safety of Navigation: Offshore Renewable Energy Installations (OREIs) - Guidance on UK Navigational Practice, Safety and Emergency Response

Distance of OREI boundary from 90% boundary of shipping route	Factors for Consideration	Tolerability
• < 0.5 nm	• X-band radar interference	• Intolerable
• 0.5 nm – 3.5 nm	• Vessel size and maneuverability, distance to parallel boundary of a TSS, s-band radar interferences, effects on automatic radar plotting aids, compliance with COLREGS	• Tolerable if risk is "as low as reasonably practicable"
• >3.5 nm	• Minimum separation distance between turbines opposite sides of a route	• Broadly acceptable

- The following mitigation measure should be implemented by OREIs during construction, operation, and decommissioning:
  - OREI developers should promulgate information and warning through notices to mariners and other means.
  - Wind farms should maintain continuous watch via very high frequency (VHF) radio, so vessel operators may communicate with the wind farm operators.
  - Safety zones of appropriate size and configuration should be established.
  - ATON should be established as appropriate.
  - Routing measures within or near the OREI should be implemented.
  - OREI should be monitored by AIS, closed circuit television, or other means.
  - OREI operators should have the means to notify vessels that infringe upon safety zones.
  - Use of guard vessels should be used as-appropriate.

<table>
<tr><th colspan="2">U.S. Coast Guard (USCG), 2016. Atlantic Coast Port Access Route Study (ACPARS) Final Report</th></tr>
<tr><td>Summary</td><td>This study was conducted by the USCG to address potential safety and navigational risk associated with the development of offshore wind installations on the Atlantic coast. This final report from 2016 was preceded by an interim report published by USCG in 2012.</td></tr>
<tr><td>Analysis Methods</td><td>ACPARS guidelines were determined by the ACPARS Workgroup, which was co-chaired by the USCG Deputy Commander, Atlantic Area and the USCG Director, Marine Transportation Systems as well as waterways management specialists from USCG Headquarters, USCG Atlantic Area, and USCG Districts One, Five and Seven, and at times other personnel from supporting offices throughout the USCG, NOAA, and the Maritime Administration.</td></tr>
<tr><td>Issues Addressed</td><td>Risk of Collision/Allision (Safe Navigation)

• Development of offshore wind installations pose a threat to navigation by increasing the risk of allisions and funneling existing vessel traffic into a smaller navigational area. While the AIS data collected demonstrate relative density of vessel traffic, it does not show how frequently vessels pass within close range of each other. This additional information could demonstrate the risk of collisions between vessels due to funneling.

• If coastwise routes are rerouted farther from shore, small vessels will be placed at a higher risk of weather-related incidents and higher sea states, and will be comingled with larger, deep draft vessels (increasing risk of collision).

• Workgroup adopted Marine Planning Guidelines which can be used during all planning phases for Wind Energy Areas (WEAs) to ensure risk to navigation remains within acceptable limits.

• Slower-moving tug and barge vessels are particularly challenged by offshore wind farms (OWF) that can either force their traffic routes farther out to sea, where they are subject to higher sea states and conflict with larger, faster vessels, or further toward shore where they face more dense traffic (e.g., at harbor entrances) and therefore complex crossing situations. Tug and barge vessels must remain in waters deep enough for the catenary to clear the bottom when towing astern.

• Deep draft vessel routes are currently less of a concern because they exist at distances farther from shore than currently-planned OWFs. However, as wind farm technology advances and begins to move farther offshore, conflicts with deep draft vessel routes may arise.

• Studying cumulative impacts of OWFs was beyond the scope of this study, however; studying cumulative impacts in a quantitative manner will be critical to reducing risk to vessel traffic.

• Establishing a routing system for the entire Atlantic coast was outside of scope for this study. While routing measures can improve predictability and organization, they can also introduce new risks by mixing previously segregated traffic and increasing traffic density in bottlenecks.

• USCG developed a methodology for classifying navigational risk into three categories, displayed as red, yellow, or green on maps. USCG refers to this as the Red Yellow Green ("R – Y – G") methodology:
  ▪ Red – these areas are not recommended for wind farms.</td></tr>
</table>

	U.S. Coast Guard (USCG), 2016. Atlantic Coast Port Access Route Study (ACPARS) Final Report
	▪ Yellow – further study is needed to determine if these areas are suitable for wind farms due to navigational risk. ▪ Green – these areas are recommended for wind farms due to low navigational risk. Port Approaches and TSS • 2 nm buffer between outer boundary of TSS and wind farm. • 5 nm buffer around entry/exit of TSS (increased buffer needed to enable vessels to detect each other visually and via radar around TSS entry/exit to avoid collisions). • Coastal shipping routes. ▪ Provide inshore corridors for coastal ships and tug/barge operations. ▪ Avoid displacing vessels farther offshore or in a way that results in mixing of vessel types. • Consider cumulative impacts of multiple wind farms. • Offshore deep draft routes considerations: ▪ Deep draft vessels have more flexibility in location of routes. ▪ Avoid creating an obstruction on both sides of a route. • Navigational safety corridors ▪ Areas where wind farm development should not be considered because they are necessary for safe navigation. Navigational Safety Corridors • In determining appropriate size of navigational safety corridors, the following should be considered: ▪ Cross-track error, which is a function of vessel characteristics and sea state. ▪ Closest point of approach, which can be as little as 0.5 to 2 nm in favorable conditions but can be 2 nm under less favorable sea states or higher vessel speeds. ▪ The corridor should allow for passage of 2 ships abeam in low density, offshore conditions and up to 3 ships abeam in higher density conditions. ▪ Other site-specific conditions including: ▪ High density areas with converging or crossing traffic. ▪ Obstructions or hazards on opposite side of route from wind farm. ▪ Severe weather/sea state. ▪ Severe currents. ▪ Mixing of vessel types (e.g., large and small vessels). ▪ Complexity of vessel interactions (e.g., fishing, recreational vessels, pilot boarding). ▪ Length of obstruction along route (i.e., size of wind farm). ▪ Routing measure of insufficient size for traffic.

U.S. Coast Guard (USCG), 2016. Atlantic Coast Port Access Route Study (ACPARS) Final Report	
	Mitigating Factors • Potential mitigating factors include: ▪ Various ATON, vessel traffic services, limited access areas, and routing measures. ▪ Low traffic density. ▪ Smaller vessels. ▪ Large distances to ports, shoals, and other obstruction (i.e., greater sea space). ▪ Other critical routes. ▪ Natural deep-water approaches that may be needed for certain vessels. ▪ Unique transits with increased sea space or draft.

<table>
<tr><th colspan="2">U.S. Coast Guard, 2007. Navigation and Vessel Inspection Draft Circular (NVIC): Guidance on The Coast Guard's Roles and Responsibilities for Offshore Renewable Energy Installations (OREI)</th></tr>
<tr><td>Summary</td><td>This NVIC describes the USCG's process and major evaluation factors for reviewing applications to build and operate OREIs, including navigation safety, traditional uses of waterways, and USCG mission. The circular details the roles and responsibilities of the USCG, lead agencies, and developers in the OREI application process; USCG serves as a subject matter expert identifying potential impacts to maritime safety, security, national defense, and protection of natural resources. The NVIC provides guidance on conducting and reviewing Navigation Safety Risk Assessments (NSRA). This guidance includes information checklists an applicant should consider and provide to USCG during the application process, including an OREI's potential impacts on vessel navigation and safety, facility characteristics, waterway characteristics, maritime traffic and vessel characteristics, USCG mission considerations, and example risk mitigation strategies.</td></tr>
<tr><td>Analysis Methods</td><td>The circular was developed with guidance from the following references and resources:
• Memorandum of Understanding between the Minerals Management Service (MMS), U.S. Department of the Interior and USCG, U.S. Department of Homeland Security, September 30, 2004
• Cooperating Agency Agreement between MMS and USCG for Programmatic Environmental Impact Statements (EIS), USCG e-mail acceptance submitted July 7, 2006
• The Ports and Waterways Safety Act (PWSA) of 1972 (Public Law 92-340, 86 Stat. 424)
• Coast Guard and Maritime Transportation Act of 2006 (Public Law 109-241)
• NVIC No. 9-02, Ch-I, Guidelines for Development of Area Maritime Security Committees and Area Maritime Security Plans for U.S. Ports, COMDTPUB P16700.I
• Risk-Based Decision-Making (RBDM), COMDTINST M16010.3 (series), and Risk-Based Decision-Making Guidelines, 3rd Edition
▪ USCG Ports and Waterways Safety Assessment (PAWSA) Guide</td></tr>
<tr><td>Issues Addressed</td><td>Vessel Movement
• The proposed location for the construction and operation of an OREI has the potential to physically affect traditional uses of a waterway, such as commercial shipping, fishing, and recreational boating.
• Navigation safety could be impaired if vessels must deviate from normal routes, or recreational ships begin entering shipping routes, to avoid OREIs. These scenarios could lead to an increased risk of collision and a reduction in water depth or sea room for safe maneuvering.
Risk of Collision/Allision (Safe Navigation)
• OREIs have the potential to impact navigation safety by impairing a mariner's ability to determine their position, identify a safe steering course, be alert to unseen dangers, detect whether a collision risk exists, and react to avoid collision.
• The structures of OREIs could block the view of the coastline, other vessels transiting a route, or features used for navigation such as landmarks, promontories, and ATON. The structures of OREIs can also limit the ability of a vessel operator to maneuver to avoid collision.
Communications (Electronic Navigation, Communication Systems)
• An OREI could potentially impact the performance of maritime electronic navigation systems, including radar and communications systems.
• OREI structures could produce reflections, blind spots, shadow areas, or other effects that impact the following radar systems:
▪ Vessel-to-vessel
▪ Vessel-to-shore
▪ Vessel Traffic Service radar-to-vessel</td></tr>
</table>

	U.S. Coast Guard, 2007. Navigation and Vessel Inspection Draft Circular (NVIC): Guidance on The Coast Guard's Roles and Responsibilities for Offshore Renewable Energy Installations (OREI)
	▪ Radio Beacons-to/from-vessel ▪ Aircraft and Air Traffic Control • Fishing, industrial, or military systems could potentially be impacted by sonar interference caused by the structures and generators of an OREI. • OREIs could potentially produce acoustic noise, noise absorption, or reflections that could either mask or interfere with ATON or sound signals of nearby vessels. • Electromagnetic fields caused by the structures, generators, and seabed cabling of an OREI may impact compasses and other navigation systems. • The noise and power created by an OREI (above or below water) could pose physical risks to the health of vessel operators and crews. **Mitigation Strategies** • Information and warnings should be distributed through notices to mariners and other means of communication. • USCG may decide to designate an OREI site as an area to be avoided, implement safety zones, or employ routing measures within or near an OREI. • The structures of an OREI should be monitored by radar, AIS, closed-circuit television, or multi-channel very high frequency (VHF) radio, including Digital Selective Calling. • Minimum distances of OREI structures from shipping routes should be determined prior to construction.

	World Association for Waterborne Transport Infrastructure (PIANC), 2018. Interaction Between Offshore Wind Farms and Maritime Navigation: MarCom Working Group Report no. 161-2018
Summary	This publication provides recommendations for assessing the required maneuvering space for ships in the vicinity of OWFs and the minimum recommended distance between shipping lanes and sea areas for a minimal risk to navigation.
Analysis Methods	A working group of experts was established to develop the guidelines using the following methods: • Reviewed existing practices with regard to navigating around offshore wind farms by consulting with stakeholders. • Considered various uses of sea room. • Reviewed recent developments in design tools such as risk assessments and modeling techniques to assess appropriate maneuvering space and minimal safe setback distances from OWFs.

Issues Addressed	Vessel Movement
	• Undertaking an FSA is recommended by the IMO, but not required. Vessel operators will make their own risk assessment when passing structures along a route. If the applicable routing measures take vessels too close, operators will shift to one side of the routing measure, which then causes the density of traffic to increase at that side.
	• When determining new routes, the FSA would inform safe distances to structures along that route using rules and regulations operators would follow.
	• Traffic lanes should be designed to make optimum use of available depths of water and safe navigable areas (1) account for the maximum depth of water; and (2) width of lanes account for traffic density, general use of area, and sea-room available.
	• Recommend traffic surveys that include all vessel types found in the area and cover at least one year of information to account for seasonal variations in traffic patterns for the study area. AIS records are useful to establish these patterns.
	• Comparison of bathymetry and navigation area descriptions make it possible to identify the interaction areas that should be analyzed.
	Risk of Collision/Allision (Safe Navigation)
	• In the event of an accident, in the aftermath, the impacted vessels may drift, and non-impacted vessels will maneuver to avoid the accident. Both drifting and evasion tactics are unanticipated and very vulnerable to meteorological and ocean conditions.
	• Hazard identification tools found to be most effective are Hazard Identification and Structured What-If Techniques meetings where stakeholders identify new hazards and authenticate existing hazards and their risk control measures.
	• Minimum distance between shipping route and wind farm can be determined as follows:
	  ▪ Starboard: 0.3 nm + 6 ship lengths + 1,640 ft (500 m) (i.e., for a ship 1,312 ft [400 m] in length = minimum distance of almost 2 nm).
	  ▪ Port: 6 ship lengths + 1,640 ft (500 m).

World Association for Waterborne Transport Infrastructure (PIANC), 2018. Interaction Between Offshore Wind Farms and Maritime Navigation: MarCom Working Group Report no. 161-2018	
	ATON • A range of telecommunications installations—radio and television masts, mobile phone base stations or emergency service radio masts—are at a similar height to offshore wind turbines. Take care to ensure that wind turbines do not passively interfere with these facilities by directly obstructing, reflecting or refracting the radio frequency electromagnetic radiation signals from these facilities. The problem at sea is sensitive because there are many radio communications and radio navigation systems dedicated to safety at sea and are both terrestrial and satellite-based radio communications systems. • Radar operators should be consulted and decide the risk of disruption based on (1) security issues (national airspace monitoring, etc.); (2) radio, land, and aviation restricted area; (3) constraints related to air and sea traffic; and (4) forecasting of weather disasters. • Reviews different types and purposes of radar to make distance recommendations for each.

