DNV·GL

REVOLUTION WIND FARM

Navigation Safety Risk Assessment

Revolution Wind, LLC

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Abbreviation	Meaning
ADLS	Aircraft Detection Light System
AIS	Automatic Identification System
ALARP	As low as reasonably practicable
ATON	Aids to Navigation
BOEM	U.S. Bureau of Ocean Energy Management
CFR	Code of Federal Regulations
Coast Guard	U.S. Coast Guard
COLREGs	International Regulations for Preventing Collisions at Sea
COP	Construction and Operations Plan
DWT	Dead Weight Tonnage
ECA	Emission Control Area
ECDIS	Electronic Chart Display and Information System
ETV	Emergency Towing Vessel
FAA	Federal Aviation Administration
FR	Federal Register
FSA	Formal Safety Assessment
GC	Gain Control
GPS	Global Positioning System
HF	High Frequency
HVAC	High-Voltage Alternating Current
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
ICAO	International Civil Aviation Organisation
IMO	International Maritime Organization
LOA	Length Overall
LOS	Line of Sight
MARCO	Mid-Atlantic Ocean Data Portal
MARCS	Marine Accident Risk Calculation System
MARI PARS	The Areas off Massachusetts and Rhode Island Port Access Route Study
MARPOL	International Convention for the Prevention of Pollution from Ships
MCA	UK Maritime & Coastguard Agency
MHW	Mean High Water
MHHW	Mean Higher High Water
MLLW	Mean Lower Low Water
MSL	Mean sea level
NGDC	National Geophysical Data Center
NMFS	National Marine Fisheries Service
NOAA	U.S. National Oceanic and Atmospheric Administration
NROC	Northeast Regional Ocean Council
NSRA	Navigation Safety Risk Assessment
NVIC	Navigation and Vessel Inspection Circular
O&M	Operations and Maintenance
OCS	Outer Continental Shelf
OREIs	Offshore Renewable Energy Installations
OSS	Offshore substation
PARS	Port Access Route Study
PATON	Private Aids to Navigation
PDE	Project Design Envelope
PPU	Portable Pilotage Unit
RODA	Responsible Offshore Development Alliance

SAR	Search and Rescue
SMC	Search and Rescue Mission Coordinator
SO_x	Sulfur oxides
TSS	Traffic Separation Scheme
U.S.	United States
UHF	Ultra-High Frequency
UK	United Kingdom
UKC	Under Keel Clearance
USCG	United States Coast Guard
UTM	Universal Transverse Mercator coordinate system
VHF	Very High Frequency
VMD	Virtual Meteorological Data
VMRS	Vessel Movement Reporting System
VMS	Vessel Monitoring System
VTR	Vessel Trip Report
WEA	Wind Energy Area
WGS84	World Geodetic System 1984 datum
WTG	Wind Turbine Generator

List of units

Unit	Meaning
dB	decibels
ft	feet
GHz	Gigahertz or 10^9 Hertz
Hz	Hertz
km	kilometers
km^2	square kilometers
kt	knots
m	meters
mi	miles
MJ	megajoules
MW	megawatts
NM	Nautical Miles
m/s	meters per second

EXECUTIVE SUMMARY

This document presents the Navigation Safety Risk Assessment (NSRA) for the Revolution Wind Farm (the Project). The Project will be located approximately 12.8 Nautical Miles (NM) (23.8 km) southeast of Block Island, Rhode Island, under a Commercial Lease for Renewable Energy Development on the Outer Continental Shelf (OCS-A 0486).

The NSRA is conducted per the guidance in U.S. Coast Guard (Coast Guard) Navigation and Vessel Inspection Circular No. 01-19 ("NVIC 01-19") (Coast Guard, 2019a). This report is intended to be used by the Coast Guard to assist with evaluating the potential impacts of the Project on the marine transportation system, including navigation safety, traditional uses of the waterways, and Coast Guard missions.

This assessment covers the following elements:

1. Site location and coordinates
2. Traffic survey
3. Offshore above water structures
4. Offshore under water structures
5. Navigation within or close to a structure
6. Effect of tides, tidal streams, and currents
7. Weather
8. Configuration and collision avoidance
9. Visual navigation
10. Communications, radar, and positioning systems
11. Risk of collision, allision, or grounding
12. Emergency response considerations
13. Facility characteristics
14. Design requirements
15. Operational requirements
16. Operational procedures

Key findings for each area are listed in Section 18 of this report. The NSRA did not identify any major areas of concern regarding the Project's impact on marine navigation.

Figure ES-1 shows Orsted's current proposed division of lease area OCS-0486 between the South Fork Wind Farm and the Revolution Wind Farm. The blue outline indicates the Lease Area (defined in Section 1), and the red outline indicates the boundaries of the Project (defined in Section 1).

The study assessed a conservative "maximum design case" layout as relevant to each hazard. For example, a layout with the largest potential footprint (shown in Figure ES-2), was used to assess collision risk from passing vessels. For assessing visual obstruction in the wind farm, 0.6 NM between Project structures was evaluated. The current proposed layout has 1 NM between Project structures and has a smaller overall footprint (Orsted et. al, 2019); however, this assessment did not evaluate the 1 NM lower-risk layout. Thus, the risk evaluated in this NSRA represents the maximum risk from any layout within the Project Design

Envelope (PDE). When the project layout and turbine selection are finalized, if the layout is outside the NSRA assumptions, the Project has advised that it will update this NSRA if necessary.

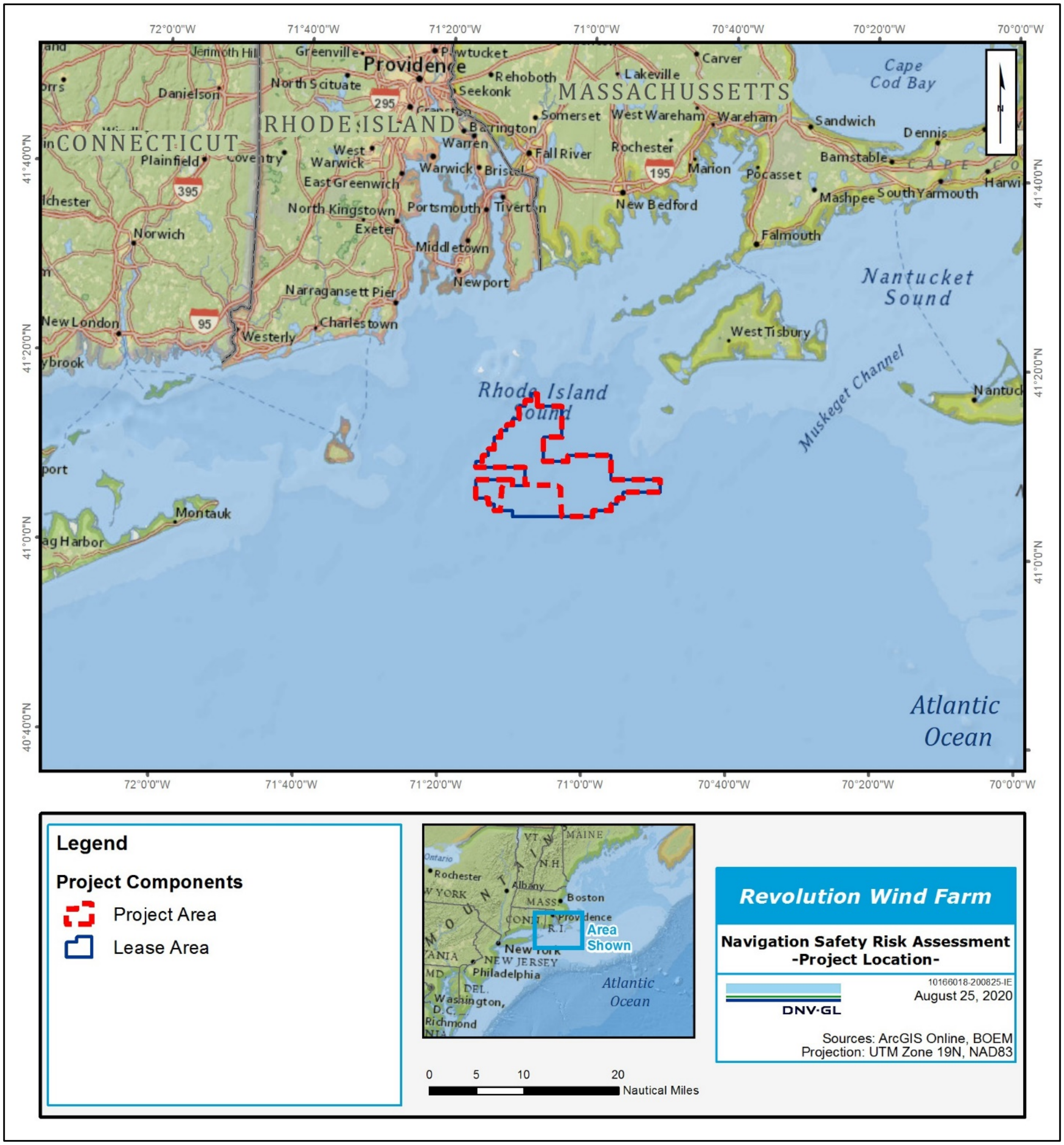


Figure ES-1 Navigation Safety Risk Assessment Study Area

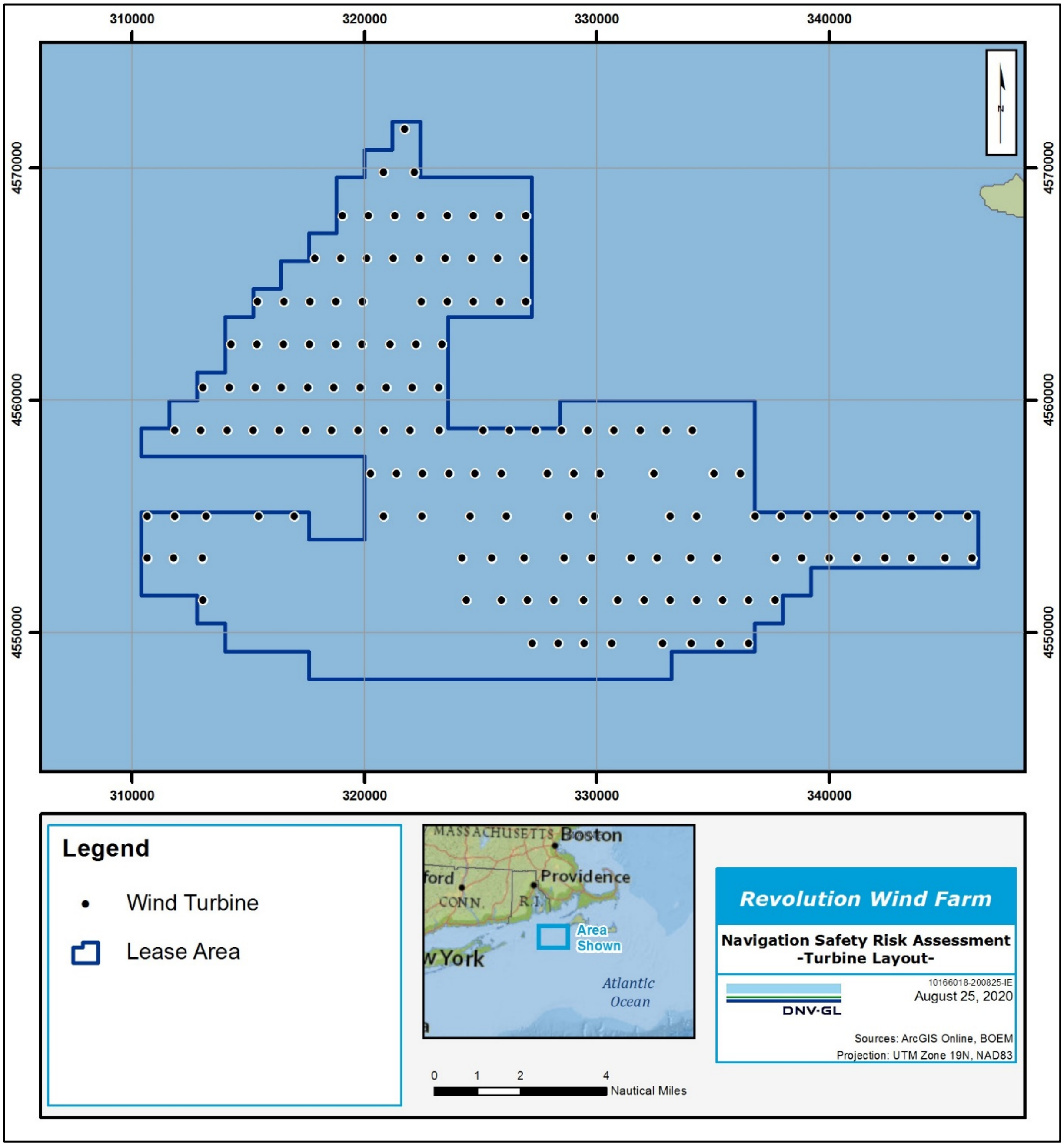


Figure ES-2 Indicative Layout used for Risk Modeling

Marine risk modeling was used to estimate the increase in the number of accidents as a result of the Project. The quantified assessment of the navigation risk for the Project concludes that a risk increase due to the Project lies almost exclusively within the Lease Area.

The marine accidents of primary concern to the quantified risk assessment are:

- Collision between two vessels
- Allision of a turbine by a vessel (sometimes called striking or impact)
- Grounding of a vessel

The modeling shows that the Project has no significant effect on grounding risk or collision risk.

Generally, most maritime allision accidents are minor in nature. Similarly, most of the allision accidents predicted by the modeling are expected to be minor in nature. This study attempts to balance the need to accurately estimate risk with the uncertainty accompanying the data and assumptions, and assure that any error is on the side of overestimating the risk.

One year of AIS data was the primary marine traffic input to the model. Additional vessel transits were added to account for both current and future traffic not represented in AIS (hereafter "non-AIS"). Commercial fishing is one such vessel type that is important in the Study Area. The number of non-AIS commercial fishing transits was estimated by scaling port departures of AIS-carrying commercial fishing vessels per the ratio of registered commercial fishing vessels not required to carry AIS (shorter than 65 ft) to those that are required to carry AIS (65 ft in length or longer).

Conservatively, all 19,611 inbound and outbound transits estimated for non-AIS commercial fishing vessels were assumed to either fish in the Project Area or transit through it. In this assessment, the modeled risk increase is 1.4 accidents per year, 99% of which are allisions. This is a best conservative maximum estimate of the additional risk that could result from the presence of the Project assuming all non-AIS commercial fishing vessel transit to or through the Project Area. If the number of transits were half of the estimate, the risk would reduce by at least half. The Project poses very little risk outside the Lease Area.

Additional risk mitigation measures whose benefits were not quantified in the model may be employed by the Project, including use of best available Automatic Identification System (AIS) technology within the wind farm. The Project will comply with Coast Guard requirements for lighting, sound signals, and marking of structures, as applicable and as determined in consultation with the Coast Guard (Orsted, 2020).

Radar operations on commercial vessels are not anticipated to be impacted by the Project. Smaller vessels operating in or near the wind turbine generators may experience radar clutter and shadowing. Most instances of interference can be mitigated through the use of radar gain controls.

1 INTRODUCTION AND PROJECT DESCRIPTION

DNV GL Energy USA, Inc. (DNV GL) conducted an independent Navigation Safety Risk Assessment (NSRA) of the proposed Revolution Wind Farm Project (the Project). The Project's offshore structures will be located within the Commercial Lease of Submerged Lands for Renewable Energy Development on the Outer Continental Shelf OCS-A 0486 Lease Area (Lease Area).

This NSRA was conducted in line with the guidance provided in U.S. Coast Guard (Coast Guard) *Navigation and Vessel Inspection Circular No. 01-19* ("NVIC 01-19") (Coast Guard, 2019a). This report was prepared by DNV GL and presents the results of the risk assessment and is intended to serve as an appendix to the Project Construction and Operations Plan.

1.1 Objective

The objective of the assessment is to address items in NVIC 01-19 that are pertinent to the Project.

The turbine size and layout have yet to be finalized, and several alternatives are being considered for the Project. To facilitate comprehensive and resilient analyses of the Project, this NSRA identified a maximum design case for each analysis herein, such that the accuracy of the analyses would not be affected by potential changes to the layout that are within the Project Design Envelope (PDE) described herein. The primary goal of applying a design envelope is to allow for meaningful assessments by the jurisdictional agencies of the proposed project elements and activities while concurrently providing the Project reasonable flexibility to make prudent development and design decisions prior to construction.

1.2 Project components

The Project will include up to 100 wind turbine generators (WTGs), which will have generating capacities between 8 MW and 12 MW each, and up to two offshore substations (OSS). An export cable will be laid between the wind farm and shore, and array cables will be laid connecting the turbines to the OSS.

The WTG model, size, and foundation type have not been selected at this time. For the purposes of the NSRA, the indicative measurements listed in Table 1-1 were used.

Table 1-1 Indicative wind turbine generator measurements (Orsted, 2020)

WTG component/parameter	8-10 MW WTG	12 MW WTG
Hub height (from mean sea level [MSL])	115 m 377 ft	156 m 512 ft
Turbine maximum height (from mean lower low water [MLLW])	197.4 m 647 ft	266 m 873 ft
Air gap (from MHHW to the bottom of the blade tip)	27 m 89.1 ft	45 m 147 ft
Monopile base width (at the sea bottom)	6 m 19.7 ft	8 m 26 ft
Jacket base width (at the sea bottom)	20 m x 20 m 66 ft x 66 ft	30 m x 30 m 98 ft x 98 ft

WTG component/parameter	8-10 MW WTG	12 MW WTG
Blade length	79 m 259 ft	107 m 351 ft
Rotor diameter	164 - 174 m 538 - 571 ft	220 m 722 ft

Table 1-2 lists the Project components.

Table 1-2 Project components and envelope (Orsted, 2020)

Project component		Project envelope characteristic
Wind farm	Foundations	• Monopile or jacket for WTGs; Jacket for OSS
	WTGs	• Up to 100 WTGs • 8 to 12 MW each • Spaced at least 0.6 NM (1.1 km) apart
	Inter-array cable	• Approximately 155 mi (249 km) of inter-array cable to connect the WTG and OSS
	OSS	• Mounted on a dedicated foundation
Export cable	Export cable (offshore and onshore)	• Up to two high-voltage alternating current (HVAC) submarine cables to convey power to shore (Export Cables) • Located within an approximately 50-mi (80-km)-long Export Cable Corridor

The study assessed maximum risk Project characteristics relevant to each evaluated hazard, which are specified in relevant sections of this report. For example:

- For risk evaluation, the Project was modeled as having 144 offshore structures. When built, the Project may have fewer structures in the array, so where uncertainty exists in the final design, the model over-estimates the risk.
- For visual navigation, the foundation type with the largest potential for visual blockage was evaluated.

For sailing vessel clearance, the foundation type with the smallest air gap was analyzed.

1.3 Site location and installation coordinates

The current Lease Area for South Fork Wind Farm and Revolution Wind Farm (Lease OCS-A-0486) comprises approximately 97,500 acres (Bureau of Ocean Energy Management [BOEM], 2012) and is shown in Figure 1-1. For the purpose of this NSRA, the Project Area is defined as the largest practical footprint of Revolution Wind WTGs and is within Lease Area (OCS-A 0486).

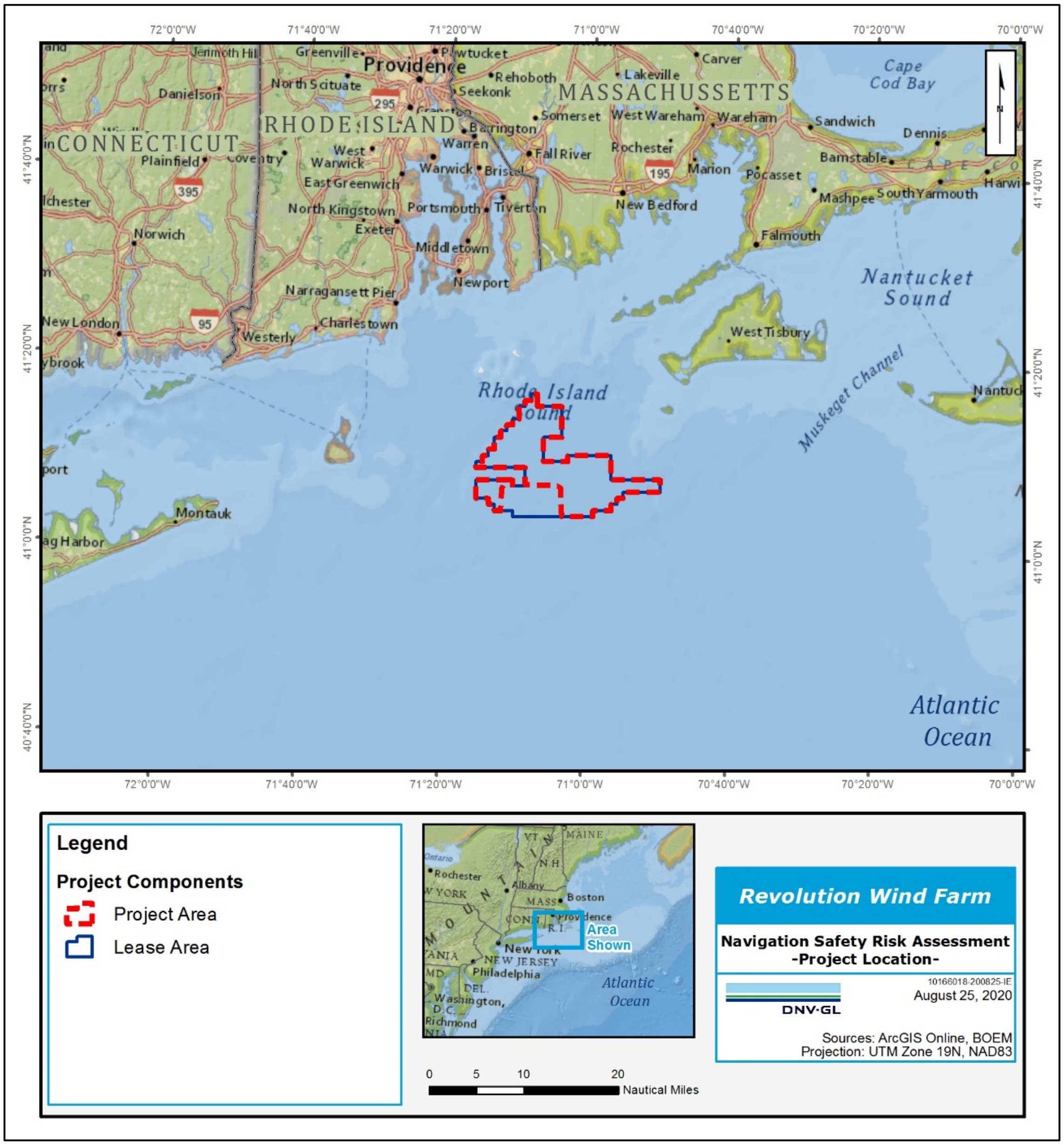


Figure 1-1 Revolution Wind Farm Project Location

The layout with the largest potential footprint (shown in Figure 1-2), was used to assess collision risk modeling from passing vessels. For assessing allision risk from vessels fishing in the wind farm, the layout with 0.6 NM between Project structures was evaluated, even though Orsted has proposed a layout with 1 NM between Project structures. Thus, the risk evaluated in this NSRA represents the maximum risk from any layout within the PDE.

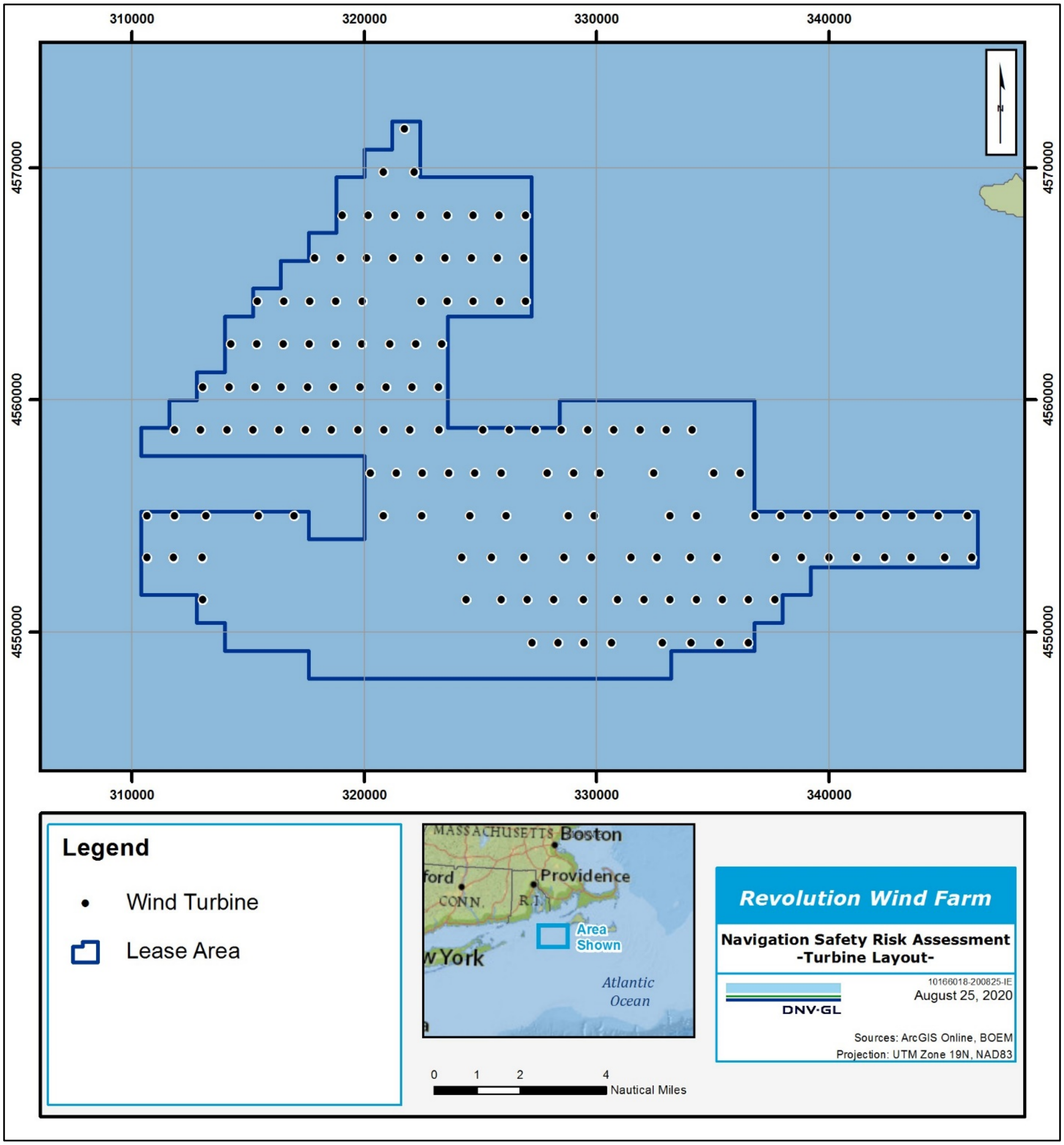


Figure 1-2 Indicative Layout used for Risk Modeling

2 TRAFFIC SURVEY

This section describes marine traffic in the vicinity of the Lease Area. The following data sources were used to identify traffic patterns:

- Automatic Identification System (AIS) data for one year, 1 July 2018 to 30 June 2019 (MarineTraffic, 2019).
- The Mid-Atlantic Ocean Data Portal, which is used for ocean planning throughout the northeastern United States (U.S.) and provides a source of local information (MARCO, 2020). Specific information used in this analysis included:
    - Commercial fishing transits inferred from Vessel Monitoring System (VMS) data, which were provided to the portal by National Marine Fisheries Service (NMFS). The most recent data products from NMFS provide processed geospatial statistics through the year 2016.
    - Density maps from Northeast Ocean Data (VMS and recreational survey data).
- The final report published by the Coast Guard for The Areas off Massachusetts and Rhode Island Port Access Route Study, referred to as MARI PARS (Coast Guard, 2020a).
- Ongoing dialogue with recreational boating and fishing industry organizations including the Responsible Offshore Development Alliance (RODA); pilot organizations; commercial maritime industry representatives; port authorities; state advisory groups (such as the New York State Fisheries Technical Working Group, the Massachusetts Fisheries Working Group and the Rhode Island Fisheries Advisory Board); and the Coast Guard. See Appendix B and Appendix C for additional detail.

The following aspects of local traffic are described in this section:

Section 2.1	Traffic patterns, density, and statistics
Section 2.2	Location of the Project in relation to other uses
Section 2.3	Anticipated changes in traffic from the Project
Section 2.4	Effect of vessel emission requirements on traffic
Section 2.5	Seasonal variations in traffic

Figure 2-1 shows the location of the Lease Area and the Study Area. The Study Area includes the Project Area and the remainder of the Lease Area and is defined as such for the purpose of evaluating marine traffic.

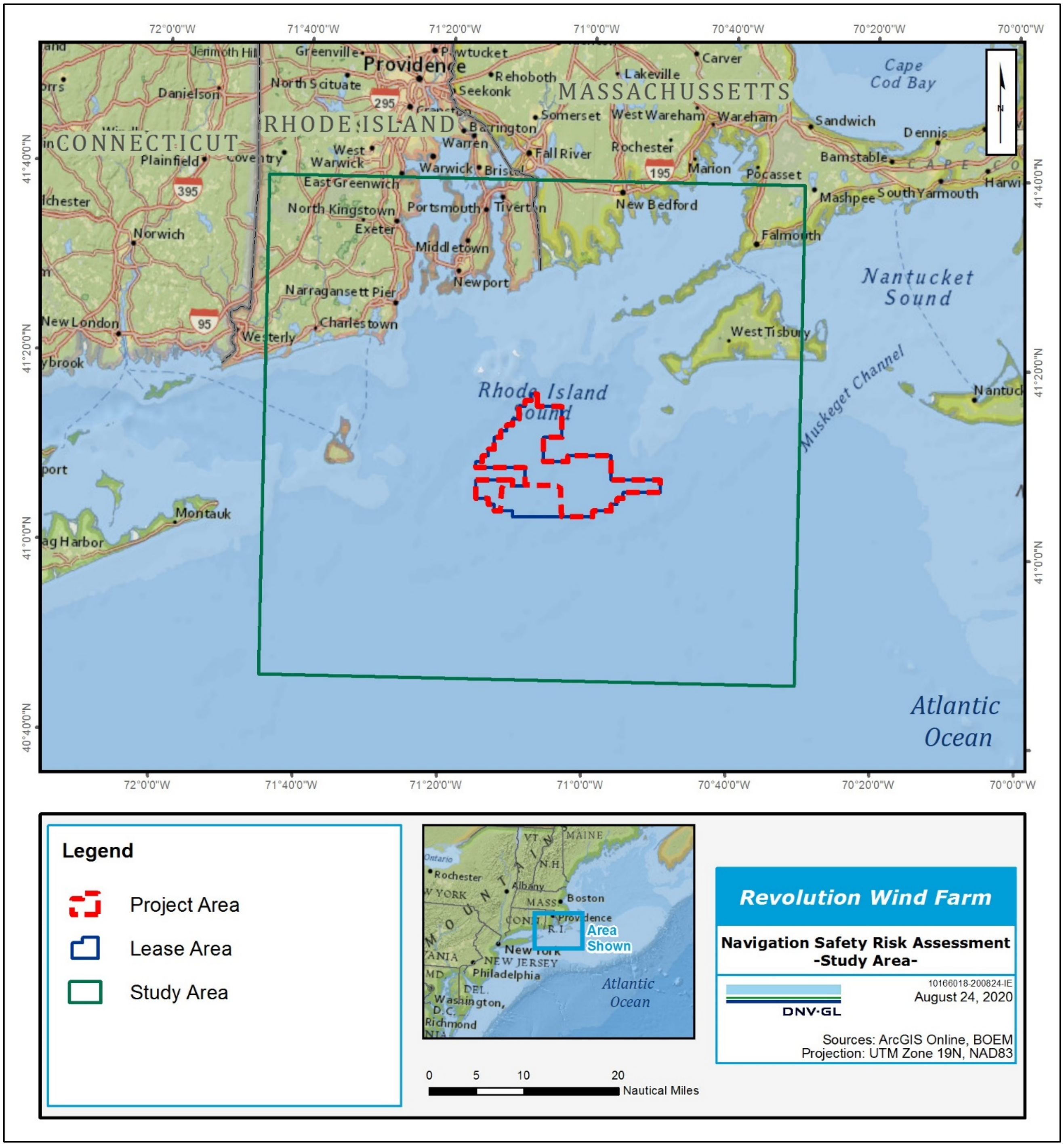


Figure 2-1 Study Area for Revolution Wind NSRA

Figure 2-2 shows the detailed navigation chart.

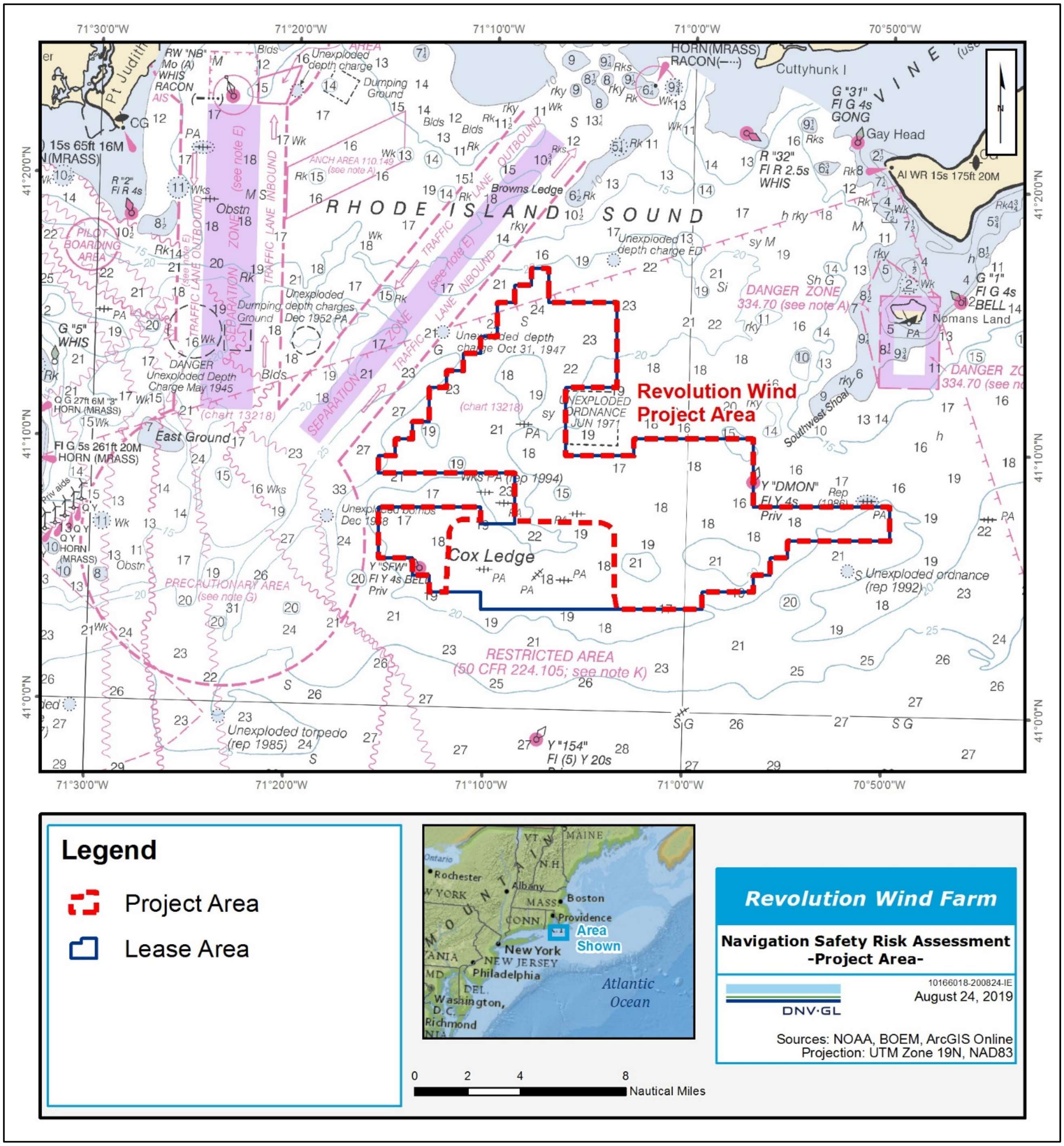


Figure 2-2 Navigation chart

2.1 Traffic patterns, density, and statistics

Traffic patterns, traffic density, and statistics were developed from one year of AIS data for the period 1 July 2018 through 30 June 2019. The data were spatially analyzed based on timestamp and proximity to create vessel tracks. Each vessel track represents a transit of a single vessel in the Study Area.

AIS carriage requirements

Most of this section focuses on traffic as presented in the AIS data. All self-propelled vessels of more than 1,600 gross tons are required to carry AIS, with certain exceptions made for foreign vessels (Coast Guard, 2019b). As a result, the dataset provides a comprehensive view of the vessels and their routes for all of the vessel categories except fishing and pleasure/recreation. Many fishing and pleasure/recreation vessels are exempt from AIS carriage requirements. Fishing and pleasure/recreation vessel density, and available statistics are discussed in Section 2.2. For each vessel type, AIS tracks, density, and speed are provided in Appendix A.

Not all vessels are required to carry AIS. In particular, foreign vessels not destined for or departing from a location under U.S. jurisdiction and some self-propelled vessels less than 1600 gross tons are not required to carry AIS under U.S. law. However, international law (IMO, 1974), which applies to all vessels in international trade, requires an AIS class A device on:

- A vessel of 300 gross tonnage or more, on an international voyage.
- A vessel of 150 gross tonnage or more, when carrying more than 12 passengers on an international voyage.

Under U.S. regulations (33 CFR 164.46), Section (b)(1), "the following vessels must have on board a properly installed, operational Coast Guard type-approved AIS Class A device:

(i) A self-propelled vessel of 65 feet or more in length, engaged in commercial service.

(ii) A towing vessel of 26 feet or more in length and more than 600 horsepower, engaged in commercial service.

(iii) A self-propelled vessel that is certificated to carry more than 150 passengers.

(iv) A self-propelled vessel engaged in dredging operations in or near a commercial channel or shipping fairway in a manner likely to restrict or affect navigation of other vessels.

(v) A self-propelled vessel engaged in the movement of: certain dangerous cargo as defined in subpart C of part 160 of this chapter, or flammable or combustible liquid cargo in bulk that is listed in 46 CFR 30.25-1, Table 30.25-1.

Use of a Coast Guard type-approved AIS Class B device in lieu of an AIS Class A device is *permissible* on the following vessels if they are not subject to pilotage by other than the vessel Master or crew:

(i) Fishing industry vessels;

(ii) Vessels identified in paragraph (b)(1)(i) of this section that are certificated to carry less than 150 passengers and that: do not operate in a Vessel Traffic Service or Vessel Movement Reporting System area defined in Table 161.12(c) of § 161.12 of this chapter; and do not operate at speeds in excess of 14 knots; and

(iii) Vessels identified in paragraph (b)(1)(iv) of this section engaged in dredging operations."

The relevant U.S. Coast Guard Captain Of The Port may also determine that voluntary installation of AIS by a vessel would mitigate a safety concern due to specific circumstances.

In general, the great majority of vessels in the Study Area except fishing vessels, pleasure vessels, and recreational craft carry AIS class A or class B equipment:

- Deep draft vessels (tankers, large passenger vessels, and most commercial ships on international voyages)
- Commercial self-propelled vessels of 65 feet or more in length, regardless of service
- Self-propelled vessels moving certain dangerous cargoes, flammable or combustible liquids in bulk
- Towing vessels of 27 feet or more in length and more than 600 hp
- Passenger vessels certificated to carry 150 or more passengers

Overview of Vessel Tracks

Figure 2-3 presents the AIS tracks for vessels transmitting AIS signals in the Study Area.

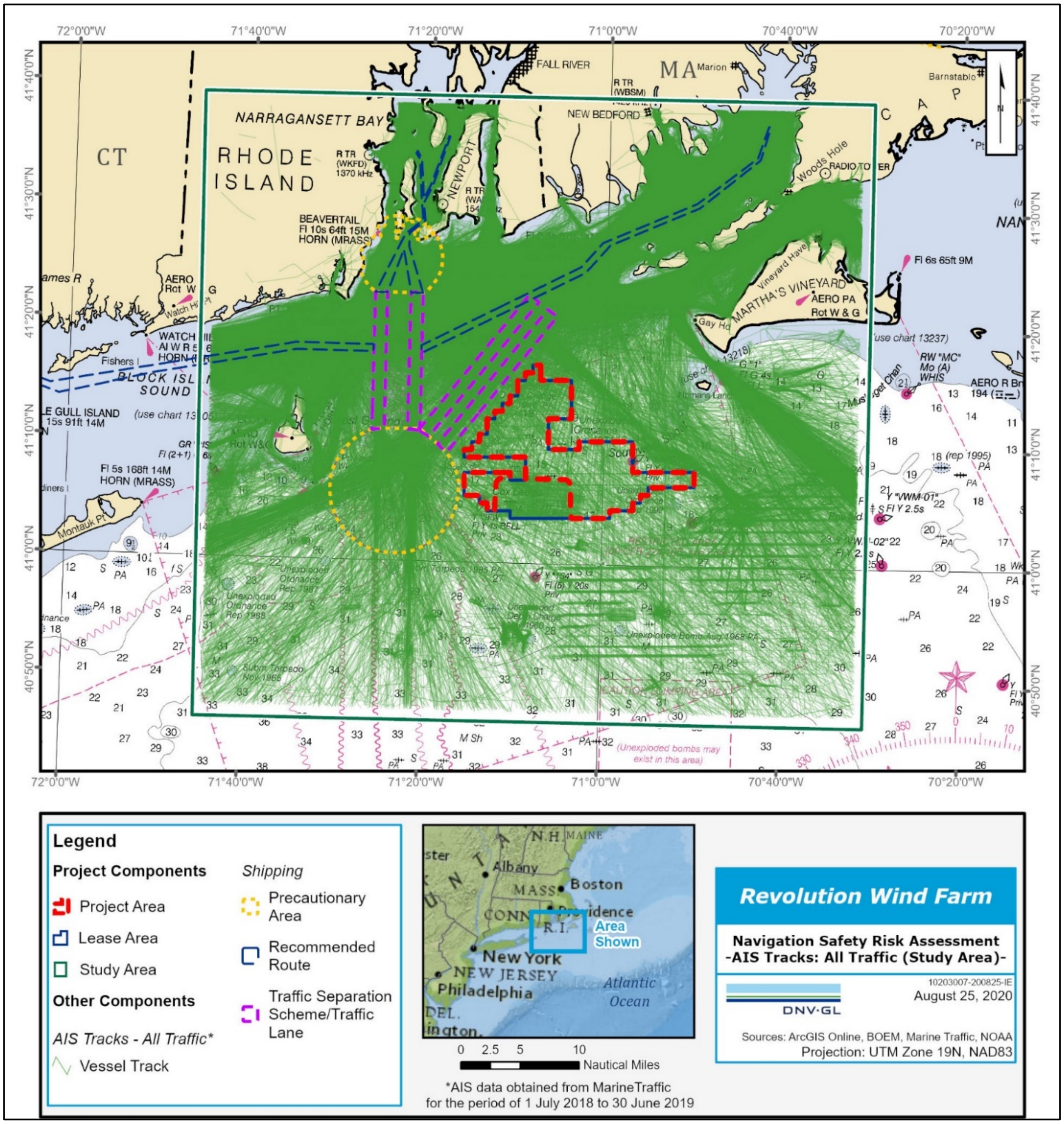


Figure 2-3 AIS tracks for all vessel types in Study Area[1]

[1] AIS data for the period 1 July 2018 to 30 June 2019 (MarineTraffic, 2019)

A closer view in Figure 2-4 shows a general traffic pattern in the Study Area in two directions: NNE-SSW and NW-SE.

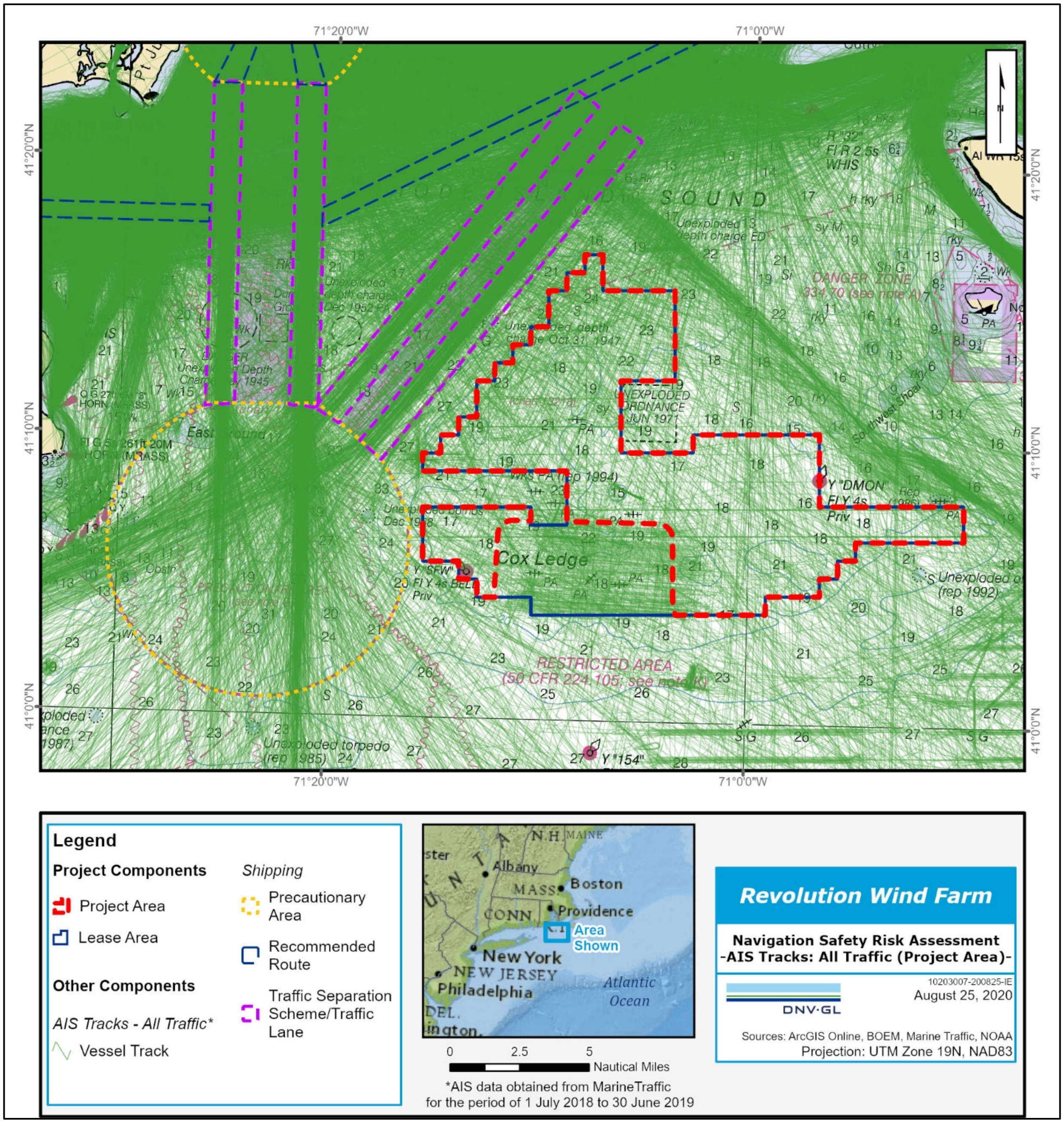


Figure 2-4 All AIS tracks in the vicinity of the Project[1]

The distribution of AIS-based tracks among the vessel types in the Study Area is shown in Figure 2-5.

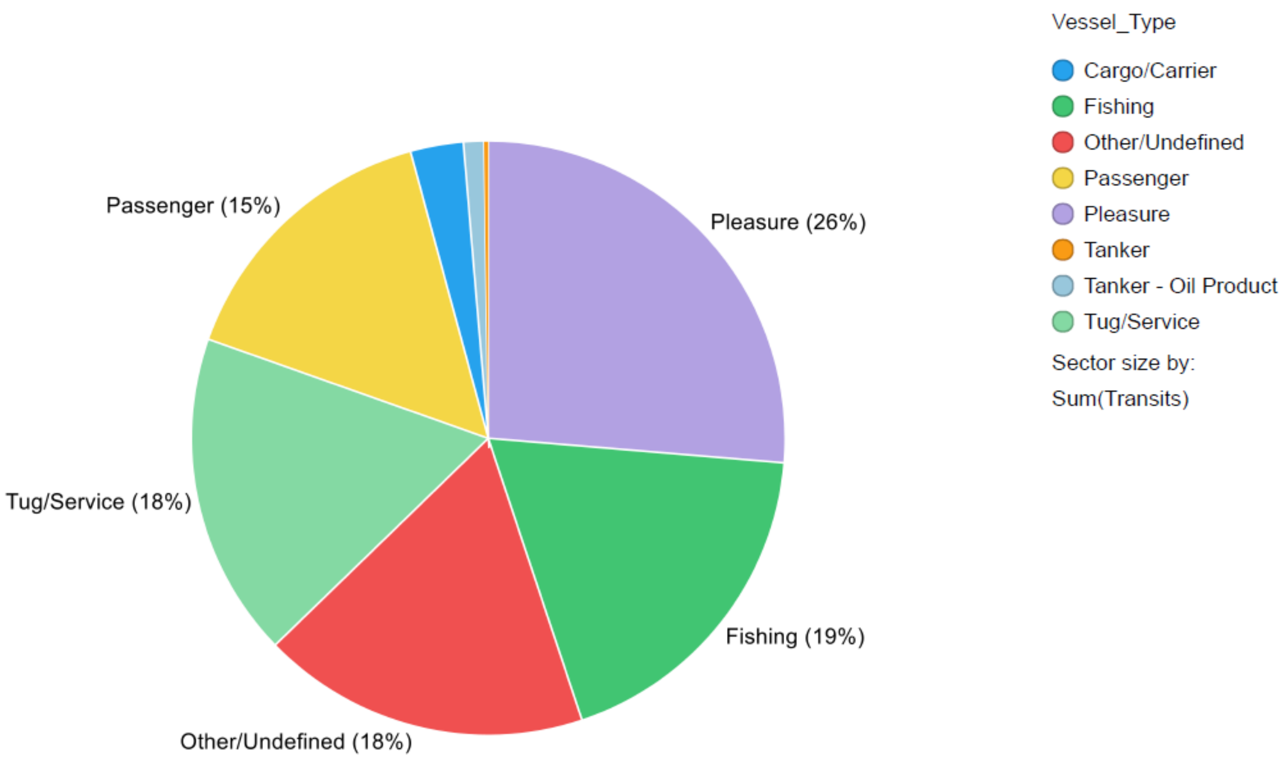


Figure 2-5 Distribution of vessel tracks in the Study Area[1]

2.1.1 Traffic patterns

Below are discussions of traffic patterns for each of the vessel types:

- Cargo, carrier, and tanker vessels
- Fishing vessels
- Passenger vessels
- Pleasure and recreational vessels
- Tugs
- Other vessels

Maps of AIS vessel tracks and track densities for each vessel type are presented in Appendix A.

2.1.1.1 Deep draft commercial vessel traffic

Cargo, carrier, and tanker vessels transport goods such as petroleum products, coal, commodities, and food to/from ports in the area. They transit the main shipping routes in the designated Traffic Separation Schemes. The AIS data show fewer than one cargo vessel and one tanker per day transited the Wind Farm Assessment Area. These vessels predominantly transit two main courses through the larger NSRA Study Area:

- South-north and vice-versa via the Narragansett Bay Traffic lanes or just west of them. The route transits to the west of the Wind Farm Assessment Area.
- East-west and vice versa between Buzzards Bay and Block Island Sound. The route transits to the north and northwest of the Wind Farm Assessment Area.

Figure 2-6 presents the tracks for cargo/carriers and tankers (those that carry hydrocarbon cargo and those that carry other cargoes). On a nautical chart, traffic separation zones are illustrated as purple rectangles. The figure shows that there appears to be little to no cargo/carrier or tanker traffic that “cuts the corner” by departing the TSS before reaching the Precautionary Area.

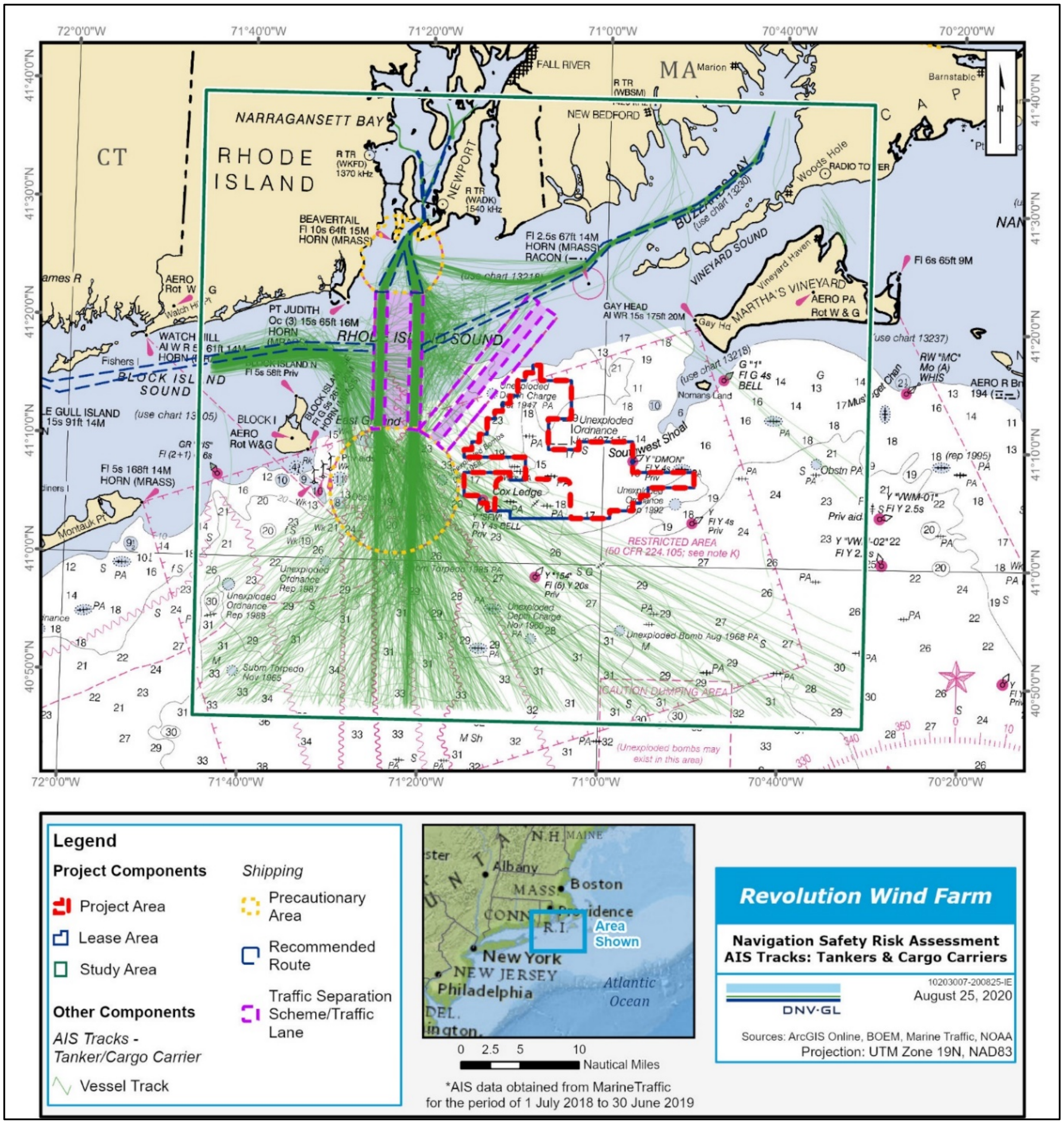


Figure 2-6 AIS tracks for tankers and cargo carriers[1]

2.1.1.2 Commercial fishing vessel traffic

Figure 2-7 presents the AIS tracks for fishing vessels in the Study Area. The fishing vessel tracks captured in the AIS data show a higher traffic density near the coastline (north and west of the Lease Area). The AIS data show a relatively low number of transits to the south of the Lease Area. Commercial fishing vessel transits are generally recognized as not fully captured in AIS data. A significant portion of commercial fishing vessels do not fall under the AIS carriage requirements (see beginning of Section 2.1).

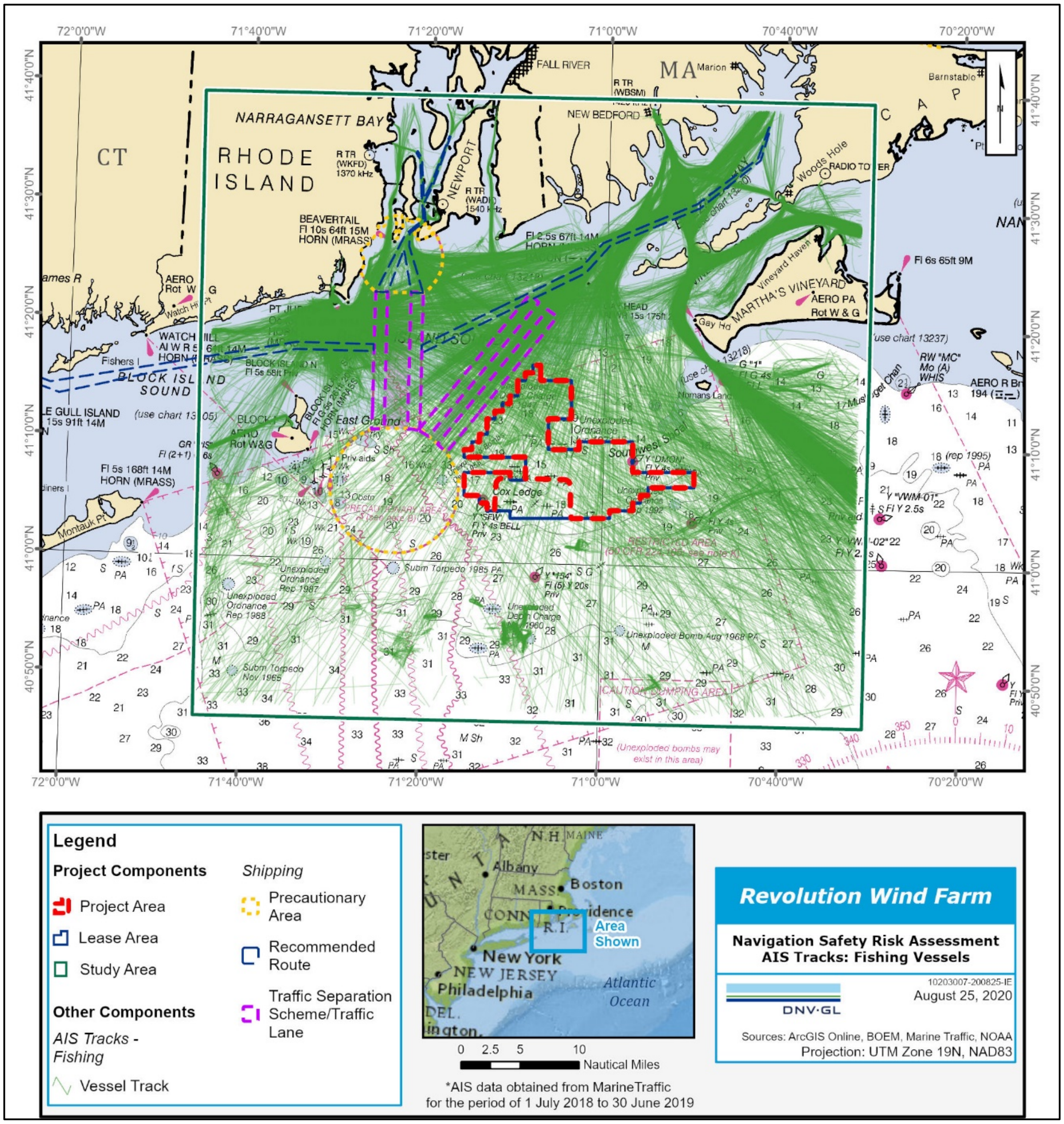


Figure 2-7 AIS tracks for fishing vessels[1]

The Coast Guard MARI PARS report (2020a) reviewed AIS data, input from marines, and its own subject matter expertise, and concluded that the Massachusetts/Rhode Island WEA "…appears to be primarily used for commercial fishing vessels engaged in fishing or transiting through the area to fishing grounds adjacent to the MA/RI WEA. Other vessel traffic includes recreational fishing and general recreational traffic (e.g., sailing vessels, vessels participating in organized marine events, etc.) that have unidentifiable origins and destinations."

The lack of AIS data to represent fishing vessel activity was accounted for when developing the risk model developed to estimate the Project's effect on navigation risk. To provide an improved estimate of commercial fishing vessel transits for modeling of navigation risk, a maximum number of transits of non-AIS commercial fishing vessels was estimated, but is not presented in Figure 2-7 or traffic statistics. It was derived for use in the model but does not include the vessel position or track information that is part of the AIS data.

An analysis of fishing vessel lengths for commercial fishing vessels registered in Rhode Island and Connecticut[2] showed that 17.5% of the registered commercial fishing vessels have lengths greater than 65 feet and hence are required to use AIS.

The number of additional commercial fishing vessel trips for vessels shorter than 65' was estimated as:

$$\text{Number of trips} = N / 0.175$$

where:

N is 3,432, the number of trips for fishing vessels longer than 65' obtained from the AIS data.

Key assumptions in the estimate are:

- All of the commercial fishing vessels with lengths of at least 65 ft are represented in the AIS dataset on departure from or approach to port, and fishing vessels under 65 ft are assumed to not be represented in the data at all.
- Fishing vessels properly self-identify as type "fishing" in AIS.
- According to more than ten years of vessel registration records in Rhode Island and Connecticut ranging from 2008 to 2019 (NOAA, 2020), an average of 17.5% of all registered vessels are at least 65 ft in length, therefore must use AIS. This study assumes that AIS data represent only 17.5% of the commercial vessel traffic at port entries/exits. The number of transits is scaled up appropriately.
- Regardless of vessel size, the number of transits per vessel is assumed to be the same. The number of transits per year taken by an average fishing vessel *longer* than 65 ft is the same as the number of transits per year taken by an average fishing vessel *shorter* than 65 ft.
- Regardless of vessel size, the routes taken are assumed to be the same. The port of departure and fishing grounds of an average fishing vessel *longer* than 65 ft is the same as the port of departure and fishing grounds of an average fishing vessel *shorter* than 65 ft. This resulted in a maximum

[2] Registered vessels with home ports in Massachusetts were also considered. A larger percentage (19 percent) of Massachusetts vessels are longer than 65 ft compared to either Rhode Island or Connecticut . It is uncertain what proportion of vessels fish in the Project Area are from Massachusetts, Rhode Island, or Connecticut. In addition, the number of vessels in Massachusetts is much larger than from the other two states. To avoid underestimating the number of fishing vessels, a conservative choice was made to use the combined registered vessels in Rhode Island and Connecticut as a proxy for all registered fishing vessels to be added to the risk model.

boundary estimate of 19,611 additional commercial fishing vessel trips inbound and outbound from ports in the NSRA Study Area.

This resulted in a maximum boundary estimate of 19,611 additional commercial fishing vessel transits inbound and outbound from ports in the Study Area.

Commercial fishing vessel density

In general, commercial fishing vessels are under-represented in AIS data. The fishing locations chosen by commercial fishing boats, and hence their routes, are closely guarded. The locations of fish populations change over time, and therefore, the level of fishing activity in a given location will vary over time as well.

Fishing activity was evaluated in two ways:

- VMS data that indicate which types of fish were caught in the Study Area
- Combined permit / Vessel Trip Report (VTR) data that indicate where specific fishing gear was used in the Study Area. VMS data are collected by National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) via type-approved transmitters that automatically transmit a vessel's position for relay to NMFS. VTR data are collated from vessel reports provided to NOAA's Northeast Fisheries Science Center.

The Mid-Atlantic Ocean Data Portal (MARCO) was accessed to provide views of commercial fishing activity in the Study Area for the period 2015 to 2016, the most recent year of available data (MARCO, 2019). The summaries presented below are from VMS data, provided by NMFS. The data are subject to strict confidentiality restrictions, which do not allow for individual vessel tracks or positions to be identified or for the underlying data to be downloaded for uses such as this assessment.

Commercial fishing vessels do not travel within prescribed vessel routes as other commercial vessel types do, and generally have non-linear density patterns that relate to preferred fishing locations.

Figure 2-8 to Figure 2-14 show commercial fishing vessel activity available for specific fish species. The scale is based on relative values rather than absolute values. The categories are "Low," "Med-Low," "Med-Hi," "High," and "Very High." Therefore, an area defined as "High" means that the fishing activity in this area is higher than average in the Mid-Atlantic region, and not higher than a specific value or range.

Fishing activity by catch

Figure 2-8 shows herring commercial fishing vessel activity at less than 4 kt. Most of the Lease Area had no recorded VMS herring fishing from 2015 to 2016. The northwest edge of the Lease Area shows average levels of fishing activity and is close to the Buzzards Bay inbound TSS.

Very High levels of herring fishing vessel activity occurred in and near lanes of dense traffic at the mouth of Narragansett Bay and near shore in Block Island Sound.

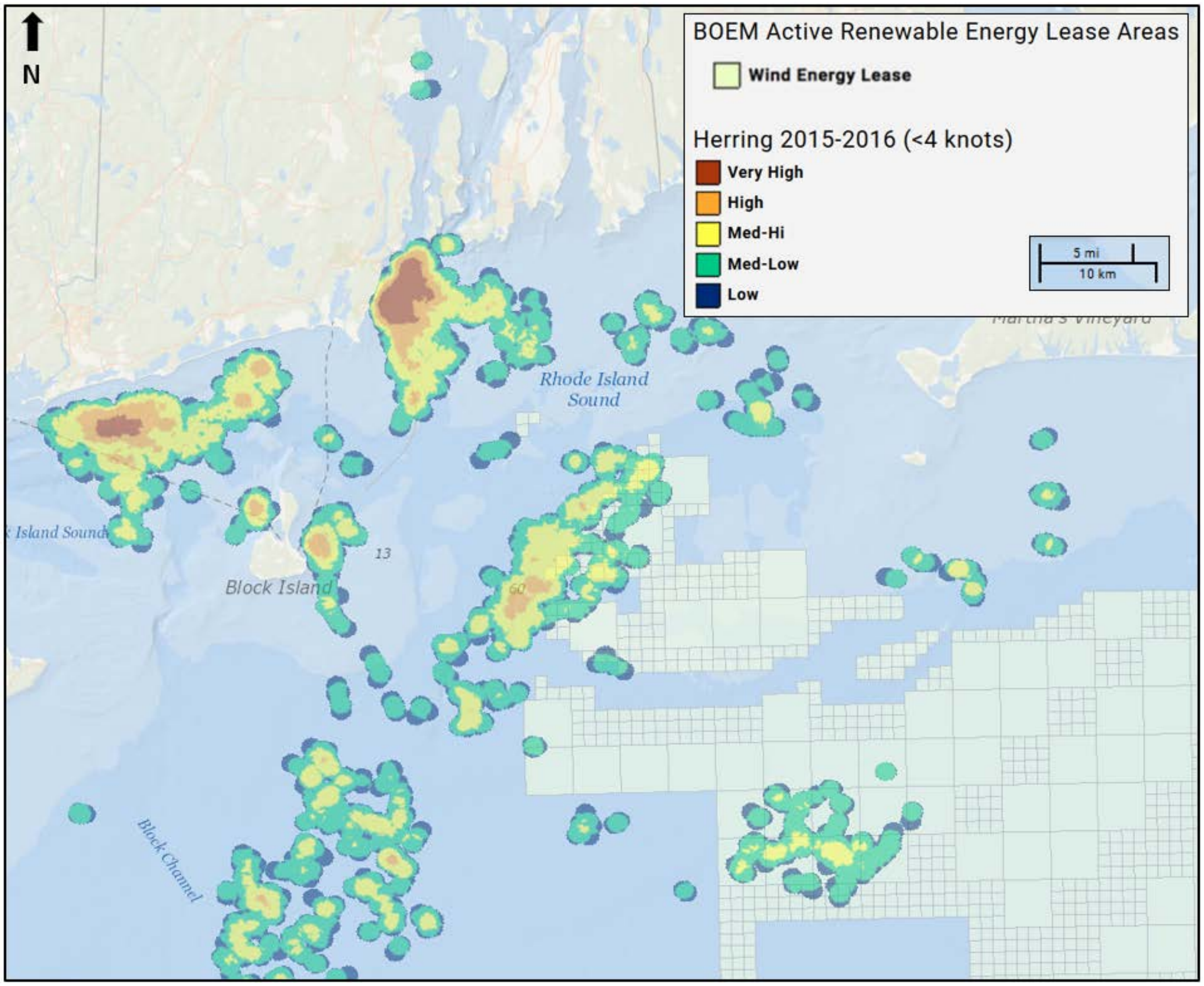


Figure 2-8 Commercial fishing vessel density map herring fishing at less than 4 kt, 2015-2016 (VMS) (MARCO, 2019)

Figure 2-9 presents monkfish commercial fishing vessel activity at less than 4 kt. In the Lease Area, monkfish fishing activity is highly varied. A couple of small “Very High” areas lie in the southern portion of the Lease Area. Most of the “Very High” fishing activities in the Mid-Atlantic region were south of Martha’s Vineyard Island, which is south and west of the Lease Area.

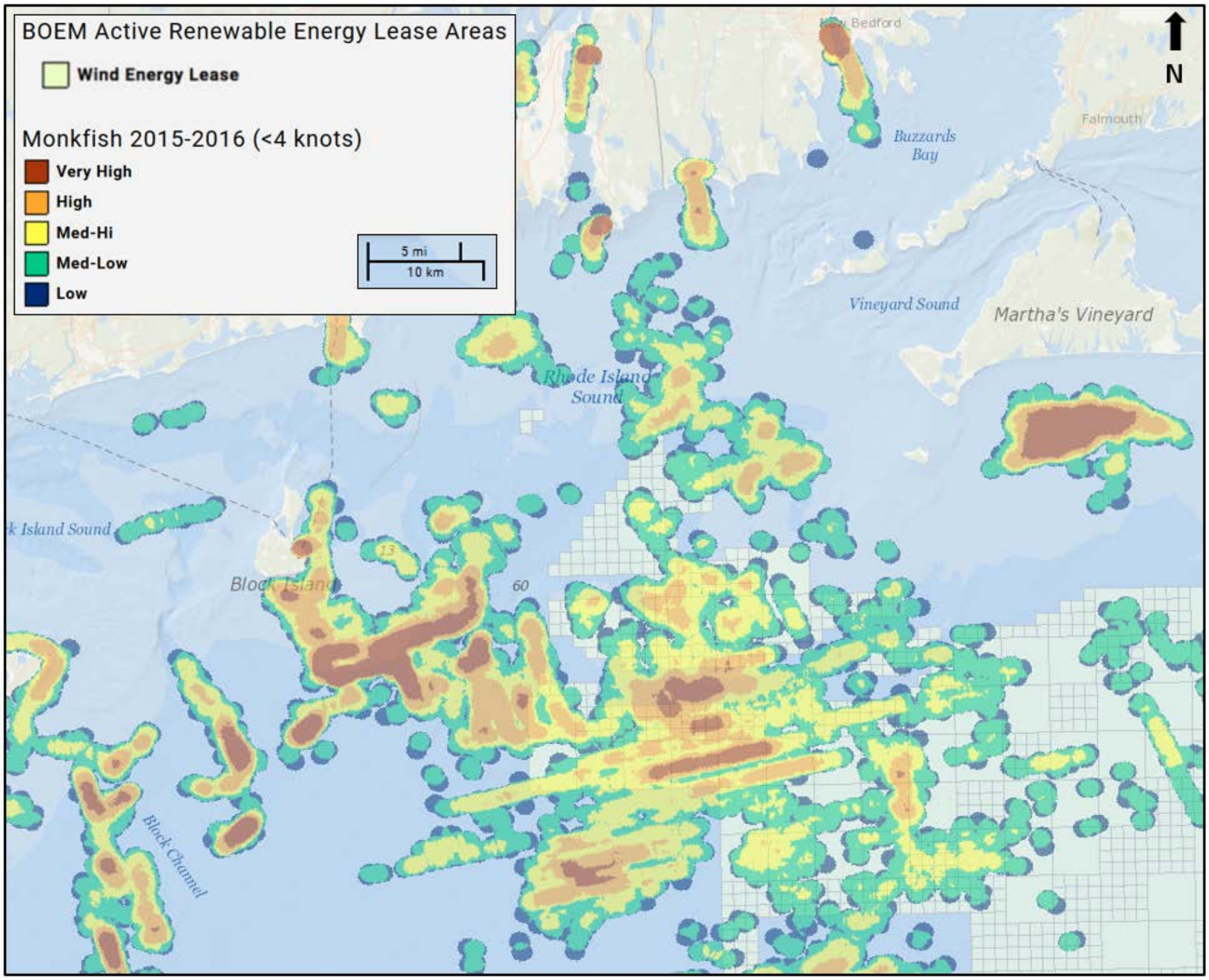


Figure 2-9 Commercial fishing vessel density map monkfish fishing at less than 4 kt, 2015-2016 (VMS) (MARCO, 2019)

Figure 2-10 shows multispecies (groundfish) commercial fishing vessel activity at less than 4 kt. Most of the Lease Area had no recorded VMS groundfish fishing from 2015 to 2016. There were a few small zones from "Low" to "High" fishing activity on its western and northern sides.

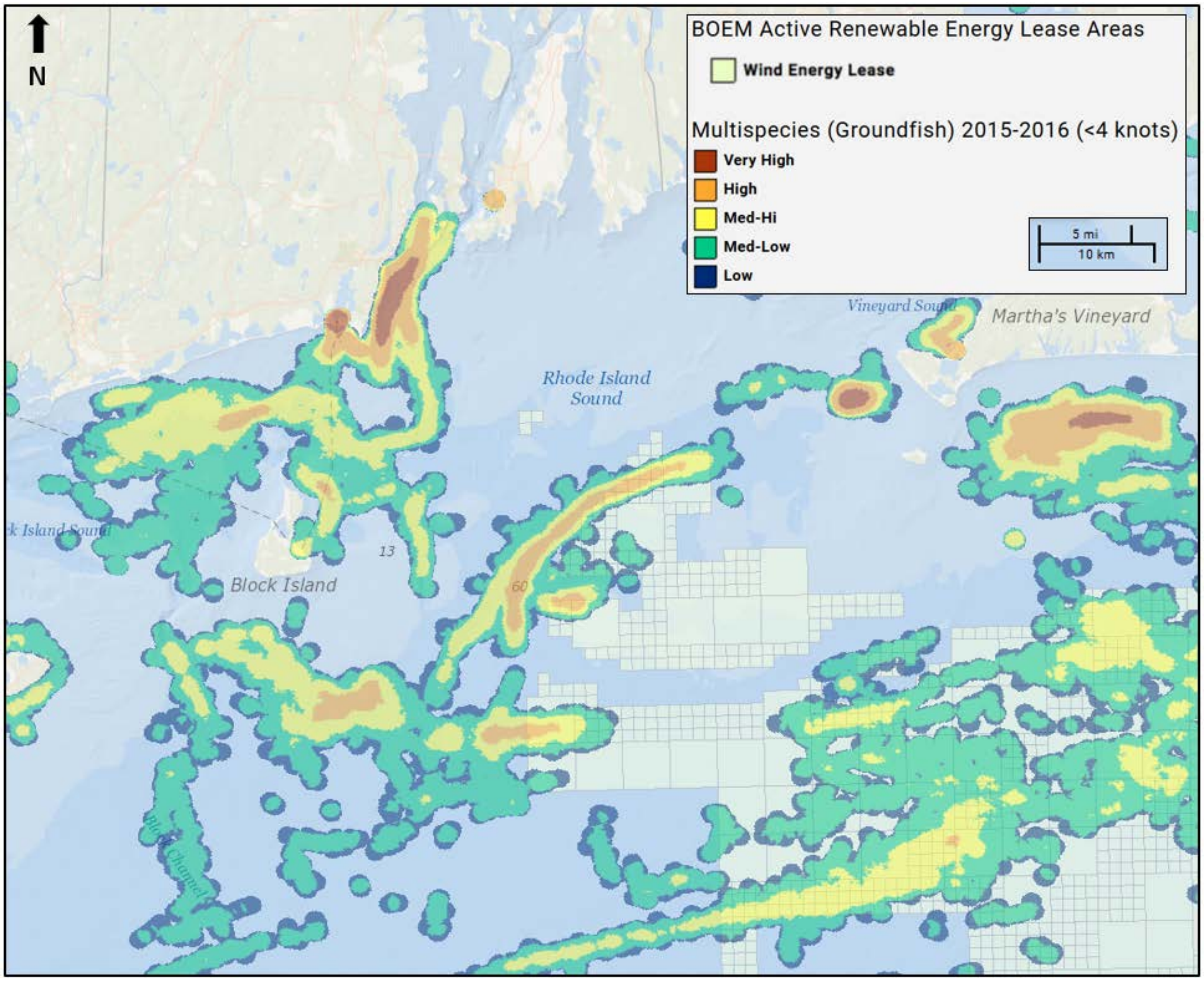


Figure 2-10 Commercial fishing vessel density map multispecies groundfish fishing at less than 4 kt, 2015-2016 (VMS) (MARCO, 2019)

Figure 2-11 presents pelagics (herring/mackerel/squid) commercial fishing vessel activity at less than 4 kt. Most of the Lease Area had no recorded VMS pelagics fishing from 2015 to 2016. Similar to groundfish, fishing activity for pelagics ranges from “Low” to “High” on the western and northern sides of the Lease Area.

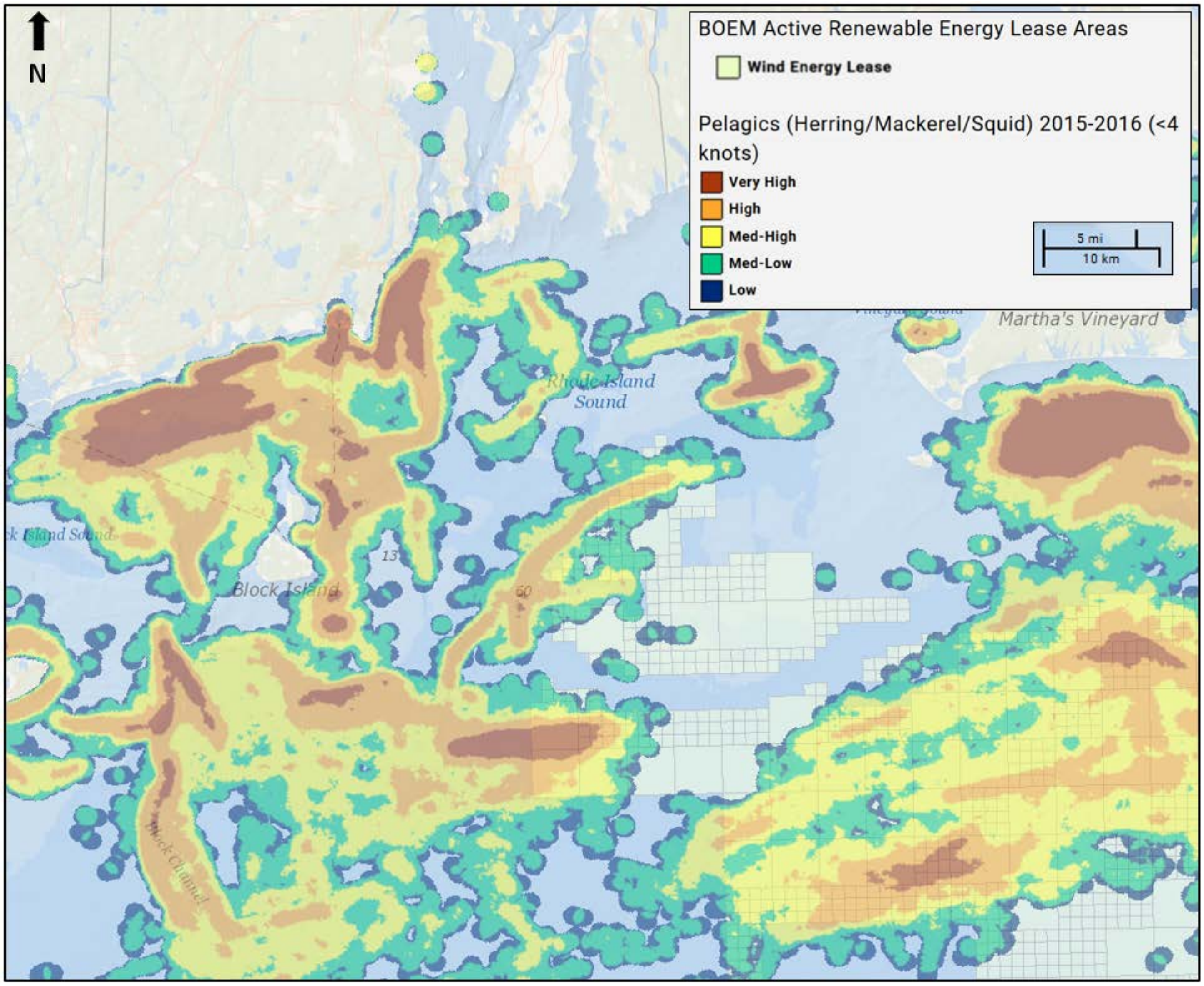


Figure 2-11 Commercial fishing vessel density map pelagics (herring/mackerel/squid) fishing, 2015-2016 (VMS) (MARCO, 2019)

Figure 2-12 shows scallop commercial fishing vessel activity at less than 5 kt. Most of the Lease Area had no recorded VMS scallop fishing from 2015 to 2016; however, specific locations showed a wide range of “Low” to “High” fishing activity.

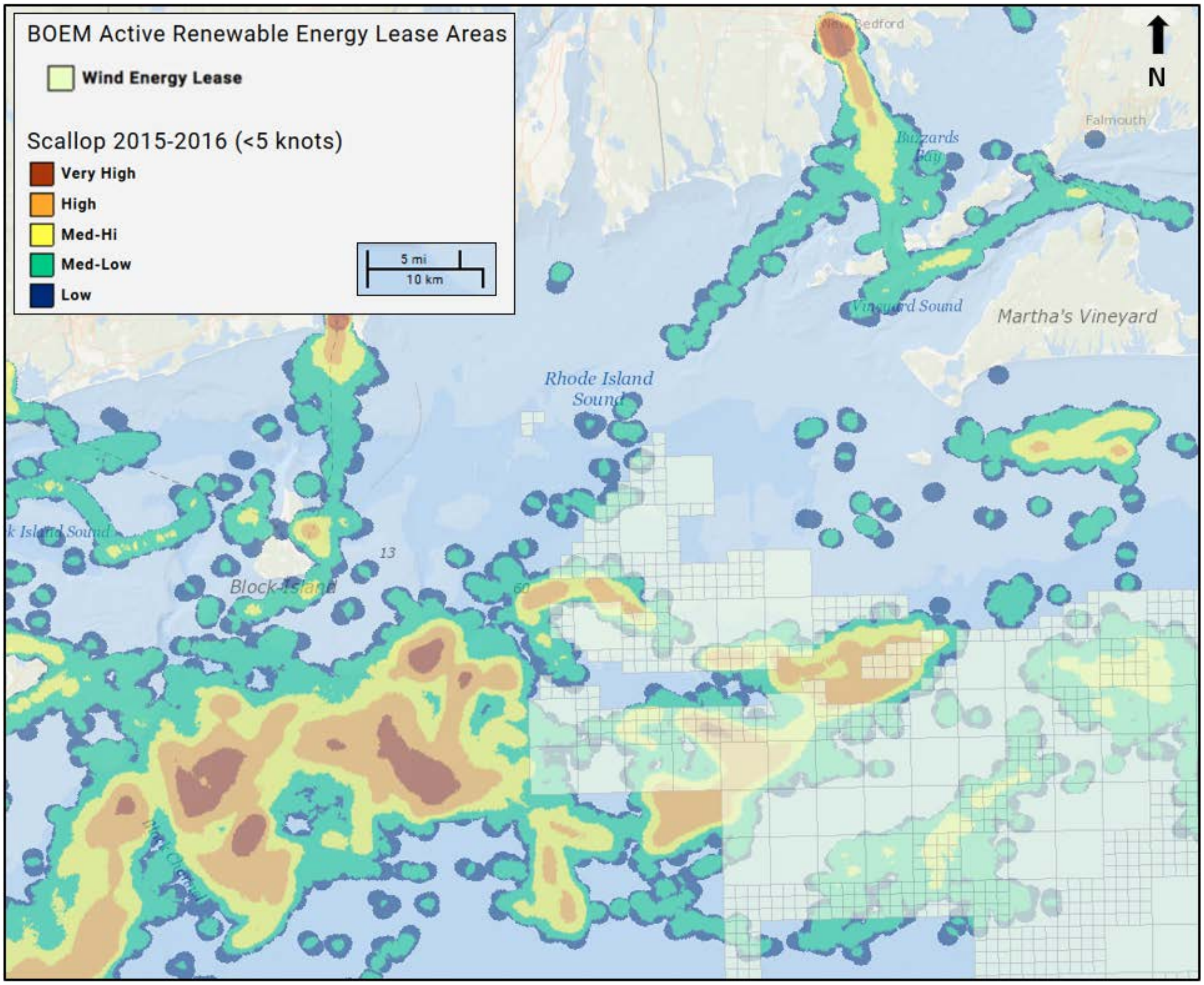


Figure 2-12 Commercial fishing vessel density map scallop fishing at less than 5 kt, 2015-2016 (VMS) (MARCO, 2019)

Figure 2-13 presents squid commercial fishing vessel activity at less than 4 kt. Most of the Lease Area had no recorded VMS squid fishing from 2015 to 2016. Similar to groundfish and pelagics, squid activity ranges from "Low" to "High" on the western and northern sides of the Lease Area.