A.2 Navigational Risk Assessment

- (de La Vega, Matthews, Norin, & Angulo, 2013) Mitigation Techniques to Reduce the Impact of Wind Turbines on Radar Services. https://www.mdpi.com/1996-1073/6/6/2859/htm – summary on page A-16
- (Deepwater Wind, 2012) Navigational Risk Assessment for Block Island Wind Farm and Block Island Transmissions System. http://www.offshorewindhub.org/sites/default/files/resources/deepwater_9-27-2012_biwfbitserappendixu.pdf – summary on page A-17
- (Deepwater Wind South Fork, 2018) Navigational Safety Risk Assessment. https://www.boem.gov/Appendix-X/ – summary on page A-19
- (DTI, 2005) Guidance on the Assessment of the Impact of Offshore Wind Farms: Methodology for Assessing the Marine Navigational Safety Risks of Offshore Wind Farms. https://webarchive.nationalarchives.gov.uk/+/http:/www.berr.gov.uk—/files/file22888.pdf – summary on page A-21
- (EMU, 2012) Neart na Gaoithe Offshore Wind Farm Environmental Statement. Chapter 17, Shipping and Navigation. https://nngoffshorewind.com/downloads/offshore-environmental-statement/ – summary on page A-22
- (ESS Group, 2006b) Revised Navigational Risk Assessment: Cape Wind Project Nantucket Sound. Project No. E159-501.16. https://www.boem.gov/Renewable-Energy-Program/Studies/CWfiles/FinalRevisedRiskNav11-16-06fullreport.aspx – summary on page A-24
- (Kearns & West, 2018) BOEM's Offshore Wind and Maritime Industry Knowledge Exchange Summary Report. https://www.boem.gov/BOEM-Maritime-Meeting-Summary/ – summary on page A-26
- (Ling et al., 2013) Final Report DE-EE0005380 Assessment of Offshore Wind Farm Effects on Sea Surface, Subsurface and Airborne Electronic Systems. https://www.energy.gov/sites/prod/files/2013/12/f5/assessment_offshore_wind_effects_on_electronic_systems.pdf – summary on page A-29
- (NYSERDA, 2017a) New York State Offshore Wind Master Plan, Cables, Pipelines, and Other Infrastructure. https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Biomass-Solar-Wind/Master-Plan/17-25f-Cables-Pipelines-and-Other-Infrastructure.pdf – summary on page A-31
- (NYSERDA, 2017b) New York State Offshore Wind Master Plan, Shipping and Navigational Study. https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Biomass-Solar-Wind/Master-Plan/17-25q-Shipping-and-Navigation.pdf – summary on page A-33
- (Rawson & Rogers, 2015) Assessing the Impacts to Vessel Traffic from Offshore Wind Farms in the Thames Estuary. https://www.infona.pl/resource/bwmeta1.element.baztech-d8b3c5a6-e9e4-444c-bf1f-6ba9e3ab1e2e – summary on page A-35

- (Scottish Power Renewables, 2018) Navigational Risk Assessment for Vineyard Wind, Appendix G: ScottishPower Renewables Technical Note. https://www.boem.gov/webteam/Vineyard%20Wind/Vineyard-Wind-COP-Appendix-III-I-Nav-Risk-Assessment.pdf – summary on page A-37
- (VanderMolen & Nordman, 2014) Wind Farms and Navigation: Potential Impacts for Radar, Air Traffic, and Marine Navigation. http://www.miseagrant.umich.edu/wp-content/blogs.dir/1/files/2012/05/Wind-Brief-9-Navigation.pdf – summary on page A-39
- (W.F. Baird & Associates Coastal Engineers, 2019) Vineyard Wind: Supplementary Analysis for Navigational Risk Assessment. – summary on page A-41

Other Sources that also Address Navigational Risk Assessment

- (UK MCA, 2016) [See page A-4]
- (USCG, 2016) [See page A-7]
- (USCG, 2007) [See, page A-10]

	de la Vega et al., 2013. Mitigation Techniques to Reduce the Impact of Wind Turbines on Radar Services
Summary	This journal article describes the potential effects of wind farms on different radar systems, including Air Surveillance Radars, weather radars, and marine radars. The article also provides an overview of the results of recent research (at the time the article was published) on mitigation techniques that can be applied to the wind turbine design or signal processing and filtering in the receiver.
Analysis Methods	The article was developed by performing a literature review of recent studies (conducted around the time the article was published) aimed at characterizing the signals scattered by wind turbines, determining the impacts of these reflected signals on radar detection, and developing mitigation techniques to minimize these impacts.
Issues Addressed	Communications (Electronic Navigation, Communication Systems) • Since marine radars at the time of this study did not include Doppler processing, echoes from wind turbines were the primary cause of marine radar interference from offshore wind farms. • Wind turbines present high radar cross section values, which create strong echoes that can merge with the echoes of small ships passing close to the wind turbines. This echo merging can cause vessels to be invisible to other radar observers or automatic plotting facilities. The magnitude of this echo merging effect is based on the radar beam's incident angle to the wind turbine. • Practical trials have shown that it is possible for experienced vessel operators to navigate safely in and around offshore wind farms and identify other ships despite radar interference from wind turbines. Mitigation Strategies • Mitigation strategies such as gap-fillers are not feasible for ship-borne radars since the systems are mobile. • The relatively low complexity and cost of marine radar systems makes the adoption of advanced signal processing techniques impractical and unlikely. • Altering the layout of offshore wind farms could potentially reduce their impacts on radar systems, including increasing the spacing between wind turbines in such a way that they become individually resolvable, helping targets within the offshore wind farm become detectable by radar systems.

<table>
<tr><th colspan="2">Deepwater Wind, 2012. Navigational Risk Assessment for Block Island Wind Farm and Block Island Transmissions System</th></tr>
<tr><td>Summary</td><td>This publication is an appendix to the Block Island Wind Farm COP. The Block Island Wind Farm is the first offshore wind installation in the U.S. and consists of five bottom-founded turbines located in state waters off the coast of Block Island, RI.</td></tr>
<tr><td>Analysis Methods</td><td>Vessel Navigation and Marine Practices Consultation:

Captain Sean Morrisey, licensed U.S. Master Mariner the Assistant Director of Maritime Security for C&H Global Security, and a principal author of the Navigational Risk Assessment
Captain Alex Soukhanov, a licensed U.S. Master Mariner, Senior Manager of Marine Transportation Programs with the Global Maritime and Transportation School at the U.S. Merchant Marine Academy
Captain Paul Costabile, Executive Director of the Northeast Marine Pilots Association

Consultation with the following State and Federal Organizations:

Rhode Island Fisheries Advisory Board
Naval Seafloor Cable Protection Office

Consultation with the following Environmental Organizations:

The Nature Conservancy
National Wildlife Federation
Conservation Law Foundation

Traffic Survey:

A survey of vessel traffic was conducted using telephone interviews and surveys, the 2010 Rhode Island Ocean Special Area Management Plan, USCG AIS data, and web-based research.
Effects on safe navigation

Construction and Operations phases

Disruption of normal traffic patterns.
Lighting and markings on turbines (i.e., ATON).

Risk of collision and allision

Effects on electronic navigation and communication systems: communication systems, radar, GPS, light signals, electromagnetic interference, and noise and sonar interference.
Effects on USCG SAR operations.
Marine environmental protection and response.
Mitigation strategies.
The U.S. Army Corps of Engineers was the lead agency on this assessment.
</td></tr>
</table>

	Deepwater Wind, 2012. Navigational Risk Assessment for Block Island Wind Farm and Block Island Transmissions System
Issues Addressed	Impact of Wind Farm and Transmission System Construction Phase • Increased vessel traffic during construction will not cause a significant increased risk to other vessel operations. • Cable laying for the transmissions system will occur within the TSS, and this risk can be mitigated with enhanced lookouts and communications. • Construction may impact planned marine recreational events (such as races) and coordination with event sponsors will mitigate these risks. • Noise caused by pile driving during construction poses a health risk to construction crews. Impact of Wind Farm and Transmission System Operations Phase • Lighting and markings on the wind turbines provide additional ATON. • Turbines will cause minor interference with light and sound signals from a nearby lighthouse on Block Island, but this will be mitigated by the lighting and markings on the turbines. Turbines will not result in significant interference with radar or communications, largely due to its small size with only five turbines. • USCG helicopter SAR operations could be limited in the area around the wind turbines. The turbines will have a 24-hour command center that can trigger an emergency shut-down of the turbines to mitigate impacts on SAR helicopters. • Turbines may impact planned marine recreational events (such as races) and coordination with event sponsors will mitigate these risks. • In-air and underwater noise generated by the wind farm will not impact vessels, ATON, or interfere with sonar.

<table>
<tr><th colspan="2">Deepwater Wind South Fork, LLC, 2018. Navigational Safety Risk Assessment</th></tr>
<tr><td>Summary</td><td>The Deepwater Wind South Fork (DWSF) Navigational Safety Risk Assessment was performed in accordance with USCG NVIC 02-07 and as part of the wind farm's COP.</td></tr>
<tr><td>Analysis Methods</td><td>Effects of tides and currents were characterized using sources of existing data (e.g., NOAA and computer modeling).
Computer modeling based on sea surface temperatures was used to simulate wind and weather in the project area. Data on past hurricane tracks was also used.
AIS data was used to collect information on vessel traffic and vessel characteristics; the Northeastern Ocean Data Portal was used to fill any gaps in the AIS data.
A combination of AIS and Vessel Monitoring Systems (VMS) data were used to map commercial fishing vessel traffic.
The risk of collision, allision, and grounding was assessed by collecting information on the historical risks in the area and modeling future risks after construction of the wind farm. Both the current state and future state assessments were modeled using the Marine Accident Risk Calculation System computer model.</td></tr>
<tr><td>Issues Addressed</td><td>Risk of Collision/Allision (Safe Navigation)
No major risks to navigation were identified, in part due to the fact that the wind farm is over 4 nm distance from any major high-vessel density deep draft commercial shipping lanes, about 15 nm from the closest land mass (Block Island), and about 19 nm from the mainland.
Based on MGN-543, the wind farm is classified as "broadly acceptable" because of its distance from major shipping lanes.
Based on modeling of the current and future state (after the wind farm is constructed) of navigational risk, it was found that the wind farm is expected to cause an increase of 0.4% of marine incidents (including collision, grounding, and allision) in the study area.
The wind farm is not anticipated to have any impact on USCG missions.
Mitigation Strategies
The following potential mitigation measure can further reduce the risks posted to navigation by the wind farm:
Most turbines within the wind farm are separated by at least 0.65 nm.
The grid-like layout of the wind turbines presents less risk to navigation than a staggered layout.
DWSF met with local fishing group to seek stakeholder input and excluded certain fishing grounds from the design of the wind farm.
DWSF will communicate with mariners regularly during construction to make mariners aware of construction activities.
DWSF will use safety zones during construction.
DWSF will define weather constraints under which construction activities will be suspended.</td></tr>
</table>

	▪ DWSF will install AIS technology on maintenance and crew vessels during operations. ▪ DWSF will implement all required lighting and marking schemes. ▪ DWSF will have a 24-hour operation monitoring center that can monitor wind farm operations and remotely shut down wind turbines if needed. ▪ All wind farm components, including turbines, the electric service platform, and cable will be marked on NOAA nautical charts.

<table>
<tr><th colspan="2">Department of Trade and Industry (DTI) (UK MCA), 2005. Guidance on the Assessment of the Impact of Offshore Wind Farms: Methodology for Assessing the Marine Navigational Safety Risks of Offshore Wind Farms</th></tr>
<tr><td>Summary</td><td>This publication provides guidance to developers of offshore wind farms on how to assess risk and identify risk controls. The prescribed risk assessment methodology produces an assessment proportionate to the scale of development and magnitude of the risks and estimates the best-case level of risk and predicts the future case level of risk.</td></tr>
<tr><td>Analysis Methods</td><td>Vessel Navigation and Marine Practices Consultation:
• DTI, with close cooperation with developers, government, agencies, stakeholders, British Maritime Technology Renewables, Ltd., and UK MCA
• Produced in cooperation with the Department of Transportation</td></tr>
<tr><td>Issues Addressed</td><td>Proportionality
• Scope and depth of the risk assessment should be proportionate to the scale of the development and the magnitude of risk.
• High risk or large-scale development would require a comprehensive hazard log, a detailed and quantified Navigational Risk Assessment, a preliminary SAR assessment/overview, and a comprehensive risk control log.
• Low risk or small-scale development would require a hazard list, a qualitative navigation risk assessment based on “expert judgement,” a SAR overview, an emergency response overview, and a risk control list.
Hazardous and Polluting Substances Spills
• A preliminary assessment would determine the likelihood of incidents occurring based on the general navigation risk assessment and types of vessels found in the area.
Risk of Collision/Allision (Safe Navigation)
• Wind farms should co-exist safely with other users: future risk should be assessed with a minimum increase to the baseline level of risk during construction, operation, and decommissioning.
• The UK, European Union (Vandendriessche et al.), and international bodies have not set any specific target for navigational safety in national or international waters.
• No target has been set for the allowable change to navigation safety caused by the development of wind farms.
• The overarching principle used in the UK is based on the UK HSE document, “Reducing Risks Protecting People,” which includes a decision-making process aimed at determining and reducing risks.
• Aim to reduce risks to the classification “as low as reasonably practical.”</td></tr>
</table>

	EMU, 2012. Neart na Gaoithe Offshore Wind Farm Environmental Statement. Chapter 17, Shipping and Navigation
Summary	This publication is a chapter in an Environmental Statement for an OWF in Scotland. Chapter 17 summarizes the Navigational Risk Assessment.
Analysis Methods	Vessel Navigation and Marine Practices Consultation: • JJ Kichner, KSEAS • ESS Group, Inc. Methodology: • Conducted a qualitative assessment of navigational risks. • Used recreational sailing data, maritime incidents, fishing sightings/surveillance data and shipping survey data recorded in the area to identify the navigational baseline activity relative the Neart na Gaoithe OWF.
Issues Addressed	Vessel Movement • Tugs in the area of the OWF can travel at approximately 13 knots, emergency response tugs can respond to a drifting or ship collision incident at the OWF within 2 hours. • A number of incidents involving recreational vessels in the area (i.e., machinery failure and adverse weather reports) involved vessels from Scandinavia that had sailed off-course. Rochdale Envelope • The Rochdale envelope method was used to develop two indicative layouts (A: 3.6-Megawatt [MW] and B: 6-MW) with layout A using the most turbines and layout B using the largest turbines. • By using the Rochdale envelope, the maximum number of turbines and offshore stations in layouts A and B, the maximum design scenario assessment of possible impacts to shipping and navigation were evaluated. Risk of Collision/Allision (Safe Navigation) • In the analysis conclusions, impacts to routing were considered minor as medium sized vessels are likely to pass within 1 nm of the OWF; there is sufficient sea room for vessels to deviate from current routes to lower use navigable routes. This route may vary slightly. • The baseline vessel-to-vessel collision level (pre-development) is 1 major collision every 1,020 years; the model showed a 5% increase to 1 major collision every 970 years. • 1,640 ft (500 m) safety zones would be applied around each turbine and construction vessel during the construction phase. These safety zones would be applied on a rolling basis, covering only the areas where construction activities are occurring at any given time. • Industry standard mitigation measures are listed in the table below. Fisheries (Commercial) • The majority of fishing activity (mainly demersal trawlers and scallop diggers) were recorded approximately 1 nm to 8 nm southwest of the site. • Based on the relatively high density of fishing activity, during the operations phase, the

EMU, 2012. Neart na Gaoithe Offshore Wind Farm Environmental Statement. Chapter 17, Shipping and Navigation

worst-case risk for a fishing vessel to collide with an OWF structure is identified as of moderate significance: once every 57 years.