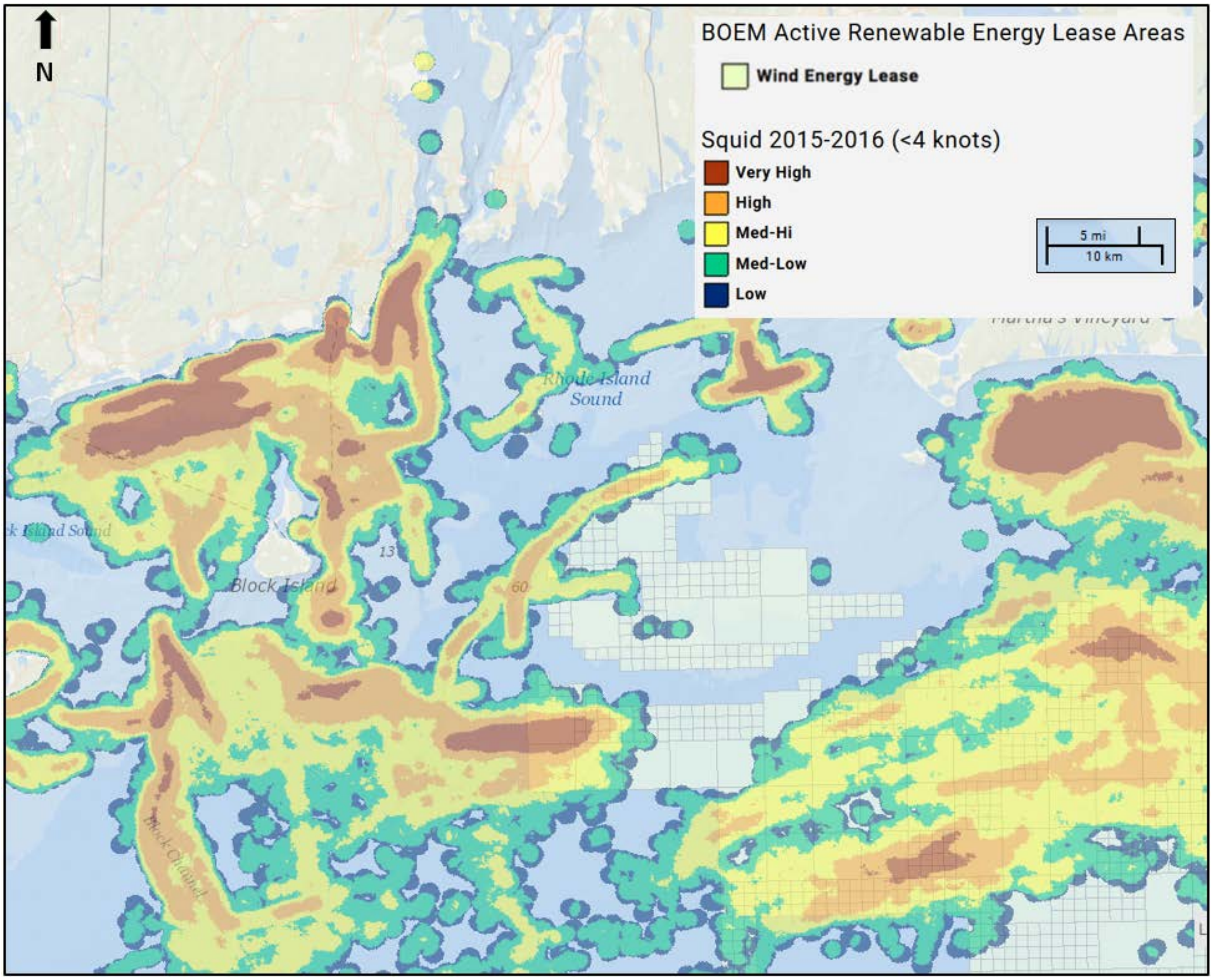


Figure 2-13 Commercial fishing vessel density map squid fishing at less than 4 kt, 2015-2016 (VMS) (MARCO, 2019)

Figure 2-14 shows surfclam/ocean quahog commercial fishing vessel activity at less than 4 kt. The northwest portion of the Lease Area includes a couple of zones with “Low” to “Very High” fishing activity. Most of the Lease Area had no recorded VMS surfclam/ocean quahog fishing from 2015 to 2016.

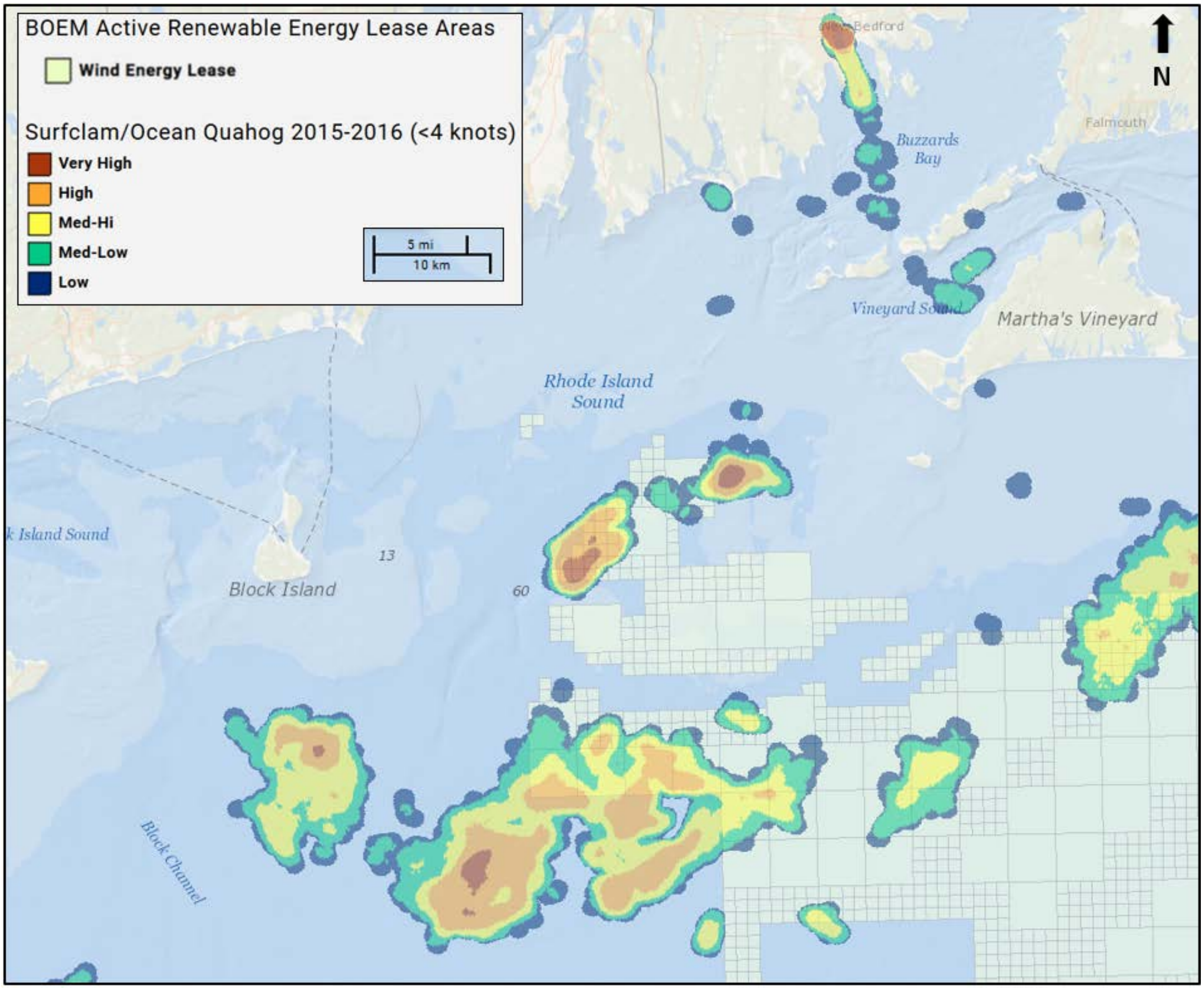


Figure 2-14 Commercial fishing vessel density map surfclam/ocean quahog fishing at less than 4 kt, 2015-2016 (VMS) (MARCO, 2019)

Fishing activity by gear

A few major commercial fishing ports in New England berth the majority of vessels that fish in the vicinity of the Lease Area. The main ports include Pt Judith, Newport, and New Bedford.

The most recent available data were obtained for fishing gear use in the Study Area. The data represent the period 2011-2015 and are provided by Communities at Sea (MARCO, 2019). Figure 2-18 to Figure 2-20 show activity level by fishing gear type, in order of relative use in the Lease Area. In general, light gillnet activity occurred throughout the Lease Area; bottom trawl and dredge occurred in the northern and western portions of the Lease Area, and there was little / no potting or longline activity in the Lease Area.

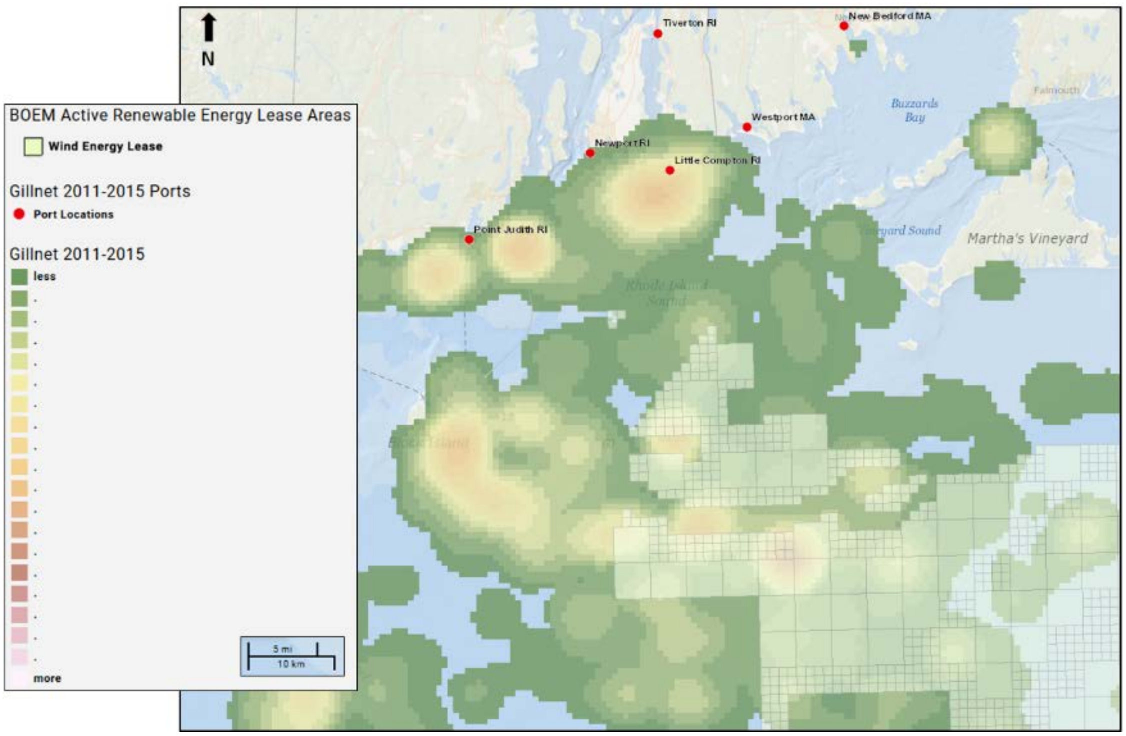


Figure 2-15 Total gillnet activity for 2011-2015 (MARCO, 2019)

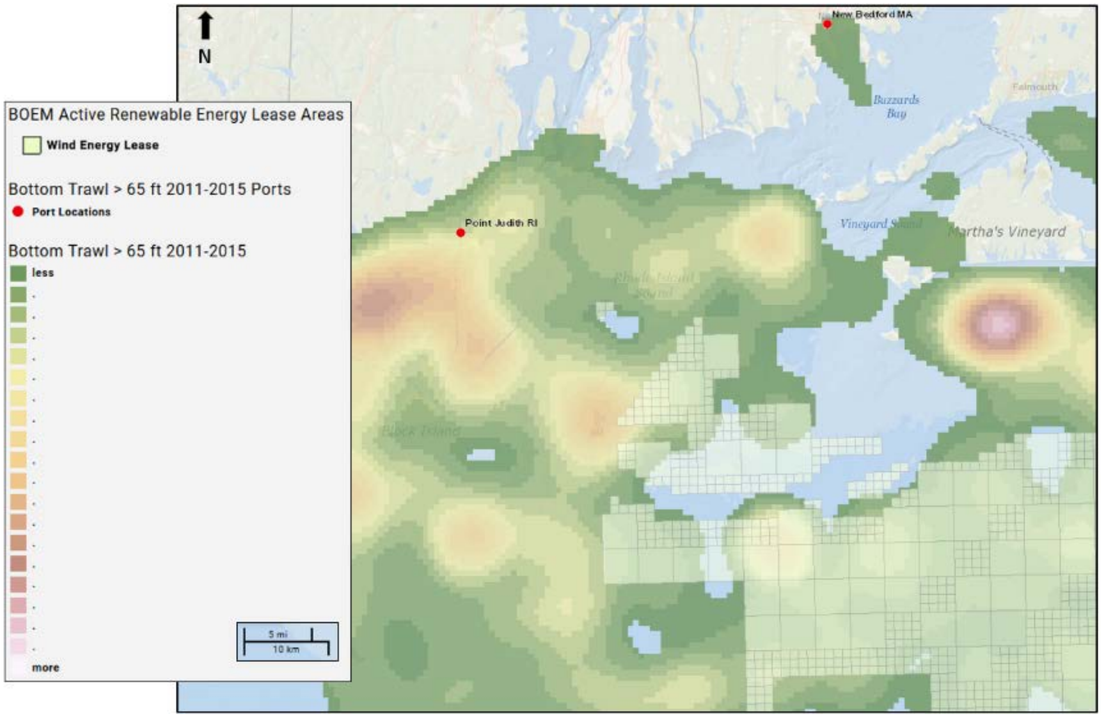


Figure 2-16 Total bottom trawl (>65 ft) activity for 2011-2015 (MARCO, 2019)

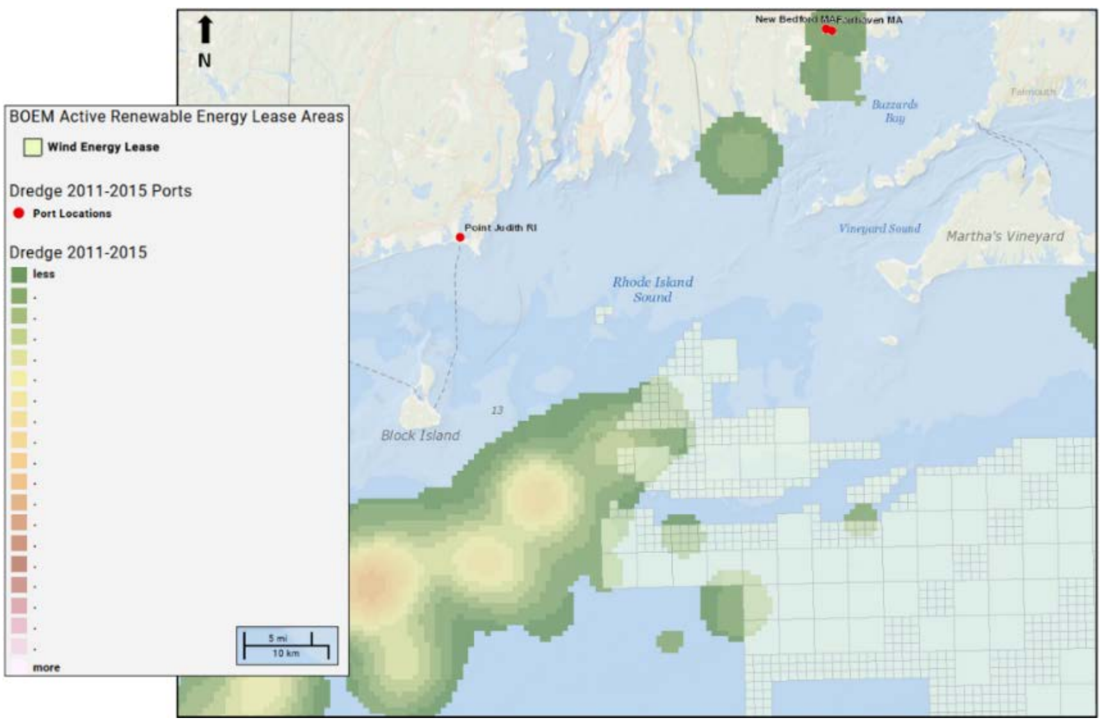


Figure 2-17 Total dredge activity for 2011-2015 (MARCO, 2019)

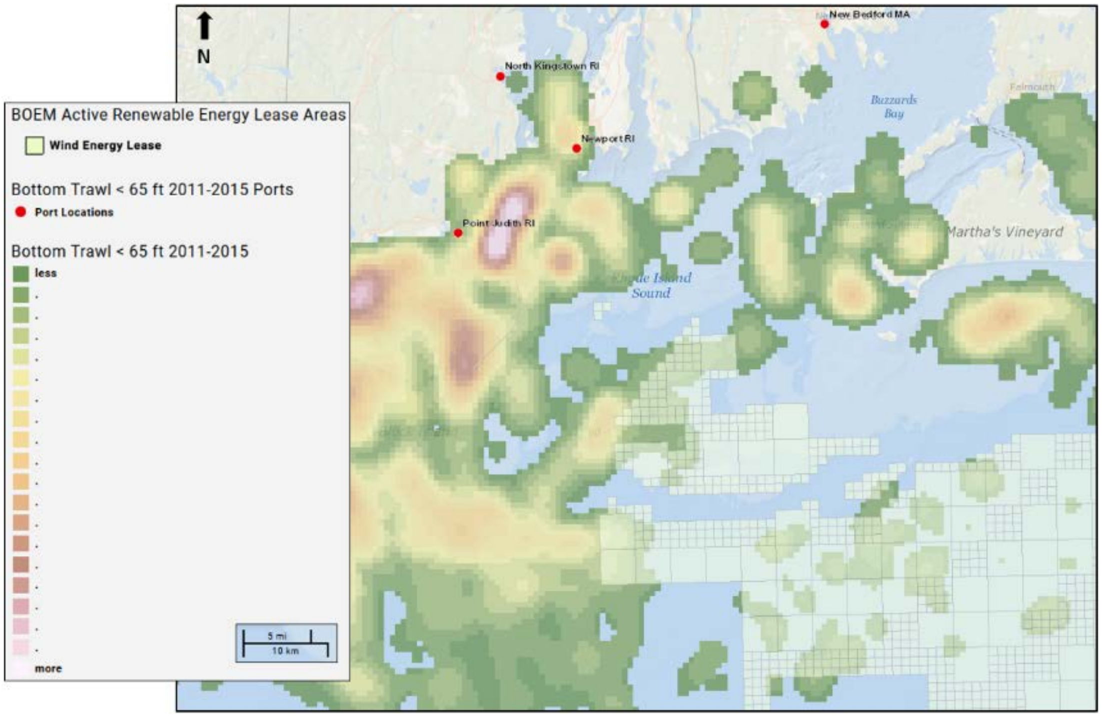


Figure 2-18 Total bottom trawl (<65 ft) activity for 2011-2015 (MARCO, 2019)

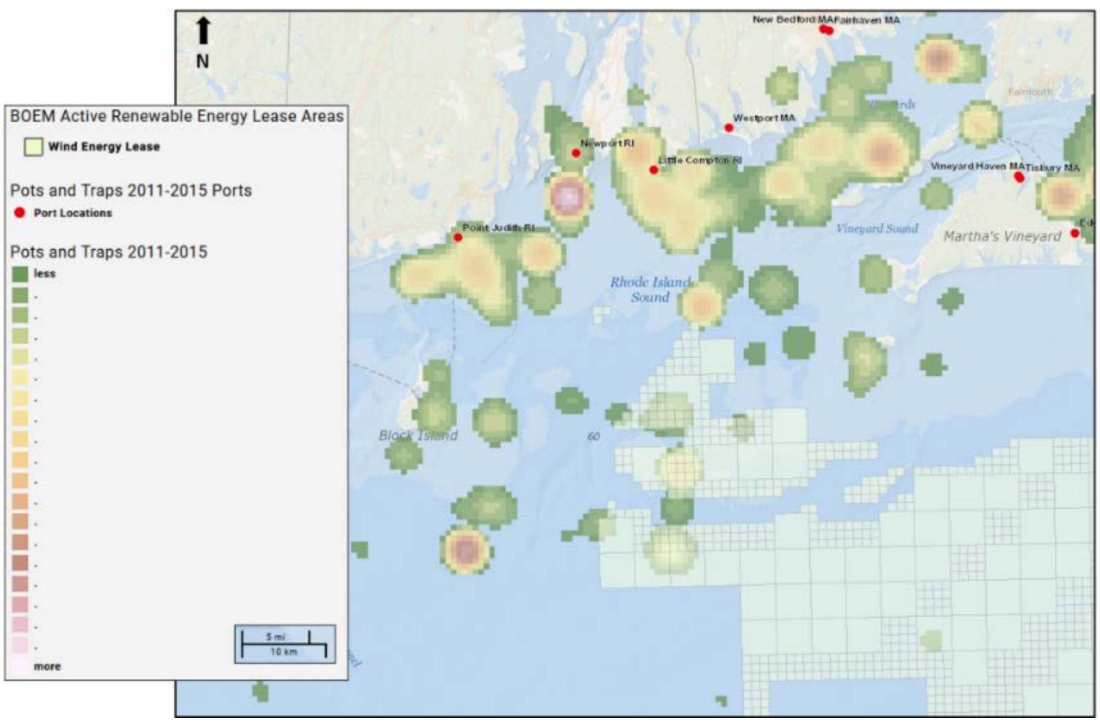


Figure 2-19 Total pots and traps activity for 2011-2015 (MARCO, 2019)

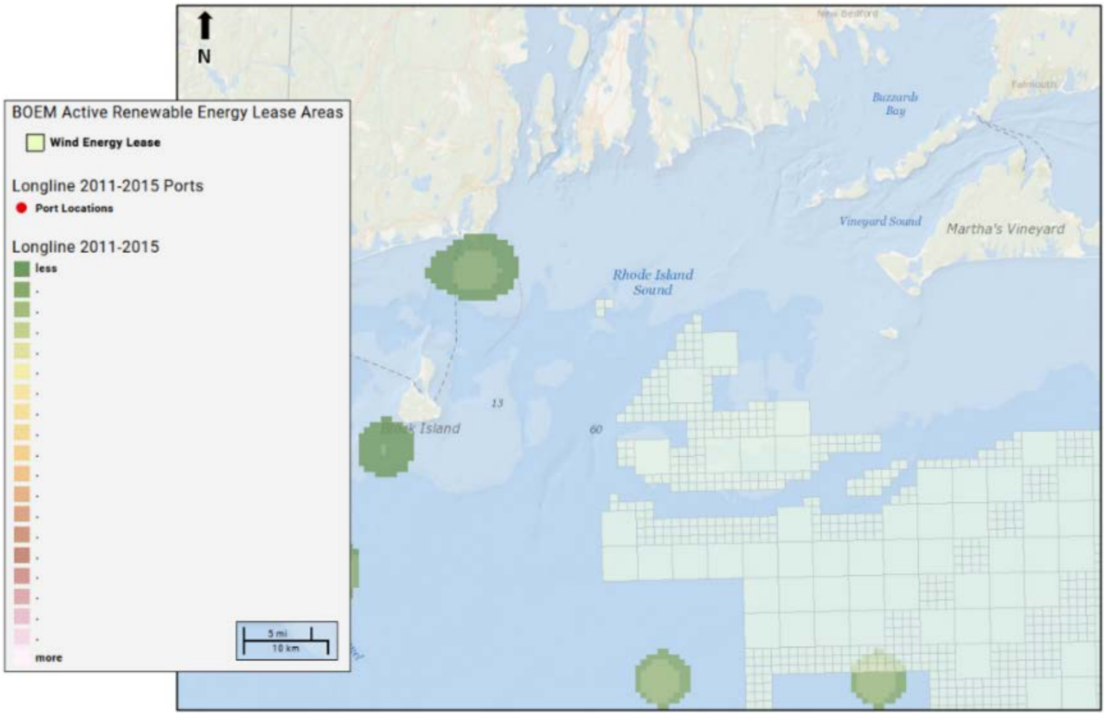


Figure 2-20 Total longline activity for 2011-2015 (MARCO, 2019)

2.1.1.3 Passenger vessel traffic

Figure 2-21 shows that passenger vessels (including ferries and cruise ships) followed established routes, primarily along the coast and used the Narragansett Bay TSS. A passenger vessel transited to the proposed South Fork Wind Farm location many times during the year, likely conducting wind farm-related studies; however, very few other vessel tracks passed through the Lease Area.

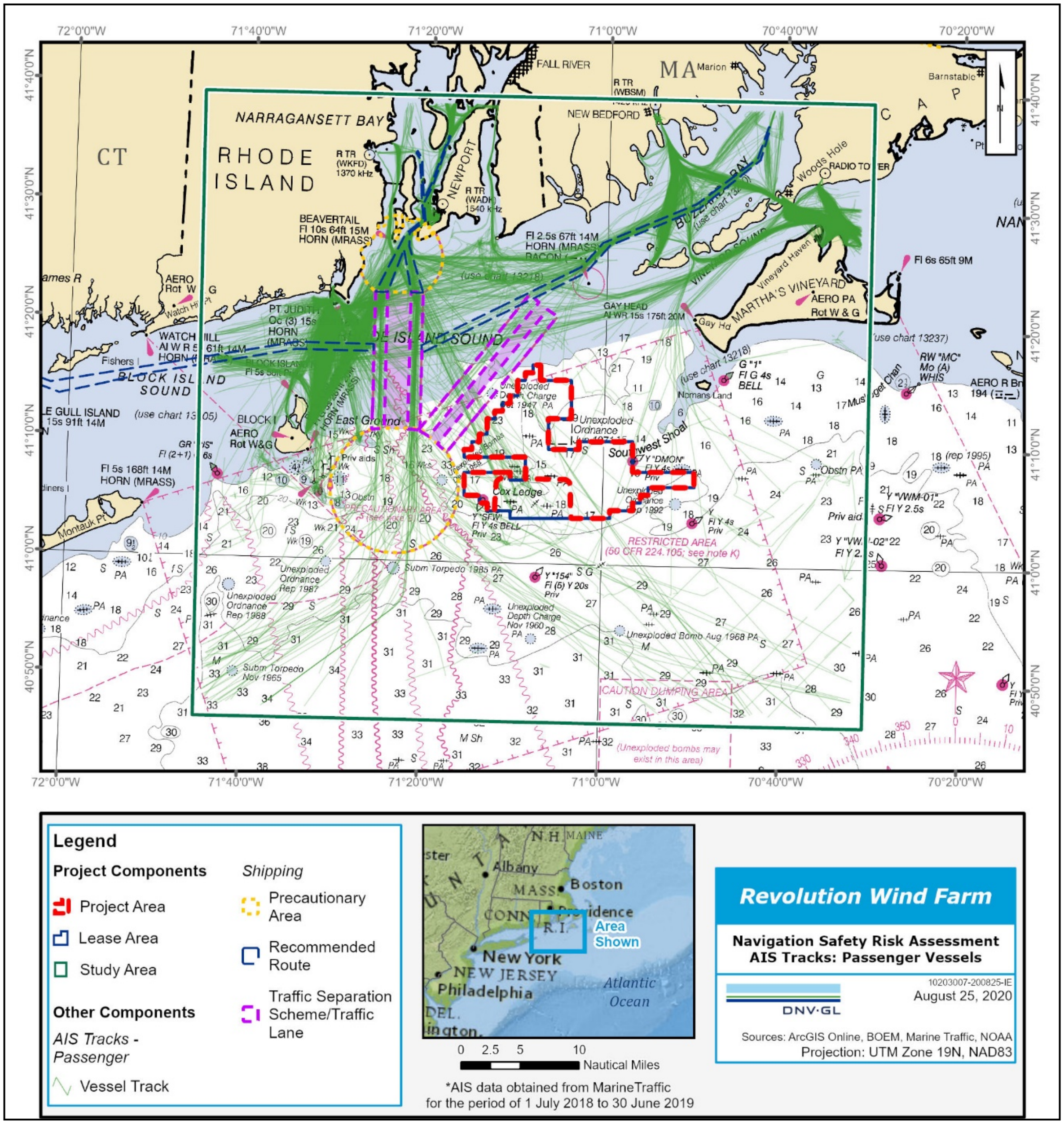


Figure 2-21 AIS tracks for passenger vessels[1]

2.1.1.4 Pleasure vessel traffic

Pleasure vessels generally include recreational boating, and are defined for the purposes of this study as AIS ship types "Pleasure Craft", "Sailing Vessel", and "Yacht". The data show pleasure and recreation vessel traffic primarily occurs near the coast (Figure 2-22), with relatively few tracks in the Lease Area. The AIS tracks that go through the Lease Area have either northwest-southeast or southwest-northeast directionality.

The density and route maps from the Mid-Atlantic Ocean Data Portal (MARCO, 2019) (Figure 2-23) indicate that recreational traffic is minimal in the Lease Area and dense near the coast.

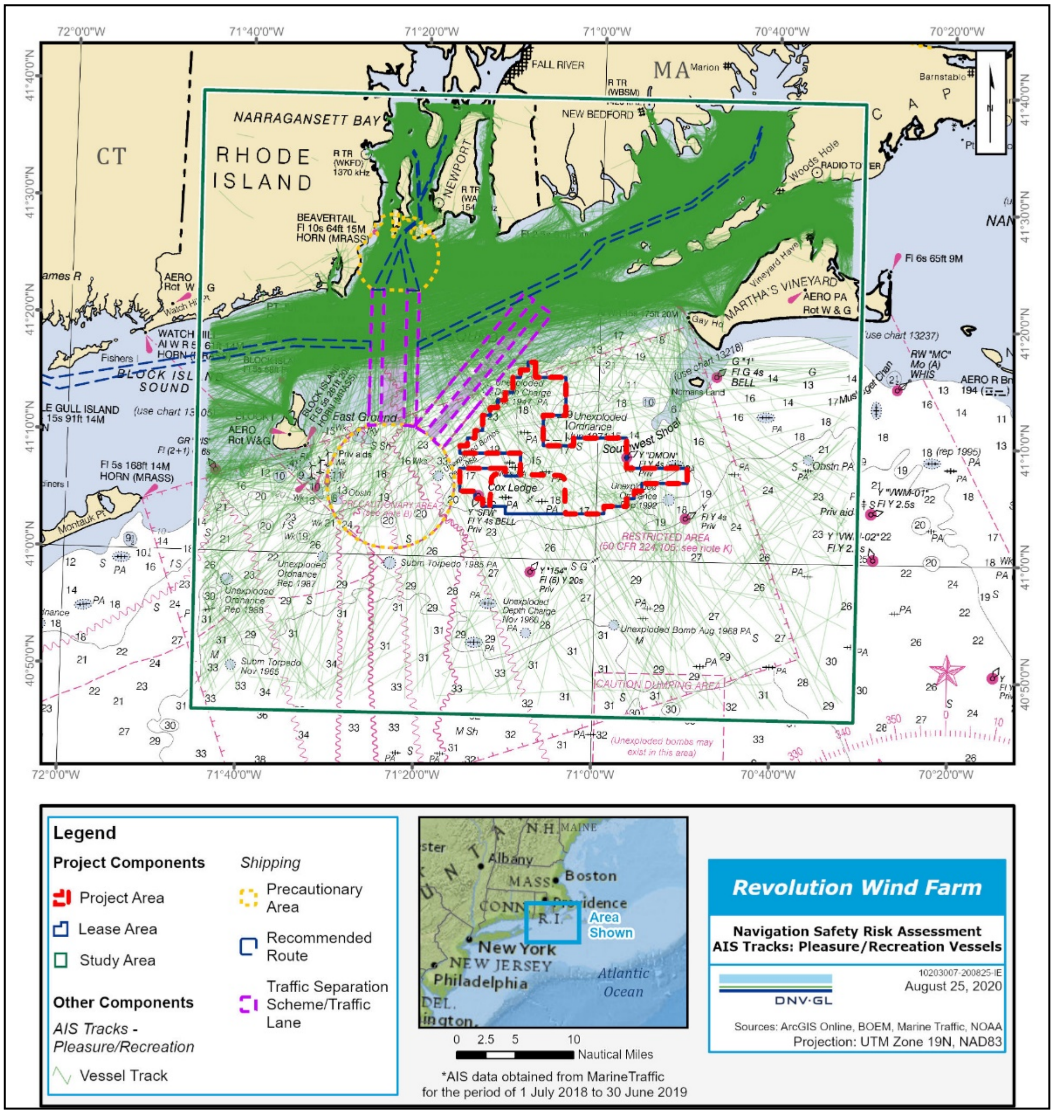


Figure 2-22 AIS tracks for pleasure / recreation vessels[1]

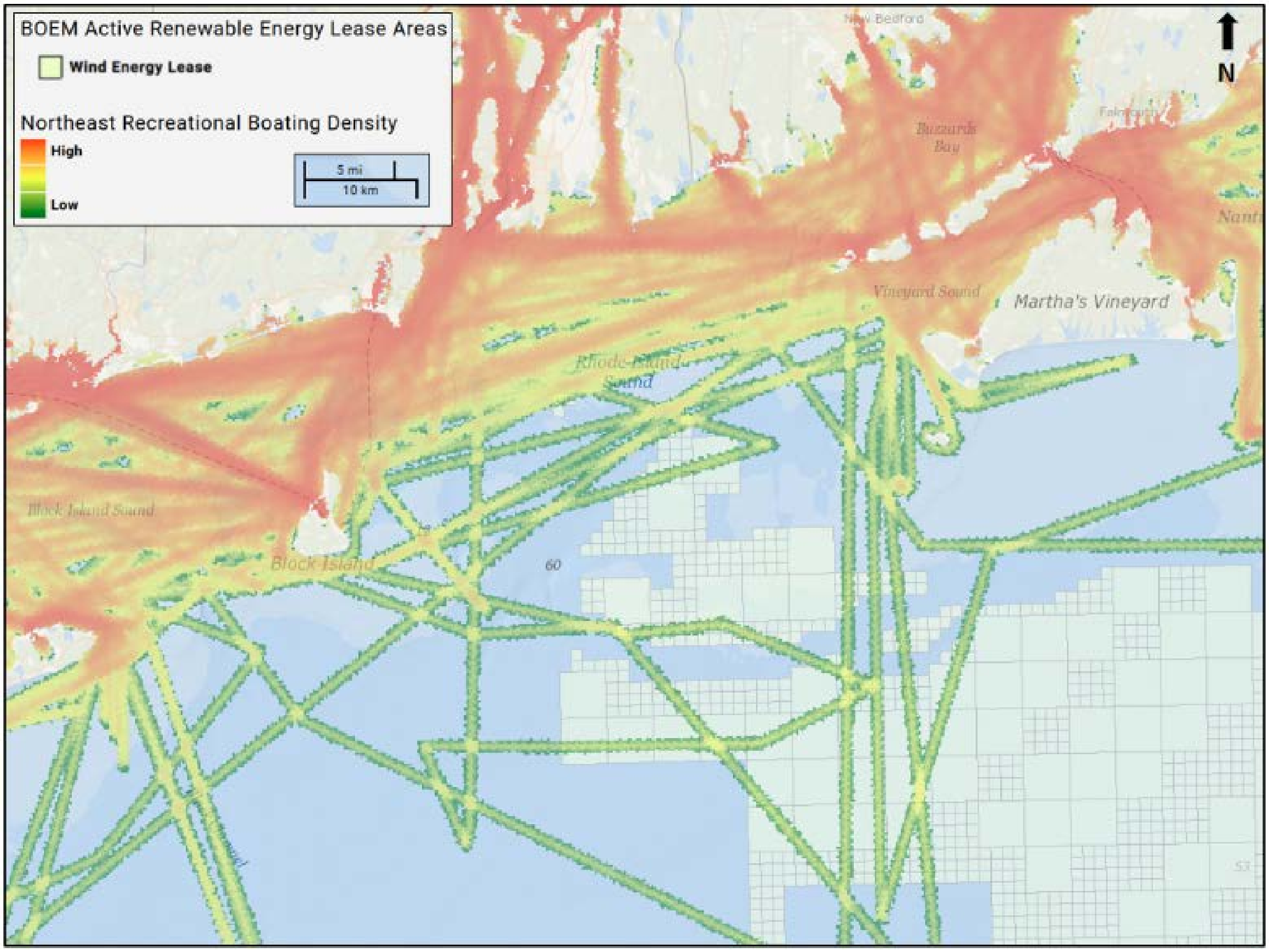


Figure 2-23 Recreational boating density (MARCO, 2019)

To ensure that the most realistic traffic is used in DNV GL's proprietary Marine Accident Risk Calculation System (MARCS) software, transits were added to the AIS data for the purposes of risk modeling (discussed in Section 11). Data on recreational boating were obtained from the Northeast Recreation Boater Activities from the Northeast Ocean Data portal. The activities are from participants in the 2012 Northeast Recreational Boater survey, conducted by SeaPlan (2013), the Northeast Regional Ocean Council (NROC), states' coastal agencies, marine trade association of industry representatives, and the First Coast Guard District[3]. The data are from a randomly selected survey of registered boaters in the 2012 boating season.

The data contain 760 registered activities in the defined Study Area: 386 for fishing activity and 374 for other pleasure activities (such as diving and swimming). Each record was implemented in the model as an outbound and a return transit. The traffic patterns derived from the AIS analysis for fishing vessels and pleasure vessels were examined and the most densely trafficked routes closest to the wind farm were selected. The additional traffic was allocated to these routes. This represents a reasonable worst-case assessment of traffic that does not transmit AIS.

[3] SeaPlan, "Recreational Boater Activities" http://www.northeastoceandata.org/files/metadata/Themes/Recreation/RecreationalBoaterActivities.pdf.

2.1.1.5 Tug/Service traffic

The AIS tracks for tugs and service vessels show distinct patterns, as seen in Figure 2-24. Most vessels transit coastwise and do not enter the Lease Area. The tugs and service vessels transiting to/from open waters take the TSS northwest of the Lease Area.

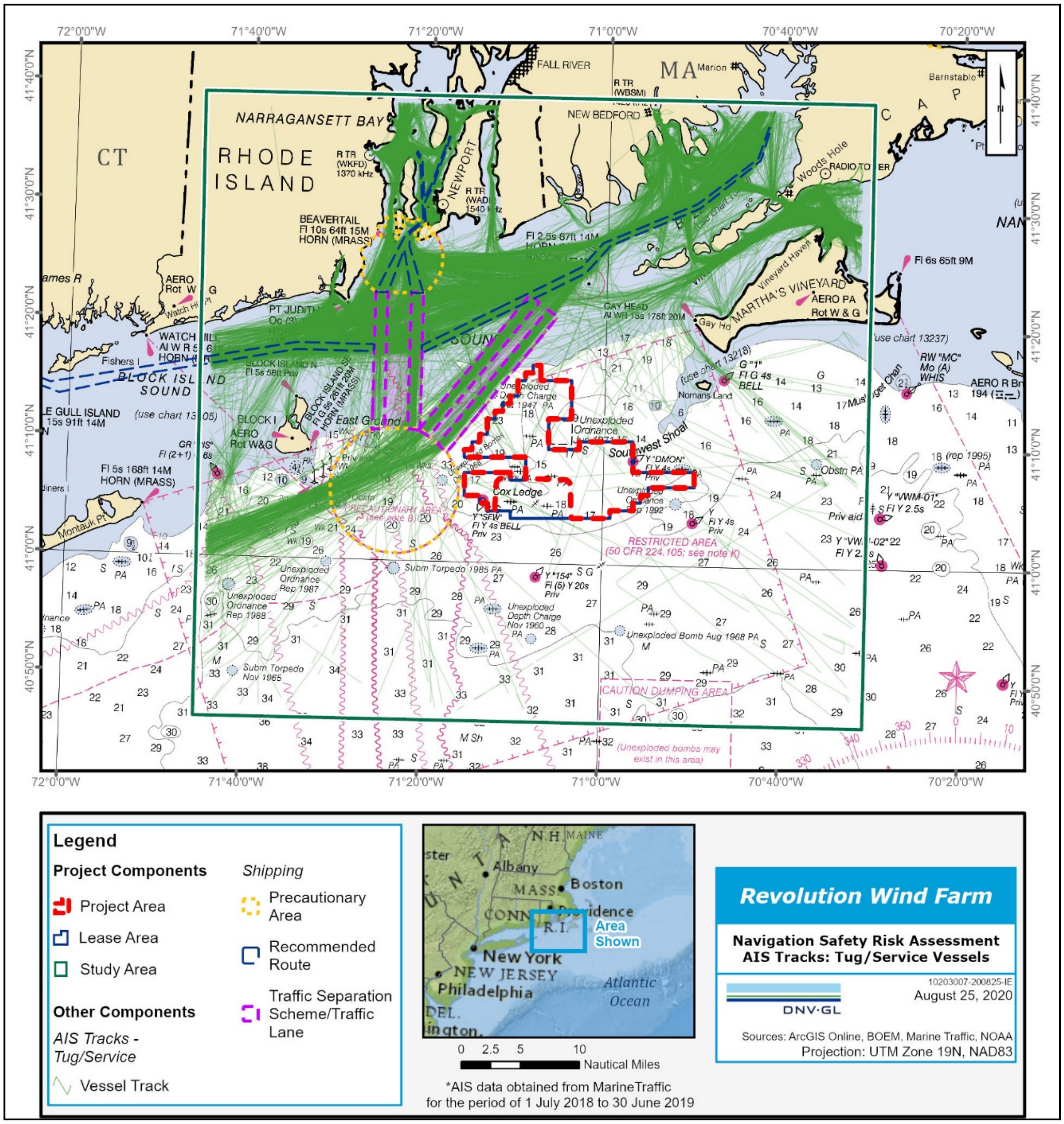


Figure 2-24 AIS tracks for tugs[1]

2.1.1.6 Other vessel traffic

AIS tracks for “Other” vessel types are presented in Figure 2-25. Other vessels are within AIS vessel sub-categories that do not clearly fit into other categories, including research vessels and military vessels. Most of these vessels generally transit near the coast and do not enter the Lease Area; however, some transit along the northeast boundary of the Lease Area. In addition, many of the tracks appear to be from research/data-gathering vessels because of the grid patterns produced by their tracks. These vessels are likely to be conducting site characterization surveys for wind energy projects.