Cables

- During construction, cable-laying vessels within the export corridor can pose additional risks. This is due to increased vessel activity and because cable laying vessels are restricted in maneuverability, leading to a potential increase in close vessel encounters (i.e., <1 nm).

Type of mitigation	Mitigation	Explanatory notes
Industry Standard	Marked on Admiralty charts	Neart na Gaoithe will be charted by the UKHO using the magenta turbine tower chart symbol found in publication 'NP 5011 - Symbols and Abbreviations used in Admiralty Charts'. Submarine cables associated with Neart na Gaoithe will also be charted on the appropriate scale charts. Export cables will be charted by the UK Hydrographic Office on the appropriate scale charts and potential to note no anchorage areas over charted cables.
Industry Standard	Information circulation	Appropriate liaison to ensure information on the wind farm, export cable and special activities is circulated in NtMs, Navigation Information Broadcasts and other appropriate media.
Industry Standard	Marking and lighting	Neart na Gaoithe structures to be marked and lit in line with NLB and IALA (O-139) guidance. As per IALA, any lighting required for aeronautical purposes is to be shielded / arranged such that it is not visible to shipping. For further details and indicative lighting/marking see Appendix 17.1: Neart na Gaoithe Offshore Wind Farm - Navigation Risk Assessment.
Industry Standard	Turbine air draught	Lowest point of rotor sweep at least 22 m above MHWS as per the MCA recommendation.
Industry Standard	Cable protection (inter-array and export)	Cables will be protected appropriately taking into account fishing and anchoring practices. Positions of the cable routes notified to Kingfisher Information Services-Cable Awareness (KIS-CA) for inclusion in cable awareness charts and plotters for the fishing industry.
Industry Standard	Compliance with MGN 371 including Annex 5	Annex 5 specifies 'Standards and procedures for generator shutdown and other operational requirements in the event of a SAR, counter pollution or salvage incident in or around an OREI.'
Industry Standard	Formulation of an Emergency Response Co-operation Plan as per MCA template	Creation of an ERCoP based on the MCA template and site Safety Management Systems (SMS), in consultation with the MCA.
Best Practice	Marine Control Centre	A Marine Control Centre will monitor vessel activity (AIS and non-AIS) by Closed Circuit Television (CCTV) and record the movements of ships around Neart na Gaoithe as well as infield (company) vessels working at the wind farm. Possible errant vessels identified in construction areas or safety zones will be identified and contacted.
Best Practice	Subsea surveys of cables and burial depths	Periodic and planned surveys of cable routes to monitor burial depths/protection and seabed mobility (cable movement).
Best Practice	Safety zones and guard vessels	Construction safety zones of 500 m around major activities to exclude vessels not associated with the works from the offshore site. Guard vessels can be used to monitor passing traffic and contact vessels which could infringe the safety zones.

<table>
<tr><th colspan="2">ESS Group, 2006. Revised Navigational Risk Assessment: Cape Wind Project Nantucket Sound. Project No. E159-501.16</th></tr>
<tr><td>Summary</td><td>This publication is an appendix to the Cape Wind Final Environmental Impact Statement. The Cape Wind project consists of 130 General Electric 3.6-MW WTGs located in Nantucket Sound, Massachusetts.</td></tr>
<tr><td>Analysis Methods</td><td>Methodology:
• Conducted a qualitative assessment of navigational risks. The USCG requested usage and impact probabilities be characterized rather than calculated. American Petroleum Institute methods were used during modeling.
Traffic Survey:
• January 2004 USCG Waterway Analysis and Management System survey, AIS data, and web-based research.</td></tr>
<tr><td>Issues Addressed</td><td>Vessel Movement
• The largest impediment to vessel movement would occur during the construction phase. Traffic would be restricted in the areas immediately surrounding construction activities.
• Outside of construction timing, the wind farm is open to unrestricted navigational access and has no exclusionary zones.
• The grid pattern for Cape Wind has a minimum 0.34 nm by 0.54 nm spacing between WTGs, which is noted as wider than the widths of existing channels in the Nantucket Sound areas routinely used by commercial vessels.
• During times of restricted visibility (i.e., nighttime or inclement weather), although the presence of the WTGs provides additional ATON, mariners would need to maintain watch and vessel control to avoid collisions with a WTG or another vessel. The area chosen for the wind farm is bound on one side by a shoal surrounded by shallower waters, which naturally impedes large vessel use and could restrict use of the area by recreational mariners and fishermen during inclement weather. One area noted for deep water where commercial fishermen typically use mobile gear was removed from consideration for WTG placement.
Vessel Anchoring
• All cables to be buried a minimum of 6 feet (ft) deep. This would restrict only the largest vessels from anchoring, which are naturally restricted from the Wind Park by shallow water depths. As is standard practice while anchoring near any structure, mariners would take into account positioning near WTGs; desired anchor scope, wind, wave, and tidal current conditions; potential for anchor drag; and the boat's swing radius.
Risk of Collision/Allision (Safe Navigation)
• COLREGS provides specific guidance on safe vessel operation and collision avoidance. Assuming these rules are implemented by mariners, the potential for ship-to-ship collision inside the Wind Park is low.
• Greatest risk for collisions is during the construction phase when vessels are moored at the WTG. If a vessel is drifting or cruising toward a WTG directly under the blade, it takes 1 to 2 minutes for the rotor to come to a complete stop.
• Potential impact intensity from the largest potential vessel in the Wind Park on a WTG. Modeling was undertaken and determined if drifting and/or cruising vessels of the size and</td></tr>
</table>

	ESS Group, 2006. Revised Navigational Risk Assessment: Cape Wind Project Nantucket Sound. Project No. E159-501.16
	nature of vessels typical to the area would not result in the collapse of a WTG after impact. Seabed Conditions • Area of influence from a single pile was 87 ft long by 35 ft wide (27 m long by 11 m wide). Sediment transport is limited to this area of influence. Considering the spacing between the WTGs (0.34 nm by 0.54 nm) and the small diameter of the monopiles, the effects of each pile on wave and current conditions would not affect adjacent monopiles; Wind Farm would not act as a pile group. Proposed ATON • All WTGs and cables be marked individually on NOAA navigation charts to serve as ATON for those navigating in and around the shoals. Private ATON would be installed within the Wind Park to add to the existing network of USCG-maintained ATON. Lighting and sound signals would be in place to aid in navigation; lighting would adhere to USCG and Federal Aviation Administration (FAA) guidelines.

<table>
<tr><th colspan="2">Kearns & West, 2018. Bureau of Ocean Energy Management's Offshore Wind and Maritime Industry Knowledge Exchange Summary Report</th></tr>
<tr><td>Summary</td><td>This publication provides a summary of a workshop consisting of presentations, panel discussions, and interactive discussions among subject matter experts from the offshore wind and maritime transportation industries. The topics covered included the design and operation of offshore wind projects, stakeholder responsibilities during the development phase, potential timelines for offshore wind projects in the Atlantic Ocean, and navigational safety concerns for commercial vessel transit in the proximity of offshore wind farms.</td></tr>
<tr><td>Analysis Methods</td><td>Vessel Navigation and Marine Practices Presentations and Panels:
• Sean Kline, Director of Maritime Affairs, Chamber of Shipping of America – Importance of Maritime Commerce
• Brian Vahey, Senior Manager – Atlantic Region, The American Waterways Operators – Tugboat Coastal Navigation Challenges
• George Detweiler, Marine Transportation Specialist, USCG Headquarters and Edward G. LeBlanc, Chief, Waterways Management Division, Coast Guard Sector Southeastern New England - Navigational Risk Assessments and USCG Responsibilities
• Dennis O'Mara, Principal Consultant, DNV Germanischer Lloyd and John Beattie, Director & Principal Risk Analyst, Anatec Ltd. – Lessons Learned from Europe
• John O'Keeffe, Manager, Operations & Maintenance and Marine Affairs, Deepwater Wind
• Hywel Roberts, Lead Environment and Consents Specialist, Ørsted
• Martin Goff, Environment & Permitting Manager, Statoil (now Equinor) Empire Wind – Strategies for Mitigating Offshore Wind Impacts to Navigation
Environmental Concerns Presentations:
• Michelle Morin, Chief, Environment Branch for Renewable Energy, Office of Renewable Energy Programs, BOEM
• Glenn Degnitz, Lead Environmental Protection Specialist, Environmental Compliance Division, Bureau of Safety and Environmental Enforcement (BSEE) – Environmental Review and Compliance of Offshore Wind Energy Projects</td></tr>
<tr><td>Issues Addressed</td><td>Vessel Movement
• Sean Kline recommended choosing a regional approach to planning offshore wind facilities over a state approach to minimize impacts during the analysis stage. Data portals and regional ocean plans should be leveraged for planning purposes. Experience from international projects demonstrates that a regional approach to cumulative effects should be considered, such as increased cumulative risk posed by extreme weather events.
• Kline suggested a 2 nm buffer around WEAs to allow for effective vessel movement. He provided the example that the 1 nm buffer for the New York WEA is too small a distance.
• Brian Vahey described how altering tugboat towing routes to accommodate offshore WEAs will create navigational conflicts since they are designed to account for historic towing routes, cross-track error (deviation between intended and actual track due to environmental forces), closest point of approach, density of vessel traffic, and limitations posed by sea characteristics and water depth. Vahey recommended that tow corridors should be planned 9 nm wide to provide enough space for 3 vessels to pass simultaneously.
• George Detweiler anticipates that USCG will only restrict activities (including fishing and</td></tr>
</table>

Kearns & West, 2018. Bureau of Ocean Energy Management's Offshore Wind and Maritime Industry Knowledge Exchange Summary Report
sailing) in and around offshore wind areas when it is necessary for ensuring navigational safety, protecting life and property at sea, and preserving environmental quality. The necessity of restrictions is determined primarily by the size of the offshore wind facility, turbine spacing, turbines axis', size and type of vessels, contents of vessel cargo, traffic volume, and environmental considerations. • The Port Access Route Study (PARS) process conducted by USCG could be used to justify and determine safety zones, security zones, recommended routes, regulated navigation areas, and other routing measures for offshore wind facilities. • Evolving technology leads to changes in turbine size and spacing between turbines, which in turn alters the potential impacts and mitigation measures of offshore wind energy facilities. • BOEM and USCG need to adopt a holistic, multi-year planning process for OCS space use that is completed in a regional fashion instead of by state. The NSRA should be evaluated to ensure they account for cumulative impacts caused by nearby wind energy leases, such as funneling, increased allision risk, impacts on SAR helicopters, and any planned safety measures. • Submarine cables pose a navigational risk to fishing vessels. Fishermen in the UK can locate these cables using the Kingfisher Database (http://www.kis-orca.eu/map#.XAq6RojwY2x). In the U.S., the Marine Cadastre (https://marinecadastre.gov/data/) contains data provided by the North American Submarine Cable Association (NASCA), with the exception of cable locations within 100 meters of land (which were removed from the dataset at NASCA's request). Cables owned by non-NASCA members can be found in the "NOAA Charted Submarine Cables" dataset in the Marine Cadastre. Risk of Collision/Allision (Safe Navigation) • Placement of fixed structures on the OCS increases the risk of vessel collision (with the new structures or other vessels) by increasing vessel traffic through funneling and reduction of sea space for maneuvering. Rerouting to accommodate offshore wind areas contributes to navigational risk for smaller vessels by increasing the chance of weather-related casualty, decreasing the stability of the vessels in deeper water, and potentially placing them in the path of deep draft vessels traveling at higher velocities. • Only 2 accidents recorded for OWFs in the UK. One was caused by a distracted fishing vessel captain, and the other when a power loss caused the steering to fail on a container ship. • Developers (such as Statoil and Ørsted) have created simulators for illustrating how a wind farm will look to vessel operators. These tools will be used in outreach meetings with maritime industry and fishermen. Communications (Electronic Navigation, Communication Systems) • Developers have found that command centers with VHF radio capabilities can reduce navigational risks when used to notify other vessels of planned activities and locations of vessels supporting construction and operation activities of an offshore wind farm. • Uniform lighting and markings of wind turbines are potential mitigation measures to reduce navigational risks. It was recommended that AIS transponders should be placed on all wind turbines. Fog horns were also suggested as a solution to reduce vessel collisions in recreational areas on a case-by-case basis. All wind turbines and cables will

	Kearns & West, 2018. Bureau of Ocean Energy Management's Offshore Wind and Maritime Industry Knowledge Exchange Summary Report
	be marked on navigation charts by the NOAA. Fisheries (Recreational, Commercial) • More data is needed on actual fishing boat movement (instead of fishing statistics). Gaps in AIS data make it difficult to quantify fishing vessels and assess their navigational risks.

<table>
<tr><th colspan="2">Ling, Hao et al., 2013. Final Report DE-EE0005380 Assessment of Offshore Wind Farm Effects on Sea Surface, Subsurface and Airborne Electronic Systems</th></tr>
<tr><td>Summary</td><td>This report was prepared for the U.S. Department of Energy to characterize the effects of offshore wind farms on several types of radar systems, including ground-based military, aviation, and weather, as well as ship-based navigation.</td></tr>
<tr><td>Analysis Methods</td><td>This report consists of a literature review, expert interviews, and computer modeling to comprehensively review the radar systems that could be impacted by offshore wind farms.</td></tr>
<tr><td>Issues Addressed</td><td>The following systems were identified as those currently used in marine vessel navigation for consideration in this study.
Long Range ATON at 100 KHz (this method has been in steep decline and is being replaced by GPS)
Non-Directional Beacon at 300 KHz
SOS (international distress frequency) at 500 KHz
SOS at 2.2 MHz
AIS/vessel traffic service at 160 MHz
GPS at 1.6 GHz
Marine Radar – S Band
Marine Radar – X Band
The literature review included studies conducted on the interaction of radar systems in the North Hoyle wind farm, UK and Homs Rev wind farm, Denmark. The North Hoyle study found that effects on radar and positioning systems were prominent. Another study found that the Kentish Flats, UK wind farm induced radar clutter that was clearly visible on radar screens. The U.S. studies reviewed focused on the planned Cape Wind farm and showed that wind farm-induced clutter can be modeled on radar screens and resembled the clutter found in the Kentish Flats radar study that was reviewed.
The following techniques can be used to mitigate the impacts of wind farms on radar:
Operational changes can be used such as rerouting vessels farther away from or around wind farms, and operators can be trained to recognize the difference between wind farm clutter and actual targets on radar screens.
Wind farms can be designed with “stealthy” turbines that minimize their radar signature, and wind farm layouts can be altered to minimize clutter seen by radar.
Radar parameters can be optimized to minimize wind farm interference, radar hardware can be upgraded, and advance processing/filtering techniques can be used.
A modeling study was conducted using generic, modeled radar equipment using S band and X band radar, and two different wind farm layouts: the proposed Cape Wind layout and a generic 10 X 10 wind farm layout (see figure below). The resultant plan position indicator display was shown and led to the following conclusions:
The presence of wind farm cluttering can make it difficult to identify and track other vessels operating within the wind farm but should not significantly affect tracking of</td></tr>
</table>

Ling, Hao et al., 2013. Final Report DE-EE0005380 Assessment of Offshore Wind Farm Effects on Sea Surface, Subsurface and Airborne Electronic Systems

vessels outside the wind farm.