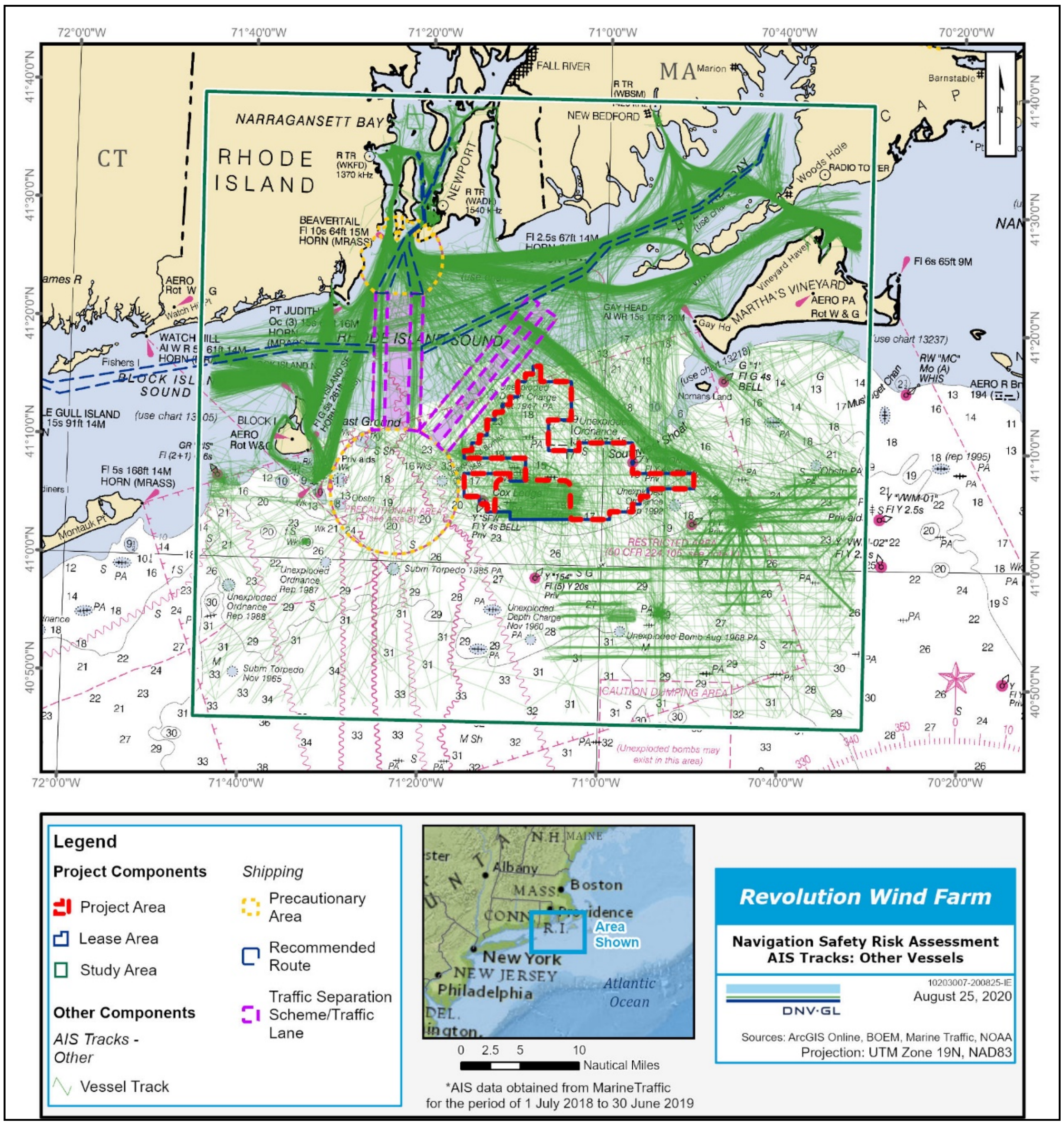


Figure 2-25 AIS tracks for other vessels[1]

Maps of AIS vessel tracks for each vessel type are presented in Appendix A.

2.1.2 Traffic density

Figure 2-26 presents a density heat map for all AIS points in the Study Area. It is worth noting that since the AIS dataset is terrestrial (from land-based AIS receivers), data quality may decrease farther from the coast, particularly beyond the Lease Area. This is more apparent for the point density maps than it is with tracks because the density relies only on the number of AIS points while tracks will connect points with variance in the space between them. The traffic density shows that vessels are closer together in space/time near shore and in the TSS.

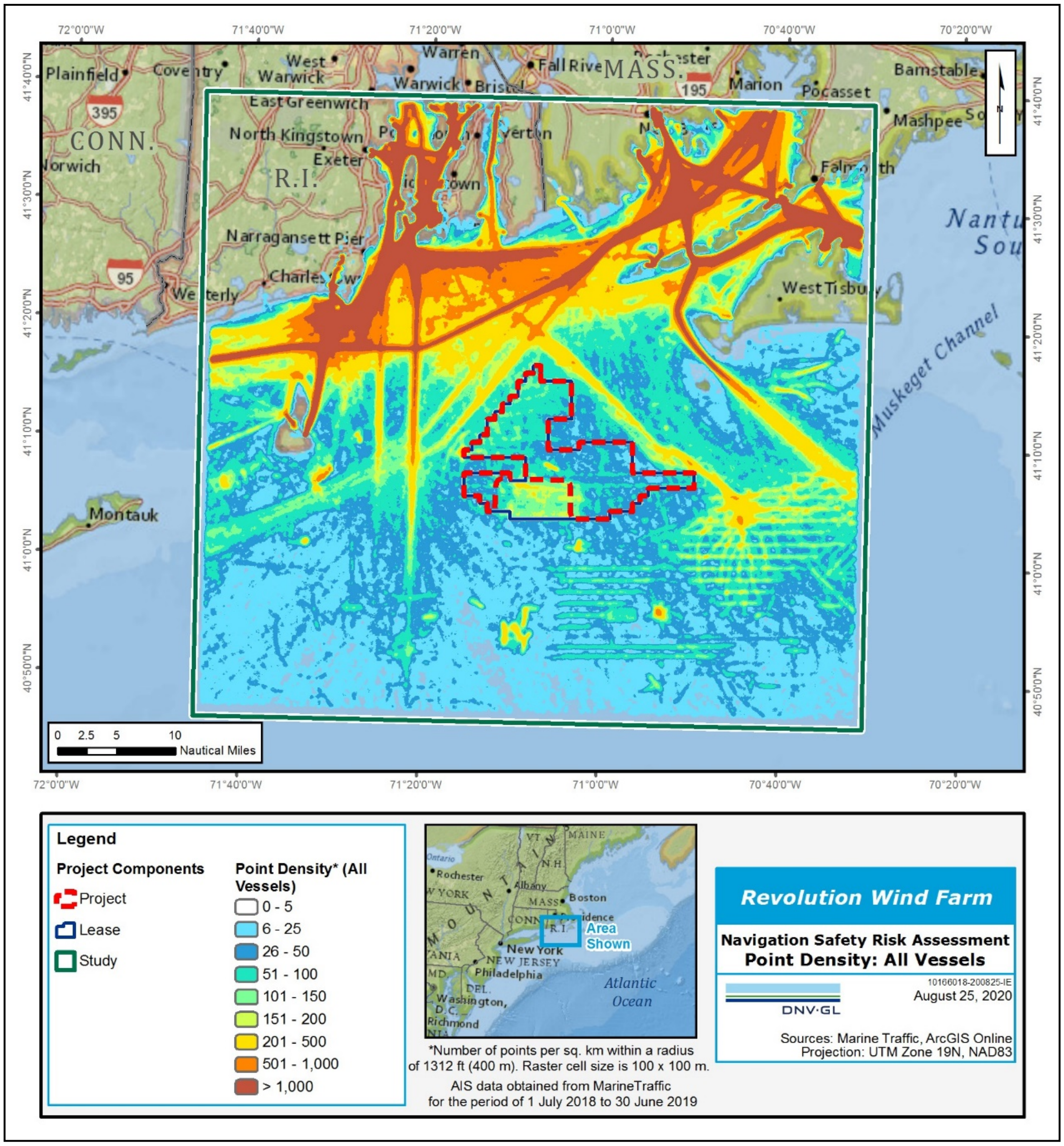


Figure 2-26 AIS point density[1]

2.1.3 Traffic statistics

This section presents the traffic statistics of the Study Area. The statistics provide insight concerning how many vessels and which types transit in specific locations and allows an estimate of the distribution of vessel types that transit in the vicinity of the Lease Area.

2.1.3.1 Transit counts

Transit counts per transect

Figure 2-27 shows the transects defined for this traffic analysis. The locations of the transects were selected to evaluate the major routes in the Study Area. The resulting number of vessels crossing each transect provides a view of the amount and types of marine traffic in the year of AIS data, July 2018 through June 2019.

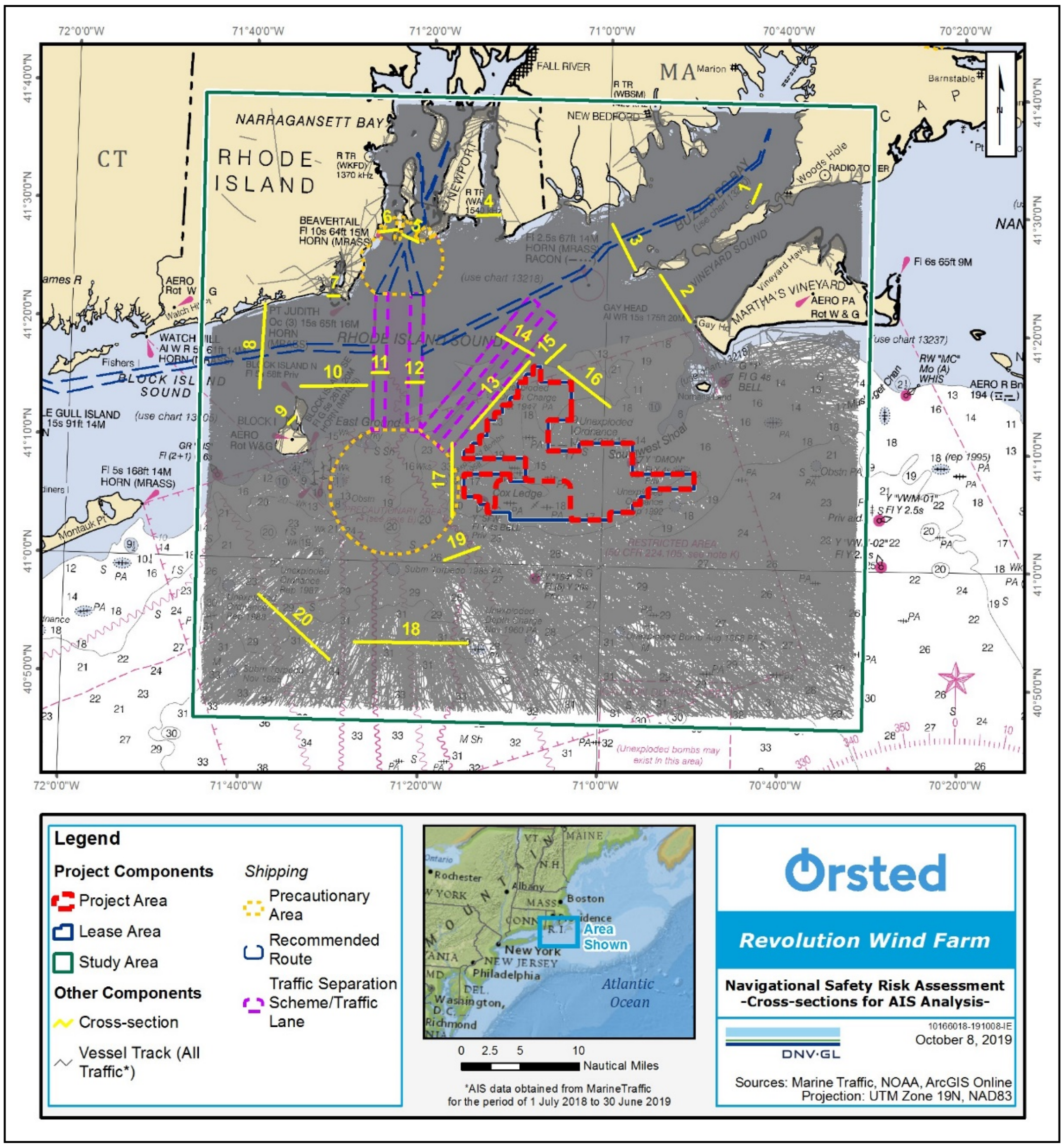


Figure 2-27 Transects used for statistical analysis of traffic[1]

Figure 2-28 presents the total number of transits per transect in the year of AIS data, July 2018 through June 2019.

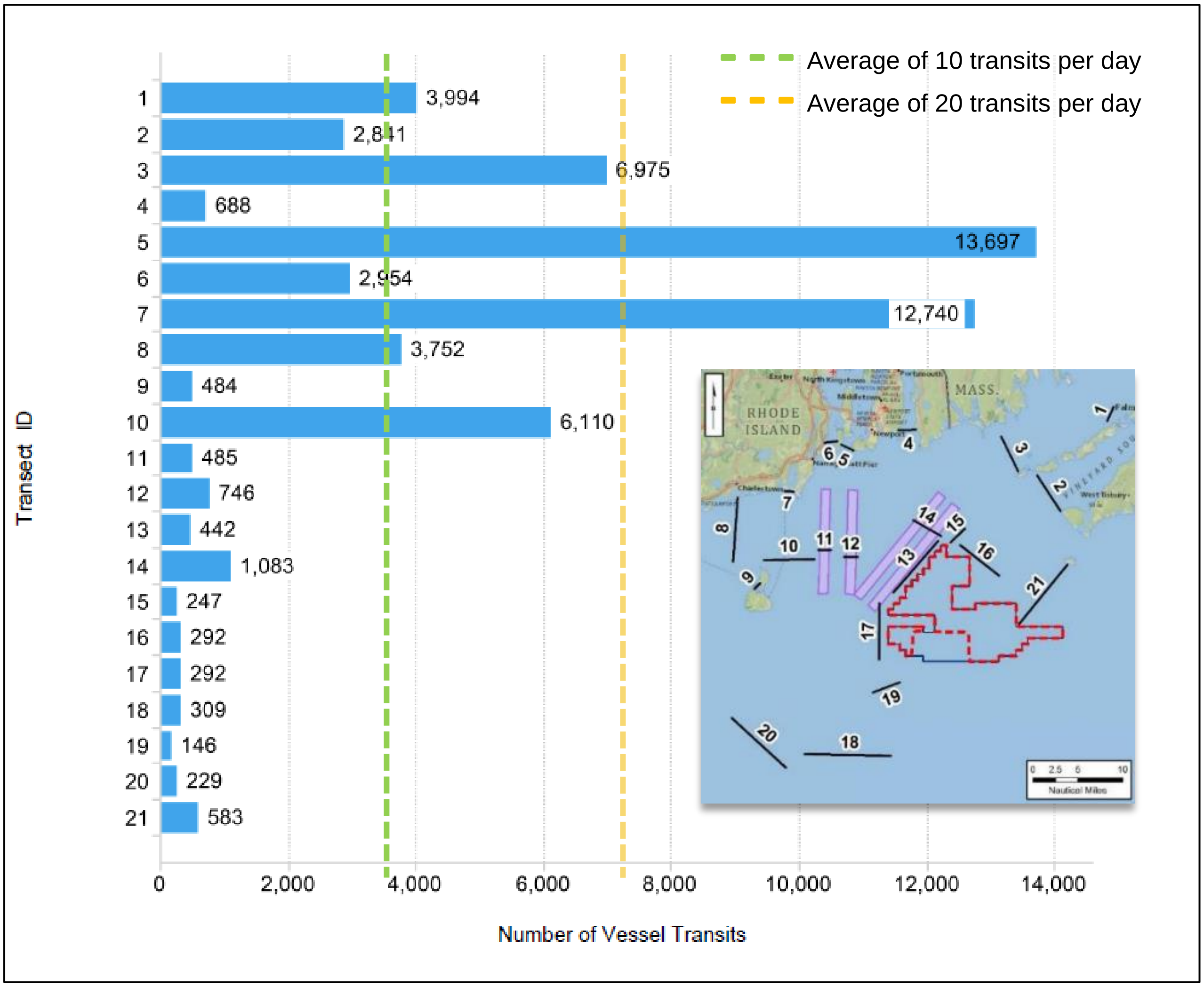


Figure 2-28 Annual number of transits per transect[1]

Most of the transects have very low traffic levels of less than 10 transits per day (less than 3,650 transits per year). Transects 5 (entrance of Narragansett Bay via East Passage) and 7 (Pt Judith) have a comparatively higher level of traffic, each with an average of 35 to 38 transits per day, 13,000 per year.

Transects 3 (entrance of Buzzards Bay) and 10 (northeast of Block Island) each have an average of slightly less than 20 transits per day, 6,000 to 7,000 per year. Transects 1 (Woods Hole Pass), 2 (entrance of Vineyard Sound), 6 (entrance of Narragansett Bay via West Passage) and 8 (entrance of Block Island Sound) average around 8 transits per day, about 3,000 transits per year.

Figure 2-29 to Figure 2-30 present the distribution of vessel types for each transect.

The cost of AIS technology has significantly decreased in the past 10 years and voluntary use of AIS in recreational vessels has increased over time; however, the adoption rates are relatively low. It is reasonable to assume that recreational fishing vessels ("pleasure" vessel type) are still underrepresented in the AIS data.

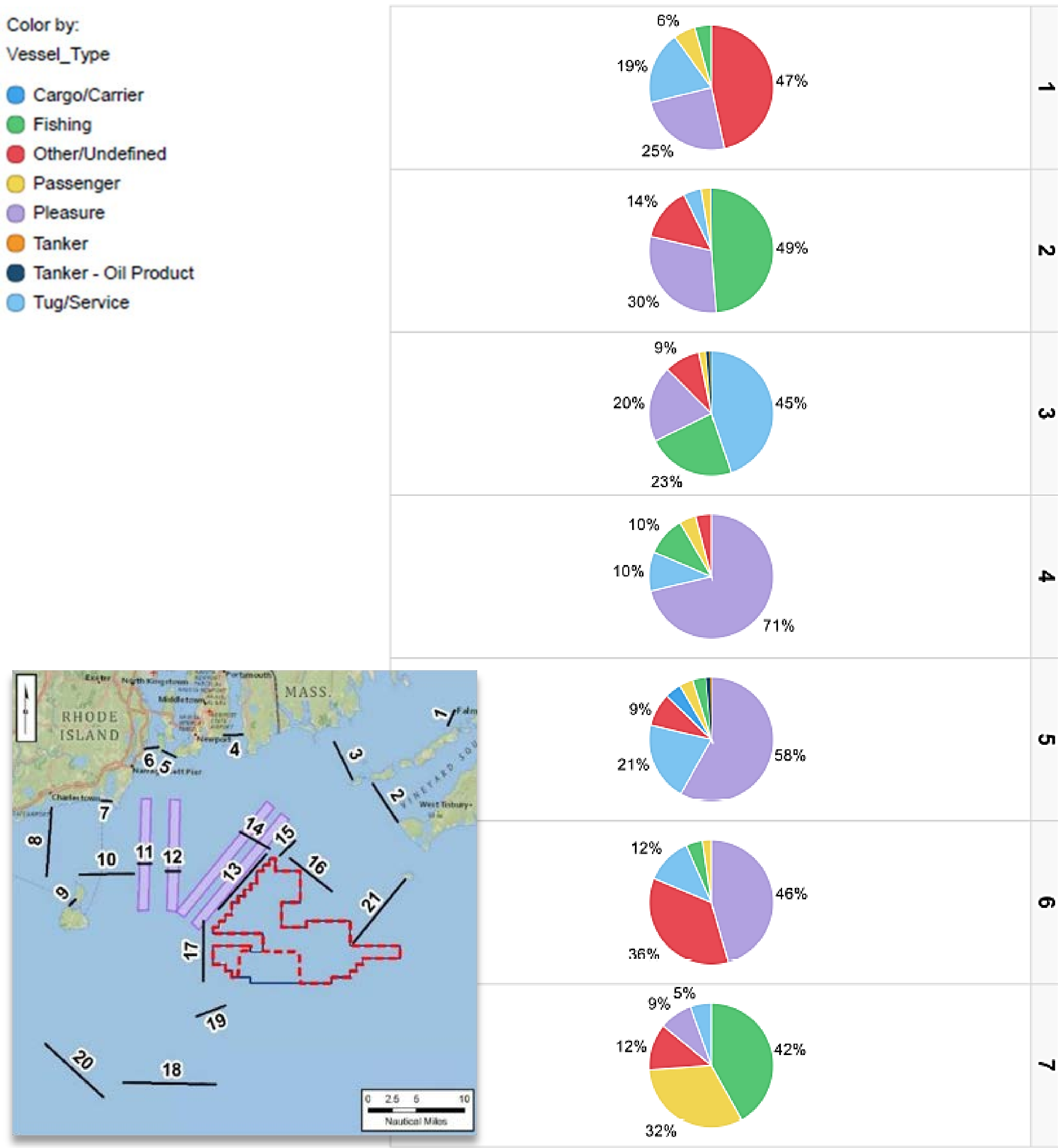


Figure 2-29 Traffic distributions for Transects 1 to 7[1]

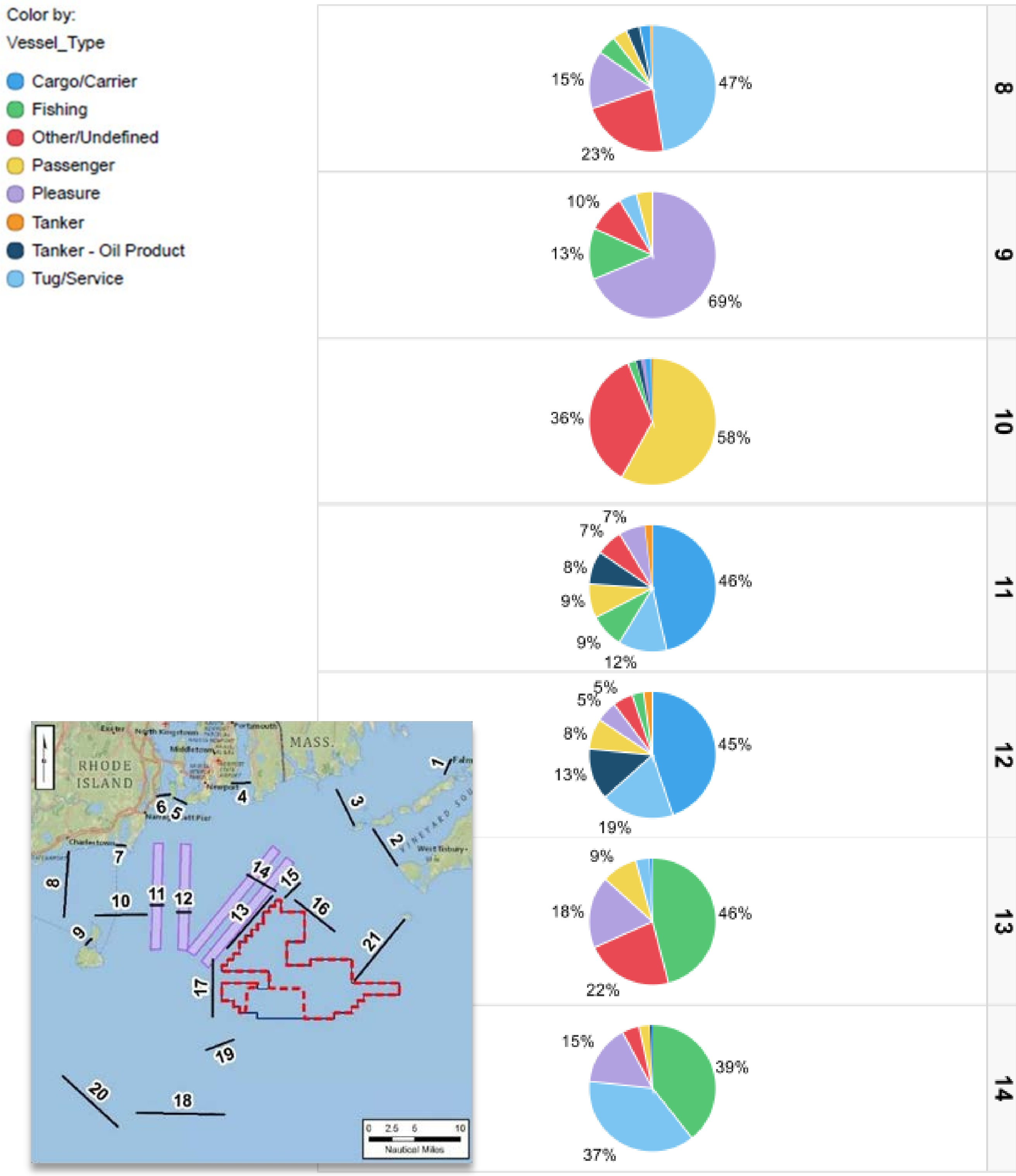
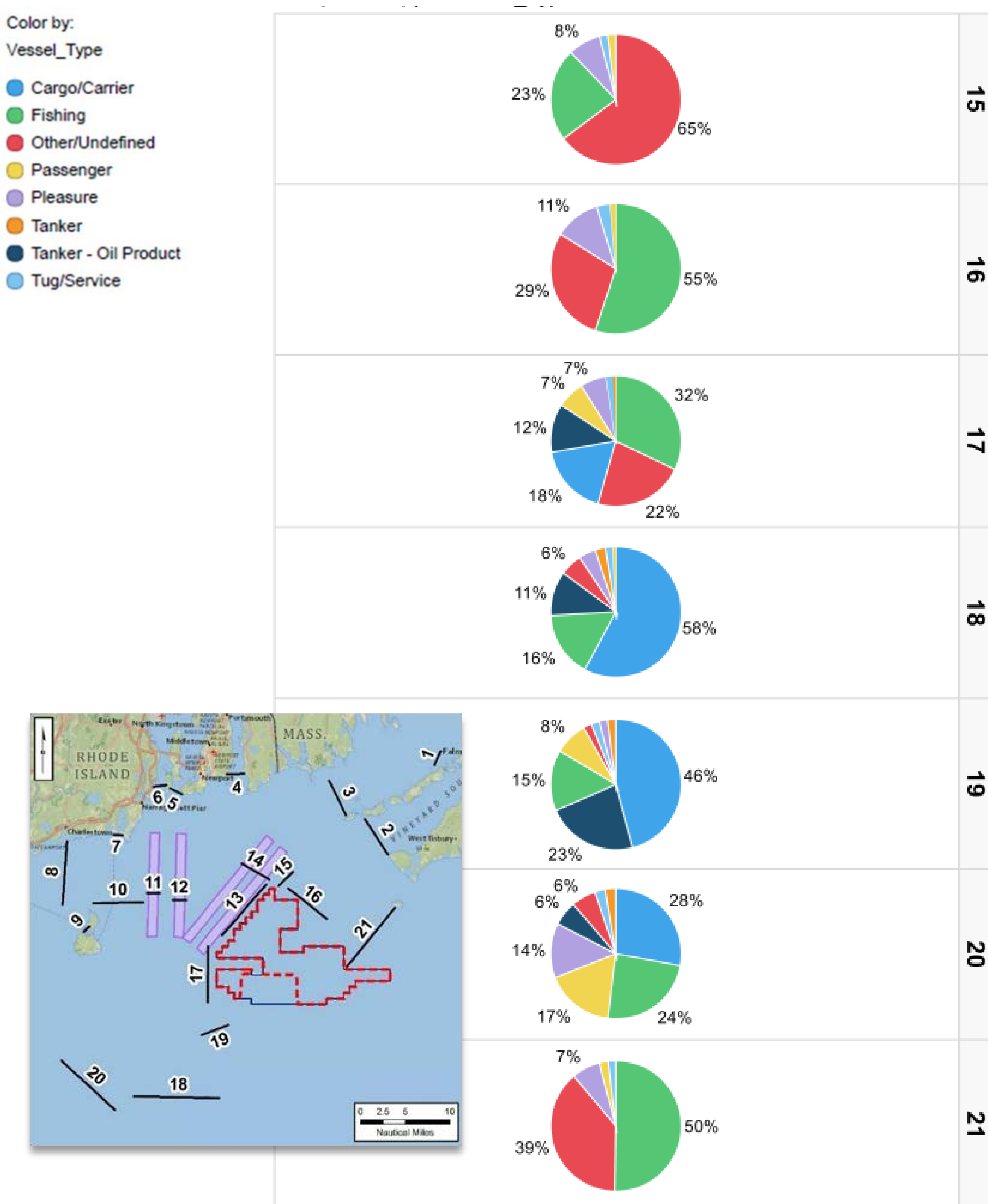


Figure 2-30 Traffic distributions for Transects 8 to 14[1]



Color by:
Vessel_Type
Cargo/Carrier
Fishing
Other/Undefined
Passenger
Pleasure
Tanker
Tanker - Oil Product
Tug/Service
15
8%
23%
65%
16
11%
29%
55%
17
7%
7%
12%
18%
22%
32%
18
6%
11%
16%
58%
19
8%
15%
23%
46%
20
6%
6%
14%
17%
24%
28%
21
7%
39%
50%
RHODE ISLAND
MASS.
Nautical Miles

Figure 2-31 Traffic distributions for Transects 15 to 21[1]

2.1.3.2 Vessel size

Vessel sizes were evaluated within the Study Area and also around the Lease Area so that differences between the two could be identified. A 5-statute-mile area (4.34 NM, 8 km) was defined around the Project Area for this evaluation based on precedent. Based on modeling results and analysis of vessel sizes, any area from 3 to 6 NM around the Project would be suitable to assess vessel sizes.

Vessel size statistics presented in this section are based on user input into each vessel's AIS system. The data show that on a percentage basis, the AIS input is less complete and contains more obvious errors (e.g., 0, 1, or not credible entries) for vessels without mandatory AIS carriage. For example, fishing vessels less than 65 ft in length are generally not required to use AIS, and more than 90 percent of these vessels do not enter a dead weight tonnage (DWT). Therefore, the AIS statistics for DWT are expected to be weighted toward larger vessels, with the result that the average of the DWT data is larger than the true average. Similar trends were noted for Length Overall (LOA) and breadth.

There are three primary uses of the ship size data and statistics:

- A general sense of the range of vessel sizes in the general area and close to the Project
- The ship's breadth and length are used in the powered and drift allision models respectively.
- A value for average dead weight tonnage (DWT) that is used in the analysis described in Section 11 to estimate allision energies. Any over-estimation of vessel size adds a margin of conservatism / over-estimates the potential allision energy and, therefore, the consequences.

The average and maximum of self-reported DWT for vessels in the Study Area are shown in Figure 2-32.

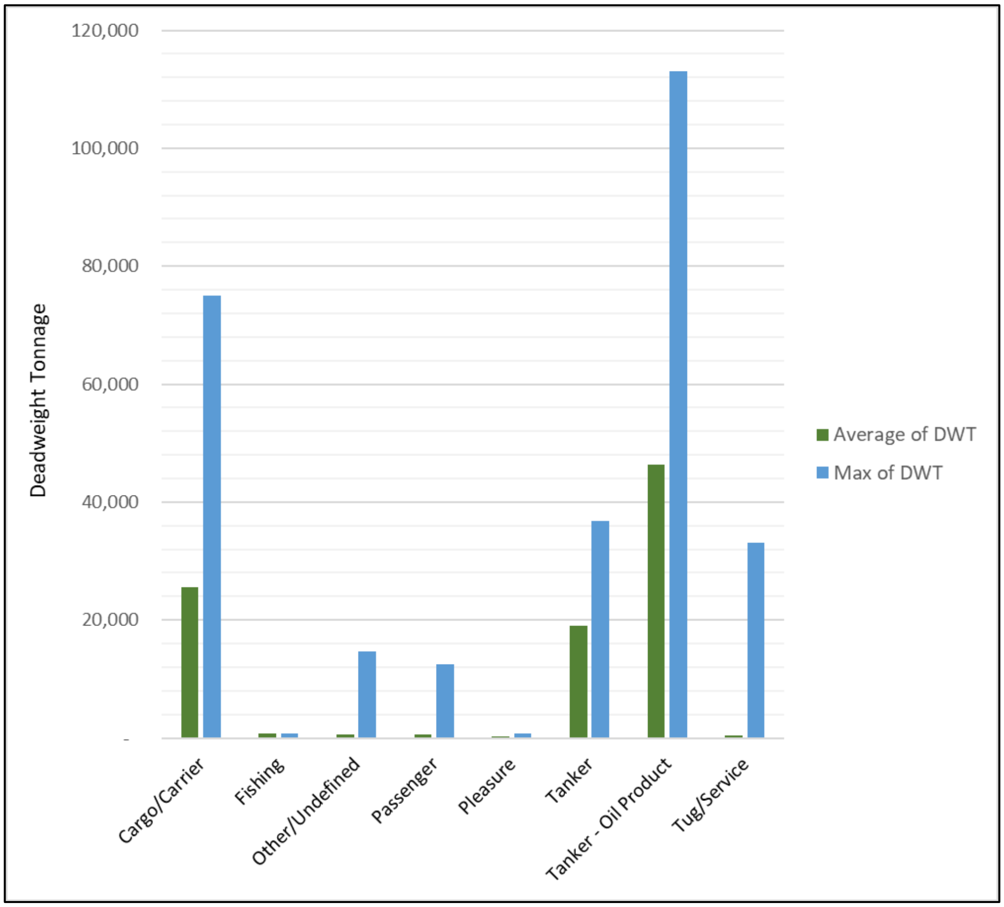


Figure 2-32 Average and maximum DWT of vessels in Study Area[1]

Size distributions for DWT, Length Overall (LOA), and beam for vessels in the Study Area are provided in Figure 2-33, Figure 2-35, and Figure 2-36. Note that the values shown represent user entries in the appropriate AIS fields. Most of the fishing vessels in the AIS dataset did not enter a value for DWT.

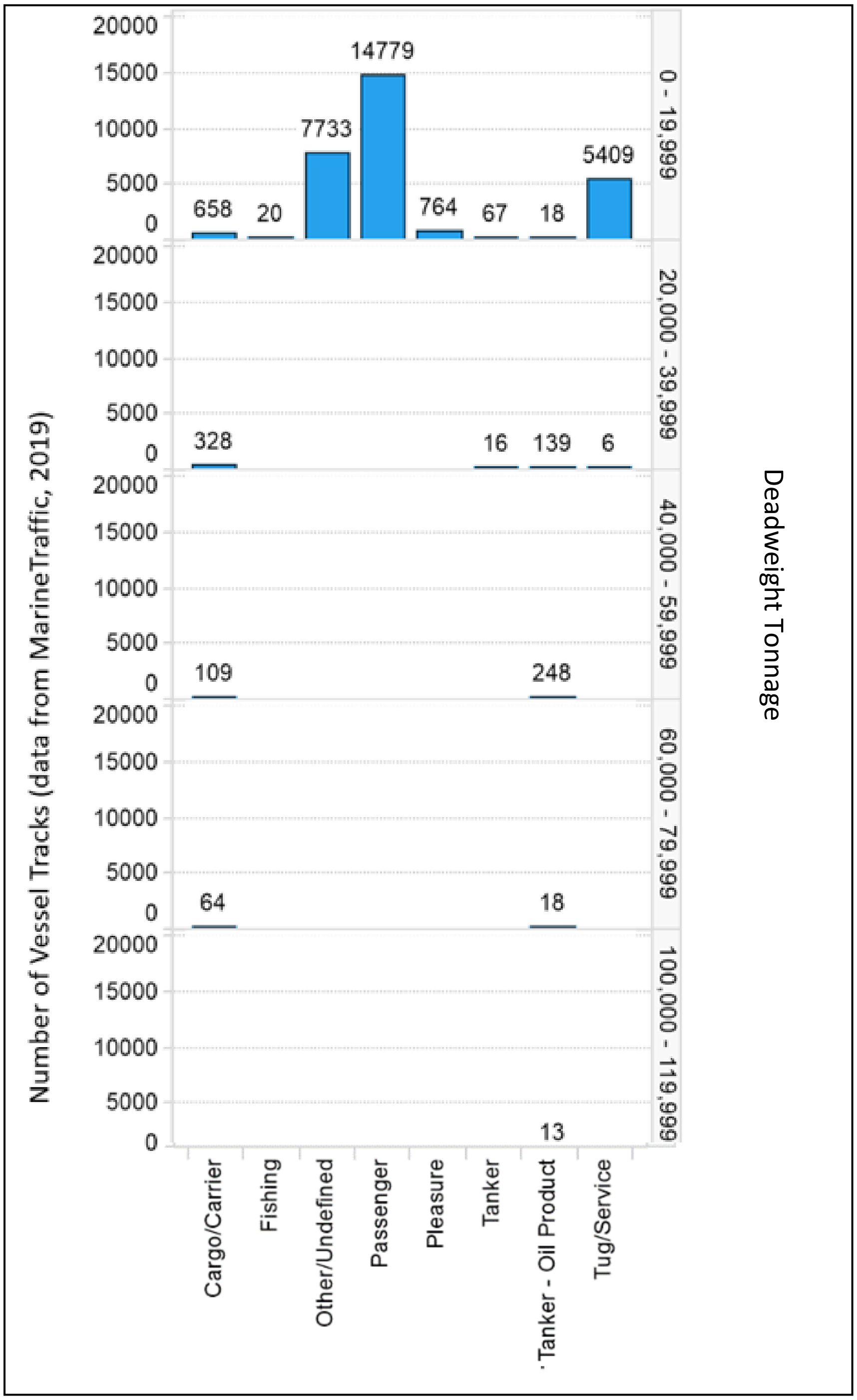


Figure 2-33 DWT distribution in Study Area per vessel type[1]

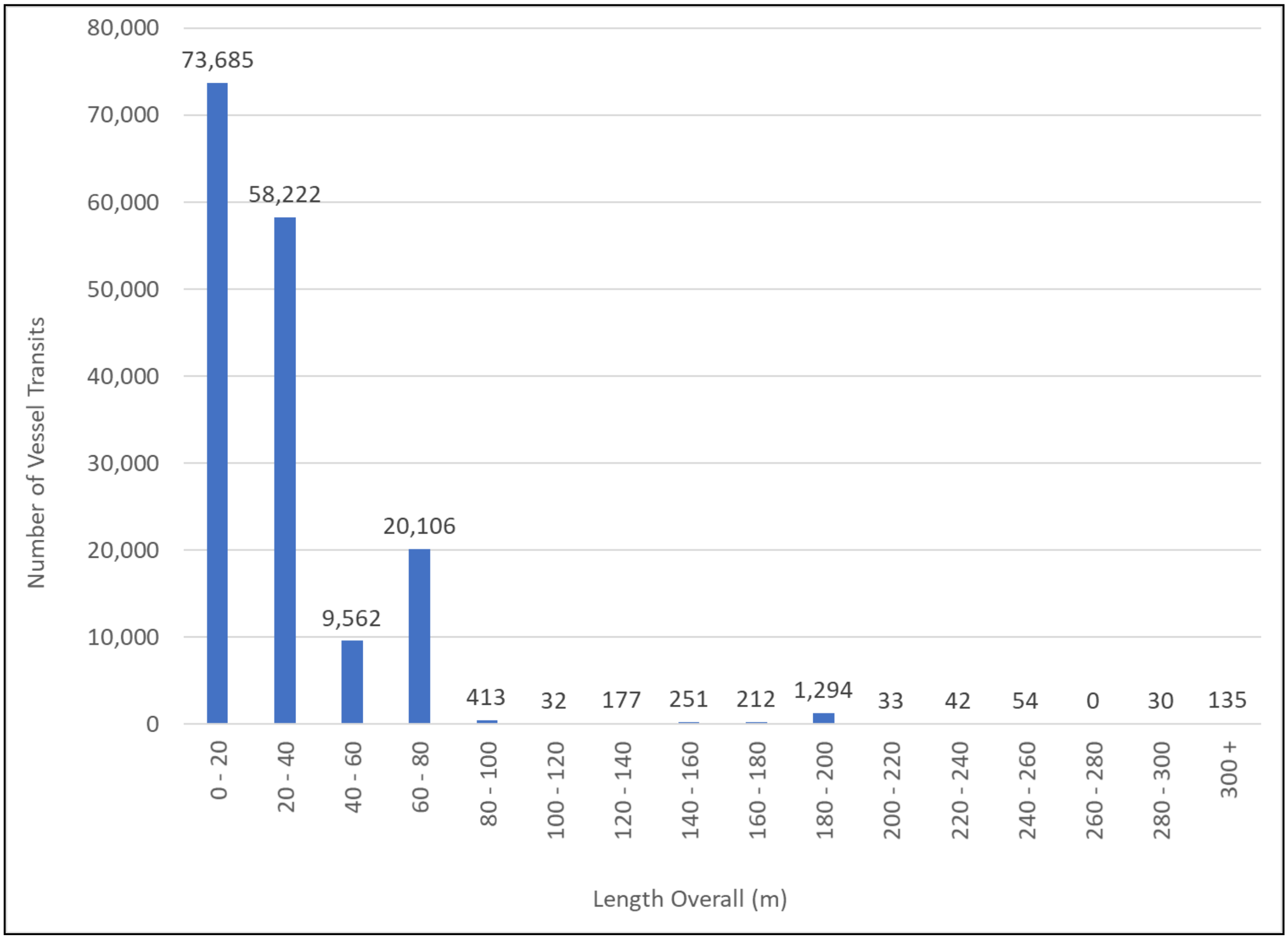


Figure 2-34 LOA distribution in Study Area[1]

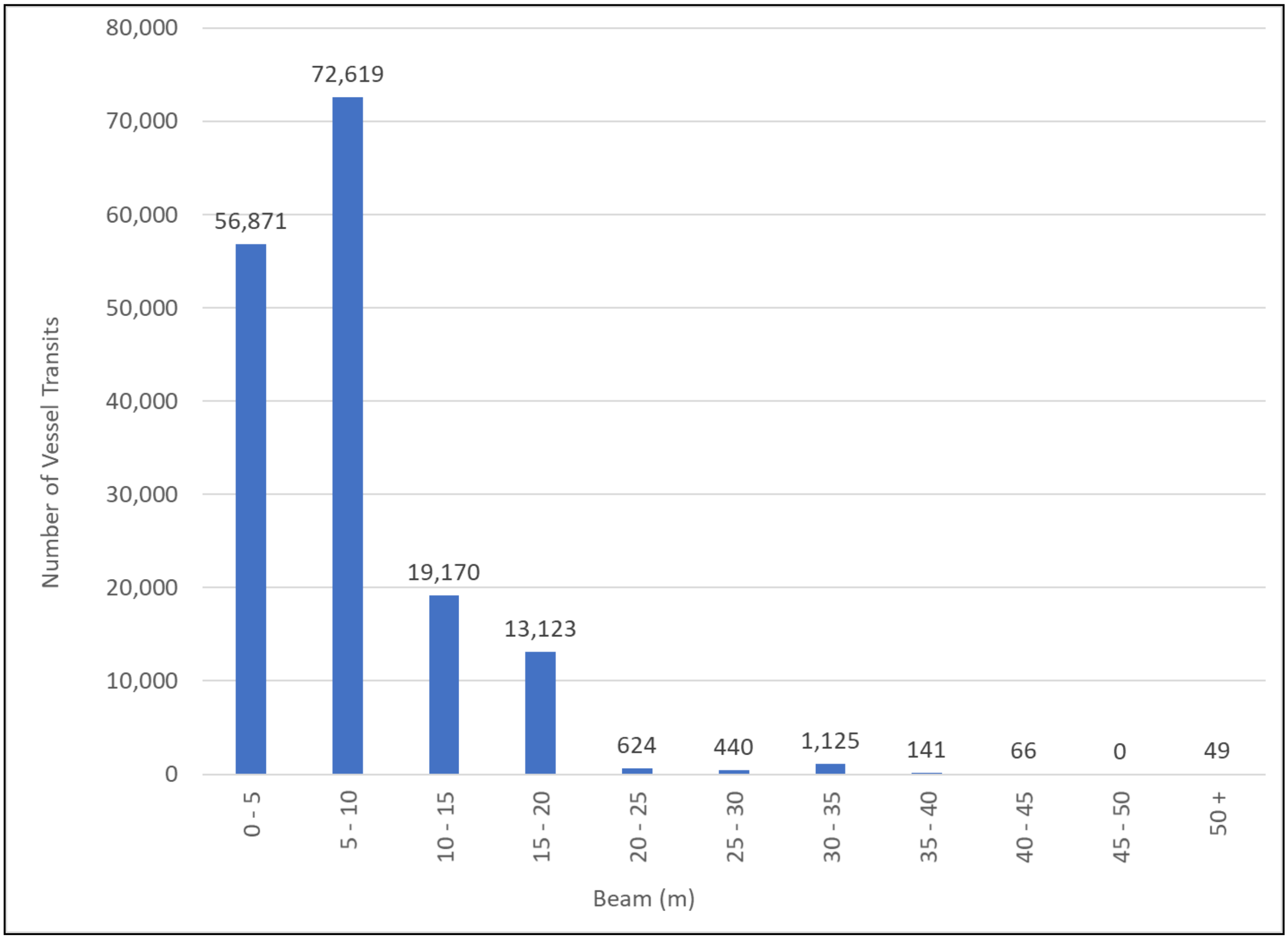


Figure 2-35 Beam distribution in Study Area[1]

The data indicate that the majority of vessels are small: less than 40 m (131 ft) LOA and less than 10 m (33ft) beam; 95 percent of the transits included data in the LOA and beam fields. However, only 18 percent of the data entries included a DWT value. DWT entries were consistently present for deep draft vessels; however, only a low percentage of the data included DWT for fishing, pleasure, passenger, tug/service, and other vessel types.