- The modeling study did not investigate a scenario where the radar was located within a wind farm.
- The researchers concluded that the model results demonstrate a moderate impact level on navigational radar.

The figure below (copied from the source document) shows the modeled effects of two offshore wind farm layouts on tracking of other vessels via radar. The red arrows indicate the presence of a vessel on the radar screen. Both figures show that the presence of the wind turbines can obscure the radar signature of a vessel within the wind farm.

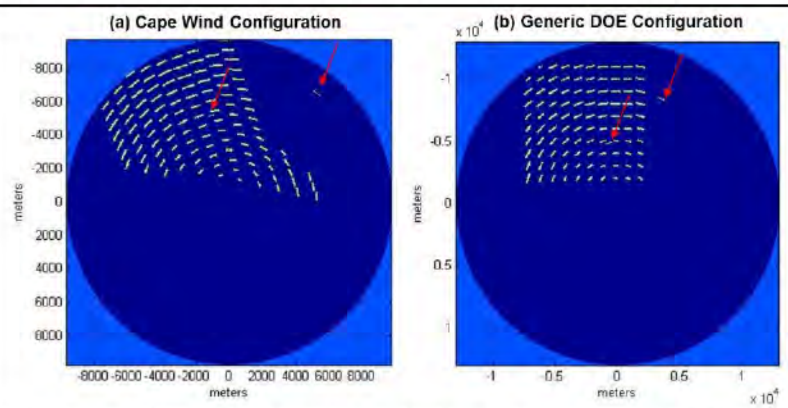


Fig. 4. Simulated PPI displays containing wind turbines and boats as seen on an S-band (3 GHz) marine radar. The red arrows mark the positions of the two boats. (a) The proposed Cape Wind configuration. (b) A generic 10x10 wind farm configuration provided by DOE.

	New York State Energy Research and Development Authority (NYSERDA), 2017a. New York State Offshore Wind Master Plan, Cables, Pipelines, and Other Infrastructure
Summary	This study is one of a collection of studies prepared for NYSERDA in support of the New York State Offshore Wind Master Plan (Master Plan). The purpose of these studies is to inform the identification of WEAs and subsequent federal decision-making related to leasing and developing OWFs in federal waters, as well as to inform state-level decision-making for offshore wind. This specific study provides an overview of the potential existing infrastructure that could affect the development of OWFs, including submarine cables, gas pipelines, buoys, wastewater treatment outfalls, and artificial reefs. The study also describes the risk of potential interactions between submarine cables from OWFs and other users of a WEA, such as fishing and shipping vessels.
Analysis Methods	Developed a geographic information system (GIS) model using data inputs from the Marine Cadastre, North American Submarine Cable Association, and NOAA. Information on other users of the seabed was gathered, analyzed, and mapped with the GIS model to provide a comprehensive overview of the potential infrastructure constraints and risks from existing infrastructure and activities in the Area of Analysis (AoA). This data was collected from a literature review, best practice guidance, applicable regulations, and consultation with other users and existing infrastructure owners and operators.
Issues Addressed	Physical Characteristics of Surrounding Waterways and Navigation • The Master Plan is based on an "offshore study area" identified in the New York State Department of State's 2013 Offshore Atlantic Ocean Study. This area spans 16,740 square miles of the Atlantic Ocean from New York City and Long Island's south shore to oceanic waters beyond the continental shelf break with an approximate maximum depth of 8,202 ft (2,500 m). Unique geographic AoAs were delineated for each individual study from the overall Master Plan offshore study area. Existing Infrastructure • Lessons learned from European projects demonstrate that developers should coordinate early in the planning process with infrastructure owners/operators and other users of an AoA within 1 nm of a proposed OWF to minimize risk of conflicts with pre-existing infrastructure. Developers should also determine site-specific requirements for cable crossings and interactions with existing infrastructure during the planning phase. • According to the USCG, navigation buoys can potentially be moved before or during the construction of OWFs if developers give the USCG sufficient notice and the both entities agree on a plan for the temporary movement and reestablishment of the buoy. Vessel Anchoring • High risk of shipping vessel anchors snagging on submarine cables or cable protection measures when they penetrate the seabed. Therefore, OWFs should be designed to avoid anchorage sites. WEAs should also be situated with sufficient distance from major shipping navigation lanes since anchors that are large and heavy enough to exceed cable burial depth and overcome protective measures may be deployed during emergencies. Most, if not all, array cables should be buried avoiding major shipping lanes. Only export cables buried at significant depths should cross under major shipping lanes. • Recreational vessels may anchor outside of designated anchorage areas. There is little risk of snag with submarine cables or cable protection systems since the anchors of recreational craft are generally not large or heavy enough to penetrate the seabed to the burial depth of array and export cables. Recreational vessel anchors are also usually not of a size to overcome cable protective measures. Developers should perform cable burial risk assessments based on the types of vessels and potential anchor interactions in an

New York State Energy Research and Development Authority (NYSERDA), 2017a. New York State Offshore Wind Master Plan, Cables, Pipelines, and Other Infrastructure	
	AoA to determine the risk of cable snag outside of anchorage areas. Fisheries (Recreational, Commercial) • Seabed fishing activities, such as trawling and scallop dredging, pose a risk to snagging on the array and export cables of offshore wind farms. This contact can damage cables or fishing gear. • Developers should evaluate the types and level of seabed fishing activities while performing burial risk assessments. Local fishermen should be consulted when designing cable protection measures to prevent risk of cable snag, damage to fishing gear, and injury to fishermen. Cables should also be buried at sufficient depths to minimize the likelihood of these harmful interactions. • For this AoA, bottom fishing hotspots are located in the northwestern quadrant with high activity for larger fishing vessels beyond the 197 ft (60 m) depth contour.

<table>
<tr><th colspan="2">New York State Energy Research and Development Authority (NYSERDA), 2017b. New York State Offshore Wind Master Plan, Shipping and Navigational Study</th></tr>
<tr><td>Summary</td><td>This study is one of a collection of studies prepared for NYSERDA in support of the New York State Offshore Wind Master Plan. The purpose of the study is to inform the identification of WEAs and subsequent federal decision-making related to leasing and developing OWFs in federal waters, as well as to inform state-level decision-making for offshore wind.</td></tr>
<tr><td>Analysis Methods</td><td>The following approach was used to assess navigation risk posed by offshore wind:
• AIS data and GIS spatial analysis tools to map vessel traffic in the area of analysis (i.e., New York Bight)
• AIS data to map the most heavily used unofficial vessel traffic routes (i.e., routes not within TSSs).
• Primary navigational risks posed by offshore wind farms, including historical incident data in the study area from the National Transportation Safety Board (NTSB).
• Best practices for minimum set-back distances between navigational routes and OWFs based on the ACPARS, MGN-543, and a review of existing European wind farms.
• Previously-identified areas for offshore wind were modified to accommodate the presence of unofficial vessel traffic lanes.</td></tr>
<tr><td>Issues Addressed</td><td>AIS Vessel Traffic Data
• Developed maps showing vessel traffic density of the following types of vessels: passenger, tug and towing, fishing, cargo, tankers, and other (e.g., military and law enforcement).
• Identified seven main unofficial vessel traffic routes (i.e., outside of TSSs) and found that three routes cross through existing boundaries for potential OWF zones.
Navigational Risks
• Presented a qualitative review of the primary risks posed by OWFs based on a review of other studies. Risks were qualitatively characterized based on the following topics:
  ▪ Use of existing navigational aids and controls (e.g., radar, sonar, radio).
  ▪ Navigation around offshore wind farms (e.g., coastwise navigation of tugs and towing vessels around OWFs).
  ▪ Navigation between OWFs (e.g., TSS route between OWFs).
  ▪ Navigation through OWFs (e.g., small recreational or fishing vessels).
  ▪ Navigation within OWFs (e.g., wind farm maintenance vessels).
• Incidents and accidents recorded around the study area based on NTSB data:
  ▪ From 2004 to 2017, 33 recorded incidents within the study area.
  ▪ Data do not show any locations or areas that are particularly prone to incidents; incidents are spread throughout the study area in an apparently random manner.
  ▪ Most incidents were a result of material failure/malfunction or personnel injury.
  ▪ Only one vessel sinking occurred, a commercial fishing vessel sunk due to heavy seas in 1998.</td></tr>
</table>

	New York State Energy Research and Development Authority (NYSERDA), 2017b. New York State Offshore Wind Master Plan, Shipping and Navigational Study
	▪ Three allision incidents, all of which involved allision of tankers or freighters with the Ambrose navigational light. Two were caused by human error; the third incident was caused by high winds. Recommended Minimum Distances • 2016 USCG ACPARS study proposed OWFs should be at least 2 nm from the outer edge of a TSS and 5 nm from the entry/exit of a TSS. Site-specific mitigations could be used to reduce those distances for certain wind farms. • MGN-543 proposes a less prescriptive approach where a setback of less than 0.5 nm is not acceptable; 0.5 to 3.5 nm is acceptable under certain conditions and if risk is "As Low as Reasonably Practicable;" and greater than 3.5 nm is broadly acceptable. ▪ MGN-543 guidance states that a vessel's track can deviate as much as 20° and can be used to calculate the necessary setback distances given a certain traffic lane length (e.g., passage between two OWFs of length 15 nm would require a width of 5.5 nm). • Distances between shipping lanes and European OWFs were reviewed and the most common distance was approximately 1 nm. Zone Boundary Modifications • Existing boundaries of the zones identified for potential OWFs were modified to accommodate 1 nm setbacks from all TSSs and unofficial, main navigational routes.

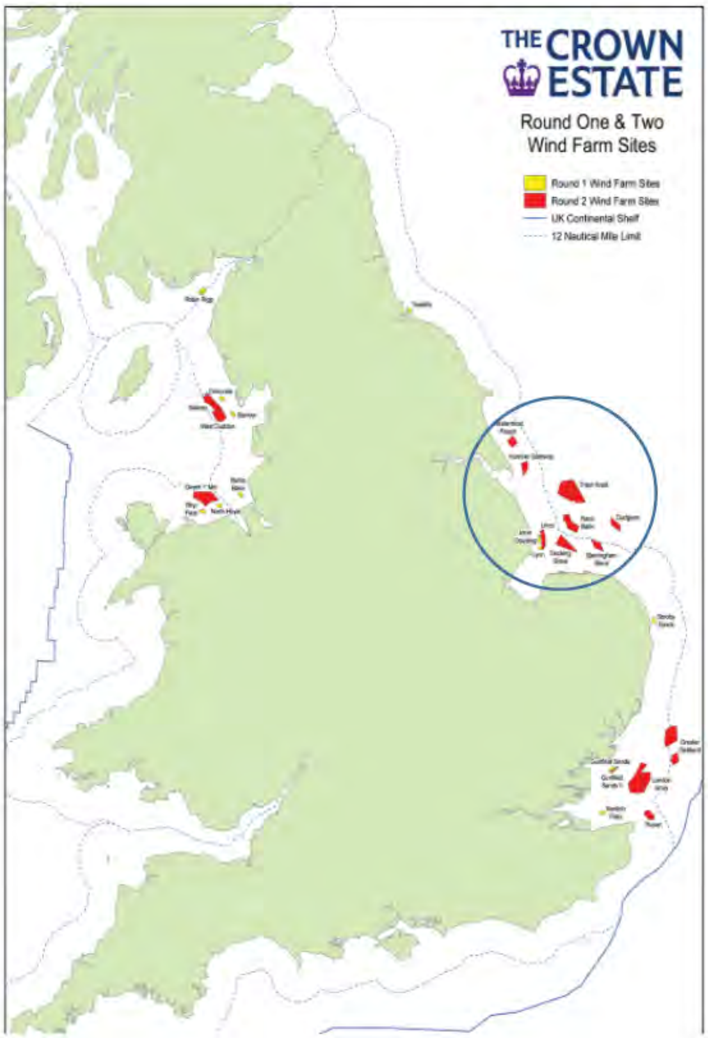
	Rawson, Andrew; Rogers, Edward, 2015. Assessing the Impacts to Vessel Traffic from Offshore Wind Farms in the Thames Estuary
Summary	This publication presents a comparative analysis of the Thames Estuary's vessel traffic before and after the construction of five OWFs. The impact of vessel traffic is specific to the location of each development, procedures in place to manage traffic, and other local constraints. The purpose of this study is to improve predictive modeling of vessel traffic around OWs and other offshore installations.
Analysis Methods	• New projects must undergo an Environmental Impact Assessment similar to the NEPA process (analysis, stakeholder engagement, etc.). • The navigational risk assessment should be distributed among consultees who are invited to comment.
Issues Addressed	Risk of Collision/Allision (Safe Navigation) • The distance should be a comfortable buffer so that if an incident was to occur onboard or another vessel was encountered, there would be sufficient sea room to make an evasive maneuver. • Visually, a wind farm may obscure smaller craft, such as recreational, fishing, or maintenance vessels. • The safety distance may be weighed against other pressures associated with additional distance, fuel, and time requirements. In general, without other constraints, commercial shipping typically follows straight routes between waypoints to reduce transit time and fuel costs. • If an OWF is adjacent to another navigational constraint, or adjacent to another OWF, vessels have reduced room to avoid a collision (choke points). • Distances from turbines have risk classifications (adapted from ACPARS): ▪ 0 to 0.45 nm is intolerable – significant impacts. ▪ 0.45 to 2 nm is tolerable – medium to high risks. 1 nm is the minimum acceptable distance to the boundary of a TSS. ▪ 2 to 3.5 nm is tolerable – low risk. ▪ > 3.5 nm – very low risk. • To better manage the risk of increased vessel traffic, the Sunk TSS established a two-way scheme. This resulted in a significant change in the traffic flow around the wind farm boundary. A 1 nm separation zone created a safety buffer. • Thanet wind farm used cardinal marks to divert traffic around the development. • Other OWFs were sited in areas of low shipping density due to depth constraints. • The use of traffic controls is aimed at offsetting the distance of shipping from the OWFs by 1 nm in all cases. It can be inferred that both the regulators and developers see 1 nm as a safe passage distance from an OWF.