Figure 2-36 through Figure 2-38 present AIS statistics for vessels in the vicinity of the Project Area.

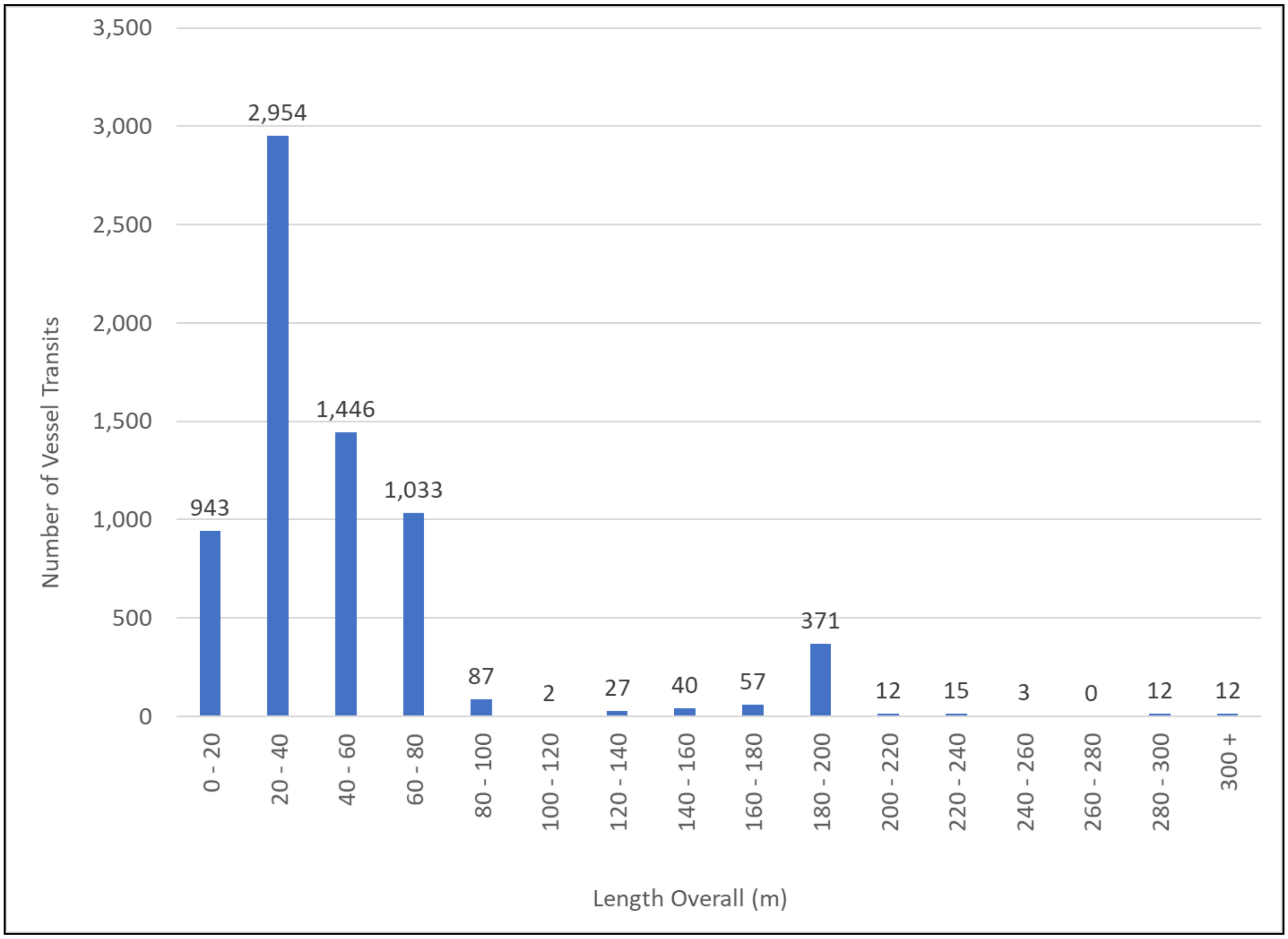


Figure 2-36 LOA distribution within 4.34 NM (8 km) of Project Area[1]

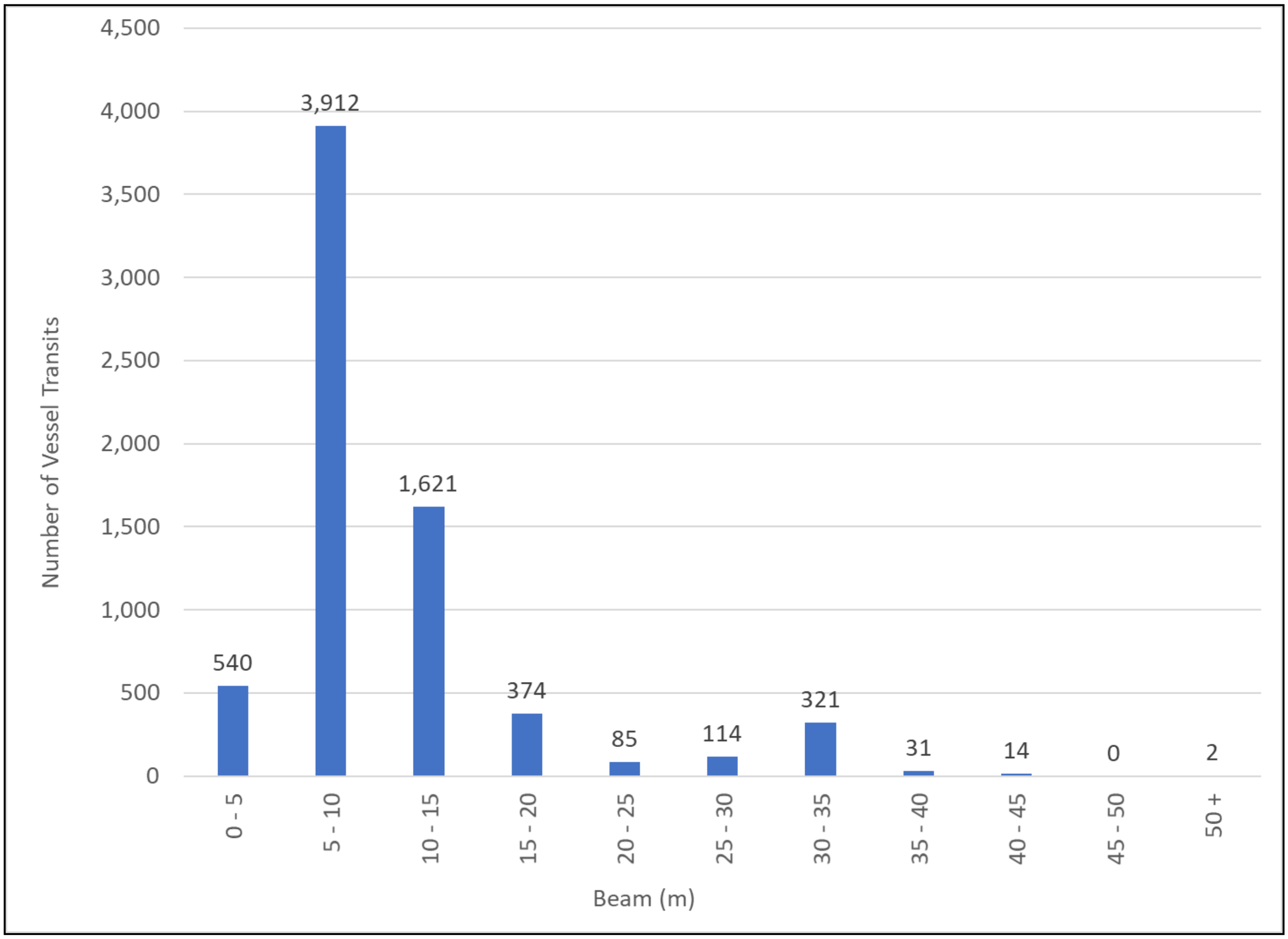


Figure 2-37 Beam distribution within 4.34 NM (8 km) of Project Area[1]

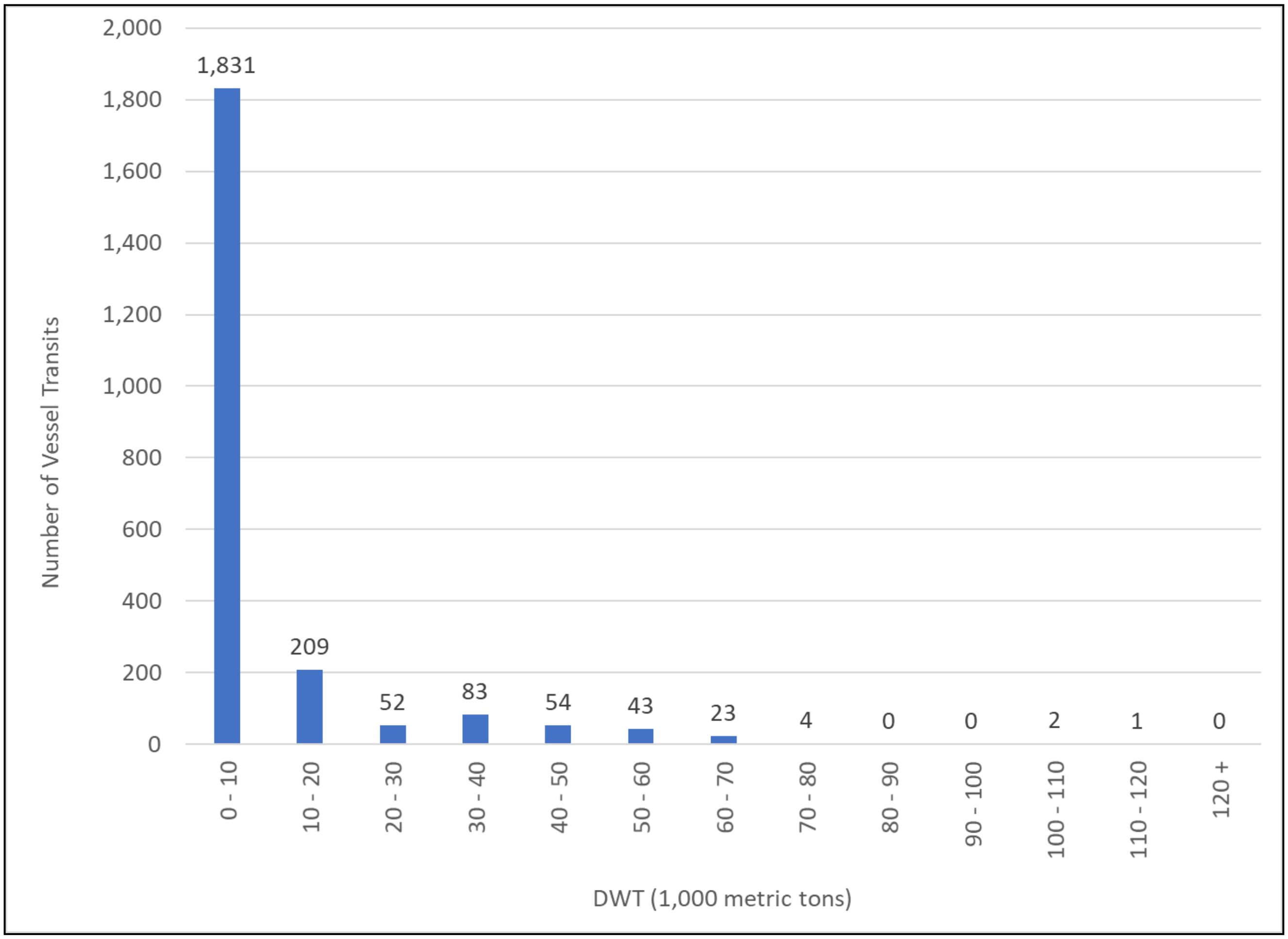


Figure 2-38 DWT distribution within 4.34 NM (8 km) of Project Area[1]

Table 2-1 presents the average DWT, LOA, and beam for vessel types in the Study Area taken from one year of AIS data (MarineTraffic, 2019). The average is based on the number of transits rather than the number of unique vessels. As expected, hydrocarbon tankers, non-hydrocarbon tankers, and cargo/carriers are the largest vessels in the Study Area.

In the vicinity of the Project, there are more LOA and beam entries: 97 percent of the AIS data points had LOA and beam values, while only 32 percent of the points had a DWT value.

Table 2-1 Summary of vessel size and track count per vessel type in the Study Area[1]

Vessel type	Count of AIS transits	Average DWT	Average LOA	Average beam
Tanker - Oil Product	436	46,315 metric tons	606 ft (185 m)	100 ft (31 m)
Cargo/Carrier	1,189	25,602 metric tons	598 ft (182 m)	98 ft (30 m)
Tanker	83	18,963 metric tons	476 ft (145 m)	80 ft (24 m)
Fishing	34,000	742 metric tons	83 ft (25 m)	24 ft (7 m)
Passenger	32,848	584 metric tons	172 ft (52 m)	40 ft (12 m)
Other/Undefined	22,045	518 metric tons	125 ft (38 m)	32 ft (10 m)
Tug/Service	22,738	421 metric tons	83 ft (25 m)	25 ft (8 m)
Pleasure	58,928	172 metric tons	55 ft (17 m)	16 ft (5 m)

Table 2-2 shows average sizes of vessels in the vicinity of the Project, within 4.34 NM (8.0 km) of the Lease Area (Table 2-2). As expected, the data in Table 2-1 and Table 2-2 show a similar pattern concerning vessel size. An exception is passenger vessels. The data show that more of the smaller passenger vessels transit near the coast rather than in the vicinity of the Project.

Table 2-2 Summary of vessel size and track count per vessel type within 4.34 NM (8 km) of Project Area[1]

Vessel type	Count of AIS tracks	Average DWT	Average LOA	Average beam
Tanker - Oil Product	114	47,573 metric tons	610 ft (186 m)	101 ft (31 m)
Cargo/Carrier	337	25,090 metric tons	616 ft (188 m)	101 ft (31 m)
Tanker	16	21,289 metric tons	502 ft (153 m)	81 ft (25 m)
Passenger	267	5,795 metric tons	236 ft (72 m)	39 ft (12 m)
Other/Undefined	2,351	1,329 metric tons	190 ft (58 m)	39 ft (12 m)
Fishing	2,774	742 metric tons	87 ft (26 m)	25 ft (8 m)
Tug/Service	595	648 metric tons	147 ft (45 m)	37 ft (11 m)
Pleasure	759	137 metric tons	77 ft (24 m)	20 ft (6 m)

2.1.3.3 Vessel speed

This section characterizes vessel speeds in the Study Area. Figure 2-39 presents speed as calculated from points in the AIS data.

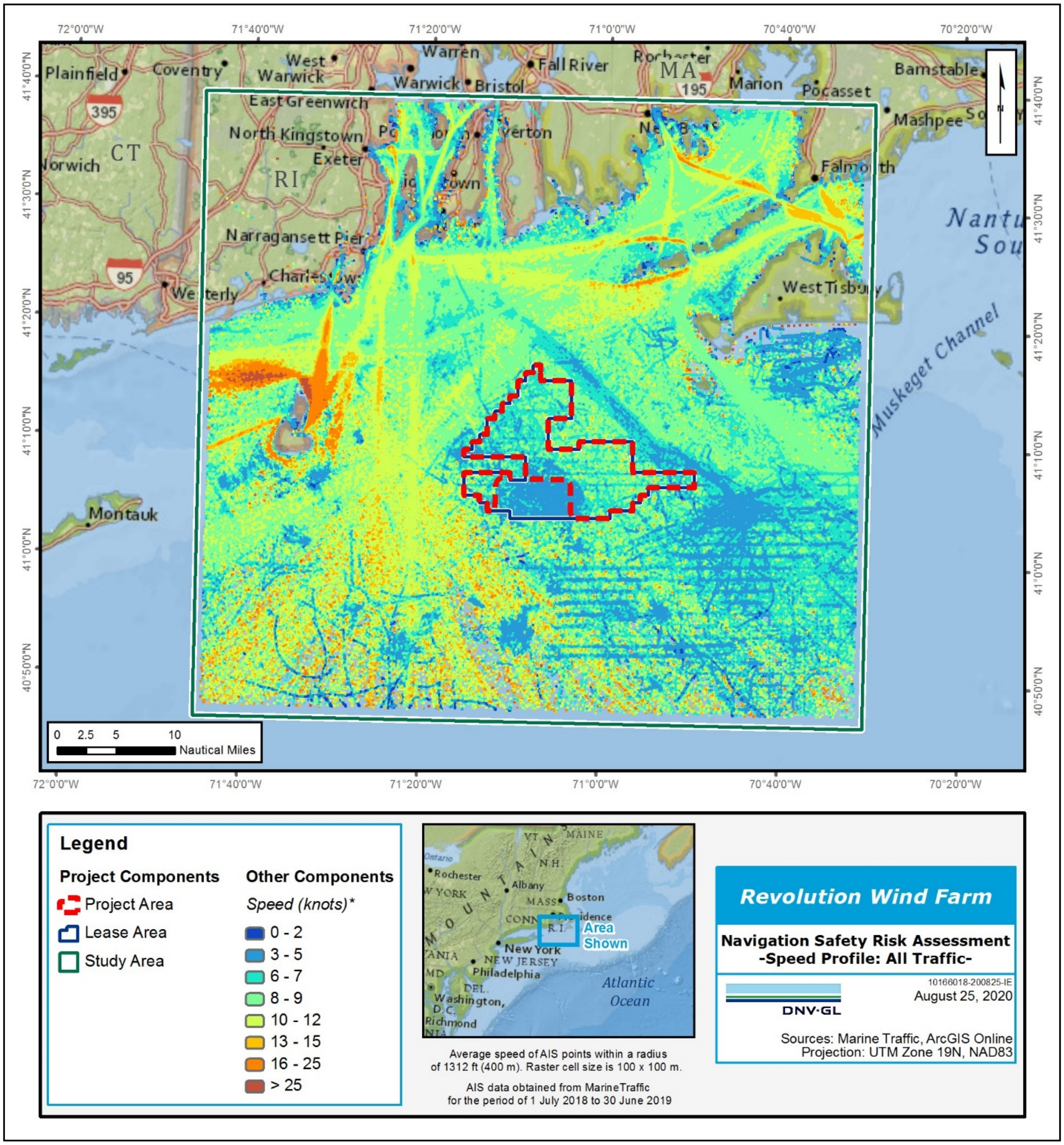


Figure 2-39 Speed profile of all vessels in the AIS data[1]

The speed of 75 percent of the vessels in the Study Area is between 5 and 15 kt (between 2.6 and 7.7 m/s). Passenger vessels have the highest average speed. Figure 2-40 shows the traffic speed distribution for each vessel type.

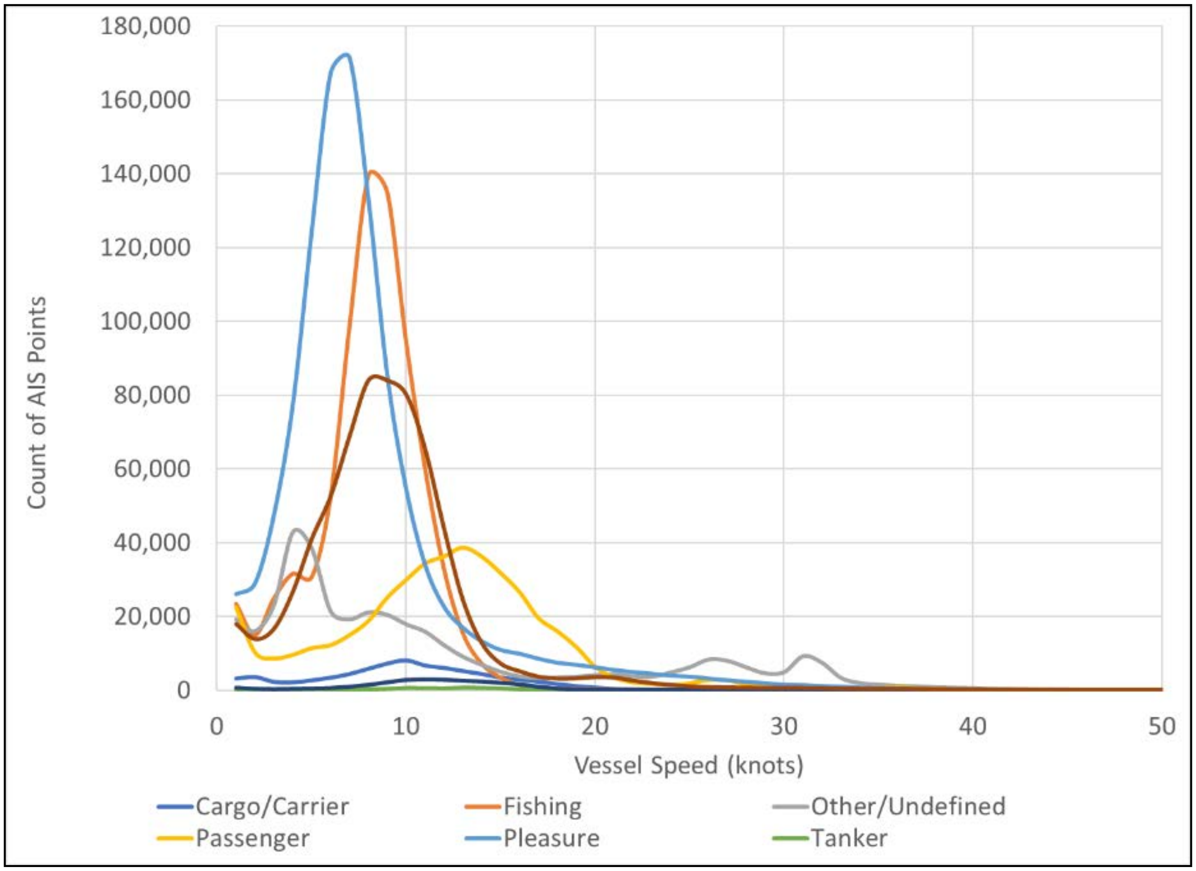


Figure 2-40 Speed profile for each vessel type in the AIS data[1]

2.1.4 Types of cargo

The cargoes arriving and departing at ports in the study area include:

- Cars
- Liquid bulk, including fuel oil
- Bulk commodities
- Dry bulk
- Aggregate
- Break bulk (equipment, lumber, metals)
- Food

2.2 Location of the Project in relation to other activities

This section describes the proximity of the Project to navigation-related aspects. Figure 2-41 shows the navigation chart around the Lease Area.

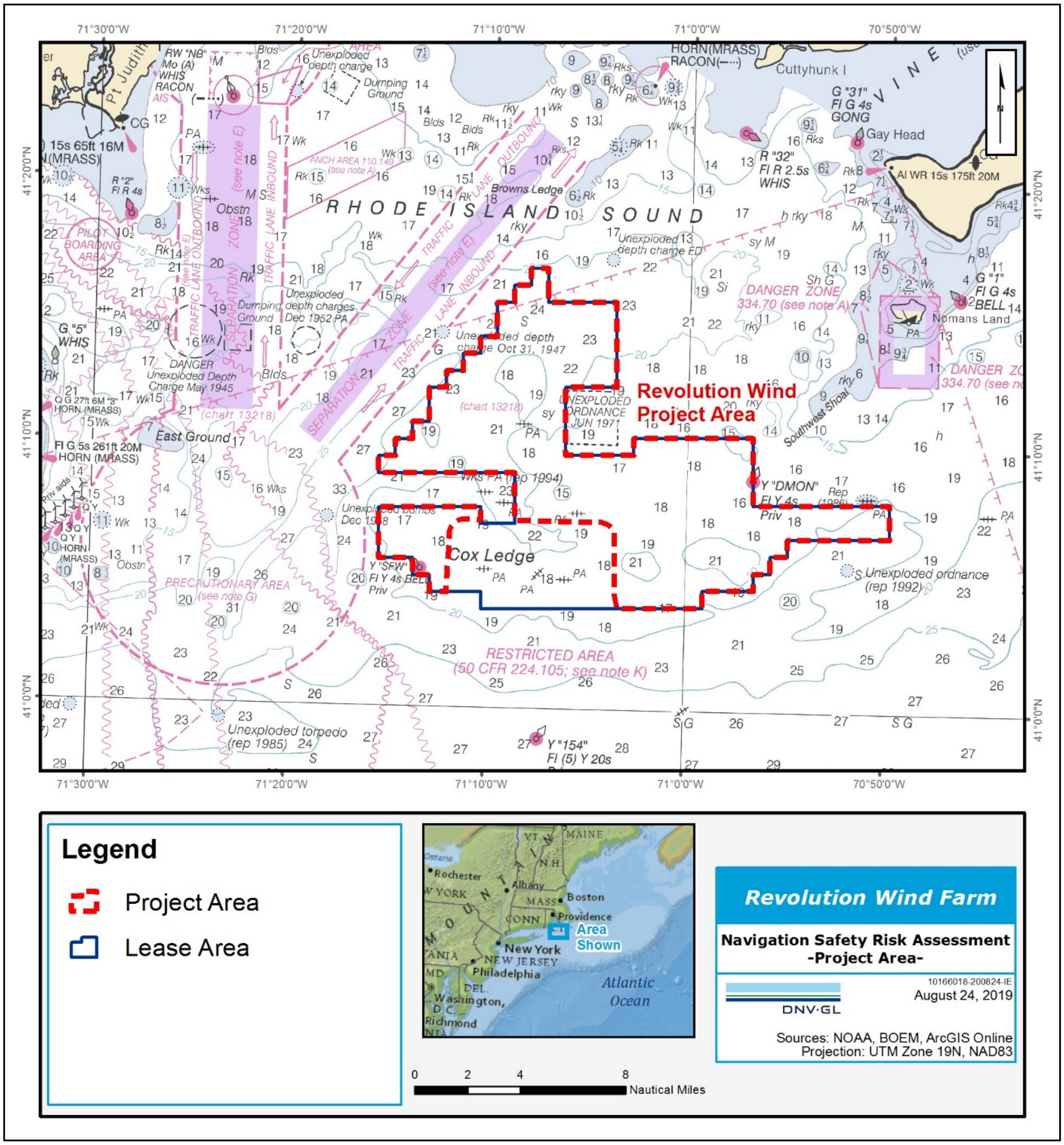


Figure 2-41 Navigation chart in the vicinity of the Lease Area

2.2.1 Proximity to non-transit waterway uses

Table 2-3 provides an overview of the Project's proximity to non-transit uses of the waterway.

Table 2-3 Proximity of the Revolution Wind Farm to non-transit waterway uses

Section in this report	Type of waterway use	Closest proximity to the proposed maximum footprint of the Project (measured from the nearest WTG)
2.2.1.1	Fishing (recreational and commercial)	Occurs within the footprint
2.2.1.2	Day cruising of leisure craft (pleasure and passenger)	Occurs within the footprint
2.2.1.3	Racing	Occurs within the footprint
-	Aggregate mining	No offshore mining activity identified within 100 NM (185 km) of the Project
2.2.1.4	Wildlife viewing	Occurs within the footprint

2.2.1.1 Fishing

The Project is co-located with use of fixed and mobile fishing gear and with recreational fishing.

Rhode Island (2019) collects data and maps for ocean uses. Figure 2-42 illustrates the fishing grounds that are used by Rhode Island commercial fixed gear fishermen. Fixed gear fishing is permitted in the majority of the Lease Area year-round except for a small portion where fishing is only permitted from springtime until 15 October.

Fixed gear consists of lobster pots, fish pots, and gill nets and are either placed on the bottom or kept afloat using buoys.

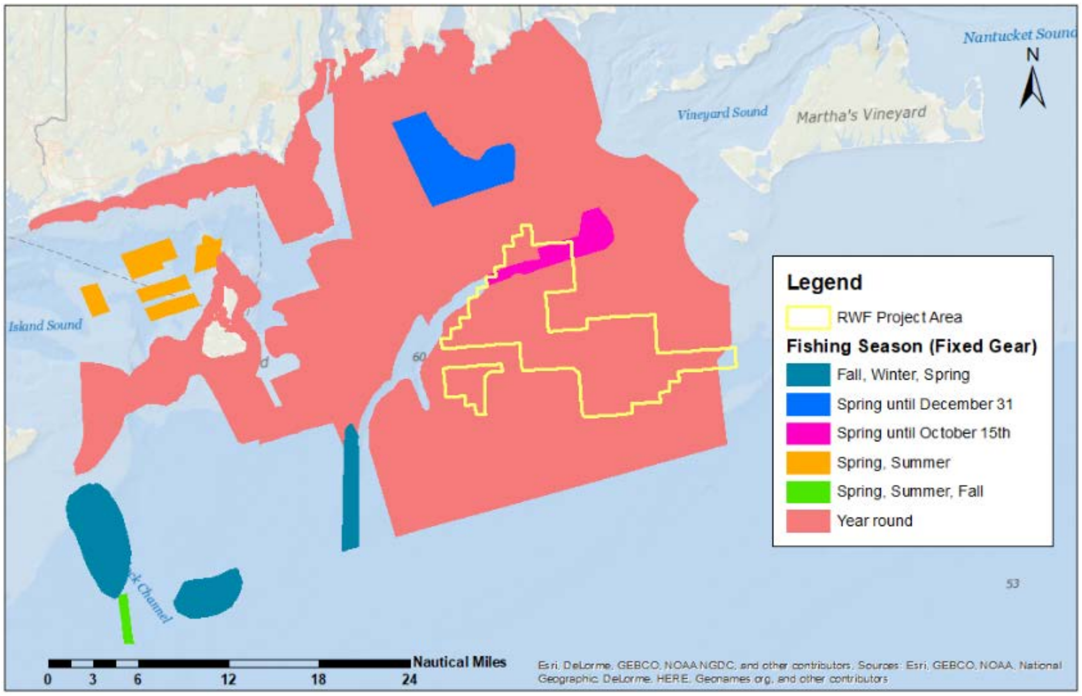


Figure 2-42 Fixed gear fishing areas by season (RI, 2019a)

Figure 2-43 illustrates the fishing grounds that are used by the Rhode Island commercial mobile gear fishermen (RI, 2019). Mobile gear consists of trawling and scallop dredging (see Section 5 for further discussion on fishing gear interactions with Project components).

The majority of the Lease Area is not fished using mobile gear, but mobile gear fishing is allowed in the southern, western, and northern portions of the Lease Area for about 25% of each year.

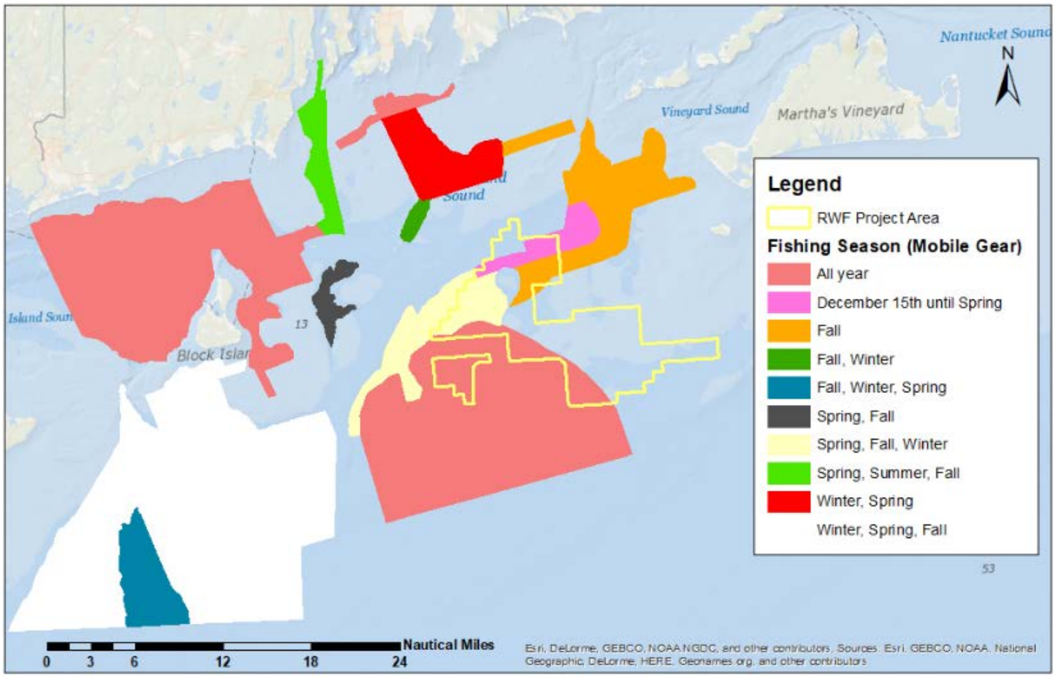


Figure 2-43 Mobile gear fishing areas by season (RI, 2019)

Common fishing techniques for recreational fishing are line fishing and angling. This type of fishing is typically conducted from relatively small boats, usually while drifting. Figure 2-44 illustrates the fishing grounds that are used by Rhode Island recreational fishermen (RI, 2019). Recreational fishing occurs in the central and southwestern portions of the Lease Area.

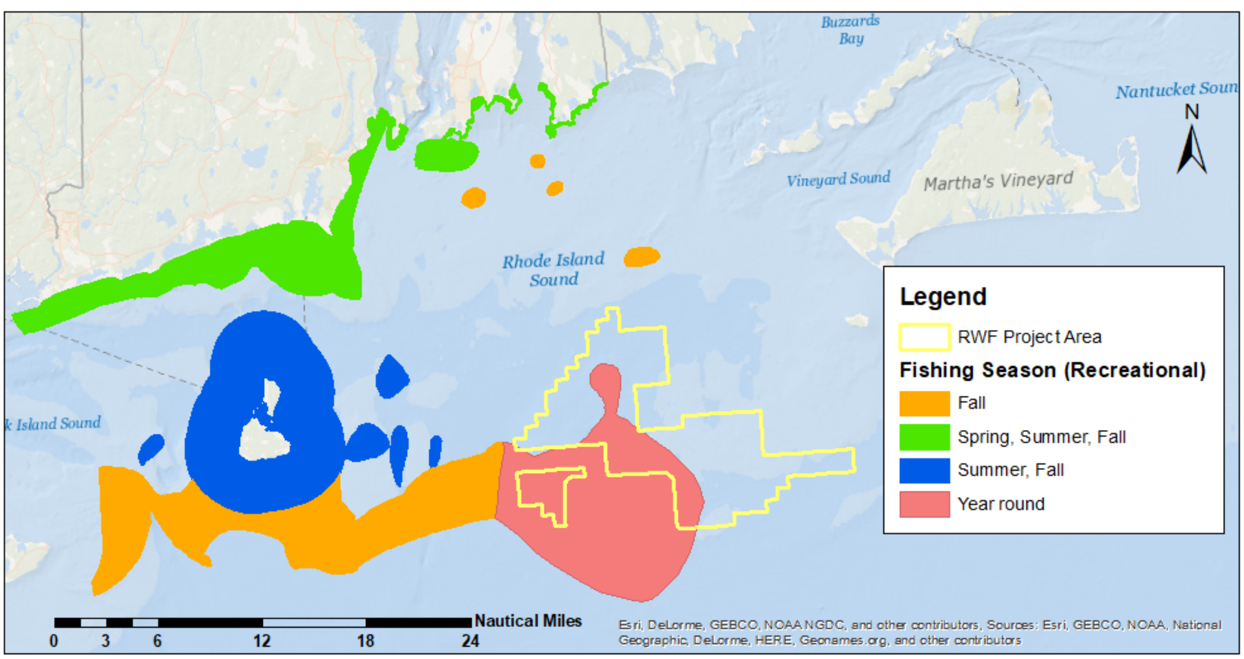


Figure 2-44 Recreational fishing areas by season (RI, 2019)

2.2.1.2 Day cruises

Pleasure craft transits in the vicinity of the Lease Area are described in Section 2.1.1.4.

Commercial day cruises in the Study Area are offered by Rhode Island Fast Ferry services, including:

- Rhode Island Lighthouse Tour
- Sightseeing cruises and sunset cruises on Narragansett Bay
- Martha's Vineyard Fast Ferry service between Quonset Point, Rhode Island, Oak Bluffs, Martha's Vineyard, and Block Island, Rhode Island.
- Offshore Wind Farm Support to transfer crew and cargo during construction and operations.

2.2.1.3 Sailing and racing courses

Figure 2-45 illustrates the typical routes of distance sailing races, some of which have historically transited through the Lease Area (RI, 2019). Future races will most likely route around the wind farm. Anecdotally, organizers of major marine events (such as the Newport/Bermuda, Bermuda/Marion, Annapolis/Newport regattas) which may transit in the vicinity of the Lease Area have indicated the event tracklines would avoid the Project Area. Though safety is one factor, the primary reason for avoiding the Lease Area is to promote a leisurely recreational event in open water." (LeBlanc, 2019).

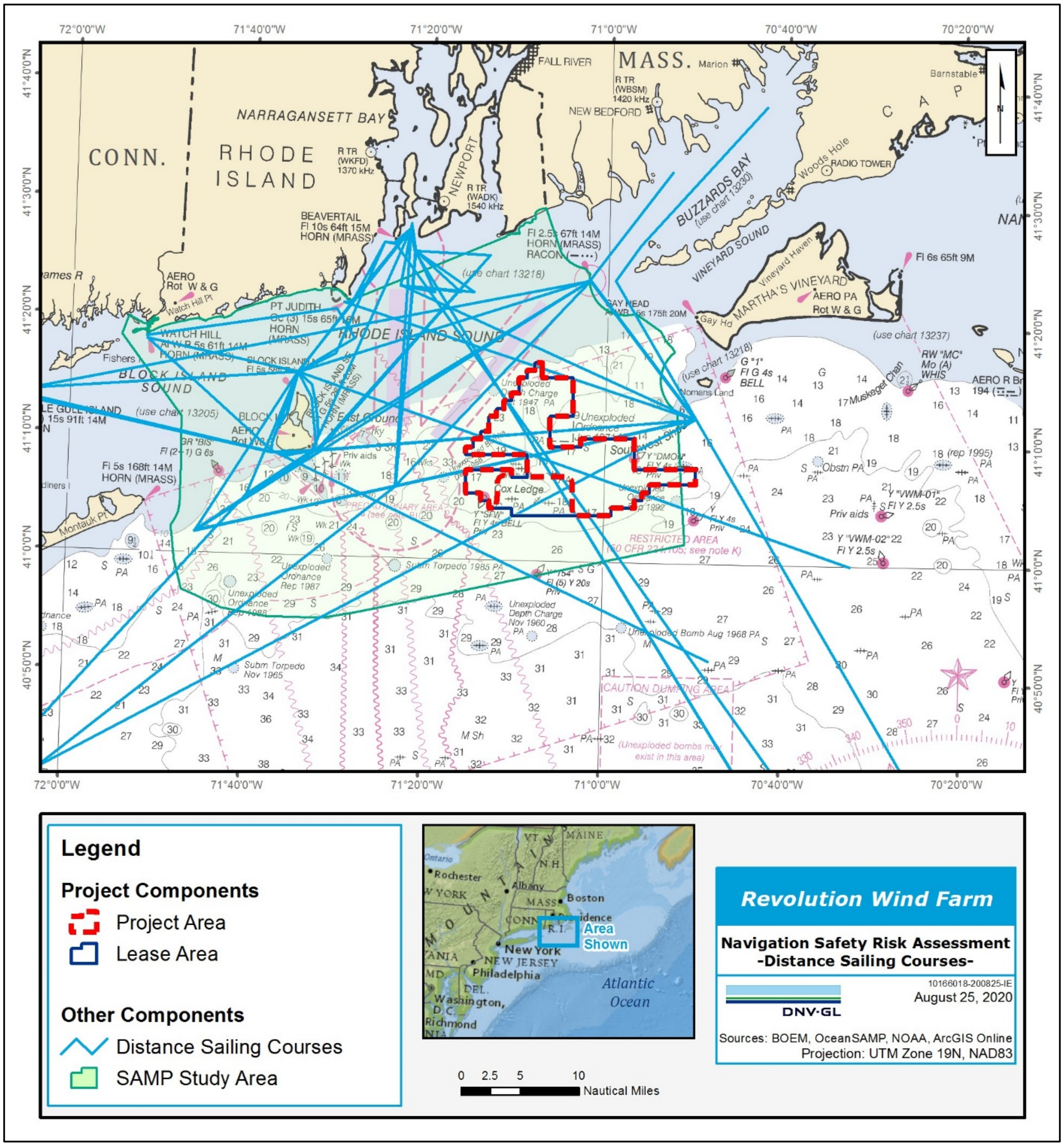


Figure 2-45 Distance sailing race courses (RI, 2019)

2.2.1.4 Wildlife viewing

Figure 2-46 illustrates the Rhode Island Sound Offshore Wildlife Viewing Areas in the Study Area, including bird watching, shark cage diving and whale watching (RI, 2019). Vessels transiting to some of these offshore wildlife viewing areas could take routes through the Project Area.