Rawson, Andrew; Rogers, Edward, 2015. Assessing the Impacts to Vessel Traffic from Offshore Wind Farms in the Thames Estuary

- Some vessel traffic near the Thanet wind farm was recorded at 0.5 nm; the crew of some vessels feel that it is a safe distance. Without traffic control measures, a greater understanding of the perceived safety distance by vessels could be ascertained.

Marine Radar

- Reports of reflections, false echoes, and other spurious effects have been seen when navigating near to a wind farm. It is not the wind turbines themselves that create effects; it is more often inadequate radar setup and configuration.



Map source: http://www.portoframsgate.co.uk/exciting-developments/wind-farms/wind-farms-map/

<table>
<tr><th colspan="2">ScottishPower Renewables, 2018. Navigational Risk Assessment for Vineyard Wind, Appendix G: ScottishPower Renewables Technical Note</th></tr>
<tr><td>Summary</td><td>In this technical note, ScottishPower applies European best practices for designing offshore wind farms to evaluate the suitability of the proposed 1 nm navigation safety channel in a northwest-southwest direction through the middle of the Vineyard Winds offshore wind development area (WDA).</td></tr>
<tr><td>Analysis Methods</td><td>AIS Data:
Clarendon Hill Consulting analyzed AIS data from 2016 and 2017 to assess vessel traffic in the Vineyard Winds WDA. Using the unique Maritime Mobile Service Identity of each vessel in AIS, Clarendon Hill gained detailed information on vessel behavior and characteristics.
Minimum Width Calculation based on PIANC Design Guidelines:
ScottishPower applied PIANC's Harbor Approach Channels Design Guidelines to this AIS data to calculate the minimum navigation safety channel width required to accommodate the largest fishing vessel observed in 2017 (traveling under adverse weather conditions).
Minimum Width Calculation based on Vessel Maneuverability:
ScottishPower used guidance from COLREGS to calculate the space required for a vessel to be able to complete a full turn as a basis of estimate for a minimum navigation safety channel width.</td></tr>
<tr><td>Issues Addressed</td><td>Physical Characteristics of Surrounding Waterways and Navigation
Vineyard Wind lease area is located southwest of the Ørsted/Eversource offshore wind farm, approximately 18 nm northwest of the Nantucket-to-Ambrose traffic lane. This area does not pose a potential conflict for commercial vessels traveling towards the Rhode Island TSS.
Vessel Movement
The major focus when designing European OWFs has been ensuring sufficient distance between known traffic routes and wind farms to allow for safe vessel navigation.
Certain countries do not allow vessel navigation through OWFs, while some impose restrictions on the maximum vessel size allowed. For example, Germany only permits the transit of vessels shorter than 78.7 ft (24 m) through OWFs during daylight (under particular weather conditions).
The UK does not impose restrictions on vessels transiting through OWFs but does provide guidance on navigating in proximity to them (MGN-543 and MGN-372).
The PIANC report Interaction Between Offshore Wind Farms and Maritime Navigation provides guidance for safe distances between OWFs and known traffic routes.
Minimum Navigation Safety Channel Width
Using PIANC Design Guidelines, ScottishPower calculated that a navigation safety channel of 241 ft (73.5 m) would be required to accommodate the largest fishing vessel observed in AIS, which had a beam of 49.2 ft (15 m). They also note that the argument could be made that if the vessel was transiting with its outriggers rigged, it would have a theoretical beam of 131.2 ft (40 m) and would require a channel width of 643 ft (196 m).</td></tr>
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	ScottishPower Renewables, 2018. Navigational Risk Assessment for Vineyard Wind, Appendix G: ScottishPower Renewables Technical Note
	• A minimum channel width of 1,181 ft (360 m) would be sufficient according to ScottishPower's COLREGS calculation, which was based on the conservative estimate of 6 ship lengths required for the largest fishing vessel to complete a full turn. • ScottishPower concludes that the proposed navigation safety channel of 1 nm would be sufficient to ensure navigation safety through the Vineyard Winds WDA, as it far exceeds the theoretical width requirements based on their calculations.

	VanderMolen, Jon & Erik Nordman, Ph.D. Michigan Sea Grant, 2014. Wind Farms and Navigation: Potential Impacts for Radar, Air Traffic, and Marine Navigation
Summary	This publication is a brief that examines the navigational challenges associated with wind turbines and the options for mitigating these effects. This includes disruption that turbines may have on radar systems, visual impacts, and effects on recreational activities.
Analysis Methods	This issue brief uses the proposed Cape Wind offshore wind project as a case study to examine impacts to navigation caused by offshore wind farms and potential mitigations for these impacts. The case study was done to inform potential offshore wind farms within the Great Lakes in the state of Michigan.
Issues Addressed	Vessel Movement • For the Cape Wind project, turbines are arranged in parallel rows .52 nm between rows and 0.34 nm between turbines in a row. • In the UK, during construction there is a 1,640.42 ft (500 m) restricted access safety zone. During operations, the zone is reduced to 164.04 ft (50 m). In the Netherlands, Germany, and Belgium, there are no safety zones during operations. • Cables are buried 6 ft (2 m) under sediment. Depth an anchor penetrates sediment depends on the anchor type, weight, and sediment type. A 10,000-pound anchor with a 7.2 ft (2.2 m) fluke would penetrate a sandy bottom to a depth of 4 ft (1.2 m). Communications Systems • The Michigan Wind Energy Resource Zone Board has been using the radar impact screening tool developed by the Department of Defense, restrictions set by FAA, and Department of Homeland Security to identify areas where the construction of wind turbines may impact long-range radar.[4] • Wind farms may be built within a radar impact zone, but steps must be taken to lessen the potential effects on radar. Issues can be addressed by adjusting wind turbine structure and location and modifying radar systems. • New blade technology is being tested at the Hare Hill wind farm, UK. Blades treated with radar absorbing materials were less detectable by the radar systems of nearby airports. This treatment increased the cost of the blades by about 10%. • 80% of long-range radar infrastructure in the interior U.S. was designed in the 1950s with the rest designed in the 1970s. Updating the radar system can reduce wind turbine interference. Improvements include updating software or out-of-date hardware. • Coastal Massachusetts agreed to updated radar to minimize the effects of OWF; Cape Wind developer agreed to pay $1.5 million for system upgrades around the project site. Lighting and ATON • USCG requires turbines have lights mounted on access platforms 35 ft (10.6 m) above the water; FAA lights are placed on top of the turbine tower. Lights should be seen at 4 nm in all directions.

[4] For additional information on the airspace tool, visit: https://oeaaa.faa.gov/oeaaa/external/gisTools/gisAction.jsp?action=showLongRangeRadarToolForm

VanderMolen, Jon & Erik Nordman, Ph.D. Michigan Sea Grant, 2014. Wind Farms and Navigation: Potential Impacts for Radar, Air Traffic, and Marine Navigation	
	• Significant peripheral structures are lighted in a unique way: this applies to turbines at the corners of the wind farm and any key turbines within the perimeter. Distance between these unique lights should be no more than 3 nm.

<table>
<tr><th colspan="2">W.F. Baird & Associates Coastal Engineers, 2019. Vineyard Wind: Supplementary Analysis for Navigational Risk Assessment</th></tr>
<tr><td>Summary</td><td>This publication is a supplement to the navigational risk assessment appendix to the Vineyard Wind COP. The Vineyard Wind project consists of installing 84 WTGs in a grid-like pattern south of Martha's Vineyard, MA. This supplemental differs from the original assessment as it adds quantitative analysis for vessel traffic and operations, safety, and communications.</td></tr>
<tr><td>Analysis Methods</td><td>Further analysis and assessment included the incorporation of VMS:
AIS
VMS data collected by NMFS
Boating survey data</td></tr>
<tr><td>Issues Addressed</td><td>Ship-borne radar systems may be affected by WTGs, creating false targets and cluttering radar displays. The most significant issue for navigating mariners is that other vessels within the wind farm may be "hidden" due to shadowing effects. Mitigation measures include:
Train local radar operators to decipher clutter and strategies to lessening those effects.
Use newer radar systems with pulse technology, target tracking, and AIS integration. AIS is noted as more reliable within the wind farm.
Use radar beacons enhancing reflections within the wind farm.
Equip wind turbines with AIS transponders.
Maneuverability distances are taken from the PIANC, which indicates that 0.9 NM is adequate to support two-way fishing vessel traffic and trawlers within the northwest-southeast corridors of the WTGs.
Wave activity within the Vineyard Wind area leans to a more restrictive maximum air draft (vertical height of vessel). Communications through Notice to Mariners would be the appropriate method to convey this restriction.
Vineyard Wind, through engagement with stakeholder groups including fishermen, committed to:
Use the largest available turbine to reduce the overall number of turbines and wind farm footprint. This eliminated 22 turbines from the proposal.
Orient the turbines in an east-west direction with a 1 NM separation between each row.
Mitigate potential impacts of any commercial fisheries impacted by the orientation, including issuance of Notices to Mariners to advise of restrictions; using directionality in corridors between rows (all gear and trawlers placed along turbines alignments in the same direction); and updating navigational charts to show turbine locations.
Corridors were designed according to the following considerations:
Width sufficient for two-way traffic when transiting or trawling in a straight line.
Width sufficient that vessels are able to safely turn to avoid collisions.
Width sufficient that trawlers are able to turn within a 0.9 NM corridor.</td></tr>
</table>

A.3 Collision and Allision

- (Christensen et al., 2001) Ship Collision Risk for an Offshore Wind Farm. https://dvikan.no/ntnu-studentserver/reports/Ship%20Collision%20Risk%20for%20an%20Offshore%20Wind%20Farm.pdf – summary on page A-43
- (Dai et al., 2013) Risk of Collision between Service Vessels and Offshore Wind Turbines. https://www.sciencedirect.com/science/article/pii/S0951832012001585 – summary on page A-44
- (ESS Group, 2006a) Methodology for Assessing Risks to Ship Traffic from Offshore Wind Farms. https://corporate.vattenfall.se/globalassets/sverige/om-vattenfall/om-oss/var-verksamhet/vindkraft/kriegers-flak/5-kriegers-flak-risk-assessment_11335732.pdf – summary on page A-46
- (Oltedal, 2012) Ship-Platform Collisions in the North Sea. https://core.ac.uk/download/pdf/52065219.pdf – summary on page A-48
- (Orbicon, 2017) Horns Rev 3 Offshore Wind Farm Navigational Risk Analysis. https://ens.dk/sites/ens.dk/files/Vindenergi/nav_risk_analysis_v3_final.pdf – summary on page A-50

Other Sources that also Address Collision and Allision

- (Deepwater Wind South Fork, 2018) [See page A-19]
- (Det Norske Veritas, 2010) [See page A-53]
- (DTI, 2005) [See page A-21]
- (EMU, 2012) [See page A-22]
- (PIANC, 2018) [See page A-12]
- (Rawson & Rogers, 2015) [See page A-35]
- (USCG, 2016) [See page A-7]
- (USCG, 2007) [See page A-10]

<table>
<tr><th colspan="2">Christensen, C.F., Andersen, L.W. & Pedersen P.H., 2001. Ship Collision Risk for an Offshore Wind Farm</th></tr>
<tr><td>Summary</td><td>This report describes the results of a ship collision risk analysis conducted by the Danish power company Sydsjællands Elektricitets Aktieselskab to determine the optimal placement of the planned Rødsand offshore wind farm in Denmark. The report also describes the major collision risks associated with offshore wind farms.</td></tr>
<tr><td>Analysis Methods</td><td>The ship collision risk analysis was conducted considering the following factors:
• Ship traffic, including the number of ships and their geographic distribution;
• Navigational routes based on the main waterways in the vicinity of the proposed wind farm;
• Environmental conditions in the area, including wind, waves, and currents; and
• The bathymetry of the area and the geometry of the wind farm.
Considered the following three collision scenarios:
• Collision caused by human error;
• Collision caused by steering failure; and
• Collision caused by propulsion machinery failure.</td></tr>
<tr><td>Issues Addressed</td><td>Risk of Collision/Allision (Safe Navigation)
• Human error is one of the major risk factors that causes ships to collide with offshore wind structures. This occurs when the ship is pointed in the direction of the structure (on a collision course) and the vessel operator fails to act to prevent the collision due to factors such as navigational error and absenteeism.
• Steering failure is another collision risk factor that causes the rudder to lock and the ship to sail in a circular path until it collides with the offshore wind structure. The diameter of this circular path is determined by the locked rudder position and the under-keel clearance. A full deflection of the locked rudder is the most common outcome of steering failure, according to general experience.
• The failure of propulsion machinery causes the ship to drift and be pushed by the force of the wind and the current. Collision occurs when the wind and current point the ship in the direction of the offshore wind structure. The study assumes that it would take at least 10 hours for the vessel operators of a drifting ship to notify the appropriate authorities and receive towing intervention. This reaction time is important for estimating risk of collision based on drift distance.
• The study's collision frequency model found that propulsion failure was the main cause of ship collision with offshore wind structures. Due to the large distance between the proposed wind farm and the local navigation routes, human error had little effect in causing ship collisions.
• The researchers obtained data on reported vessel accidents in the vicinity of the Rødsand wind farm site between 1990 and 2000 from the Danish Navy. During this 10-year period, 2 groundings were recorded near the proposed wind farm site. This validates the model's estimated collision return frequency of approximately 6 years for the wind farm.</td></tr>
</table>

	Dai, et. al., 2012. Risk of Collision between Service Vessels and Offshore Wind Turbines
Summary	This report describes the collision hazards and major factors influencing collision risk between service vessels and offshore wind farms. It includes example incidents of offshore wind farm collisions and provides statistics on analogous accidents from the offshore oil and gas industry. The report provides a risk assessment framework for service vessel collisions with offshore wind turbines.
Analysis Methods	Researchers created a risk assessment framework for analyzing the contributing factors and magnitude of collision risks between service vessels and offshore wind turbines. The research team performed probability estimations by extrapolating collision data from the offshore oil and gas industry. Collision simulations were conducted by applying this framework to different impact scenarios to identify the force, energy, and vessel speed in each scenario. The results of these simulations were applied to propose potential mitigation measures.
Issues Addressed	Risk of Collision/Allision (Safe Navigation) • Even at slow speeds, service vessel collisions have the potential to damage the structure of offshore wind turbines. Collision damage to offshore wind turbines poses potential risk of crew member injury, expensive production outages, and increased maintenance and repair requirements. This collision risk must be considered early in the design phase of OWFs. • To reduce navigation safety concerns associated with shipping lanes and other maritime traffic, OWFs are being planned and constructed farther offshore. These deepwater areas are more exposed and require larger service vessels to withstand the harsher conditions. The use of larger service vessels enhances collision risk by increasing the potential energy and resultant severity of impact with offshore wind turbines. • Major risk factors that could potentially cause collision between a service vessel and offshore wind turbine include inadequate crew training, procedure violation, and complex equipment. • Major operational activities that may lead to collision between a service vessel and offshore wind turbine include: ▪ Head-on collision when a vessel hits a turbine at a high speed after failing to stop; ▪ Maneuvering collision when a vessel operator misjudges a turn or maneuvering action and hits a turbine at a low speed; and ▪ Drifting collision when a vessel experiences power failure or dynamic positioning system failure and drifts into a turbine from the force of the wind and waves. Previous Offshore Wind Collision Incidents • Very little publicly-available data exists on offshore wind accidents, which makes it challenging to base collision risk analyses on historical data. This lack of data may indicate negligence in recording or disclosing collision incidents related to offshore wind farms. • The Caithness Windfarm Information Forum database provides brief descriptions of offshore wind farm accidents that have been reported in news articles. The research team scoured the database (up to June 30, 2012) and found only 1 incident related to service vessel collision in which a jack-up barge crashed into a wind turbine in the Scroby Sands farm off the coast of Norfolk, UK on October 6, 2006. Collision with the barge broke about 20 centimeters off the tip of the turbine blade and interrupted major maintenance work. • The report provides an example of a near-miss collision incident on September 21, 2003 in which a float dock broke free and almost collided with a wind farm in Lolland, Denmark.