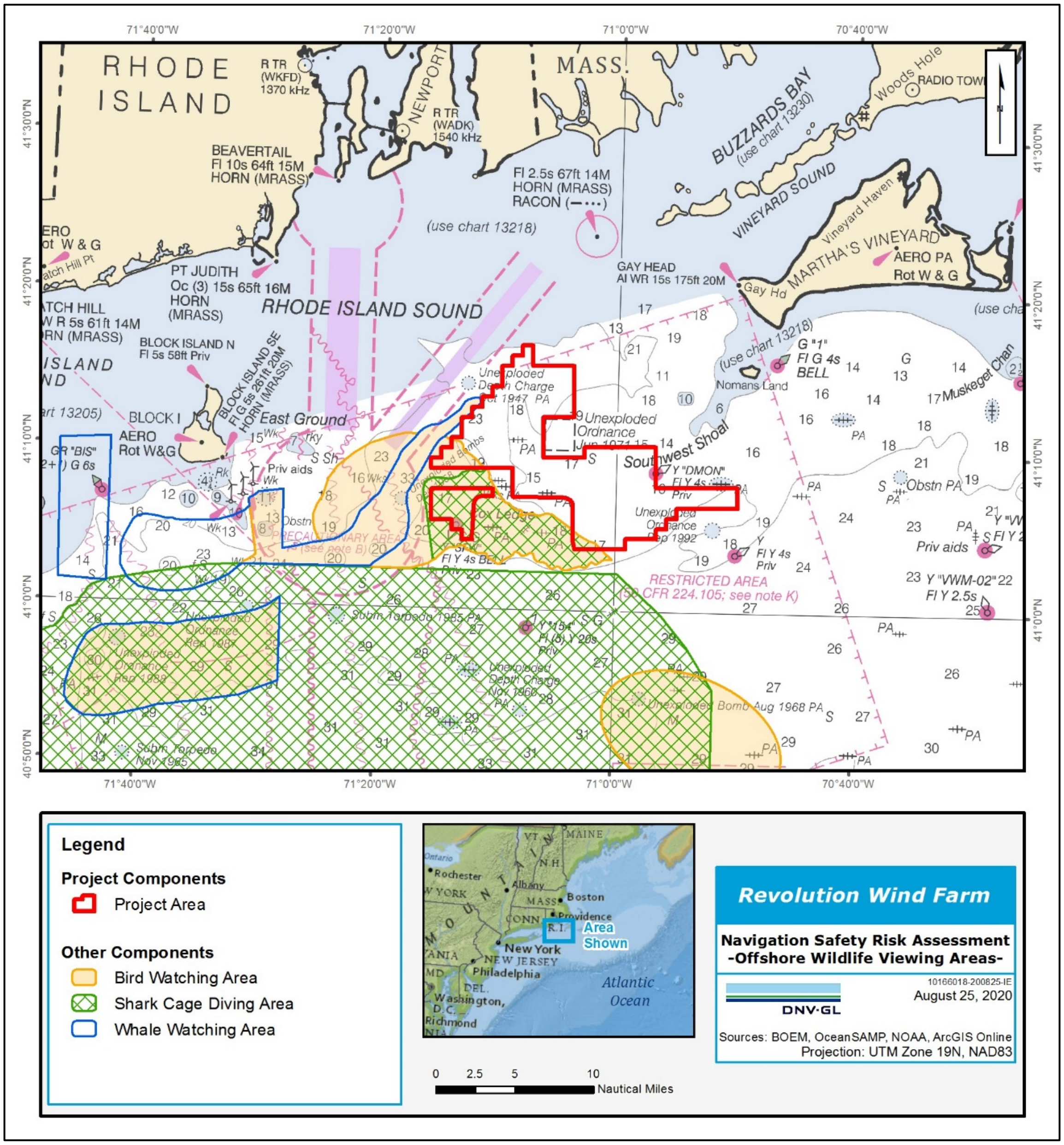


Figure 2-46 Offshore wildlife viewing areas[4]

[4] There are apparent differences in wildlife viewing areas between the above OceanSAMP GIS layers, Ocean SAMP downloadable paper maps (RI OceanSAMP, 2009d), and the 2010 OceanSAMP report (RI, 2010). This NSRA used the GIS layers.

2.2.2 Proximity to transit-related waterway uses

Table 2-4 summarizes the Project's proximity to transit-related uses of the waterway.

This assessment models vessel patterns to estimate the change in accident risk from the Project, accounting for traffic patterns. Transit-related waterways uses, including routes and speeds, are represented in the AIS data. The data and an estimate of transits not in the data are accounted for in the risk model presented in Section 11 and Appendices D and E. Waterway uses listed in Table 2-4 that are accounted for in the model are quantified. The other waterway uses, anchorage grounds, safe havens, port approaches, and pilot boarding areas, are not close to the Project Area and based on a qualitative evaluation based on distance, are not relevant to the collision, allision, or grounding risk from the Project.

Orsted has ongoing dialogue with merchant mariners who transit in the vicinity of the Project. There is a common understanding that vessels in coastal and international trade will take routes around wind farms. Concerning Revolution Wind Farm, no merchant marines that were consulted expressed concerns or reservations about doing so. (Orsted, 2020)

Table 2-4 Proximity of the Project to transit-related waterway uses

Type of waterway use	Discussed in NSRA section	Closest proximity to the proposed maximum footprint of the Project (measured from the nearest WTG)
Transit routes used by coastal or deep-draft vessels, ferry routes	2.2.2.1	No transit routes identified within the footprint. The closest routes to the Project are: • 1.2 NM (2.2 km) (Inbound Buzzards Bay Traffic Lane) (coastal vessels) • 2.5 NM (4.6 km) (passenger route north of the Lease Area) • 3.1 NM (5.7 km) (Outbound Buzzards Bay Traffic Lane) (coastal vessels)
Transit routes used by fishing vessels	2.2.2.2	Occurs within the footprint.
Shipping routes	2.2.2.3	No international shipping routes identified within the footprint. The closest routes are the Buzzards Bay Traffic Lane: • 1.2 NM (2.2 km) (Inbound) from the Project • 3.1 NM (5.7 km) (Outbound) from the Project
Routing measures or precautionary areas	2.2.2.4	No routing measures identified within the footprint. The closest routing measures are: • 1.2 NM (2.2 km) from the Project (Inbound Buzzards Bay Traffic Lane) • 3.1 NM (5.7 km) from the Project (Outbound Buzzards Bay Traffic Lane) The closest precautionary areas is 0.6 NM (900 m) west of the Project.

Type of waterway use	Discussed in NSRA section	Closest proximity to the proposed maximum footprint of the Project (measured from the nearest WTG)
TSS	2.2.2.4	No TSS identified within the footprint. The closest TSS are: • 1.2 NM (2.2 km) from the Project (Inbound Buzzards Bay Traffic Lane) • 3.1 NM (5.7 km) from the Project (Outbound Buzzards Bay Traffic Lane)
Anchorage grounds or safe havens	2.2.2.5	No anchorages or safe havens are identified within the footprint. The closest designated anchorage is 6.7 NM (12.4 km) (Brenton Point Anchorage Ground) from the Project. Anchoring within the Project footprint is not apparent in the AIS data.
Port approaches	2.2.2.5	No port approaches are identified within the footprint. The closest port approach is 12 NM (23 km) from the Project (Cuttyhunk Island).
Pilot boarding or landing areas	2.2.2.5	No pilot boarding or landing areas identified within the footprint. The closest pilot boarding area is 12 NM (21 km) from the Project.

2.2.2.1 Coastal, deep-draft, and ferry routes

Transit routes used by coastal vessels, deep-draft vessels, and ferry routes are described in Section 2.1.1.1. None of these routes have been identified within the Lease Area; the closest routes are 1.2 NM (2.2 km) (Inbound Buzzards Bay Traffic Lane), 2.7 NM (5.0 km) (passenger route north of the Lease Area), and 3.1 NM (5.7 km) (Outbound Buzzards Bay Traffic Lane) from the Project.

Of particular importance is that the AIS data show that cargo, carrier, and tanker vessels transit the Narragansett Bay TSS, which is farther from the Project than the 2 NM guideline distance in NVIC 01-19. These deep draft vessels are notably very few in the AIS data in the Buzzards Bay TSS closer to the Project (see Section 2.1.1.1).

2.2.2.2 Transit routes used by fishing vessels

Transit routes used by fishing vessels may traverse the Lease Area. Because of the locations of fishing activity (Section 2.1.1.2) it is likely that the majority of the fishing-related transits occur in the western half of in the Lease Area.

2.2.2.3 Shipping routes

International shipping traffic uses the established TSS:

- Buzzards Bay – inbound lane is 1.2 NM (2.2 km) from the nearest Project structure.
- Narragansett Bay – inbound lane is more than 4 NM (8 km) from the nearest Project structure.

2.2.2.4 Routing measures, precautionary areas, and separation zones

Distances from routing measures, precautionary areas, and TSS are listed in previous Table 2-4. NVIC 01-19 suggests a risk-based review of safe distances, which is provided in this section.

In NVIC 01-19 Enclosure 3: Marine Planning Guidelines, the recommended navigation safe distances for planning are:

a) 2 NM from the parallel outer or seaward boundary of a traffic lane.

b) 5 NM from the entry/exit (terminations) of a Traffic Separation System. A Traffic Separation System "is an internationally recognized measure that minimizes the risk of collision by separating vessels into opposing streams of traffic through establishment of traffic lanes," (IMO, 2019a). Vessel use of the TSS in the Study Area is voluntary (Coast Guard, 2004).

The Marine Planning Guidelines are based on general risk principles; their primary intent is to inform marine spatial plans. Site-specific risk assessments, like this one, estimate the incremental risk increase related to a project and ways to reduce either the consequences or likelihood of the risk. Risk-informed decisions benefit from higher resolution analysis, such as risk modeling, to support decision making when more information is available about a specific Project. .

NVIC 01-19 lists site-specific considerations for potential contributions to risk. Of these, the following aspects are accounted for in the risk model (see Appendix E and Section 11):

- High density traffic areas (interpreted in the context of large international ports)
- Obstructions/hazards on the opposite side of a route
- Weather/sea state conditions
- Currents
- Mixing of vessel types
- Complex vessel interactions
- Undersized routing measures

Large distances along a route is the only consideration not accounted for in the model. However, based on the traffic survey, only a small percentage of the traffic in the vicinity of the Project is engaged in west-bound international trade and would presumably arrive at a U.S. port after being at sea for a significant duration.

NVIC 01-19 also provides a list of potential risk mitigation measures, which either currently exist or are proposed in association with the Project:

> "(a) Mitigating factors include aids to navigation, pilotage, vessel traffic services, precautionary areas, areas to be avoided, anchorages, limited access areas, and other routing measures. Mitigating factors can be used to lower risk in many ways, such as increasing predictability of vessel traffic, increasing local knowledge and expertise, increasing situational awareness, or improving navigation. Proper marking and lighting of the structures of a wind farm can be used for navigation purposes improving the ability to fix a vessel's position;

(b) Low traffic density. Low traffic density will decrease vessel interactions and allow for more space for transiting vessels to maneuver;

(c) Predominantly smaller vessels. If only smaller vessels call on a port or if large vessel transits are very infrequent, smaller planning distances may be appropriate; especially if other mitigations are in place for the large vessel transits, such as tug escorts or moving safety zones;

(d) Distance from ports, shoals and other obstructions. If there are large distances to other hazards vessels will be able to adjust their route to ensure safe transits; and

(e) Aids to Navigation. Enhanced Aids to Navigation may assist vessels in more accurately determining their position as well as identifying potential hazards."

The PDE provides for:

a) 1.2 NM (2.2 km) from the parallel outer or seaward boundary of a TSS, which is 0.8 NM less than the planning guideline.

b) 1.5 NM (2.8 km) from the entry of the TSS, which does not explicitly meet the guideline. However, no Project WTGs are within the TSS Precautionary Area (Coast Pilot 2 §167.101); the closest WTG is 0.6 NM from the Precautionary Area.

The Coast Guard Marine Planning Guidelines are generic, and NVIC 01-19 emphasizes that each project must be assessed on its own merits, on a case-by-case basis. With respect to tower locations in the vicinity of the inbound (seaward) lane of the Buzzards Bay TSS, there are several key factors that reduce the risk:

- Commercial vessels (including tug-and-tows) entering the inbound (seaward) lane of the Buzzards Bay TSS are subject to the requirements of a Coast Guard Regulated Navigation Area (RNA) that requires enhanced communications and voyage planning protocols. See 33 CFR 165.100.
- Additionally, commercial vessels (including tug-and-tows) entering the inbound (seaward) lane of the Buzzards Bay TSS are subject to the requirements of the Coasts Guard's Buzzards Bay Vessel Movement Reporting System (VMRS), which is a mandatory reporting system used to actively monitor and track vessel movements by a 24-hour vessel traffic monitoring center. Vessels subject to VMRS regulations must also following prescribed operating requirements, such as (if applicable), towing astern with as short a hawser as safety permits, secure prior Coast Guard approval before entering the VMRS, etc. Although the boundary of the VMRS zones is slightly east from the inbound lane of the Buzzards Bay TSS, the vast majority if not all vessels subject to VMRS meet all of its requirements before entering the TSS, as doing otherwise is impractical (e.g., if the vessel entered the TSS without meeting the VMRS requirements and was then ordered to turn around, or not allowed to transit through the VMRS zone, that could create a hazardous situation.) See 33 CFR 161.11 to 161.13.
- The majority of commercial vessel traffic entering the inbound lane of the Buzzards Bay TSS, and virtually all tug-and-tow traffic, is intending to transit the Cape Cod Canal to ports further north, such as Boston, Massachusetts, or Portland, Maine. In addition to being subject to the Coast Guard's Buzzard Bay VMRS as discussed above, these vessels must also adhere to the provisions of the U.S. Army Corps of Engineers' Cape Cod Canal Control navigation regulations (33 CFR 207). These regulations provide for additional measures and precautions that must be taken by commercial vessels intended to transit the Canal to ensure navigation safety. The Army Corps of Engineers'

control center is in communications with eastbound commercial vessel traffic well before that traffic enters the inbound lane of the TSS to ensure compliance with Canal regulations.

- The state of Massachusetts requires that an escort tug accompany all tank barges carrying 6000 or more barrels of oil. The escort tug must be equipped with twin screws and twin propulsion, have a minimum shaft 4000 horsepower, have a minimum 50 tons bollard pull, provide propulsive thrust to any part of a 360-degree arc, and be equipped with a minimum American Bureau of Shipping (ABS) Fire Fighting 1 classification and Maltese Cross A1 (Massachusetts General Law M.G.L. c. 21M, s. 6).
- The Coast Guard has an active rulemaking underway that proposes to require that Federally-licensed pilots direct and control the movement of tank barges transiting Buzzards Bay laden with 5000 or more barrels of oil or other hazardous material, and also require escort tugs under certain weather or equipment conditions. These regulations, should they become final, would provide additional safety measures for vessels entering the inbound lane of the Buzzards Bay TSS (docket USCG-2011-0322).

The Marine Planning Guidelines' 2 NM minimum distance from a TSS is based on solid, general principles of risk management and its best use is during marine spatial planning. The Guideline suggests that project-specific modeling can be used to inform safe distances when a project is already sited.

Based on the risk assessment of collision in Section 11, the Project does not significantly increase the risk of collision for deep draft or tug-and-barge vessels in the TSS or routes taken by deep draft vessels around the Lease Area. However, there is a quantifiable increase in risk of allision within the Lease Area. The modeling presented in Section 11 shows that the risk of allision for the types of vessels required to transit the TSS, cargo/carrier, tanker, and tanker-oil , is 0.02 per year, equivalent to a recurrence interval of 1 in 50 years.

2.2.2.5 Anchorages, safe havens, approaches, or pilot areas

Figure 2-47 shows the designated anchorages in the area. The closest anchorage is Brenton Point Anchorage Ground, located 6.7 NM (12.4 km) from the Project; therefore, no measurable effects are anticipated related to anchorages. No significant anchorage activity is indicated by the AIS data in the Lease Area.

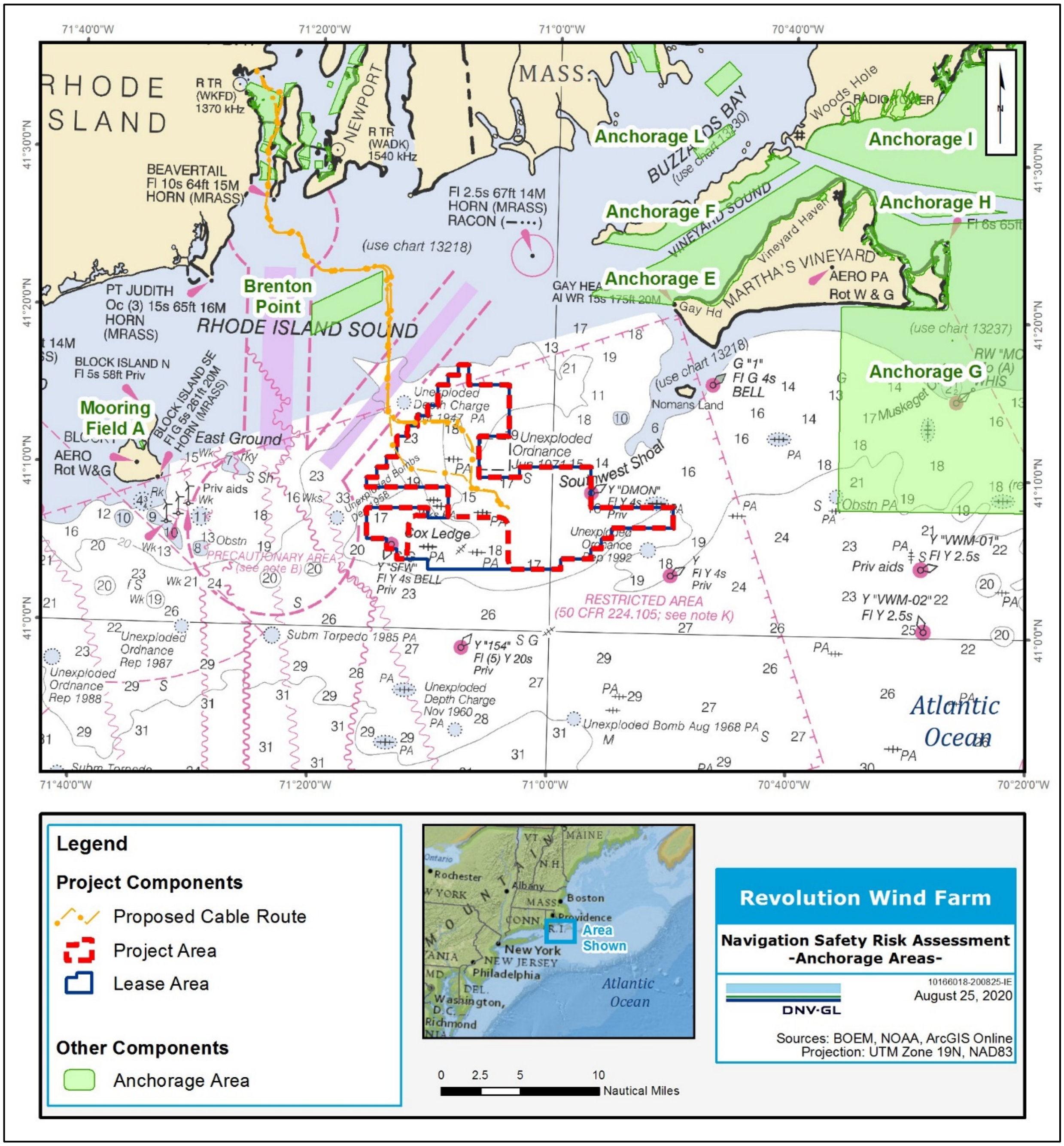


Figure 2-47 Anchorage areas

United Kingdom (UK) guidance to mariners strongly recommends that vessels operating in a wind farm "avoid anchoring except in emergencies as the anchor could easily be fouled." (MCA, 2017b) It is possible that a vessel could anchor in the Project Area in an emergency situation if the captain of the vessel identifies it as the safest course of action available at the time. Based on discussions with mariners piloting vessels in international trade, it is extremely unlikely that a deep draft vessel would encounter a situation where anchoring in the Project would be the best available option.

Figure 2-48 shows nearby pilot areas. The Project is a minimum of 12 NM (21 km) from the closest pilot boarding area.

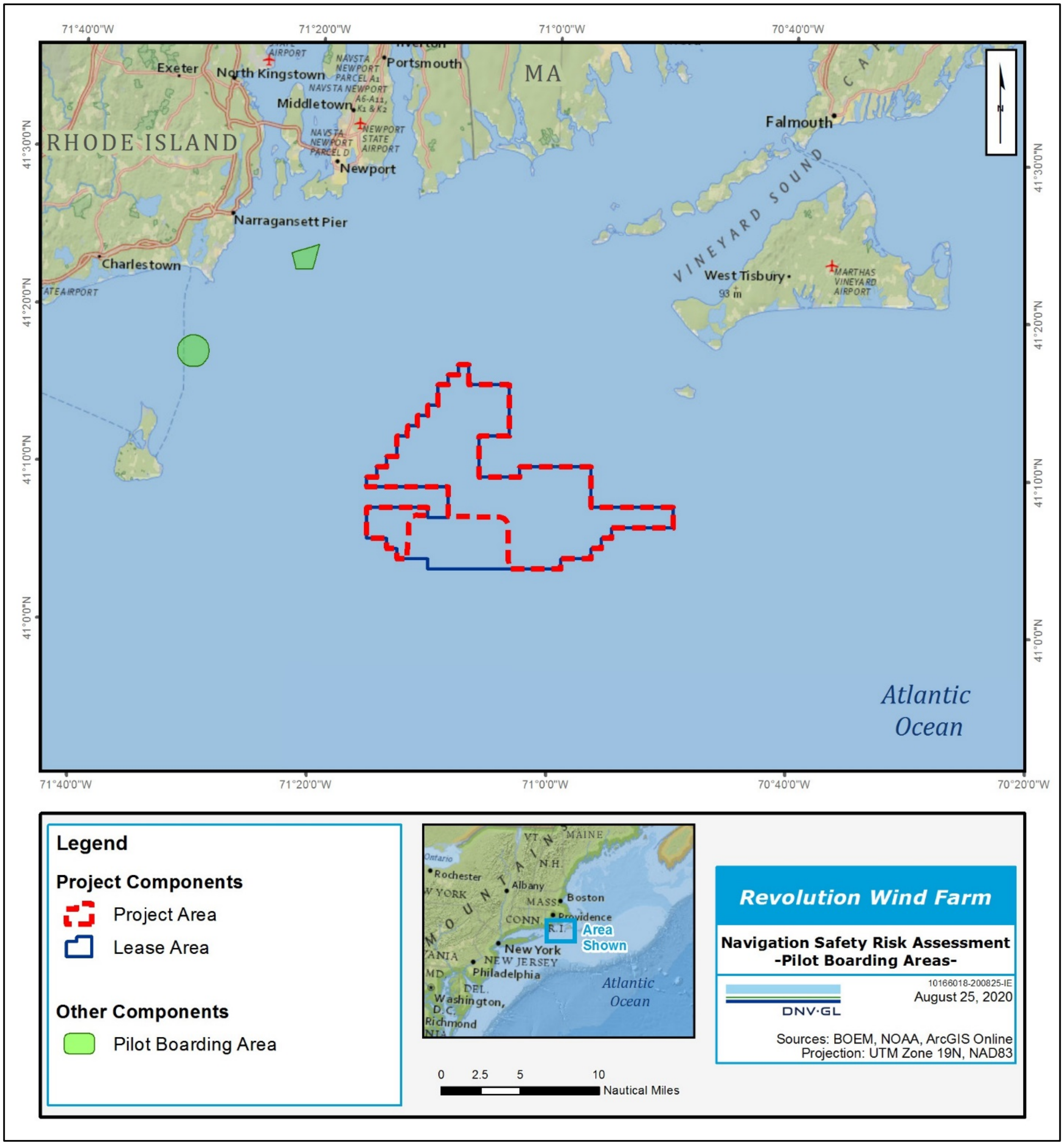


Figure 2-48 Pilot boarding areas

2.2.3 Proximity to other uses of interest

Table 2-5 describes the proximity of the Project to other uses of interest.

Table 2-5 Proximity of the Revolution Wind Farm to other uses of interest

Type of waterway use	Closest proximity to the proposed maximum footprint of the Project (measured from the nearest WTG)
Fishing grounds or routes used by fishing vessels to fishing grounds	Occurs within the footprint. Fishing grounds lie within the Project Area and are discussed in Section 2.1.1.2. Routes that fishing vessels in AIS take through the wind farm to, for example, fishing areas near the edge of the Outer Continental Shelf, are nearly uniformly distributed across the Lease Area, and are oriented generally northwest or southeast (see previous Figure 2-7).
Within the jurisdiction of a port or navigation authority	None identified within the footprint
Offshore firing/bombing ranges or areas used for military purposes	The Lease Area is within the Narragansett Military Operations Area. No specific military activities have been identified within the Lease Area; however, aircraft and submarine use occur nearby. The closest identified military use is submarine transit lanes, approximately 9 NM (17 km) from the Project.
Existing or proposed offshore renewable energy facility, gas platform , or marine aggregate mining	None identified within the footprint. Figure 2-49 shows nearby energy-related facilities. The closest identified existing renewable energy facility is Block Island Wind Farm, approximately 10 NM (19 km) from the Project. The closest identified proposed energy facility is the South Fork Wind Farm, which shares a border with the Project. WTGs will be installed in South Fork Wind Farm in a pattern consistent with the Project. See the discussion below concerning other proposed wind farms in the area. No offshore oil and gas platforms or marine aggregate mining has been identified in the Study Area.
Existing or proposed structure developments or existing designated offshore disposal areas	No other existing or proposed non-energy structures were identified within the Study Area. None identified within the footprint, the closest designated disposal area is 6.3 NM (11.7 km) from the Project Area.
Aids to navigation (ATON) and/or Vessel Traffic Services	The closest Federal ATON is Squibnocket Lighted Bell Buoy 1; several other buoys are nearby. No negative effects from the Project are anticipated on existing ATON. Section 9 provides further discussion concerning ATON. The closest Vessel Traffic Services are Vessel Movement Reporting System (VMRS) Buzzards Bay and Cape Cod Canal Control.

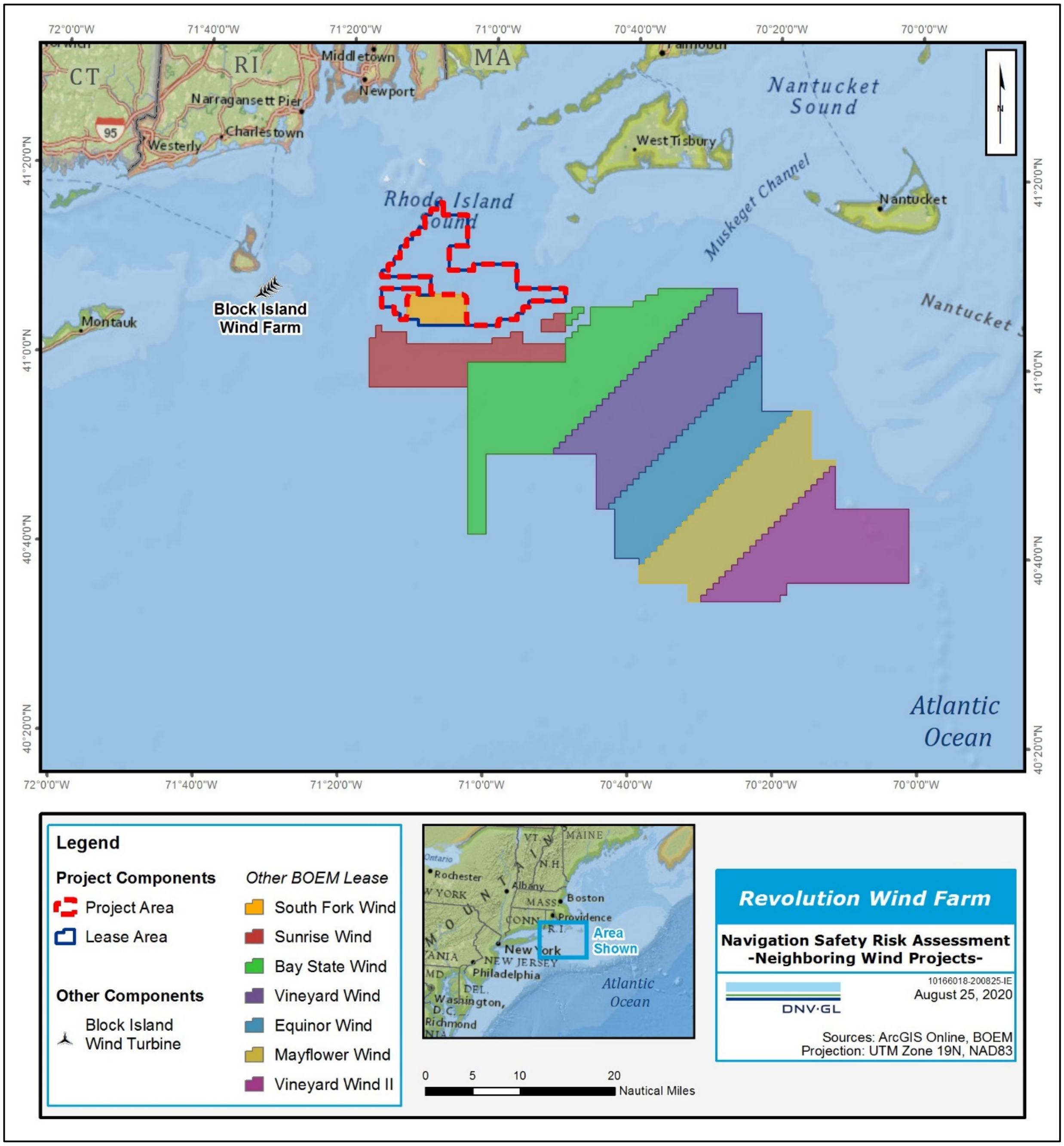


Figure 2-49 Operational and proposed neighboring wind energy projects

2.3 Anticipated changes in traffic from the Project

The risk model built for this assessment includes a representation of traffic in a Base Case, before the Project, and a Future Case, after the Project is constructed. The following reasonably foreseeable changes to marine traffic resulting from the Project are included in the Future Case:

1. Additional non-Project traffic that might be generated by the presence of the wind farm.
2. Alternative traffic routes that would be used instead of existing routes. Deep draft vessels and tugs are anticipated to choose routes around wind farms once they are built.

Each is described below.

Additional traffic added to the future case

The adjustments described in this section are to the Future Case MARCS model, with the Project.

It is anticipated that there will be public interest in the Project that could potentially lead to pleasure tours of the wind farm and a potential increase of recreational traffic (including recreational fishing). It is difficult to estimate a precise number of vessels per year that will be added to local traffic patterns. To incorporate the potential tours, excursion, and recreational (including recreational fishing) traffic surrounding the Project, it is assumed that there will be 100 trips per year. This is a conservative estimate for the first operational year of the Project. It is anticipated that as time passes, there will be less tour traffic and the increase in vessels may diminish. This study aims to present the conservative case with the most probable traffic, as opposed to an average traffic scheme over a longer period. This additional traffic in the Future Case is included in the Pleasure vessel category and is allocated a new route from Narragansett Bay to the wind farm.

Modification of traffic routes in the future case

Currently, some shipping routes traverse the area where the wind farm is to be constructed. Some ships will choose not to navigate through the wind farm. At this time, the extent to which they will adjust their course is a matter of speculation. For the purposes of modeling, DNV GL developed alternative routes for these vessels based on general principles of (1) avoiding the wind farm footprint, (2) minimizing the additional distance transited, and (3) accounting for existing routing measures.

Deep draft ships (cargo, tanker, and tanker oil types) as well as tug/service vessels that routed through the wind farm in the AIS data were re-allocated to these alternative routes outside of the wind farm for the Future Case. Other vessel types (fishing, other, passenger and pleasure) are modeled as continuing to navigate through the wind farm in the Future Case.

2.4 Effect of vessel emission requirements on traffic

The International Maritime Organization (IMO) implemented limits on sulfur (SO_x) emissions in defined Emission Control Areas (ECAs) in North America and other locations (IMO, 1997). Since 1 January 2015, vessels in international trade must use fuel with a maximum of 0.10 percent sulfur content when within 200 miles of the U.S. coast (or comply by controlling emissions) (Figure 2-50). Typically, vessels switch to the more expensive low-sulfur fuel prior to entry in the ECA, which is expected to have no effect on traffic patterns near the Project.

Figure 2-50 Project Area and boundary of the North American Emission Control Area

Additional fuel restrictions will be in place as of 1 January 2020. The International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI (IMO, 1997) contains a global requirement regarding fuels used in ships in international trade. On 1 January 2020 ships using fuel oil must have a maximum of 0.50 percent (mass basis) sulfur content in their fuel or be fitted with an approved equivalent means of compliance, such as a scrubber. Switchover to lower sulfur fuel will continue take place outside the ECA boundary, with no effects relative to the Project.

2.5 Seasonal variations in traffic

The AIS dataset used in this assessment covers a time span of one year. Seasonal variations in traffic were analyzed by comparing the annual average number of tracks to the value for each season and for each vessel type. Figure 2-51 and Figure 2-52 show the relative number of transits per season for each of the evaluated route transects. Figure 2-53 shows the seasonality for the transects with fewer vessel crossings: transections 15 through 21.

In general, traffic is significantly higher in the summer than in any other season. In the year of data, summer increases were the greatest for Pleasure and Other/Undefined vessel types, although passenger and fishing vessels also showed significant increases.

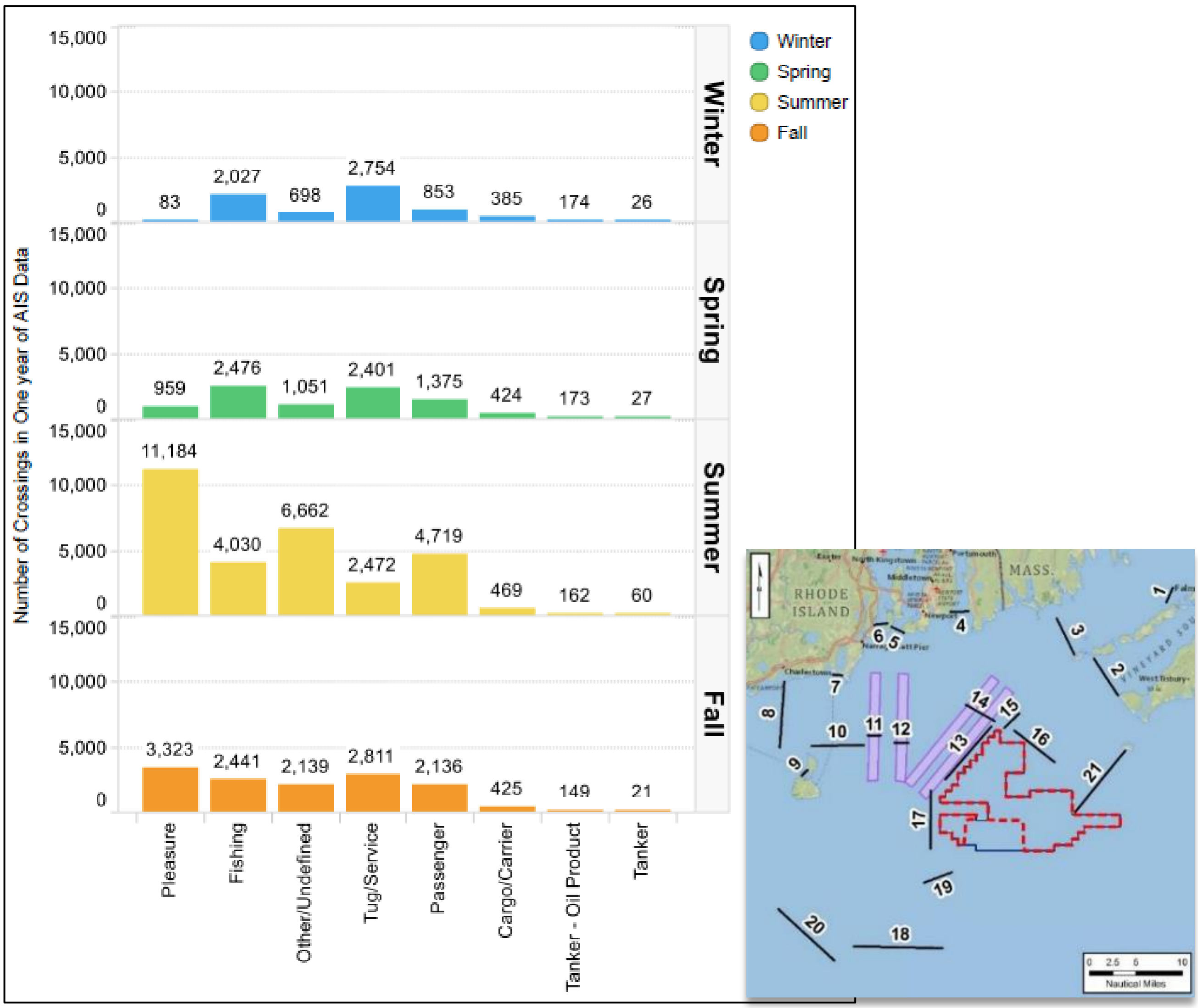


Figure 2-51 Seasonality of vessel transits per vessel type[1]

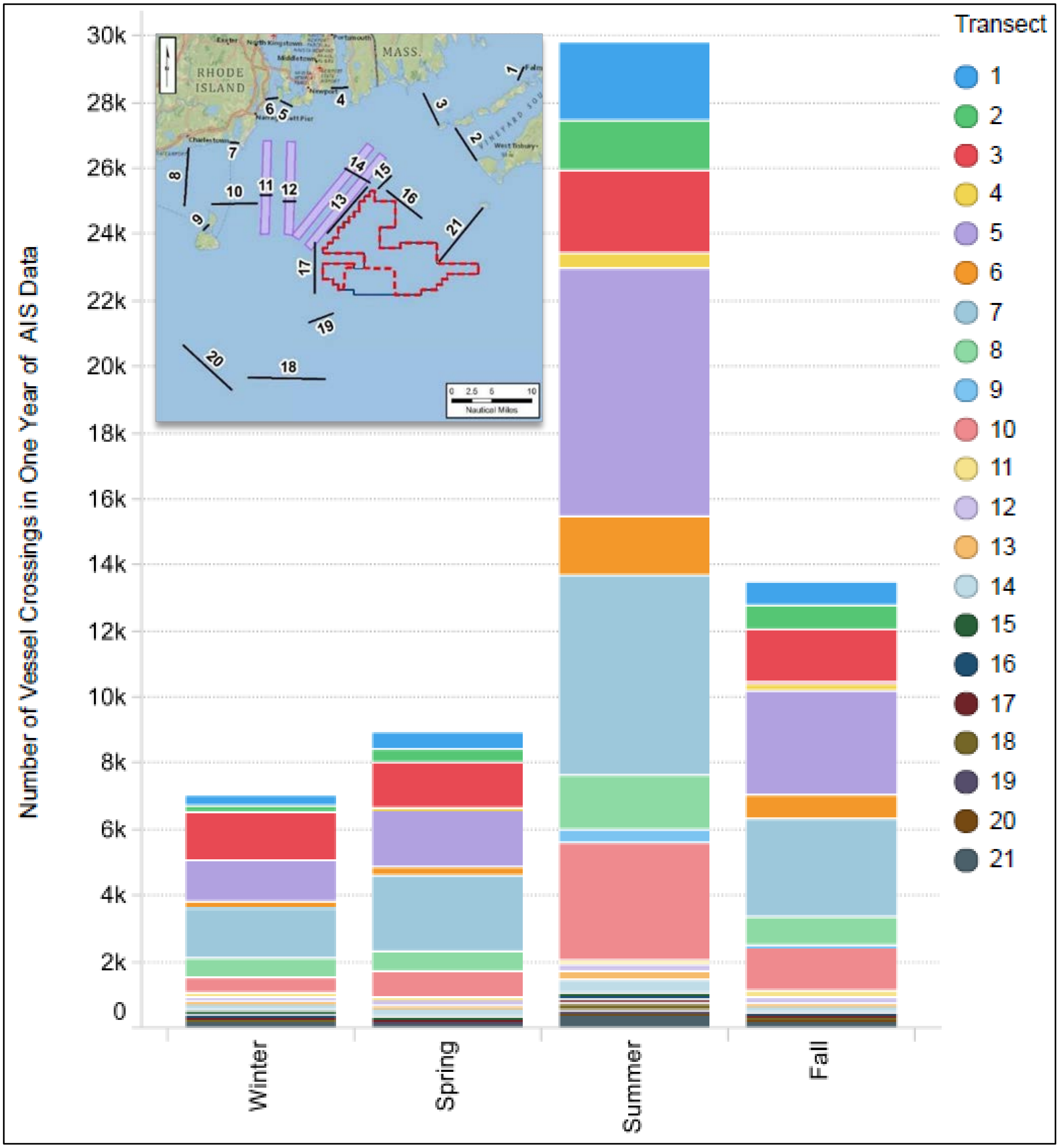


Figure 2-52 Seasonality of vessel tracks crossing all route transects[1]

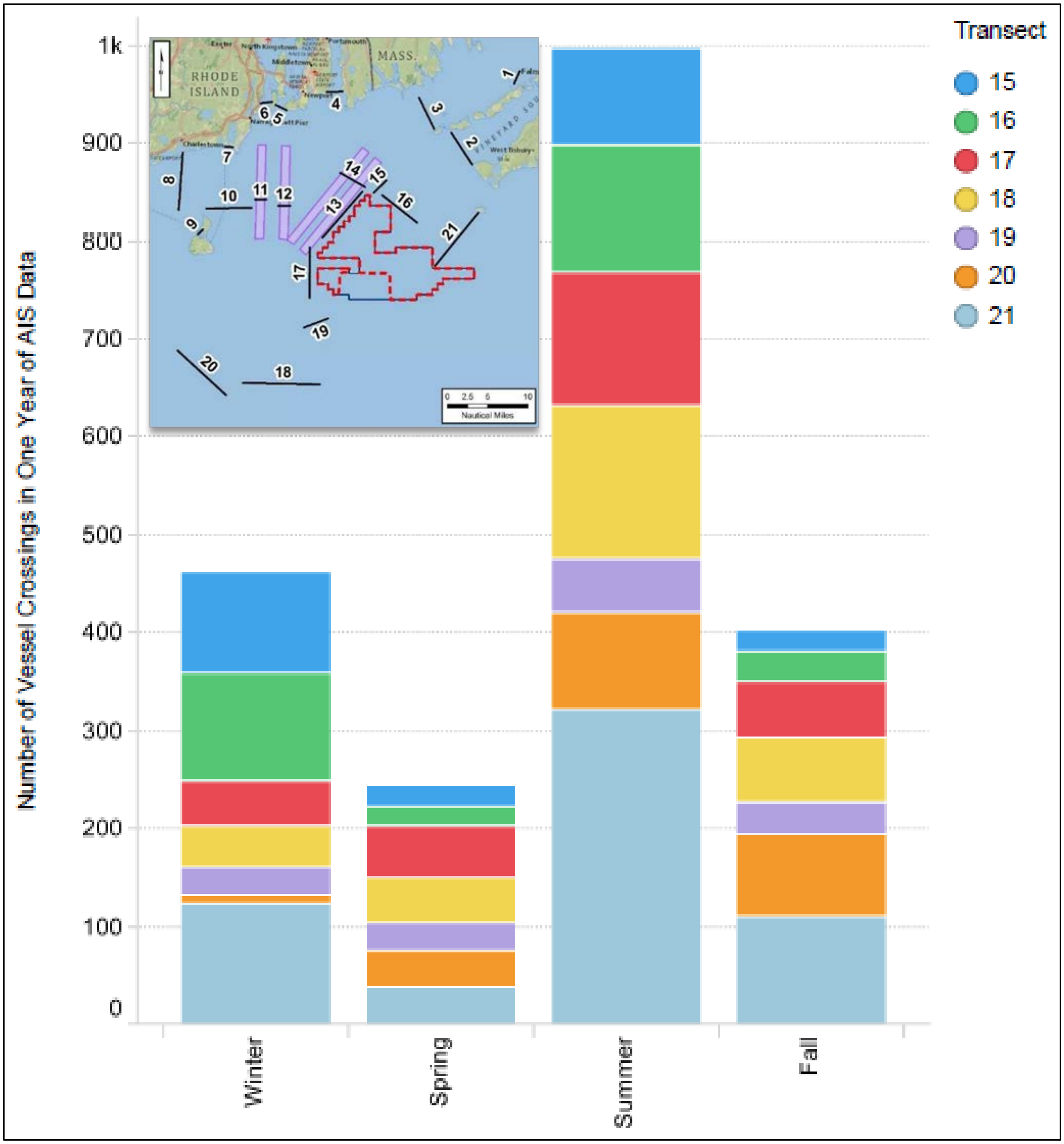


Figure 2-53 Seasonality of vessel tracks crossing transects 15 through 21[1]

Key conclusions concerning seasonality of traffic are:

- Pleasure vessel traffic shows the strongest seasonal increase of any of the traffic types. Summer traffic across the entrance of Narragansett Bay via East Passage (transect 5) showed the greatest increase.
- Fishing vessels show significantly higher traffic in the summer across nearly all the evaluated routes. The route with the largest increase in traffic is at Pt Judith (transect 5 and others). Large percentage increases are noted at Block Island (transect 9) and southbound toward the edge of the continental shelf (transect 18); however, the number of transits at these locations is low compared to highly transited lanes at large international ports.
- Similarly, vessels identified as “Other” or undefined show higher traffic levels in the summer, particularly on the western side of the Study Area.
- Passenger vessel traffic is generally highest in the summer and fall, but there is no strong pattern concerning the seasonality associated with any of the routes.
- Tug and service vessels show small increases in the fall and winter.
- Cargo/carrier, oil tanker, and non-hydrocarbon tanker traffic show no distinct seasonality.