	Dai, et. al., 2012. Risk of Collision between Service Vessels and Offshore Wind Turbines
	The turbines of this wind farm have also incurred damage from service vessel components, including J-tubes and boat landings. Analogous Offshore Oil and Gas Collisions • Statistics regarding collisions between service vessels and offshore oil and gas installations provide a frame of reference for OWFs due to similarities in environmental conditions and operating procedures of visiting vessels. • Between 2001 and 2010, service vessels were responsible for 24 of the 26 reported collisions with offshore oil and gas installations on the Norwegian Continental Shelf. • The UK HSE reports that between 1975 and 2001, 514 of the 557 collision incidents between ships and oil and gas platforms were caused by service vessels. While the majority of these collisions were low-energy and caused minor damage, 5 of the incidents with standby or supply vessels caused severe damage. • According to the Norwegian Petroleum Safety Authority, 6 of the 26 collisions that occurred on the Norwegian Continental Shelf between 2001 and 2011 had extreme damage potential.

<table>
<tr><th></th><th>ESS Group, 2006. Methodology for Assessing Risks to Ship Traffic from Offshore Wind Farms</th></tr>
<tr><td>Summary</td><td>This publication summarizes and evaluates risk assessment methodologies for navigational risk to ship traffic from offshore wind farms. The goal of this publication is to assist in the development of a consistent approach.</td></tr>
<tr><td>Analysis Methods</td><td>Vessel Navigation and Marine Practices Consultation:
• Vattenfall
• Swedish Energy Agency
• Swedish Maritime Safety Inspectorate
• Swedish Maritime Administration
• SSPA Sweden AB
Methodology:
• Literature review on risk assessment, collision risk models, and regulatory guidelines.
• Interviews with international experts.
• Case study analysis to assess and compare collision probability methods.</td></tr>
<tr><td>Issues Addressed</td><td>National Guidelines
• Describes guidelines used or processes followed by 12 countries for permitting related to locations where offshore WEAs were constructed prior to 2007.
Risk of Collision/Allision (Safe Navigation)
• Six collision models have been developed/remodeled for WEAs. Notable graphics detailing distances are below.
• The German risk acceptance criteria include a minimum distance from shipping lanes to a WEA of 2 nm plus 1,640 ft (500 m) (safety zone according to UNCLOS convention article 60). This assumes specific variables – average ship speed, minimum ship size, maximum drift speed of disabled ships, and others.
• In one of the models (Germanischer Lloyd), shipping lanes at a large passage distance are shown to have a bigger contribution to the powered collisions than the shipping lanes which are less than 5 nm from the planned WEA.
• Risk reduction measures: minimizing construction time; marking the WEA as prohibited on all charts and handbooks; equipping radar equipment and antennas with redundant transmission, VHF or radio frequency units; installing navigation lights; declaring safety zones around each WTG; installing at least two AIS transponders; implementing safety manuals and emergency plans; and installing camera and video equipment for observational use.
• Consequence reduction measures: construct WTG in a way that causes as little damage as possible to ships (structural damage is kept low; housing, tower, and rotor blades of WTG fall away from the ship); use fenders and other structural constructs that are collision-friendly; use environmentally friendly coolants for transformers; equip WTGs with fast shutdown and emergency brake; at substation, install helicopter pad and docking locations for tugs and rescue boats; mark WTGs with unique identifiers; implementing safety manuals and emergency plans; and bury cables.</td></tr>
</table>

ESS Group, 2006. Methodology for Assessing Risks to Ship Traffic from Offshore Wind Farms

Table 3.4. Probability of a ship ramming a wind farm (wind farm P12, the Netherlands) (SAFESHIP 2005).

Model used	***The centre line of all traffic lanes is moved with … nm away from the wind farm***			***All standard deviations are multiplied by***			
	0 nm[1)]	***0.5 nm***	***1.0 nm***	***1.00[1)]***	***0.75***	***0.5***	***0.25***
GL	0.1418	0.0481	0.0137	0.1418	0.0542	0.0049	4.3E-08
MARIN	0.0060	0.0024	0.0009	0.0060	0.0040	0.0027	0.0019

[1)] These are the base cases when the centre lines positions and the standard deviations are not changed.

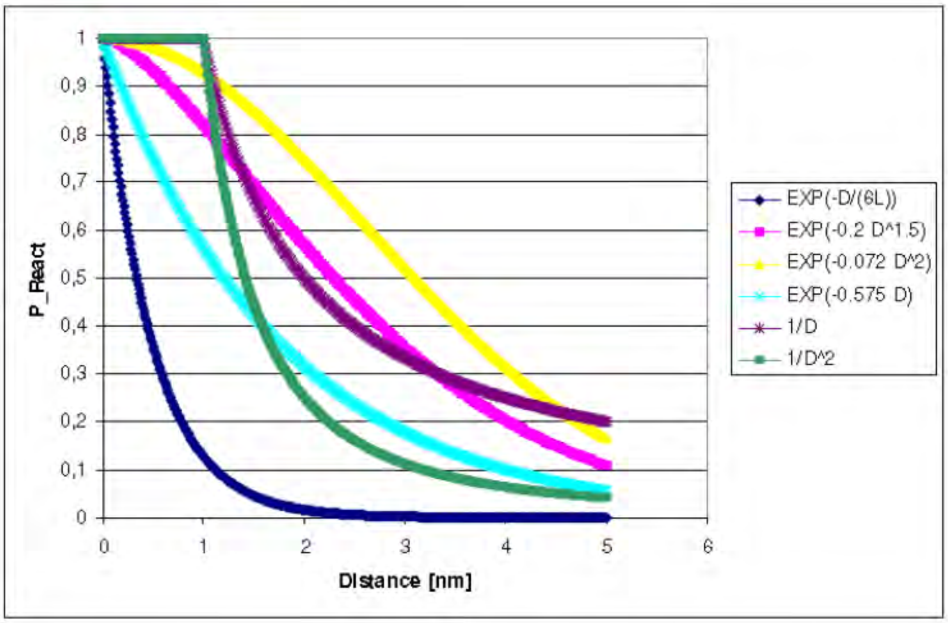


Figure 5.9. Weightings for offshore platforms presented by MARIN (all curves except for exp(-D/(6L))) (van der Tak and Glansdorp (Year unknown)). $P_{react}(x) = \exp(-D/(6L))$, where L = ship length, is suggested in the literature to be used together with the causation factor (Fujii and Mizuki 1998). The ship length (L) is assumed to be 150 m.

Oltedal, Helle A, 2012. Ship-Platform Collisions in the North Sea	
Summary	This academic article describes collisions between vessels and offshore oil and gas platforms on the Norwegian Continental Shelf in the North Sea from 2001 to 2011. The study identified common causal and underlying personal, situational, and organizational factors that lead to collisions. Information on the causes of vessel collisions with oil and gas platforms can inform risk evaluations of vessel collisions with offshore wind platforms.
Analysis Methods	Study conducted a review of existing literature on collision incidents between ships and stationary offshore platforms. The literature review includes six case studies of individual collisions.
Issues Addressed	Risk of Collision/Allision (Safe Navigation) • Between 2001 and 2011 there were 26 collisions between visiting vessels and offshore platforms on the Norwegian Continental Shelf. • Collisions with platforms were divided into two broad categories: powered collisions in which the vessel is using its propulsion system at the time of collision and unpowered collisions in which the vessel has lost power and drifts into a platform. One study assigned the cause collisions into the following categories: misjudgment of vessel captain, weather, equipment failure, problems with anchors or mooring ropes, and other. ▪ The study found that the most common cause of collisions was misjudgment of the vessel captain (46%), and weather was the second most common cause. ▪ A study by the UK HSE found that human error caused 45% of collisions, equipment failure caused 33%, and external factors caused 22%. ▪ A study by the Norwegian PSA found that the most important factors leading to collisions was poor safety culture, poor understanding of training and advanced technical equipment, poor bridge team communications, and vessels not sufficiently warned by installations when approaching due to a lack of notation on navigation charts or proper lighting and warning systems not being implemented. Based on this literature review, the following main categories of causes of ship to platform collisions are as follows: human control failure, mechanical/technical control failure, design failure, external factors, and other. Collision Case Studies • The direct causes of the case study incidents were either unmonitored approach related to inadequate transfer of command or human deficiency in detecting or interpreting a technical state or error. • In two of the case studies, a lack of redundancy was identified as the reason for human error. For example, two navigators are required on the bridge at the same time in offshore shipping, which one navigator checking the tasks of the other to ensure redundancy. In two of the case studies, the second navigator was not checking the work of the first navigator as required. • In all six case studies, human behavior leading to the incident was considered normal operational practice onboard, even though it was outside of the formal safety procedures. The unsafe behavior was not reported in the safety management system because it had become normalized and was therefore not corrected. • To address this drift from normal, safe operations and the normalization of unsafe behavior, shipping safety management systems should strive to identify and understand

	crews' drift from formal guidelines and procedures.

<table>
<tr><th colspan="2">Orbicon, 2017. Horns Rev 3 Offshore Wind Farm Navigational Risk Analysis</th></tr>
<tr><td>Summary</td><td>This study provides an update to the navigational risk assessment for the proposed Horns Rev 3 OWF. This assessment models collision risk based on traffic patterns of vessels passing in the vicinity of an OWF and examines the potential impacts of allowing fishing activities within an OWF.</td></tr>
<tr><td>Analysis Methods</td><td>Methodology

• A mathematical collision probability model was used to estimate the frequency of powered and drifting vessel-turbine collisions during the operation of the Horns Rev 3 OWF. Ship traffic based on AIS data was used to project collision frequency of vessels passing in the vicinity of the OWF. VMS data was used to estimate collision risks of vessels fishing within the OWF.

Traffic Survey

• AIS data from passing ships was analyzed to perform a traffic survey of the amount, distribution, and main routes of traffic in the vicinity of the Horns Rev 3 OWF. Researchers evaluated 2016 AIS data in conjunction with 2012 AIS data from the original Horns Rev 3 environmental impact assessment. The 2016 AIS data included information on all ships greater than 300 gross tons and all vessels longer than 15 m. When the 2012 AIS data was collected, only ships longer than 79 ft (24 m) were required to transmit AIS information. This expanded requirement enhanced AIS data on fishing vessel passages in 2016, since most of the fishing vessels in the vicinity of the OWF were small, local ships.
• 2015 VMS data on the speed, type, and quantity of fishing in the Horns Rev 3 OWF area was used to model the potential collision risks from allowing fishing activities within the OWF. This VMS data was recorded for all fishing vessels longer than 12 m.
• Leisure crafts that were not covered by AIS did not have obtainable vessel traffic data and were not considered.</td></tr>
<tr><td>Issues Addressed</td><td>Physical Characteristics of Surrounding Waterways and Navigation

• The Horns Rev 3 OWF is planned to be constructed north of Horns Rev (Reef) and the existing Horns Rev 2 OWF. This area is located 20 to 30 kilometers (km) northwest of Blåvands Huk, the westernmost point of Denmark. Water depths in this area are between 10 to 21 m. The OWF will consist of 49.8-MW turbines spaced approximately 1 to 1.5 km away from each other. Horns Rev 3 is close to the main traffic route on the west side of Horns Rev and will cause ships to reroute slightly further north to avoid the OWF.

Risk of Collision/Allision (Safe Navigation)

• Based on the collision probability model and associated assumptions, an overall return period of 38 years was calculated for both drifting and powered collisions with the Horns Rev 3 OWF. The biggest contributor to this risk was drifting collisions from the main traffic route west of the OWF. In most instances, the drift direction of a vessel traveling on this route will point toward the turbines. This route is situated close to the OWF, which limits the possibility of repairing a drifting vessel in time to prevent collision. This route also has the highest rate of traffic in the area. The second major contributor to collision risk was powered collisions from vessels traveling around the eastern side of the OWF. These vessels will have to reroute slightly farther north once the OWF is constructed and will likely travel as far south (and as close to the turbines) as possible to minimize this detour.