In addition to the data analysis, local mariners were engaged to capture their views concerning the potential impacts of the Project on navigation. A summary of these discussions is included in Appendix C.

3 OFFSHORE ABOVE WATER STRUCTURES

This section describes:

- Hazards posed by Project components to vessels
- Project clearances and vessel types
- Emergency rescue activities in the Project Area
- Noise from the Project
- Potential damage to Project components from allision by a passing vessel

3.1 Hazards to vessels

The hazards posed to vessels from the Project are:

- Air draft (clearance) – WTG blades could pose a hazard to a vessel with a mast or other structural component taller than 32 m (106 ft) above Mean Higher High Water (MHHW) for the smallest, 8 MW turbines. Section 3.2 discusses this risk.
- Keel clearance – A jacket leg could pose a hazard to a deep draft vessel depending on the hull shape if the vessel was extremely close to the jacket leg. Vessels passing at a safe distance will be well away from the jacket legs. The primary scenario of concern for keel clearance would be allision with the jacket near the waterline, because the angle of a leg on a four-leg jacket is more vertical than a typical oil tanker hull. Section 6 discusses water depths.
- Subsea (buried) cable – A subsea cable could pose a hazard to a vessel if an anchor penetrated the seabed to the depth of the cable at a cable location or impacted cables that are otherwise protected. See further discussion below.
- Stationary object at/near the waterline – The sea level portion of monopile or jacket foundation with associated J-tubes could pose a hazard to: (1) a vessel on course with the foundation or (2) a vessel adrift and being pushed (primarily by the wind) toward the foundation. Section 11.1 discusses the consequences of an allision with a Project structure and Section 0 presents an estimate of the frequency of an allision with a Project structure.
- Mobile gear fishing techniques – These techniques are employed near and within the boundaries of the Project. These techniques present an additional potential hazard to and from mobile fishing gear and operations potentially damaging Project submarine power cables by penetrating the seabed or impacting unburied cables that are otherwise protected. The higher risk fishing activities include bottom trawling and shellfish dredging. Both activities are expected near the Project Area and export cable. Assurance that the cable is buried at sufficient depth for any gear type, and/or adequately protecting cable that cannot be buried to target burial depth, and/or using gear that has limited penetration depth in the wind farm are important risk controls. The Bureau of Ocean Energy Management (BOEM) recommends a minimum burial depth of 3.28 ft (1 m) and at least a single armor layer to reduce the likelihood of interactions between fishing activities and a subsea cable (BOEM, 2011). To reduce risks associated with vessel anchor or fishing gear snag on Project subsea cable, the cable target burial depth is four- to six-foot (1.2 to 1.8 m) and includes at least a single

armor layer. Where possible, the cable will be buried to a depth of four to six feet deep. Cable protection measures will be employed where cable burial depth is not adequate. To ensure the risk is sufficiently mitigated, a separate cable burial risk assessment will be conducted for the Project, and the results of that study will inform the depth of burial as well as cable protection measures for the Project.

- Radar clutter – WTGs and the movement of turbine blades can potentially interfere with communication signals from radio and radar transmitters by either blocking or reflecting the signals. See discussion in Section 10.2.
- Noise – Sound from Project components will add to background noise levels. See discussion in Section 3.4.

A cable burial risk assessment will be conducted for the Project, and the results of that study will inform the target depth for the cables. A similar study was recently conducted in the region (Deepwater Wind, 2012). It concluded that disturbance of the seabed from fishing gear was found to be less than 1.6 ft (0.49 m) below the surface of the seabed.

Table 3-1 Penetration depth of fishing gear (Szostek et al., 2017)

Gear	Penetration depth in fine sand	Penetration depth in fine clay	Penetration depth in course sand
Trawl boards, beam trawls, and scallop dredges	< 1.3 ft (< 0.4 m)	< 1.3 ft (< 0.4 m)	1.6 ft (0.5 m)

3.2 Vessel clearances from project components

The air draft required by a vessel is the distance between the waterline and the highest point on the vessel. The air clearance is the additional space between the highest point on the vessel and the hazard, relevant to this assessment, a turbine blade. The tips of WTG blades on a 8 MW turbine are about 10 m to 25 m away from the monopile (Ostachowicz et al., 2016). Therefore, the restricted air clearance exists only within a narrow range of distance from the structure.

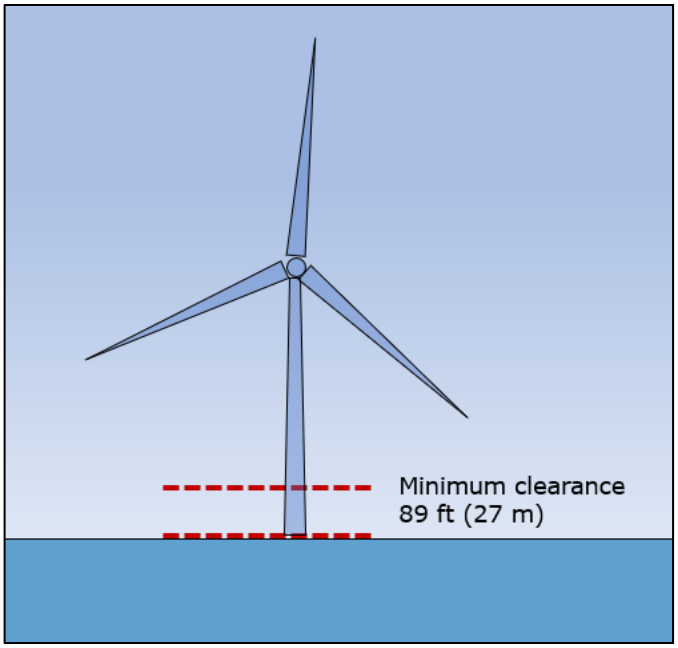


Figure 3-1 Illustration of blade tip clearance

All WTG foundations will indicate the as-built air gap on the structure. The minimum blade tip heights within the PDE are shown in Table 3-2.

Comparing this distance to the types of vessels in the AIS dataset, the following vessel types typically have air drafts that exceed the Project envelope, and could be exposed to the hazard from a blade:

- Oil Tanker
- Tanker
- Cargo/carrier
- Sailing vessels with masts taller than the air clearance of the selected wind turbines

These vessels are not expected to transit through the wind farm, in line with safe practices (IMO, 1972).

Table 3-2 Air clearance envelope (minimum) for wind turbines

WTG blade tip	Wind turbine class	
	8 - 10 MW	12 MW
Minimum blade tip height from mean sea level (MSL) (Orsted, 2020)	28 m (93.5 ft)	46 m (151 ft)
Blade tip minimum height from MHHW (based on data from NOAA, 2019c)	27 m (89.1 ft)	45 m (147 ft)

3.3 Emergency rescue activities and project components

The Coast Guard will provide search and rescue services in U.S. waters in and around offshore wind farms, including the Project. It is anticipated that emergency response assets (vessels, aircraft) from federal, state, local, commercial, and private sources may be utilized within the wind farm should an emergency situation arise.

To facilitate search and rescue within the Project footprint (and all potential U.S. offshore wind farms) Orsted conducted both table-top and operational exercises with the U.S. Coast Guard at the Block Island Wind Farm. These exercises demonstrated the Coast Guard's capability to search in the vicinity of WTGs with both vessels and aircraft, and rescue (extract) an injured person from a nacelle. Additionally, Ørsted hosted U.S. Coast Guard officials, including search and rescue specialists, at its Marine Coordination Center in Grimsby, England and the nearby Race Bank offshore wind farm. The site visit included observations and discussion of United Kingdom Maritime and Coastguard Agency (UK MCA) search and rescue best practices, organization, and operational processes. Future exercises during operations and additional simulation exercises are planned (Orsted, 2020).

Table 3-3 lists key rotor tip specifications provided in the PDE (Orsted, 2020).

Table 3-3 Rotor tip envelope for wind turbines

Blade tip height	Wind turbine class	
	8 - 10 MW	12 MW
Upper blade tip height [MSL]	197.4 m 647 ft	266 m 873 ft
Hub height [MSL]	115 m 377 ft	156 m 512 ft
Lower tip height [MSL]	33 m 108 ft	46 m 151 ft
Maximum rotor diameter	164 m 538 ft	220 m 722 ft

In 2005, the MCA conducted trials using at the UK North Hoyle Wind Farm using a Sea King Mark III helicopter (MCA, 2005), and with 5 MW WTGs, which are smaller and more closely spaced than those in the PDE. The study concluded that the wind farm had no noted effects on:

- Radio communications to and from the aircraft
- VHF homing system
- Compass readings
- Helicopter flight into a regularly spaced wind farm and launch a surface rescue vessel in good visibility

Effects of varying levels were noted regarding:

1. *"Radar returns from structures. Side lobes* [depth estimated at less than 50 m] *limited target detection when vessels were within 100 meters of turbines."*

In poor visibility, voice communications and radar are the primary means of casualty detection, whether wind turbines are present or not. Radar detection is reduced for vessels that are close to turbines.

2. “Limitations in approach distances from turbines in clear weather.”
3. “Inability to effect surface rescues within wind farms in restricted visibility.”
4. “Tracking, by vessel or shore-based marine radar, of helicopter movements within wind farms was generally poor.”
5. *“Increase of aircraft power requirements downwind of the wind farm.”*
   However, there was no noticeable increase in turbulence (MCA, 2005)

The study identified measures that reduced risk to the rescue activity, both of which will be implemented in the Revolution Wind Farm:

- Ability for an operator to remotely lock turbine blades in rotation and in yaw and feather the blades
- Uniformly spaced turbines will allow helicopters to be used for radar search

The U.S. Coast Guard MARI PARS (2020a) report examined potential navigation safety and search and rescue (SAR) issues associated with anticipated offshore wind farm development in the area. The report concluded that a wind turbine array “developed along a standard and uniform grid pattern with at least three lines of orientation and standard spacing” (such as proposed for the Project) would maintain the Coast Guard’s ability to conduct SAR operations within the project area.

3.4 Noise

Pile driving, if used during construction, would pose the most significant noise level of any Project-related activity. It is anticipated that the Coast Guard will implement a safety zone around construction-related vessels and activities (see Section 5.1 for more detail about safety zones). Noise levels outside the safety zone are not expected to have negative effects on navigation safety or Coast Guard missions.

Operational noise from an offshore wind farm is generated primarily by mechanical equipment or by aerodynamic interactions. The mechanical noise from the WTGs and OSS are anticipated to be minimal. The aerodynamic noise is strongly dependent on local conditions such as wind speed and is expected to be within similar ranges of the predicted levels for Horns Rev 3 : 111 dB(A) to 113 dB(A), for 8 MW and 10 MW turbines (Energinet.dk, 2014).

International Regulations for Preventing Collisions at Sea (COLREGs) Annex III (IMO, 1972) describes the required sound signal intensity and range of audibility for vessels by length. Table 3-4 summarizes the requirements. The COLREGS requirements assume an average background noise level at the listening posts of a vessel to be 68 dB (IMO, 1972).

Table 3-4 Intensity requirements of whistle (IMO, 1972)

Length of vessel in meters	1/3-octave band level at 1 m in dB	Audibility range in NM
200+	143	2
75-200	138	1.5
20-75	130	1
<20	120 / 115 / 111*	0.5

*for frequency ranges 180-450 Hz / 450-800 Hz / and 800-2100 Hz, respectively

An estimated background noise level of 68 dB is greater than the noise level of a wind farm from 1,148 ft (350 m) away (68 dB and 35-45 dB respectively), therefore noise from the Project turbines is not anticipated to pose any negative effects on navigation in the region; the background noise level is much greater than the noise from the Project.

3.5 Project structure impact analysis

This section describes the potential damage to a WTG from a marine accident and provides a sense of whether or not WTGs may present a hazard to navigation if struck.

The damage from a powered allision is generally more severe than from a drift allision, and therefore presents the most conservative damage case. Therefore, this assessment focuses on the consequences from a powered allision of a WTG by a vessel transiting at cruising speed within the Project. This is a reasonably conservative scenario and provides a high-end estimate of the potential damage.

The level of damage is directly related to impact energy transmitted by the ship to the WTG, which is dependent on the weight and speed of the vessel. Specific consequences of an allision with a WTG are highly dependent on the inherent design strength of the structure. The discussion below relates to generic designs.

A study published in 2017 in the Ocean Engineering Journal discusses ship impact consequences to monopile and to jacket fixed-bottom foundations when struck by a 4,000-ton class vessel (Moulas et al., 2017).

Should a vessel hit a monopile foundation, three main factors that influence the location and extent of the damage to the foundation are the collision energy, the height of the vessel, and the area of impact. Vessels with a lower profile are expected to result in less damage to the monopile due to the stiffness of the design (Moulas et al., 2017). Due to this, it is unlikely that smaller vessels (including pleasure and recreational fishing) will damage the monopile to the extent that it may collapse. For monopile foundations, studies show that the damage ranges from minimal (possibly not even in need of repair) to severe plastic deformation and permanent indentation (Moulas et al., 2017). At higher allision energies, the monopile foundation is likely to deform below sea level, nearer to the seabed, and will likely not collapse.

Should a vessel strike a jacket foundation, the main factors affecting the resulting damage include the vessel speed and impact area. When a vessel strikes a WTG at a low velocity, the damage to the jacket foundation may not be extensive and may not even require repairs. However, for a 4,000-ton vessel traveling at about 7.8 kt, the forces generated are sufficient to cause multiple failures of joints and/or rupture of elements of a jacket foundation. This is equivalent to 32 MJ.

Given the range of vessel sizes (Table 3-5) and speeds (Table 3-6) found in the AIS dataset, a range of impact energies is estimated for each vessel type, shown in Table 3-5.

Table 3-5 Vessel sizes in the AIS dataset[1]

Vessel type	DWT (metric tons)		
	Low	Average	High
Tanker – oil/gas products	1,241	46,315	113,005
Cargo & carrier	1,750	25,602	75,005
Tanker	9,240	18,963	36,771
Tug/Service	1*	421	33,095
Other & undefined	20	518	14,620
Passenger	70	584	12,512
Pleasure (incl. recreational boating)	1	Insufficient data	711
Commercial fishing	Insufficient data	Insufficient data	Insufficient data

* Likely typographical errors in AIS input

The speeds in Table 3-6 are based on the speed profiles in the AIS dataset, and applying similar distributions as are used in the MARCS model: high speed is calculated as 120 percent of the representative speed based on AIS data. The low speed is half of the representative speed.

Table 3-6 Assumed vessel speed when allision occurs

Vessel type	Low speed (kt)	Representative speed (kt)	High speed (kt)
Cargo & carrier	4.8	9.5	11.4
Commercial fishing	3.8	7.5	9.0
Other & undefined	5.7	11.3	13.6
Passenger	5.9	11.7	14.0
Pleasure & recreation	3.8	7.5	9.0
Tanker	5.5	11.0	13.2
Tanker - oil/gas product	5.4	10.8	13.0
Tug & service	4.3	8.5	10.2

A rough estimate of kinetic energy (in joules) is obtained using the following formula, together with inputs of DWT (in kilograms) and speed in (in meters per second):

$$E_k = \frac{1}{2} DWT * Speed^2$$

Figure 3-2 gives the resulting range of kinetic energies.

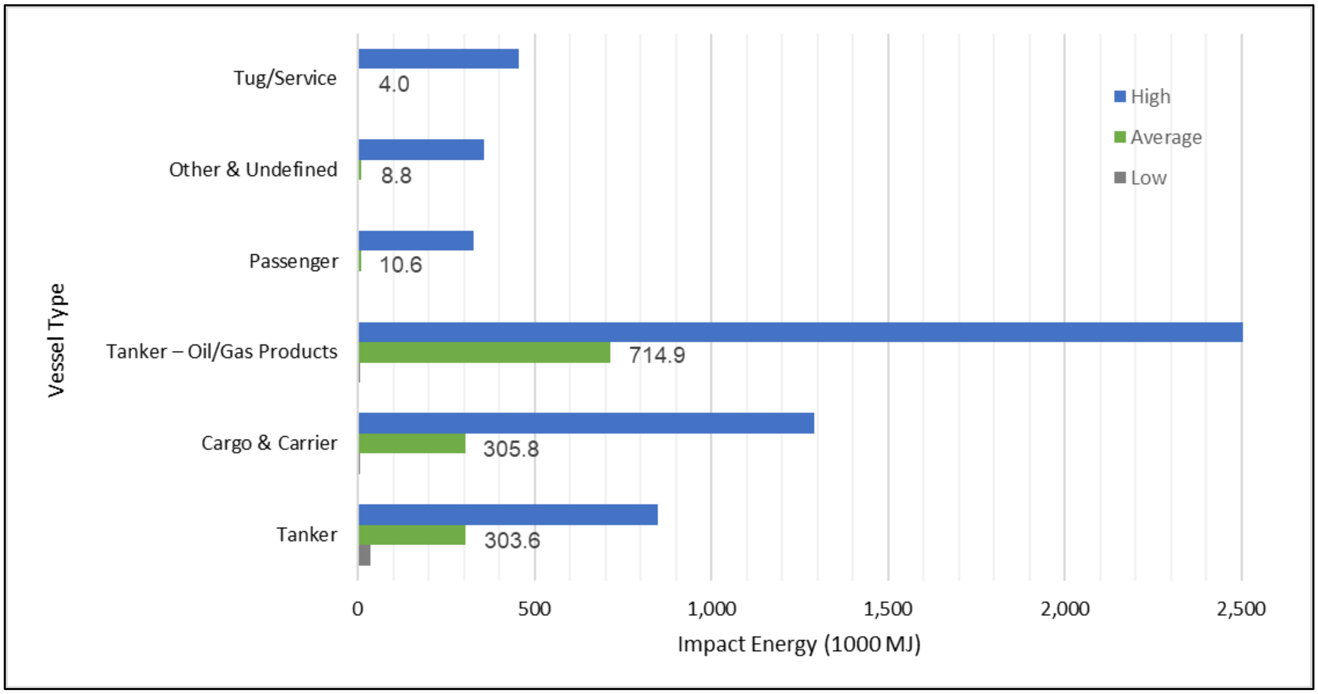


Figure 3-2 Ranges of kinetic energy per ship type

The estimated energies are considered extreme bounds because:

1. The kinetic energy is assumed to be received by the WTG. However, the energy received by the WTG structure will be less than the kinetic energy, as some of the energy will be dispersed during the collision (e.g., vessel hull plastic deformation, vessel movement/rotation).
2. The estimated minimum and maximum speeds are probably much higher than the reality. In case of a near-collision situation, the crew will do everything they can to avoid the collision, and if it is not avoidable, at least decrease vessel speed.

Due to the range of sizes and speeds of vessels in this study, it can be concluded that pleasure and fishing vessels are unlikely to cause extensive damage to a jacket because of their low tonnage and average speeds. Deep draft vessels such as tankers and carriers have a greater potential to cause damage to the jacket, even at lower speeds.

The highest postulated consequences would be from allision by a non-oil tanker, oil tanker, or cargo/carrier. An impact by a large vessel at average cruising speed is expected to cause severe damage, potentially jacket failure, depending on the design of the jacket.

As previously stated, it is not anticipated that tankers of any deep draft / large vessel types will transit within the Project. Based on the powered allision results of the MARCS model during operation, there is a <0.001 annual frequency of a powered allision involving a tanker (carrying oil products or not) or cargo/carrier; less than one in 1000-year event.

During construction, the primary risk is from an on-site construction vessel allision with a WTG while transiting through the wind farm. However, construction vessels are anticipated to be travelling at low speeds through the construction zone and are unlikely to cause significant damage in the event of an allision. Based on the low speeds that are expected in a construction zone, a drifting or direct strike from a construction or work vessel is unlikely to cause extensive enough damage to a monopile or jacket based on the WTG strength analysis discussed earlier in this section.

In terms of damage to the WTG, neither pleasure vessels nor recreational fishing vessels should be able to cause significant damage, regardless of tower design.

4 OFFSHORE UNDERWATER STRUCTURES

The Project does not include underwater devices. All cables will be buried below the seabed or otherwise protected on the seabed and all structures on the seabed will extend above the water line.

Subsea cables are a hazard to anchoring and to fishing with bottom gear; conversely, anchoring and fishing with bottom gear are hazards to Project components. It is anticipated that deep draft vessels and tugs will avoid the wind farm and sail in historical or designated lanes; however, smaller vessels, such as pleasure vessels and commercial fishing vessels, will likely transit the wind farm. Some of these vessels will fish in the Project Area and some will transit through the Project Area and not fish during the transit.

For commercial fisheries, the primary fishing gear in the Rhode Island and Massachusetts wind energy areas are gillnet, dredge, pot, bottom trawl, and midwater trawl (Kirkpatrick et al., 2017). As an indication of the level of activity, Figure 4-1 presents the annual revenue from these fisheries for the five-year period 2007 to 2017. Three gear types represent 59 percent of the permits and 83 percent of the revenue: dredge, bottom trawl, and gillnet. Longline and hand fishing combined represent about 8 percent of the permits and less than 1 percent of the total revenue.

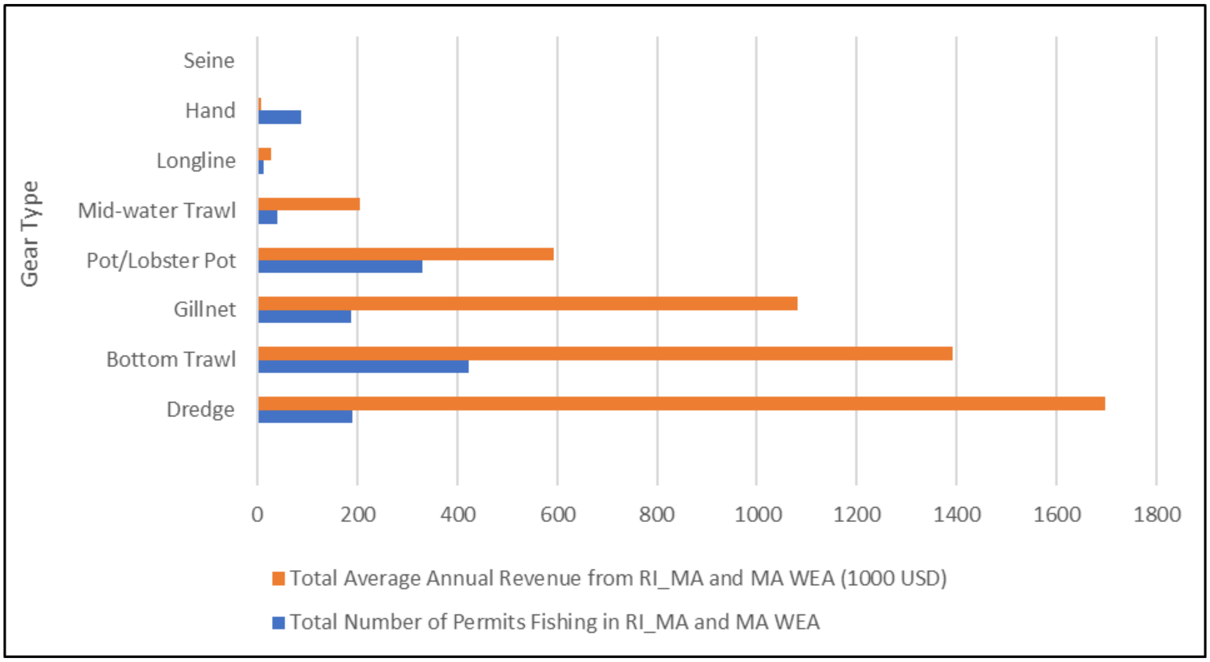


Figure 4-1 Number of commercial permits and revenue per year (2007–2012) (Kirkpatrick et al., 2017)

Anchoring, bottom trawling, and dredging pose the greatest risk of contact. To reduce the risks associated with these hazards, the cable target burial depth is one meter (3.28 ft) and includes at least a single armor layer. Where possible, the cable will be buried to a depth of four to six feet deep. In addition, and to assure the risk is sufficiently mitigated, a separate cable burial risk assessment is being conducted for the Project, and the results of that study will inform the depth of cable burial for the Project and cable protection measures where necessary. See the Project Construction and Operational Plan (COP) Section 3.3.7.2 for further details.

5 NAVIGATION WITHIN OR CLOSE TO A STRUCTURE

This section assesses:

- The safety of navigation in and near the Project during construction
- The safety of navigation in and near the Project during operation.
- Potential effects on anchorage areas.

Orsted has an ongoing dialogue with local mariners on the potential effects of the Project, which is summarized in Appendix C.

5.1 Construction phase navigation risks

Offshore construction activities could be a hazard and Project construction vessels could experience hazards from passing vessels. Two primary means of reducing this risk are updates to mariners from the Project and safety zones around construction activity.

The Project has committed to informing fishermen and other mariners about offshore activities related to the Revolution Wind Farm. Fisheries liaisons and a team of fisheries representatives are based in regional ports, and updates will be provided to mariners online and via twice-daily updates on Very High Frequency (VHF) channels.

Safety zones can also protect mariners from potential hazards during construction activities. It is anticipated that the Coast Guard will implement safety zones during construction of the Project, as they did for construction of the Block Island Wind Farm (18 FR 31862).

To reduce the likelihood of an allision or collision during construction, Project safety vessel(s) will be on scene to advise mariners of construction activity. (Orsted, 2020)

The Elijah E Cummings Coast Guard Authorization Act of 2020[5], which is pending final congressional approval as of 1 September 2020, when this assessment was issued, would provide the Coast Guard authority to establish and enforce safety zones on the Outer Continental Shelf (OCS) for activity related to wind energy development and operation. While this legislation has not been signed into Federal law by the President at the time of this NSRA publication, it is fully expected it will become law by the time construction of the Project begins. As the Coast Guard has advocated for this authority and supported the legislation, it is reasonable to assume that subsequent to Orsted's request, temporary safety zones will be established and enforced to protect mariners during construction and selected maintenance activities.

Orsted will include notice and status of safety zones in its frequent Mariners Information posted to the website https://us.orsted.com/mariners and through weekly Local Notice to Mariners submitted to the Coast Guard. However, in the unlikely event that safety zone authority has not been granted to the Coast Guard by the time project construction begins, the project will coordinate closely with the U.S. Coast Guard to develop an alternative plan to facilitate vessel safety. (Orsted, 2020)

[5] H.R. 6395, Elijah E. Cummings Coast Guard Authorization Act of 2020, https://www.congress.gov/bill/116th-congress/house-bill/6395/text#H07669B44D8C54EC9887FF078B3A3165F

Such a plan may include:

- Use of private safety vessels to monitor construction sites and alert mariners of construction activities
- Regular presence by Coast Guard and/or Coast Guard Auxiliary vessels and aircraft
- Placement of marker buoys to clearly delineate construction areas
- Active engagement with applicable waterways users and stakeholders to advise of the nature and duration of construction activity

As with all marine navigation, all vessels, including construction and service vessels, are required to follow COLREGs (IMO, 1972). Vessels have the obligation to use all available means appropriate to the prevailing circumstances and conditions to determine if risk of collision exists. If there is any doubt, the vessel operator will assume that there is a risk of collision (IMO, 1972). This applies to vessels that should take special precautions when navigating within the vicinity of the WTGs, particularly in limited visibility. COLREGs also state that every vessel shall proceed at a safe speed so that proper and effective actions could be taken to avoid collision, and the vessel could be stopped within a distance appropriate for the prevailing circumstances and conditions. To determine a safe speed as defined in the COLREGs, the elements a vessel will consider include but are not limited to the following (IMO, 1972):

- The state of visibility
- The traffic density (including fishing vessels or other vessels)
- The maneuverability of the vessel with reference to stopping distance and turning ability in prevailing conditions
- The state of wind, sea and current, and the proximity of navigational hazards

In addition to the above hazards, Project construction vessels may experience hazards from weather or sea state and from each other. Risk controls for these hazards include daily / weekly team briefings and a Project construction guideline that defines wind, sea state, and other constraints under which activities will start/continue or will stop/be discontinued. Conditions and forecasts will be monitored to aid proactive planning and early warning of future unsafe conditions.

Additional information on construction vessels and ports is provided in COP Sections 3.3.9 and 4.1.8.1.

5.2 Operations phase navigation risks

In contrast to Project construction, safety / exclusion zones are not anticipated during Project operation. Therefore, vessels will be free to navigate close to and within the Project.

The Project will lay on charted depths of 26.8 to 48.4 m (88 to 159 ft). Vessels that choose to navigate through the Project will not be draft limited; therefore, grounding risk exists only outside the Project footprint.

To the north of the Project Area is the TSS of the Buzzards Bay Entrance. Large deep-draft vessels navigating near the Project transit within the TSS (see Section 2.1.1.1) and are anticipated to be within the TSS under normal circumstances. The few deep draft vessels noted in Section 2.1.1.1 that currently cross both of the TSS and enter the Project Area are expected to route around the Project once it is constructed. The potential hazards include collisions between vessels or allisions with Project structures.

It is expected that mariners, including mariners onboard Project service vessels, will strictly adhere to all COLREGs and will be aware of the prevailing environment and situation to avoid unsafe situations. The PDE provides sufficient sea room for fishing, pleasure, and service vessels to transit between WTGs if the risks have been considered and a vessel is transiting at a safe speed per COLREGs (IMO, 1972).

It is also anticipated that deep draft vessels (excluding commercial fishing vessels) will not choose to transit through the wind farm. The PDE provides a minimum of 0.6 NM (1.1 km) of space between WTGs. This design is a navigation risk mitigation measure and provides sufficient room for anticipated vessels to transit through and safely maneuver within the Project.

The NVIC 01-19 Enclosure 3 provides Marine Planning Guidelines, which are intended to inform the NSRA and siting of offshore wind structures such as WTGs and OSS, but not affect the boundaries of existing leases. There are no national or international requirements regarding minimum distances between offshore wind structures and shipping routes. General guidance is provided in U.S. and UK Marine Planning Guidelines based on minimum distances needed for maneuvering of generic large deep draft vessels. Table 5-1 lists the generic guidelines concerning safe navigation distances referenced in the NVIC and compares them to Project characteristics.

Table 5-1 Relationships between generic guidelines (Coast Guard, 2019a) and Project characteristics

<table>
<tr><th>Generic guideline</th><th>Project characteristics</th><th>Comments</th></tr>
<tr><td colspan="3">TSS or port approaches planning guidelines</td></tr>
<tr><td>2 NM from the parallel outer or seaward boundary of a traffic lane (based on risk for 300 to 400 m vessels)</td><td>12 WTGs in the evaluated layout would be within 2 NM of the Buzzards Bay TSS inbound traffic lane.</td><td rowspan="2">Planning guidelines are ideally applied prior to selection of potential project locations. A project and site-specific risk assessment can provide higher quality decision support. The results of the Revolution Wind risk assessment are presented and discussed in Section 11.

The proximity of the TSS traffic is accounted for the risk modeling.

See the discussion of vessels transiting in the vicinity of the inbound lane of the Buzzards Bay TSS in Section 2.2.2.4 and risk results in Section 11.</td></tr>
<tr><td>5 NM from the entry/exit (terminations) of a TSS</td><td>WTGs in the evaluated layout are outside the Buzzards Bay 5-NM radius Precautionary Area. Some WTGs (approximately 10 to 19) would be located within 5 NM of the inbound entrance to the Buzzards Bay TSS.</td></tr>
</table>

Generic guideline	Project characteristics	Comments
Coastal shipping route planning guidelines		
Identify a navigation safety corridor to ensure adequate sea area for vessels to transit safely	Available sea room is identified on all sides of the Project Area for potential new routes after the Project is constructed.	See new traffic routes created for modeling in Section 2.3 and Appendix E.
Provide inshore corridors for coastal ships and tug/barge operations	The Project Area does not overlie significant coastwise traffic.	The Project Area does not materially affect vessels on coastal routes because traditional coastwise routes are closer to shore.
Minimize displacement of routes further offshore	The Project Area does not overlie significant coastwise traffic.	The Project Area does not materially affect vessels on coastal routes because traditional coastwise routes are west of the Project Area.
Avoid displacing vessels where it will result in mixing vessel types	The Project overlies fishing, passenger, and to a lesser extent, oil tankers and cargo/carrier vessel traffic. Fishing vessel tracks generally run NE-SW and NW-SE with nearly equal distribution across the Lease Area. In general, the passenger vessels appear to have the Lease Area as their destination. The oil tanker, and cargo/carrier vessel tracks occasionally transit the far western side of the Lease Area.	Fishing and passenger traffic may choose to transit to or through the wind farm rather than around it, or may have the wind farm area as a destination. The density of pleasure vessel tracks is very low, so not many vessels would need to transit around if they chose to do so. Passenger, oil tanker, and cargo/carrier vessels could take an alternate route around the Project Area as a minor route deviation. See new traffic routes created for modeling in Section 2.3 and Appendix E.
Identify and consider cumulative and cascading impacts of multiple Offshore Renewable Energy Installations (OREI), such as wind farms.	Offshore wind lease areas lie directly to the south and southeast of the Project Area.	See Section 11.4.
Offshore deep draft routes		
Offshore deep draft routes	The Ambrose-to-Nantucket Safety Fairway and Nantucket-to-Ambrose Safety Fairway deep draft vessel routes lie 30 NM (55 km) to the southeast and are outside foreseeable influence of the Project.	No anticipated effects.

Generic guideline	Project characteristics	Comments
Navigation safety corridors		
Cross track error	Since the Project is southeast of a TSS, AIS data for tug-tow vessels were reviewed to identify if vessel tracks entered the Lease Area near the TSS. The vessels kept tightly within the TSS and for the period 2011-2018 (without 2014), only one tug track has the potential to be interpreted as having an excursion into the Project Area (2013).	No anticipated meaningful effects. AIS data for the Wind Energy Areas off Rhode Island and Massachusetts was reviewed in the Coast Guard MARI PARS report (2020a), which states, "The data confirmed that the frequency of tug and tow vessel transits is low."
Closest point of approach	The Project is not in established traffic lanes and is not reasonably expected to result in significant re-routing of traffic.	No anticipated meaningful effects.
Density of traffic	The Project Area does not have high traffic densities; the maximum densities seen in the AIS data are low. See Section 2.2.2 and Section 2.5.	Accounted for in risk modeling.
Other site-specific considerations		
Crossing or converging routes	See Appendix E.	Accounted for in risk modeling.
Hazards on opposite sides of a route	None identified.	
Severe weather/sea state	Severe weather and sea states occur in the Project Area. See Section 7, Section 11, and Appendix E.	Accounted for in risk modeling.
Severe currents	NA	
Displacement of vessels into routes with other vessel types	See new traffic routes created for modeling: Section 2.3 and Appendix E.	Accounted for in risk modeling.
Complexity of vessel interactions	Generally low traffic density in the Project Area.	Accounted for in risk modeling.
Transit distance affected by a new hazard	See above, "Avoid displacing vessels where it will result in mixing vessel types."	Accounted for in risk modeling.
Undersized routing measures	None identified.	Accounted for in risk modeling.

The MCA issued a guidance document on Safety of Navigation: Offshore Renewable Energy Installations (OREIs) – Guidance on UK Navigational Practice, Safety and Emergency Response. It defines safe distances between a commercial shipping lane and wind farm. This guidance is used throughout the North Sea and European locations with significant experience in the assessment and installation of wind farms.

The categorization of "safe" distances defined in this study are based on navigation safety buffers of the vessels and the potential impacts of WTGs on radar (see Section 10.1). The risk classification of WTG distances as developed in this study are defined in Table 5-2.

Project WTGs are expected to be in the "Tolerable if As Low As Reasonably Practicable [ALARP]" or "Broadly Acceptable" ranges.

Table 5-2 Tolerability of distances from shipping lane to WTG (MCA, 2017a)

Distance of turbine boundary from shipping route (90% of traffic, as per Distance C)	Factors for consideration	Tolerability
<0.5nm (<926m)	X-Band radar interference Vessels may generate multiple echoes on shore based radars	INTOLERABLE
0.5nm – 3.5nm (926m – 6482m)	Mariners' Ship Domain (vessel size and manoeuvrability) Distance to parallel boundary of a TSS S Band radar interference Effects on ARPA (or other automatic target tracking means) Compliance with COLREG	TOLERABLE IF ALARP Additional risk assessment and proposed mitigation measures required
>3.5nm (>6482m)	Minimum separation distance between turbines opposite sides of a route	BROADLY ACCEPTABLE

The closest shipping route to a Project structure is the inbound Buzzards Bay TSS, at a distance of 1.2 NM (2.2 km). According to the UK tolerability criteria, this is between broadly acceptable and intolerable. This category lies within the domain of individual mariners to determine a safe course, and requires a wind project developer to demonstrate that all reasonably practicable mitigation measures have been implemented, which makes the risk As Low As Reasonably Practicable, or ALARP.

A demonstration of ALARP requires weighing the potential benefits of a measure with the costs of implementing the measure. In many instances, this is a straightforward cost-benefit calculation. However, when several parties bear the burden of the cost and the benefits are not proportionally distributed to them, it can be very challenging. Additional discussion on risk mitigation and ALARP is in Section 11.3.

5.3 Project impact on anchorage areas

NVIC 01-19 guides the applicant to consider the effect the Project will have on anchorage areas. Figure 5-1 presents the designated anchorage areas in the area. The closest anchorage is Brenton Point Anchorage Ground , located 6.7 NM (12.4 km) to the northwest. No anchorage areas lie to the south. The Project is not expected to have any effect on vessel anchorage operations.

The cable route is presented in Figure 5-2.