• Depending on the vessel's collision path and size, a powered or drifting vessel could potentially collide with several turbines. Through a process called shielding, most vessels are stopped by the first collision and only damage a single turbine. However, larger ships are more likely to hit and damage multiple turbines.</td></tr>
</table>

	Orbicon, 2017. Horns Rev 3 Offshore Wind Farm Navigational Risk Analysis
	• During the construction phase, the probability of OWF collisions increases due to the potential for vessel operators overlooking temporary safety markings, partially-constructed turbines not being detected on radar, and vessels navigating the same routes they used to take before OWF construction began. The probability of service ships colliding with other vessels traveling on navigational routes also increases during construction. The probability of powered OWF collisions can be higher during the construction phase than during the operations phase due to the high potential for human error. The probability of drifting OWF collisions is likely to be lower during construction than during operations since the likelihood of collision increases gradually as more turbines are erected, the safety zones established during construction could cause vessels to choose alternate routes, and the increased presence of service vessels (such as tugboats) could help prevent drifting vessels from colliding with turbines when used for intervention. • The probability of OWF collisions is likely to be lower during the decommissioning phase than during construction since ship traffic would have already been altered to accommodate the established OWF by that point and the number of turbines gradually decreases with deconstruction. • Environmental impacts of OWF collision events will vary based on the vessel type. The most severe environmental impacts occur when the collision of an oil tanker or chemical tanker with a turbine causes a leak in the vessel's storage tanks. The probability of an oil or chemical spill can be lessened by design measures such as double hull tanks. A spill of bunker oil can occur upon collision between a turbine and any type of vessel, but bunker protection can lessen the likelihood. Fisheries (Commercial) • According to AIS and VMS data, fishing activities frequently occur in and around the OWF area. It is expected that fishing vessels will be allowed to fish within the OWF with restrictions on vessel size (less than 24 m), number of simultaneous vessels (3 or fewer), and allowable fishing activities. It is also anticipated that fishing will continue in the vicinity of the OWF, with vessel operators maintaining a 656 ft (200 m) distance from the wind turbines. The collision model assumes that this 656 ft (200 m) buffer will only be violated when vessel operators accidentally forget to turn or vessels drift into the OWF after steering or motor failure. • Based on the collision probability model and associated assumptions made, an overall return period of 20 years was calculated for both drifting and powered collisions from fishing vessels within the OWF. However, since there is no experience with collision incidents from fishing activities within an OWF, the calculated collision return period is based heavily on assumptions of potential vessel behavior and carries a high level of uncertainty. • Fishing vessels are unlikely to create enough potential energy to cause a turbine to collapse upon impact since they are usually small and travel at low speeds (less than 5 knots). Fishing vessels are likely to incur severe damage and potential crew mortality upon collision with a turbine. Based on their small size in relation to the turbine, head-on collisions with fishing vessels occur more often than glancing collisions.

A.4 Commercial Fisheries

- (Det Norske Veritas, 2010) Interference Between Trawl Gear and Pipelines. Recommended Practice DNV-RP-F111. https://rules.dnvgl.com/docs/pdf/DNV/codes/docs/2010-10/RP-F111.pdf – summary on page A-53
- (Mattera, 2018) Affidavit Rationale for Commercial Fishing Industries Required East & West Turbine Layout for Wind Energy Areas for Rhode Island and Massachusetts Including Bureau of Ocean Energy Management OCS Lease Sites A-0486, A-0487, A-0500, A-0501. – summary on page A-56
- (Poseidon Aquatic Resource Management Ltd., 2015) Fish Resource Access Mapping Project (RAMP) Economic Analysis and Literature Review. https://www.seafish.org/media/1417509/fishramp_economic_analysis_and_literature_review_2015.pdf - summary on page A-58
- (Vettenfall Wind Power Ltd., 2017) Thanet Extension Offshore Wind Farm Preliminary Environmental Impact Report, Volume 2, Chapter 9: Commercial Fisheries. https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010084/EN010084-000605-6.2.9_TEOW_CommFish.pdf - summary on page A-60

Other Sources that also Address Commercial Fisheries

- (EMU, 2012) [See page A-22]
- (Deepwater Wind, 2012) [See page A-17]
- (Kearns & West, 2018) [See page A-26]
- (NYSERDA, 2017a) [See page A-31]
- (W.F. Baird & Associates Coastal Engineers, 2019) [See page A-41]

Det Norske Veritas, 2010. Interference Between Trawl Gear and Pipelines. Recommended Practice DNV-RP-F111

Summary

This publication contains recommended practices for subsea production systems related to fishing trawl gear and undersea pipelines. The analysis provides load effects on pipelines from trawl gear interference. Similarities in fishing gear interference may be inferred with undersea equipment related to WTGs. Trawl equipment characteristics and frequency must be established. Then, analysis and design with respect to impact, pull-over, and hooking was conducted. The impact energy to be used in testing of coated pipe sections was calculated. The effect of pull-over was found through global analysis and the capacity to resist possible hooking was checked by applying a certain lifting height.

Analysis Methods

- Trawl gear data carried out on North Sea and Norwegian Sea.
- Data for equipment use in 2005 and projected to the near future.
- Testing impact energy based on the qualification impact energy and the test rig efficiency factor.

Issues Addressed

Definitions

- Impact: initial phase where a trawl board, beam shoe, or clump weight hits a pipeline. Lasts hundredths of a second. Local resistance of the pipe shell, including any protective coating and/or attached electric cable protection structure that is mobilized to resist the impact force.
- Pull-over: second phase where the trawl board, beam trawl, or clump weight is pulled over the pipeline. Lasts 1-10 seconds; dependent on water depth, span height, and other factors.
- Hooking: situation where nearby trawl equipment is “stuck” under the pipeline. Seldom occurring accident where forces as large as the breaking strength of the warp line may be applied to the pipeline in extreme cases.
- Diagrams of trawl gear are below:

Typical trawl gears are illustrated in Figures 1-1 to 1-3.

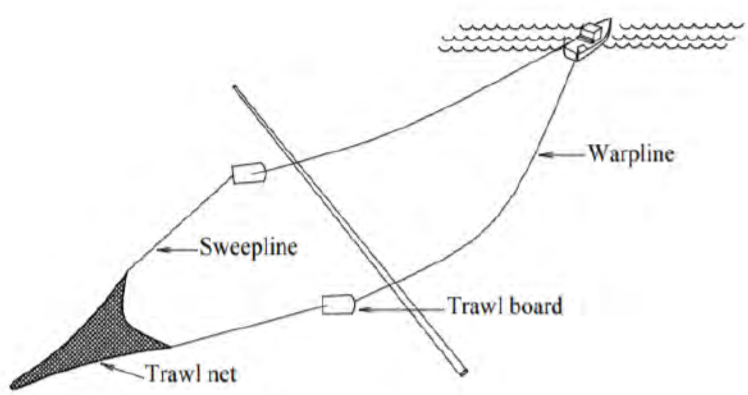


Figure 1-1
Typical otter trawl gear crossing a pipeline

Det Norske Veritas, 2010. Interference Between Trawl Gear and Pipelines. Recommended Practice DNV-RP-F111

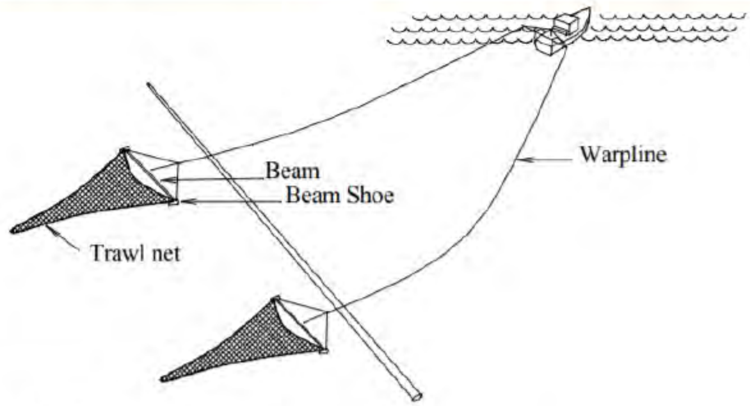


Figure 1-2
Typical beam trawl gear crossing a pipeline

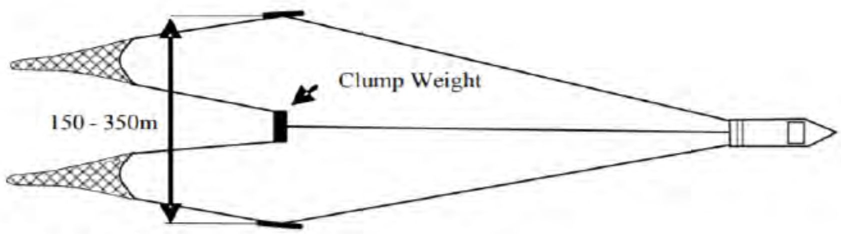
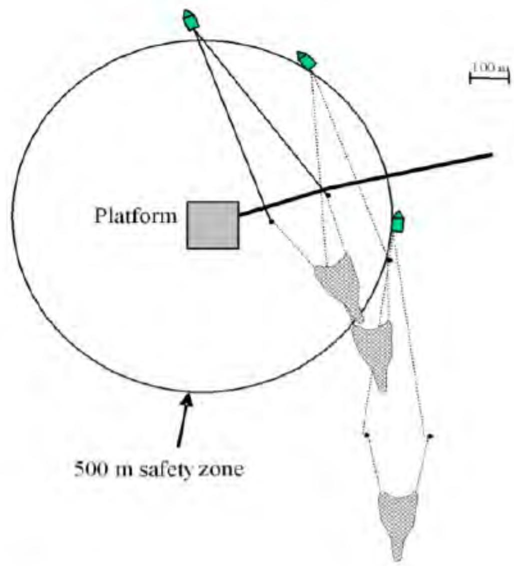


Figure 1-3
Typical twin trawling with clump-weight.

	Det Norske Veritas, 2010. Interference Between Trawl Gear and Pipelines. Recommended Practice DNV-RP-F111
	 **Figure 1-4** **Possible trawl vessel and bottom trawl gear positions when fishing around platform safety zone.** Risk of Collision/Allision (Safe Navigation) • Impact assessment covers: ▪ Calculations of impact energy level the system will absorb. ▪ Calculations of pipe steel wall capacity with respect to specified denting acceptance criterion. • Provides equations for the intensity of impacts, pull-overs, and hooking with pipeline and associated movement, over time, from repeated occurrences. Equations depend on various factors, including dimensions, pipeline materials, coating, and content, water depth and temperature, soil/sand type, and type of trawling equipment.

<table>
<tr><th colspan="2">Mattera, Frederick. 2018. Affidavit Rationale for Commercial Fishing Industries Required East & West Turbine Layout for Wind Energy Areas for Rhode Island and Massachusetts Including Bureau of Ocean Energy Management OCS Lease Sites A-0486, A-0487, A-0500, A-0501</th></tr>
<tr><td>Summary</td><td>This affidavit from Frederick Mattera, Executive Director of the Commercial Fisheries Center of Rhode Island, explains the potential impacts to fixed and mobile gear fishermen operating in WEAs in Rhode Island and Massachusetts BOEM OCS lease sites. Specifically, Mattera describes the wind turbine layout and spacing distance that would minimize navigational challenges and collision risks for fishing vessels and their associated gear.</td></tr>
<tr><td>Analysis Methods</td><td>Mattera prepared this affidavit through consultation and collaboration with leaders from each fixed and mobile gear fishing association within the Commercial Fisheries Center of Rhode Island. These leaders and their affiliation are listed below:
Christopher Brown, President, RI Commercial Fishermen's Association
Greg Mataronas, President, RI Lobstermen's Association
Michael Marchetti, President, Eastern New England Scallop Association
Todd Sutton, President, Ocean State Fishermen's Association
Rick Bellavance, President, RI Party & Charter Boat Association
Donald Fox, Fleet Manager, Town Dock Commercial Fishing Fleet
David Spencer, President, Newport Fishermen's Association</td></tr>
<tr><td>Issues Addressed</td><td>Fisheries (Commercial)
Mobile gear fishing tow routes have followed an East-to-West pattern in the fishing grounds associated with the referenced OCS lease sites since 1996 when a gentleman's agreement was reached between fixed and mobile gear fishermen to reduce navigational risk posed by equipment conflicts. Using the Long Range ATON-C navigation system as a benchmark, fixed gear fishermen agreed to position their gear along the "0's" and "5's" line, while mobile gear fishermen would tow their gear in an East and West direction between these borders.
Mobile gear fishermen use existing East and West tracks to avoid marked “hangs” on the ocean seabed that could potentially damage their equipment, including rocks, planes, debris, and sea wrecks.
Mobile gear fishermen pursue some species (including winter flounder and yellowtail flounder which congregate around seams (bearing lines, depths, or contours of the ocean floor) that naturally follow an East and West pattern in this area.
Insufficient spacing between turbines can force vessels to fish in confined areas increasing the risk of gear or vessel damage, or serious crew injury caused by snagging on another vessel's equipment, or on scour or cable protection measures, or the turbines themselves.
Mitigation Strategies
The affidavit maintains that positioning wind turbines in an East and West layout pattern with a spacing of 1 nm between turbines would reduce navigational and equipment risks for fixed and mobile gear fishermen in the referenced BOEM OCS lease sites.
An East and West turbine layout with 1 nm spacing allows sufficient space for mobile gear fishing vessels to tow or pass side-by-side when avoiding collisions with turbines, scour or cable protection measures, fixed fishing gear, and seabed hangs. This proposed turbine</td></tr>
</table>

Mattera, Frederick. 2018. Affidavit Rationale for Commercial Fishing Industries Required East & West Turbine Layout for Wind Energy Areas for Rhode Island and Massachusetts Including Bureau of Ocean Energy Management OCS Lease Sites A-0486, A-0487, A-0500, A-0501	
	layout would also leave sufficient room for vessels to haul up part of their gear to turn, stop to haul back their gear, and maneuver while pursuing fish marks detected on fish sounders or avoiding vessels towing in opposing directions. • The proposed 1 nm spacing would also allow fixed gear fishermen sufficient space to tow their equipment around the wind turbines, reducing risk of snagging on scour or cable protection measures and the turbines themselves.

<table>
<tr><th colspan="2">Poseidon Aquatic Resource Management Ltd., 2015. Fish Resource Access Mapping Project (RAMP) Economic Analysis and Literature Review</th></tr>
<tr><td>Summary</td><td>As part of a larger study, the Fish RAMP was undertaken by the Agri-Food and Biosciences Institute to review the spatial constraints imposed on commercial fishing by offshore development in Northern Ireland.</td></tr>
<tr><td>Analysis Methods</td><td>The section summarized here, Section 3, is a literature review on the topic of navigational constraints imposed on commercial fishing by offshore wind farms.</td></tr>
<tr><td>Issues Addressed</td><td>Commercial fishing maneuvering within offshore wind farms is constrained by the presence of turbines, platforms, cables, and associated scouring prevention devices such as concrete mattresses which can be placed over cables and at turbine foundations. There may also be spatial constraints imposed by regulatory agencies such as safety zones around turbines where ships may not enter for a period.

These constraints are affected by the spacing of turbines and other platforms; the method of protecting cables (i.e., burying, concrete mattresses, or rock armor); size of fishing vessels; type of fishing gear used; and weather and sea state.

The spacing of the wind turbines determines the amount of sea space available for fishing vessels and gear to maneuver. As offshore wind technology advances, new offshore wind farms are trending toward fewer turbines with higher generation capacity, in contrast to older wind farms with more low-capacity turbines.

Spacing of Wind Turbines
Offshore wind farms are generally arranged in linear columns and rows of turbines. Turbines can have a variety of different foundations including steel jackets, monopiles, and gravity-based foundations, each of which requires a degree of scouring protection such as rock armor or concrete mattresses. These forms of scouring protection, along with the turbine foundation and structure, can entangle commercial fishing gear resulting in regulatory agencies often designating a safety zone around turbines. The report states that consultation with European fisheries representatives cites 1 km (0.54 nm) as a minimum distance between turbines to allow commercial fishing operations within an offshore wind farm.
Arrangement of Subsea Cables
Subsea power cables associated with offshore wind farms include inter-array cables which connect individual turbines and typically a single export cable that transmits power to shore. Where cable burial is not possible, a degree of scour protection must be provided over cables. Mobile fishing gear cannot be deployed over cable scour protection measures such as mattresses because of the risk of entanglement. Inter-array cables that cannot be buried can be designed in a manner to allow a “fishing corridor” between rows of turbines; however, this may not be technically feasible depending on design constraints.
Vessel and Gear Types
Smaller vessels that tend to operate a variety of gear are better-suited to fishing within offshore wind farms. Larger vessels that tend to tow heavy gear are less well-suited due to limited sea space and room for maneuvering. Potters operating long strings of pots (i.e., fixed gear) have an increased risk of entanglement, but can reduce this by deploying shorter strings. Beam trawlers can reduce the weight of their beams to reduce</td></tr>
</table>

Poseidon Aquatic Resource Management Ltd., 2015. Fish Resource Access Mapping Project (RAMP) Economic Analysis and Literature Review

ground penetration reducing risk of entanglement; demersal otter trawlers can reduce their gear spread and avoid twin trawls. Table 3 below (copied from the source document) shows the maximum gear spread for various fishing gear types.

Table 3: Maximum fishing gear spreads (Source: Forewind, 2013)

Gear	Maximum gear spread
Beam trawl	40 m between beam trawl outer shoes
Demersal otter trawl	220 m between otter boards
Industrial sandeel trawl	120 m between otter boards
Seine netting	2.9 km^2 per operation

Table 3-4 below (copied from the source document) shows additional constraints and for various fishing and gear types.

Table 3-4: Summary of potential physical and management constraints of offshore wind farms for various fishing gears

Gear type	Construction	Operation
Trawler	Construction safety zones of 500 m from perimeter of construction works. Potential for up to 1 km advisory precautionary area around entire wind farm boundary. Although, potential for all gears to operate within boundary of site if construction works are being phased and early communication of this is provided by the developer.	Operational safety zones of 500 m around offshore platforms. No safety zones around turbines, although 50 m safe operating distance is expected. 500 m roaming safety zone during major maintenance activities. Resumption of fishing within corridors between turbines, assuming that cabling has been sufficiently buried or is designed to allow for 'fishing corridors'. Dependant on gear spread (twin and pair trawling is unlikely to be possible).
Scalloper		Safety zones as per trawler. Resumption of fishing within corridors between turbines, assuming that cabling has been sufficiently buried to enable dredging or is designed to allow for 'fishing corridors'.
Potter		Safety zones as per trawler. Resumption of fishing dependant on length of pot strings and tidal conditions. Gear conflict may also be an issue due to concentration of activity within 'fishing corridors'.
Netter		Safety zones as per trawler. Drift netting unlikely to be possible. Potential for fixed nets to be set between turbines, dependant on tidal conditions as high risk of entanglement with infrastructure.
Seiner		Safety zones as per trawler. Based on gear spread of up to 2.9km^2, resumption of fishing within a wind farm is unlikely.

	Vettenfall Wind Power Ltd., 2017, Thanet Extension Offshore Wind Farm Preliminary Environmental Impact Report, Volume 2, Chapter 9: Commercial Fisheries
Summary	This document is part of an Environmental Impact Report (EIR) prepared for the Thanet Extension Offshore Wind Farm, UK. Chapter 9 of the EIR focuses on impacts to commercial fisheries. This summary focuses on the maximum design scenario assessed for potential impacts to commercial fishing vessel navigation within the offshore wind farm.
Analysis Methods	The EIR draws on a wide range of data sources and methods including commercial fishing data from the UK, France, Denmark, and the Netherlands from VMS surveillance data, relevant guidance and policies, and stakeholder consultation.
Issues Addressed	The following impacts may affect commercial fishing vessels: • 1,640 ft (500 m) safety zone around construction activities and construction vessels, as well as installed infrastructure such as turbines and platforms. • Maximum of 34 turbines with a minimum spacing of 0.52 nm x 0.77 nm. • Potential increased travel time to fishing grounds if maneuvering around obstructions or safety zones. • Increased construction vessel traffic during construction phase present a navigational risk. • Obstacles can be left on the seabed after the construction phase (e.g., lost equipment for trenching of cables) that can entangle fishing gears. • Potential gear entanglement with export cables and inter-array cables.

A.5 Recreational Fisheries and Other Recreational Activities

- (Hooper et al., 2017) Recreational use of offshore wind farms: Experiences and opinions of sea anglers in the UK. - summary on page A-62
- (Smythe & Bidwell, 2018) Identifying Indicators of Offshore Wind Benefits: Focus Groups. - summary on page A-63
- (Stanley, 1989) Utilization of Offshore Platforms by Recreational Fishermen and Scuba Divers off the Louisiana Coast. https://www.ingentaconnect.com/content/umrsmas/bullmar/1989/00000044/00000002/art00020# - summary on page A-64
- (Vandendriessche et al., 2017) Recreational Fishermen and Wind Farms: Current Use and Perception. - summary on page A-66

Other Sources that also Address Recreational Fisheries and Other Recreational Activities

- (Kearns & West, 2018) [See page A-26]
- (NYSERDA, 2017a) [See page A-31]

	Hooper et al, 2017. Recreational Use of Offshore Wind Farms: Experiences and Opinions of Sea Anglers in the UK
Summary	This is an academic study on the use of OWFs for recreational fishing in the UK.
Analysis Methods	Information on recreational fishing of OWFs in the UK was gathered via an online survey that was distributed to recreational fishing clubs, fishing magazines, and social media. The survey generated 199 usable responses.
Issues Addressed	Fisheries (Recreational) • Average distance traveled offshore for survey respondents fishing in OWFs was 10 nm. • 75% of UK wind farms are located within 10 nm of shore, suggesting that distance from shore is not a barrier to fishing OWFs. • Over 80% of respondents reported that they fish at least sometimes near artificial structure such as ship wrecks or offshore platforms. • About 25% of respondents reported fishing within or around the perimeter of OWFs. • Median distance from an offshore wind turbine during fishing was 328 ft (100 m), and 24% of respondents reported fishing within 82 ft (25 m) of wind turbines. • About 25% of respondents viewed OWFs as having positive effects on recreational fishing, particularly because commercial fishing is excluded from within OWFs. • Survey responses suggest that most recreational fishermen are willing to travel to OWFs and fish within them, and concern about the safety of being near wind turbines is not a major deterrent to potential fishermen. • A sizable minority of survey respondents have already fished OWFs, and those that have not expressed interest in doing so.

	Smythe, Tiffany & Bidwell, David. 2018. Identifying Indicators of Offshore Wind Benefits: Focus Groups
Summary	This study focused on public perceptions of the Block Island wind farm related to boating, tourism, fishing, and other forms of recreational activities. The study was done for BOEM to inform future policymaking around wind farms in the U.S. Because Block Island is the only U.S. wind farm currently in operation, it provided a unique opportunity to study public reaction to offshore wind. This summary focuses on the topic of recreational fishing.
Analysis Methods	The study involved a series of focus groups organized by topic and recorded commonly-raised concerns by participants. The topics included recreational boating and sailing, recreational fishing, charter excursions, and tourism and recreation.
Issues Addressed	The study presents results in the areas of tourism and recreation, recreational boating and sailing, charter excursions, and recreational fishing. This summary focuses on recreational fishing because the other topics are beyond the scope of this literature review. For recreational fishing, focus group perceptions of the Block Island wind farm were mostly positive and focused on the aggregation of fish species around the wind farm, leading to better fishing opportunities. Recreational fishermen stressed that it was important for them to have access to fish around the turbines and expressed positive views of the aesthetics of the wind farm. There were some negative reactions to the wind farm. Some recreational fishermen were concerned about the increased fishing pressure in the wind farm area due to increased recreational fishing. One person who practiced surf fishing had a negative reaction to the wind farm due to its impact on the viewshed. Charter boating and fishing focus group participants commented that the wind farm is much more easily accessed from Block Island ports than from mainland ports. The Block Island wind farm is about 26 nm from the nearest mainland port (Point Judith) and about 5.2 nm from Old Harbor on Block Island. One participant commented that charter boats from the mainland would be prohibitively expensive due to fuel costs, while charter boats from Block Island were popular.

<table>
<tr><th colspan="2">Stanley, Wilson, 1989. Utilization of Offshore Platforms by Recreational Fishermen and Scuba Divers off the Louisiana Coast</th></tr>
<tr><td>Summary</td><td>This academic study gathered information from recreational fishermen and divers using a survey. While the study is somewhat dated, it provides evidence for the distance that recreational fishermen are willing to travel offshore to fish on artificial structures (in this case, offshore oil and gas platforms).</td></tr>
<tr><td>Analysis Methods</td><td>Surveys were distributed to coastal Louisiana recreational fishing and diving groups and to participants in coastal fishing tournaments. The survey was also published in a Louisiana sports fishing magazine.</td></tr>
<tr><td>Issues Addressed</td><td>Fisheries (Recreational)

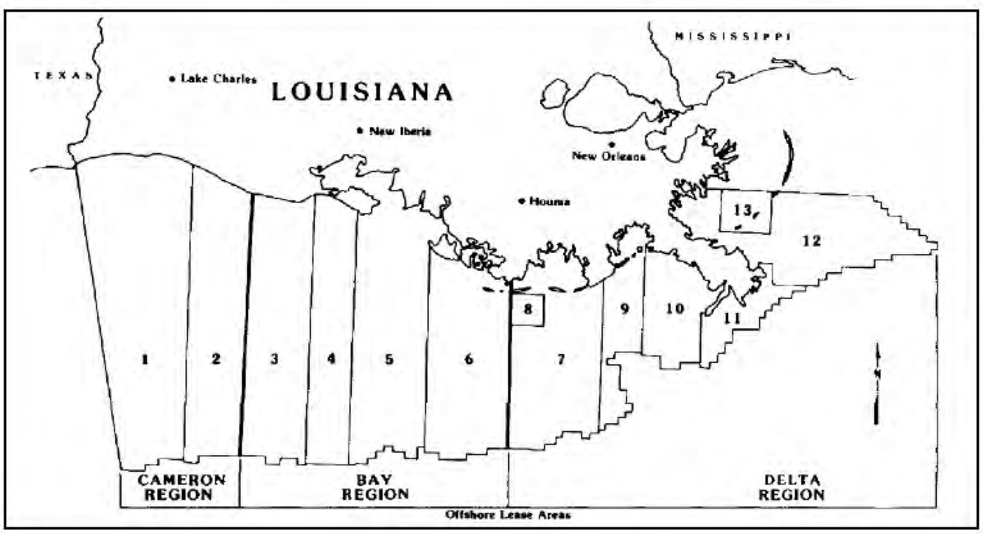
Recreational fishermen in the Gulf of Mexico highly prefer fishing on artificial reefs due to the lack of natural hard bottoms in the region. Approximately 37% of saltwater fishing trips are conducted near artificial reefs and 70% of recreational fishing trips within the EEZ occur on artificial reefs.
Information on the mean one-way distance traveled by recreational fishermen was collected and broken out by three regions in the Gulf of Mexico: Cameron region in the western Gulf, Bay region in the central Gulf, and Delta region in the eastern Gulf.
Mean one-way distance traveled for the three regions for recreational fishermen was:

Mean distance traveled to Delta was 33.86 nm.
Mean distance traveled to Bay was 42.50 nm.
Mean distance traveled in Cameron was 44.83 nm.

Mean one-way distance traveled for the three regions for divers was:

Mean distance traveled to Delta was 39.65 nm.
Mean distance traveled to Bay was 45.22 nm.
Mean distance traveled in Cameron was 76.50 nm.

The following map shows the location of the Cameron, Bay, and Delta Regions in the Gulf of Mexico:



</td></tr>
</table>

	Stanley, Wilson, 1989. Utilization of Offshore Platforms by Recreational Fishermen and Scuba Divers off the Louisiana Coast
	To summarize, recreational fishermen were willing to travel up to approximately 45 nm offshore to fish artificial reefs on offshore energy platforms. Divers were willing to travel approximately 77 nm.

<table>
<tr><th colspan="2">Vandendriessche et al., 2016. Recreational Fishermen and Wind Farms: Current Use and Perception</th></tr>
<tr><td>Summary</td><td>This academic study was published as a chapter in a larger book, titled “Environmental Impacts of Wind Farms in the Belgian Part of the North Sea, Environmental Impact Monitoring Reloaded.” The article reviews existing literature on the impact of OWFs on recreational fishing.</td></tr>
<tr><td>Analysis Methods</td><td>This study conducted a survey of recreational fishermen in Denmark. A total of 224 completed questionnaires were returned as part of the survey. Within Belgium, OWFs are closed to vessels not involved in maintenance or scientific research, so they are currently closed to recreational fishing.</td></tr>
<tr><td>Issues Addressed</td><td>Fisheries (Recreational)
• Recreational fishermen are required to stay back 1,640 ft (500 m) from wind turbines preventing them from fishing close to the best fish habitat, which is on the artificial reef created by the wind turbine platform.
• Recreational fishermen reported mainly fishing over areas with soft sediment bottoms (i.e., sand banks) or over shipwrecks.
• Species caught in the wind farm area include sea bass, pouting, whiting, saithe, dab, sole, plaice, flounder, sharks, and rays.
• Only about 2% of survey respondents reported that they fish in a wind farm area; these respondents cited an abundance of fish and lack of competition from other recreational fishermen as reasons for preferring the wind farm area.
Fishermen’s Perception of OWFs
• Most fishermen stated that they preferred avoiding fishing near OWFs due to:
▪ Entering the wind farm areas is not allowed for safety reasons.
▪ Belgian wind farms are too far away from harbors to reach.
▪ Charter vessels do not travel to OWFs.
▪ OWFs are protected areas for fish and should be respected as such.
▪ Noise from the wind turbines is a deterrent.
▪ About 40% of survey respondents stated they would fish within OWFs if it were allowed; 32% stated that they would not fish within OWFs even if it were allowed.</td></tr>
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