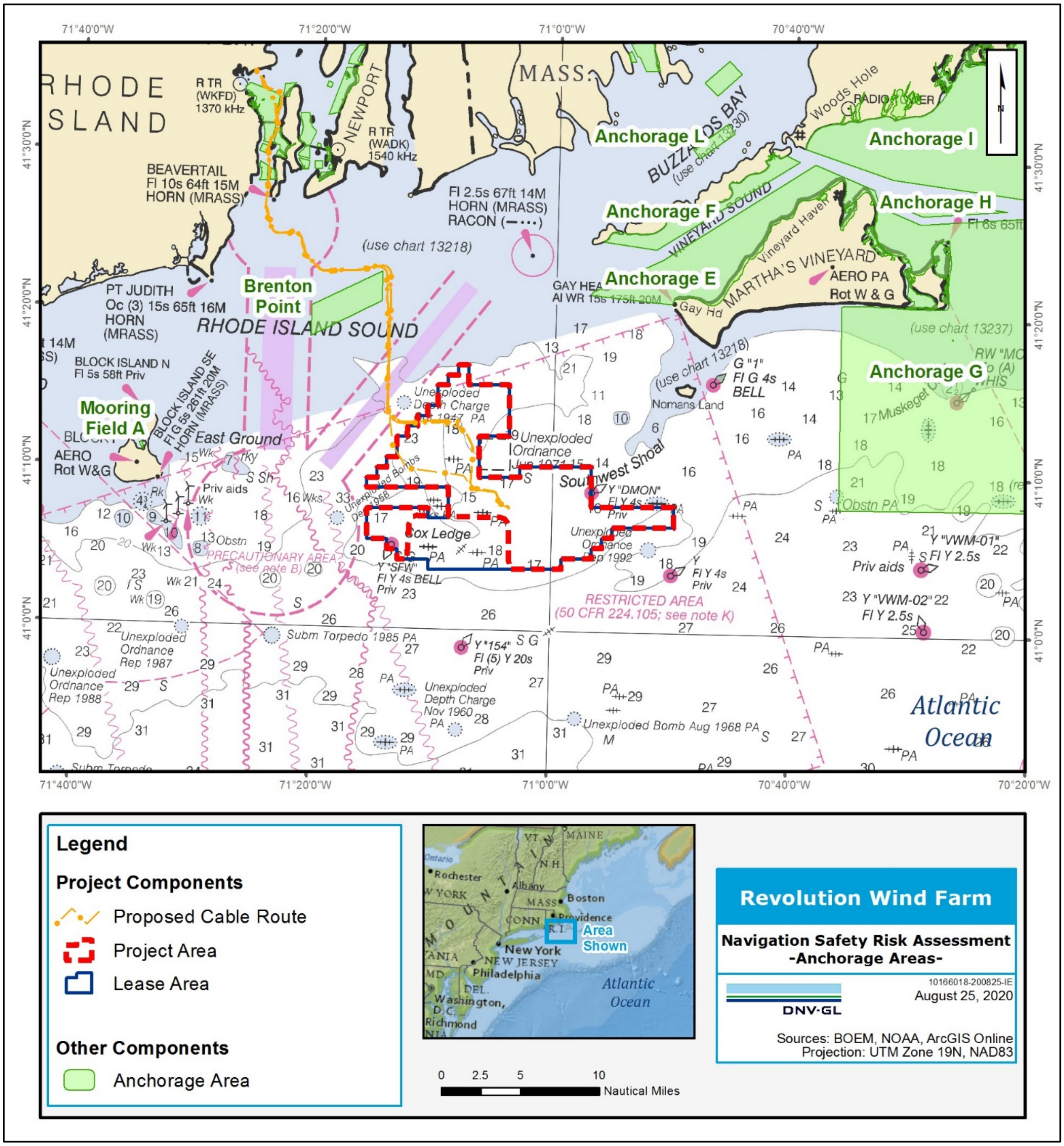


Figure 5-1 Designated anchorage areas in study area (NOAA, 2017)

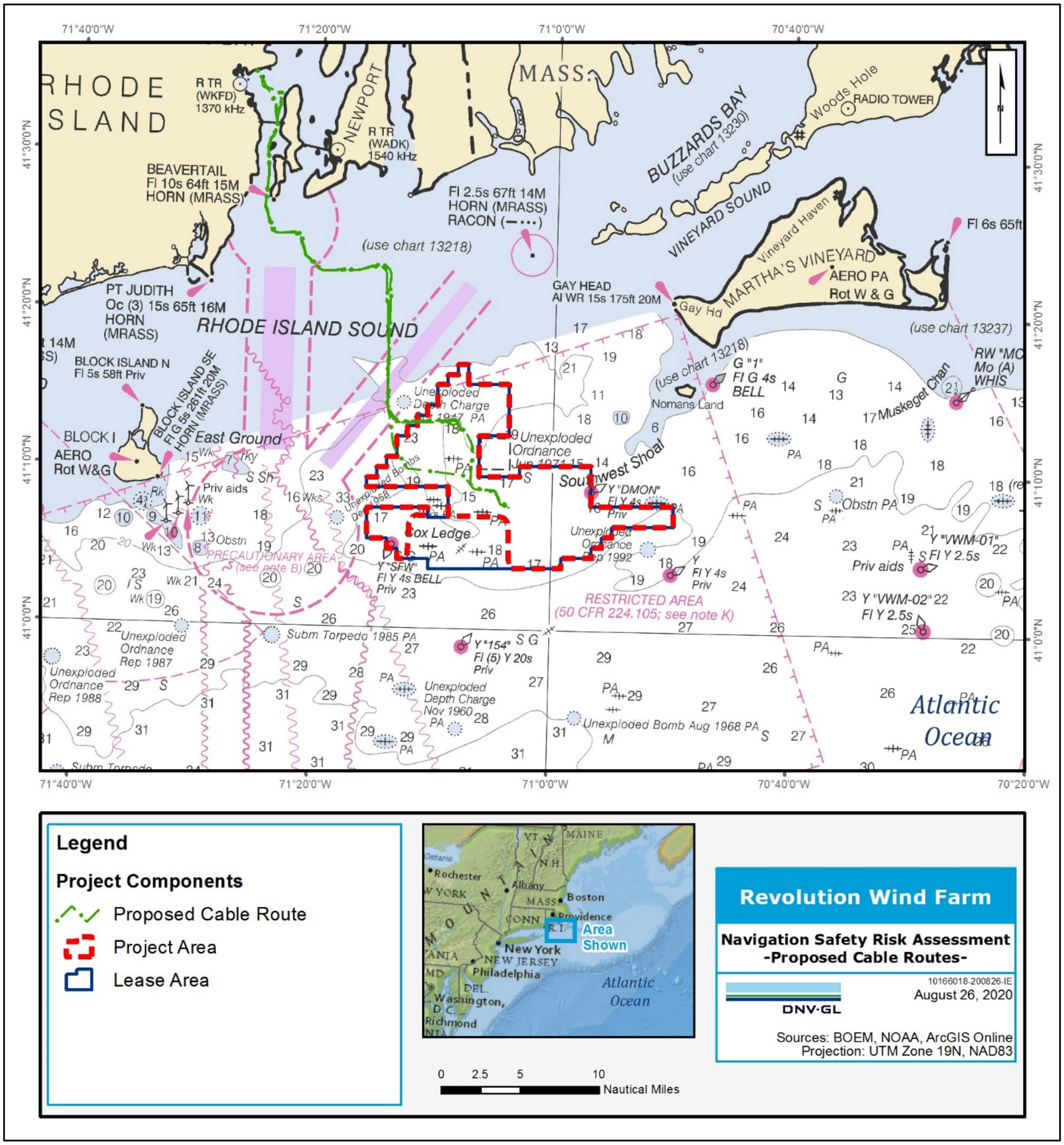


Figure 5-2 Project cable routes

Deviations from "normal" anchorage activities have the potential to introduce an additional risk of damage to the subsea cables. Ships rarely drop anchors (even more unlikely outside of normal operations) but this can damage the cable if an anchor is dropped directly on top of a cable or dragged across a cable line (BOEM, 2011). Credible events that could cause damage to the cable line include human or mechanical failures leading to emergency anchoring of a deep draft vessel, and fishing activities discussed in Section 2.2.1.1.

Emergency anchorage has the potential to damage the export cable should an anchor penetrate the seabed to the applicable cable burial depth or penetrate applicable cable protections on the seabed to the extent the cable cannot reasonably be buried. Standard industry practice is that anchoring in a wind farm is a potentially hazardous activity and should be undertaken only by Project-related vessels or in emergency situations. To mitigate this risk, Project cables will be buried and / or protected on the seabed, marked on charts, and their location will be monitored periodically to detect any movement. See COP Section 3.3.7.2 for further details.

Based on the average DWT of vessels in the AIS dataset (see Section 2.1.3), only tankers carrying oil products have an average tonnage greater than 50,000 DWT, and very few large vessels transit near the Project Area (see previous Figure 2-38). All other vessels in the AIS dataset are generally smaller and less likely to cause damage to the export cable even in an emergency anchorage situation. Fishing activities and cables that pose hazards to one another are discussed in Section 3.1.

Based on historic events, construction vessels are the most likely to inadvertently damage a cable during normal operations if unaware of the location (BOEM, 2011). However, proper marking of the cable on applicable navigation charts will reduce this risk. The Project has also committed to publishing frequent Notices to Mariners in the area that will make all non-Project vessels aware of all locations where damage is possible.

6 EFFECT OF TIDES, TIDAL STREAMS, AND CURRENTS

The Project WTGs and OSS will be located offshore in waters where underkeel clearance, tides, and currents are not generally of concern to mariners. Table 6-1 provides a summary of the waterways' characteristics and Figure 6-1 shows the Project on a nautical chart.

Table 6-1 Summary of waterways characteristics

Site characteristic	Summary	Source
Tidal range	Semi-diurnal tide with mean range of 1 m (2 ft)	Shonting and Cook (1970)
Tide height	3.0 ft (0.8 m) mean high water 3.2 ft (1.0 m) mean higher high water	OSU Tidal Inversion Software (Egbert and Erofeev, 2010); National Oceanic and Atmospheric Administration (NOAA) coastal chart 13218 (2019a), Block Island station 8459681 (2019b); Montauk station 8510560 (2019c).
Tidal stream speed (surface)	0.6 knots (0.3 m/s) 1-year (tidal) 0.6 knots (0.3 m/s) 50-year (tidal)	DNV GL report on metocean design criteria (2018)
Tidal stream direction (set)	NW (flood), SE (ebb)	DNV GL report on metocean design criteria (2018)
Current speed (surface)	1.8 knots (0.9 m/s) 1-year (residual) 2.9 knots (1.5 m/s) 50-year (residual) 1.9 knots (1.0 m/s) 1-year (total) 2.9 knots (1.5 m/s) 50-year (total)	DNV GL report on metocean design criteria (2018)
Current direction	NW-SE (tidal) W-E (residual)	DNV GL report on metocean design criteria (2018)
Water depth	26.8 m – 48.4 m [MSL]	NOAA National Geophysical Data Center (NGDC) (1999)
Waves	Average monthly wave heights were 2.9 – 6.9 ft (0.9 – 2.1 m) in 2018, with waves greater than 9 ft occurring with 5 percent frequency	Coastal Data Information Program (2019) Coast Pilot 2 (NOAA, 2019a)

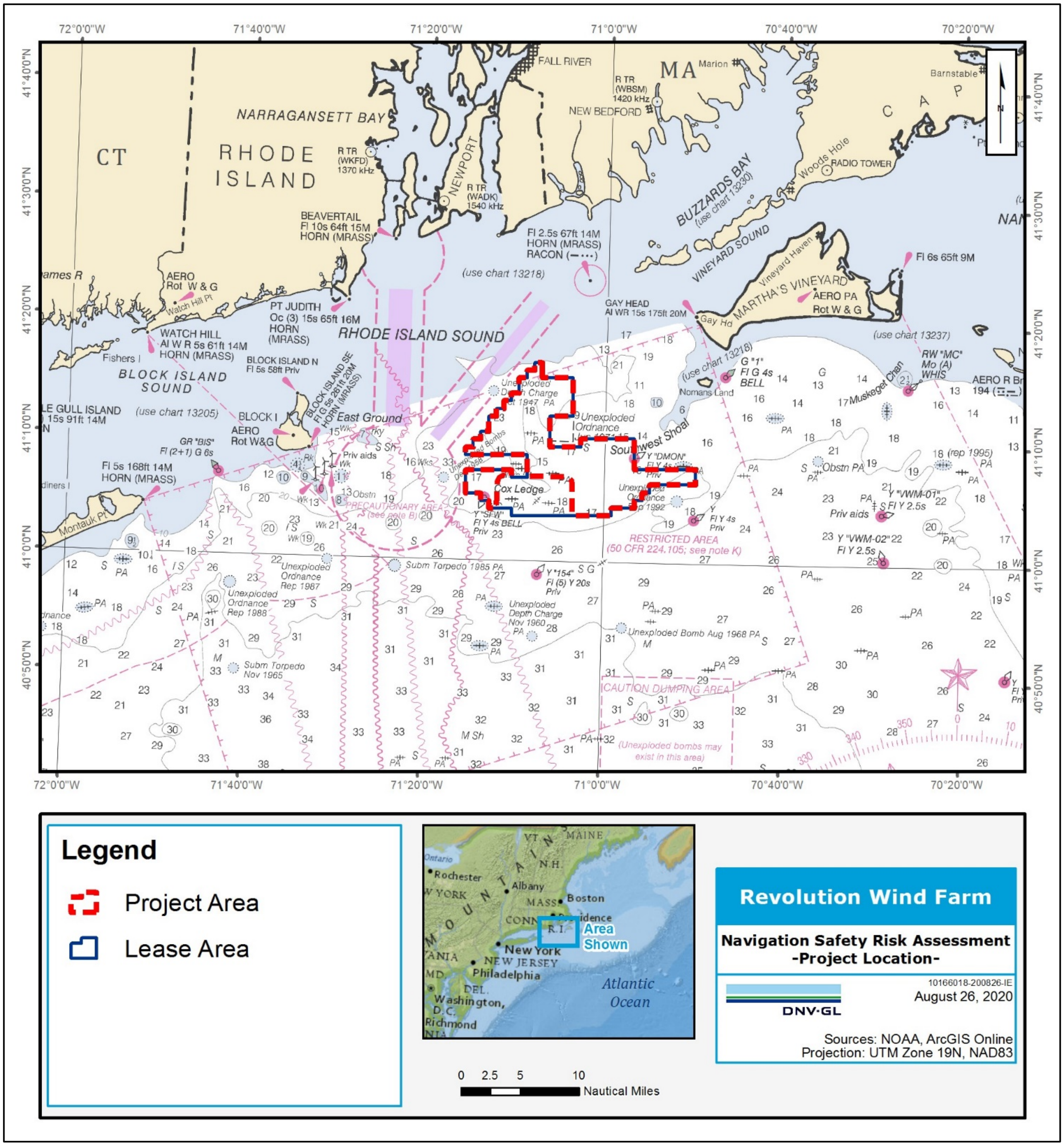


Figure 6-1 Location of Revolution Wind Farm on a navigation chart

6.1 Tides

Tides and currents are not directly measured in the Project Area. Measurement devices were installed in the Lease Area earlier in 2019. Alternative means of estimating tides and currents were used to assure a complete year is represented in this assessment. A summary of the data and the estimated results are provided in the sections below; further discussion is provided in the DNV GL report on metocean design criteria for South Fork Wind Farm (DNV GL, 2018).

There is no tidal measurement at the Project site, so tide heights were determined using two different methods:

- Analysis of tide height measurements from nearby NOAA stations
- Simulations using the Oregon State University (OSU) Tidal Inversion Software (Egbert and Erofeev, 2010)

The closest NOAA stations to the Project site that offer tidal data are Block Island, RI (NOAA station 8459681) and Montauk Point, NY (NOAA station 8510560), which are 15 NM (28 km) WNW and 30 NM (58 km) west of the Project site, respectively.

Table 6-2 summarizes the available tidal data. The Block Island station was removed in July 2004, but usable data are available for the period 8 April 1998 to 31 October 2000 (NOAA, 2019a). The Montauk station is still in operation and data from 2010-2017 were analyzed (NOAA 2019b).

Table 6-2 Summary of tides at Block Island

	Mean Lower-Low Water	Mean Low Water	Mean High Water	Mean Higher-High Water
Block Island average	0.1 ft (0.0 m)	0.4 ft (0.1 m)	2.7 ft (0.8 m)	3.2 ft (1.0 m)
Block Island extreme	-2.1 ft (-0.6 m)	-1.5 ft (-0.5 m)	4.0 ft (1.2 m)	4.6 ft (1.4 m)
Montauk average	0.3 ft (0.1 m)	0.5 ft (0.2 m)	2.6 ft (0.8 m)	2.9 ft (0.9 m)
Montauk extreme	-0.2 ft (0.1 m)	-0.1 ft (0.0 m)	3.0 ft (0.9 m)	3.2 ft (1.0 m)

The East Coast of America 1/30° domain of the Oregon State University Tidal Inversion Software was used to estimate the tide heights at the southeast and northwest corners of the Project site (Egbert and Erofeev, 2010). This data set has a spatial resolution of 1/30°, simulating 8 tidal constituents and it assimilated 531 cycles of Topex/Poseidon, 114 cycles of Topex/Tandem and 108 cycles of ERS/Envisat satellites. The model also assimilated tide gauges along the coast of the domain.

Table 6-3 Summary of modeled tide data

Tide height relative to MLLW	SE corner	NW corner
Highest astronomical tide	4.7 ft (1.4 m)	4.8 ft (1.5 m)
Mean sea level (MSL)	1.8 ft (0.5 m)	1.8 ft (0.6 m)
Lowest astronomical tide	-0.7 ft (-0.2 m)	-0.7 ft (-0.2 m)

The tidal summaries above are generally consistent with the tide information provided on NOAA coastal chart 13218 (NOAA, 2019a), which shows a Mean High Water (MHW) level at Old Harbor, Block Island, of 3.0 ft (0.9 m) and a Mean Higher High Water (MHHW) of 3.2 ft (1.0 m) at Old Harbor, Block Island.

6.2 Tidal stream and current

Estimates of tidal stream and residual current speeds were obtained using a combination of the Admiralty TotalTide software (2001), the HYCOM model (HYbrid, 2018), the MIKE 21 simulation package (DHI, 2005a and 2005b), and the Oregon State University Tidal Inversion Software (Egbert and Erofeev, 2010).

Table 6-4 summarizes the tidal stream and residual current speeds based on analysis of the modeled results.

Table 6-4 Summary of tidal stream and residual current speeds in the Lease Area

Omni-directional surface extremes	Tidal stream speed	Residual current speed	Total surface current
1-year	0.6 knots (0.3 m/s)	1.8 knots (0.9 m/s)	1.9 knots (1.0 m/s)
50-year	0.6 knots (0.3 m/s)	2.9 knots (1.5 m/s)	2.9 knots (1.5 m/s)

The DNV GL metocean report (2018) also estimated the directional frequency of the tidal stream, residual current, and total current. The annual average directional frequency distributions are shown in Figure 6-2 below and follow an overall NW (flood) – SE (ebb) pattern (NOAA, 2018).

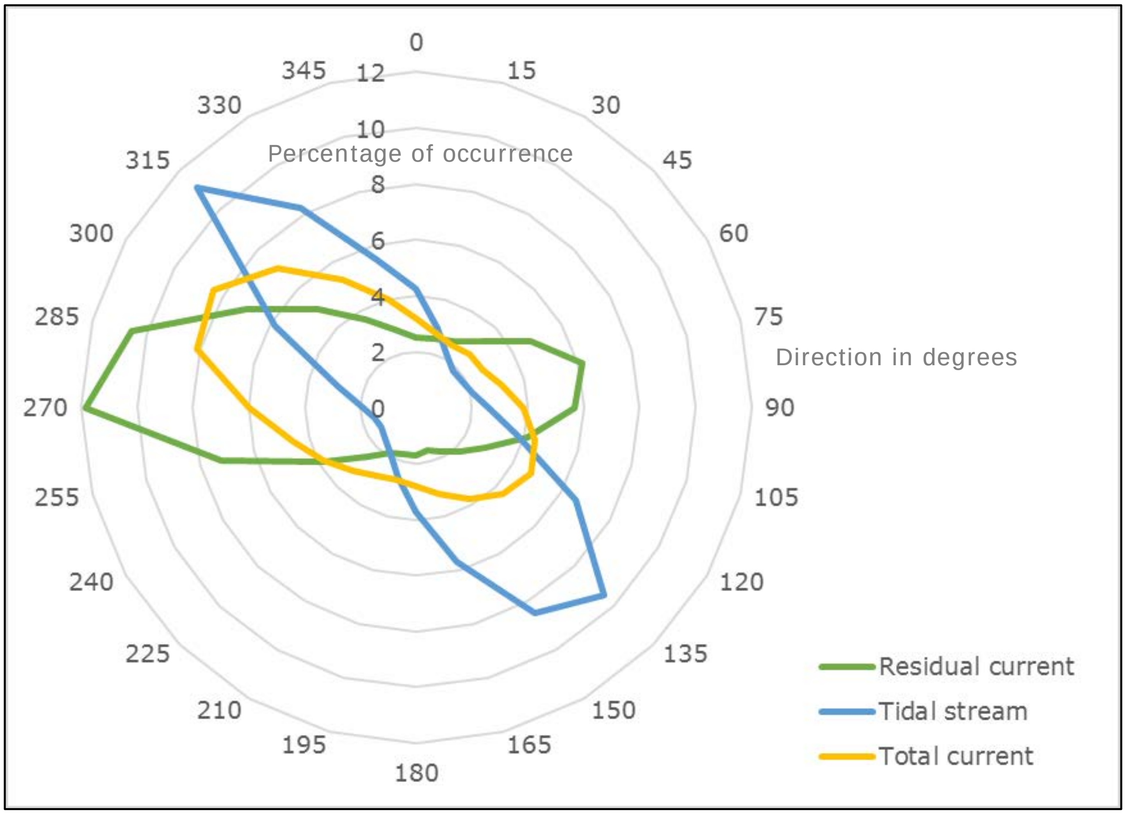


Figure 6-2 Tidal stream and current directional frequency (%) in the Lease Area

The axis of the wind turbine layout is a north-south, east-west grid-like pattern. The effect of sea state and possible engine failure are directly accounted for in the modeling described in Section 11 that estimates the effect of the Project on the risk of collision, allision, and grounding. The tidal stream is low in the Project Area, and is not expected to significantly affect the navigation risk.

It is not anticipated that the WTGs and OSS will affect the general set and rate of the tidal stream or current. Anticipated impacts, if any, to tides, currents, air column, water column, seabed, or sub-seabed are discussed further in the appropriate section(s) of the Construction and Operations Plan.

6.3 Bathymetry

Data from the National Geophysical Data Center was used to determine water depths across the Project site (1999). Water depths at the Project site range from 26.8 to 48.4 m (88 to 159 ft).

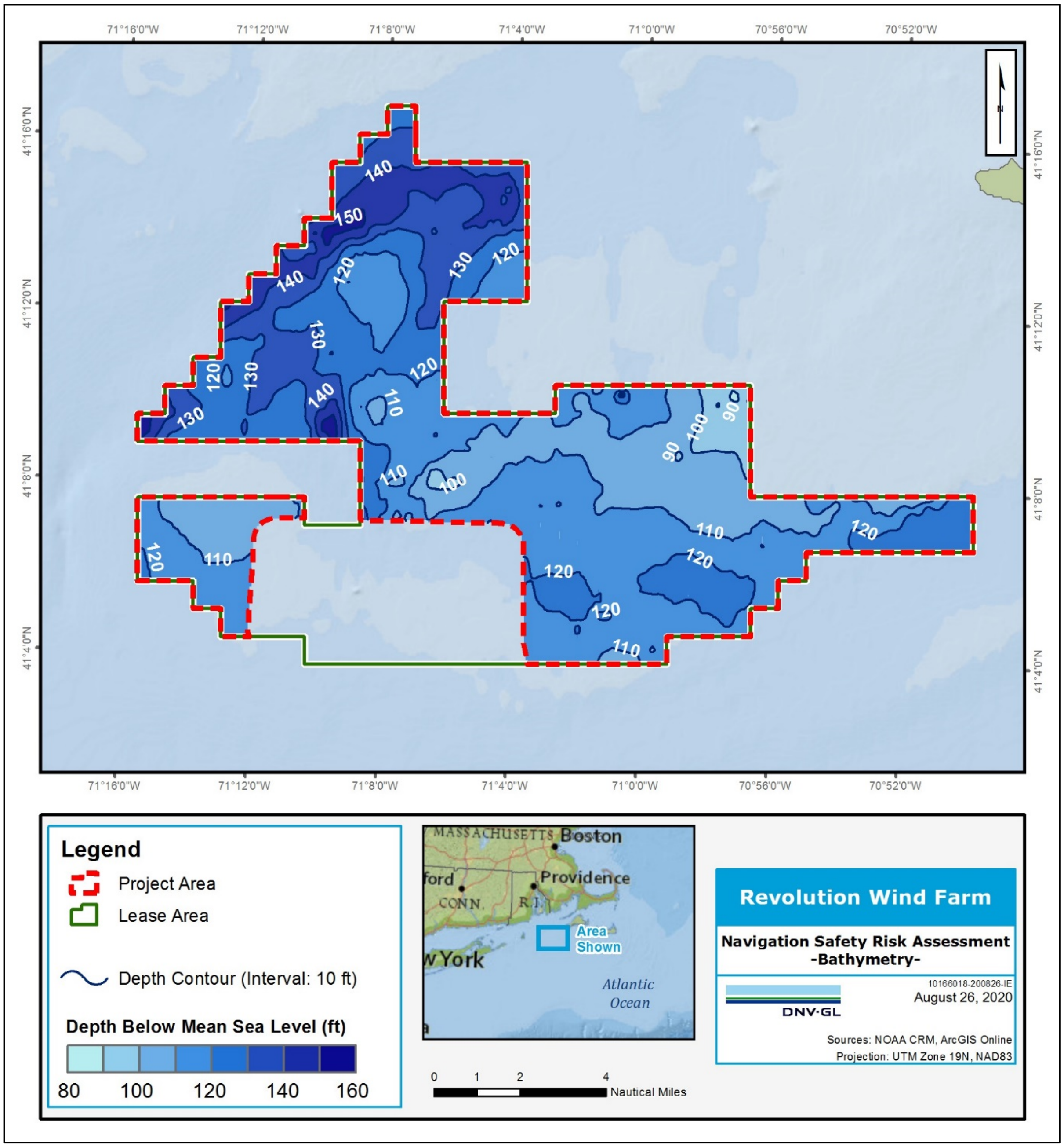


Figure 6-3 Bathymetry of the Revolution Wind Lease Area (NOAA, 1999)

7 WEATHER

Table 7-1 summarizes relevant weather characteristics in the Project Area. The effect of wind speed, wind direction, visibility, and possible engine failure are directly accounted for the modeling described in Section 11 regarding the risk of collision, allision, and grounding.

Table 7-1 Summary of weather characteristics

Site characteristic	Summary	Source
Wind speed at 33 ft (10 m) height	14.1 knots (7.2 m/s) mean 55.1 knots (28.3 m/s) maximum hourly average 64.2 knots (33 m/s) 10-minute average (50-year return) 81.7 knots (42 m/s) 3-second gust (50-year return)	DNV GL Virtual Met Data
Prevailing wind direction	WSW	DNV GL Virtual Met Data
Visibility	91.4% > 8 NM (4.3 km) visibility	Block Island State Airport (NOAA, 2019a)
Ice	Floating ice is not present. Ice drop from light ice accretion may occur <9 days/month Nov.-Mar. Ice drop from moderate accretion is unlikely with <1 day/month Jan.-Feb. Ice throw is unlikely due to turbine control strategy and minimal moderate ice accretion.	Coast Pilot 2 (NOAA, 2018); RI (2010); Merrill (2010)

7.1 Winds

No on-site wind speed measurements are available within the Project. To provide an accurate view of wind at the site, DNV GL's Virtual Met Data (VMD) system was used to generate a 17.5-year time series of hourly wind speed and wind direction at a horizontal resolution of 1.1 NM (2.0 km). Summaries of these generated data at 33 ft (10 m) elevation are presented below.

Figure 7-5 and Figure 7-2 present the average and maximum hourly wind speeds expected for each month of the year over this period, respectively. It can be observed that the highest wind speeds occur between November and February, while the lowest wind speeds occur between June and August. DNV GL finds this to be consistent with other wind speed datasets reviewed in this region.

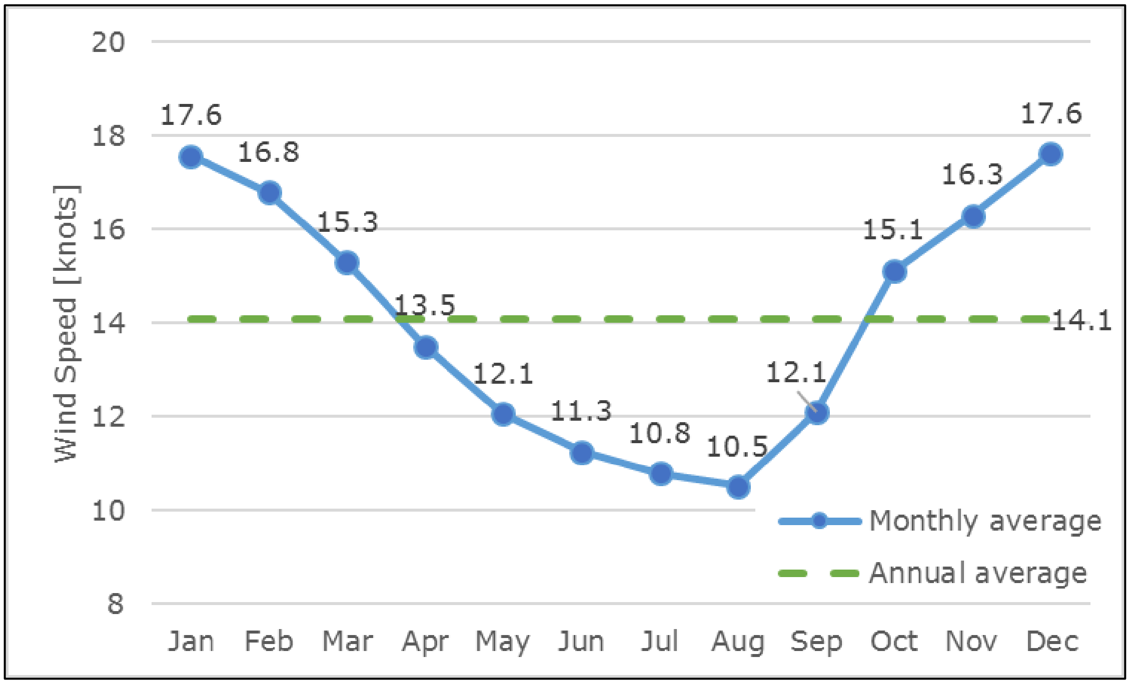


Figure 7-1 Average hourly wind speeds expected in the Lease Area at 33 ft (10 m) height above MSL

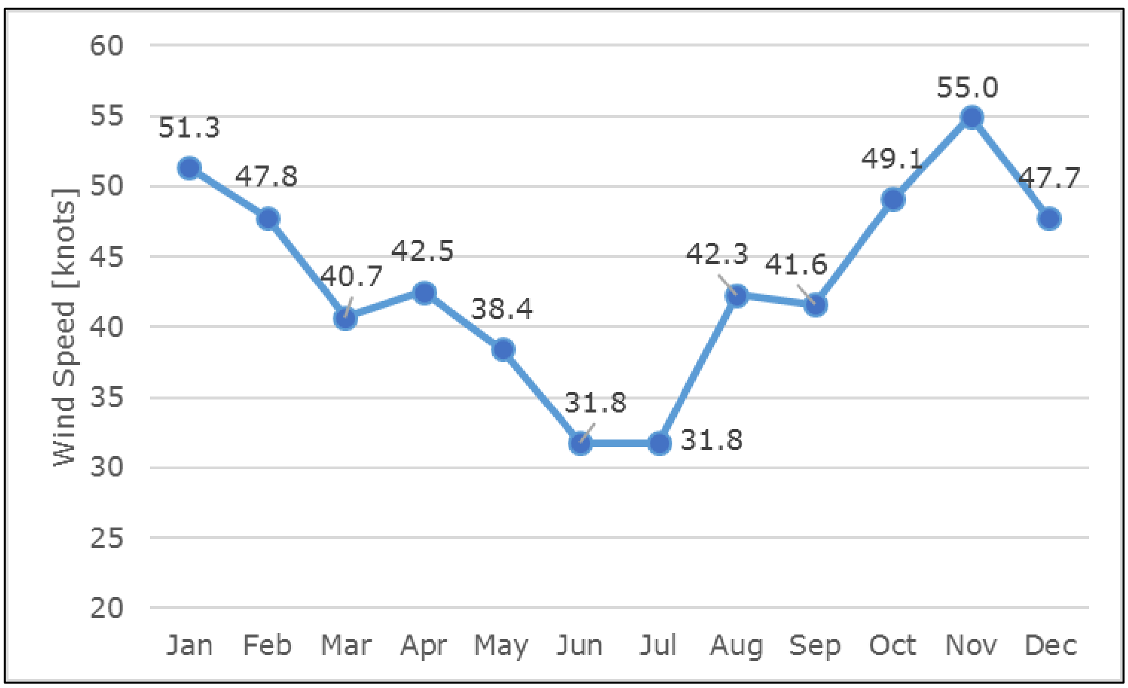


Figure 7-2 Maximum hourly winds speeds from 17.5-year VMD in the Lease Area at 33 ft (10 m) height above MSL

The 17.5-year mean wind speed at 33 ft (10 m) elevation is 14.1 knots (7.2 m/s). The distribution of wind speeds over this period is shown in Figure 7-3.

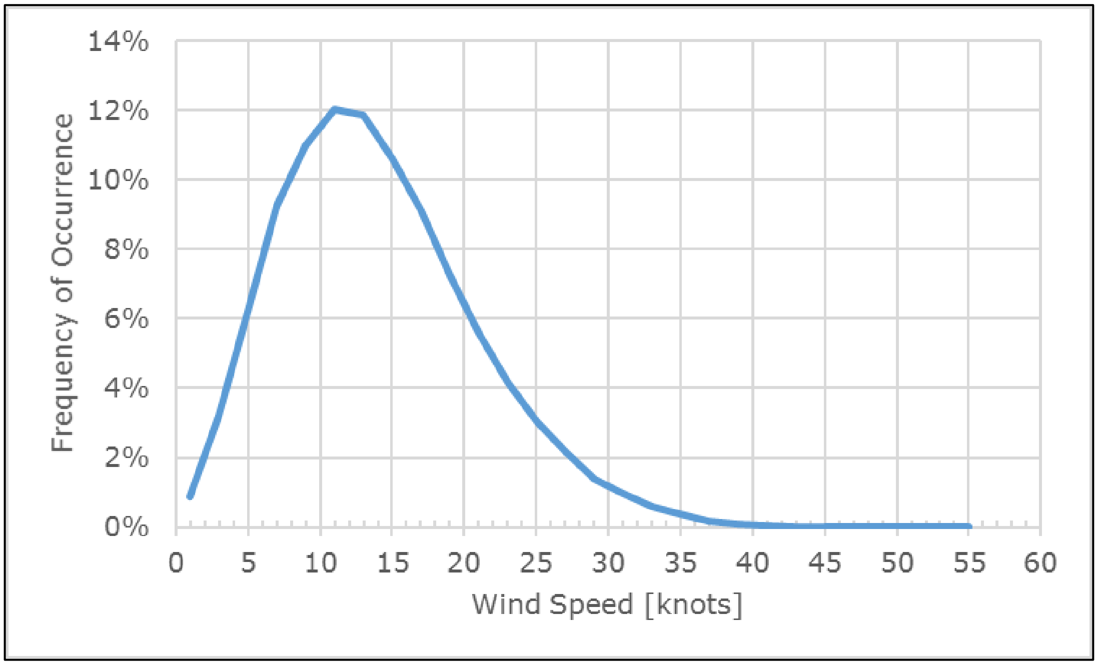


Figure 7-3 Distribution of wind speeds in the Lease Area at 33 ft (10 m) height above MSL

The prevailing wind direction is from the west-southwest. Figure 7-4 presents the distribution of wind directions over this period. The distribution of wind directions (the wind rose) shows that winds come from almost all directions over the course of a year, although the wind comes from the southwest to west the majority of the time.

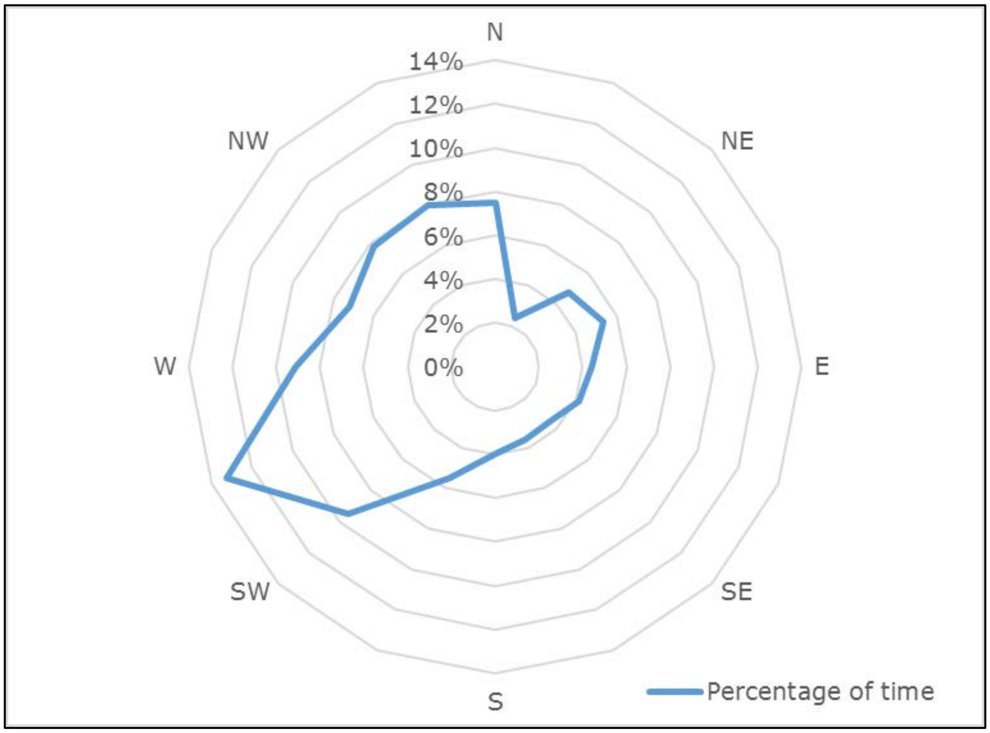


Figure 7-4 Wind direction distribution expected in the Lease Area at 33 ft (10 m) height above MSL

Hurricanes are not common near the Project. There is a greater threat of tropical and extra tropical storms in the months of September and October (Knapp et al., 2010). The International Best Tracks for Climate Stewardship database track data was used to identify hurricanes that passed near the Project Area between 1969 and 2019 (NOAA, 2019e) (Table 7-2 and Figure 7-5). Of the 80 storms passing within 5 degrees of the Project Area, 85% were Category 1 or tropical events.

Table 7-2 Number of Cyclones within 5 Degrees of the Project Area (NOAA, 2019e)

Hurricane Scale (Saffir Simpson)	Number of occurrences 1969-2019
Tropical Depression	19
Tropical Storm	49
Category 1	27
Category 2	11
Category 3	5
Category 4	1
Total	**112**

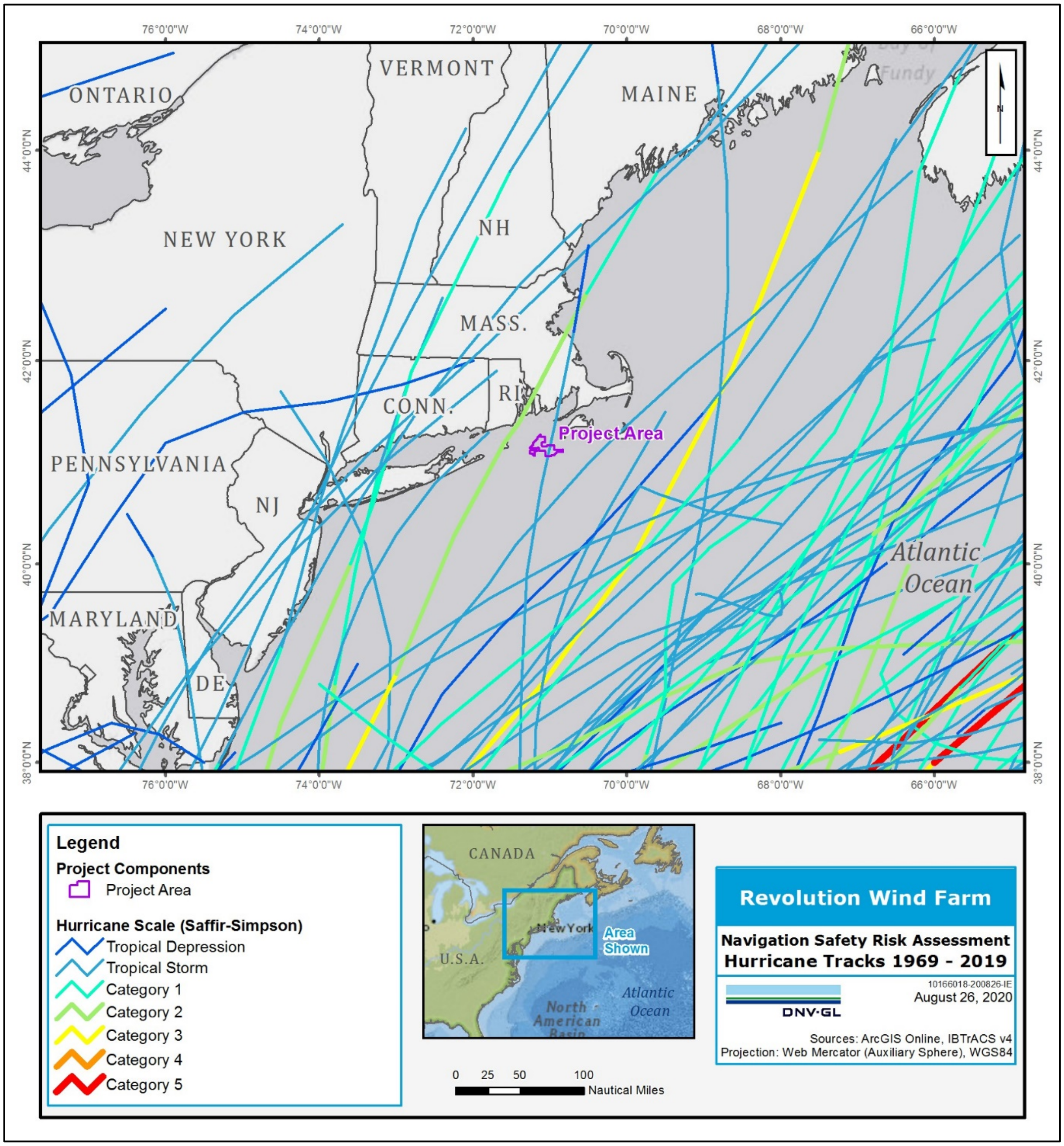


Figure 7-5 Tracks of cyclones within 5 degrees of the Project Area (1969-2019)(NOAA, 2019e)

7.2 Consideration of vessels under sail

Vessels under sail could enter the Project Area. In line with rule of prudent seamanship, vessels should proceed with caution near any man-made structure that decreases visibility. Potential hazards to vessels under sail from Project structures were reviewed, such as wind masking, turbulence, and sheer. In the expert judgment of experienced sailors, realization of these hazards requires the vessel to be closer to a turbine than prudent seamanship would advise, regardless of weather.

7.3 Visibility

Visibility data were obtained from Climate Data Online for Block Island State Airport station 94793 (NOAA, 2019b). This is the closest station with available visibility data and is therefore taken to be the best available data for visibility conditions at the site.

Figure 7-6 summarizes 10 years of visibility data from the Block Island State Airport station. Visibility was less than 2 NM about 8.6 percent of the time. April, May, and June are most likely to have hours of visibility less than 2 NM due to any of several factors, including fog, haze, snow, rain, etc.

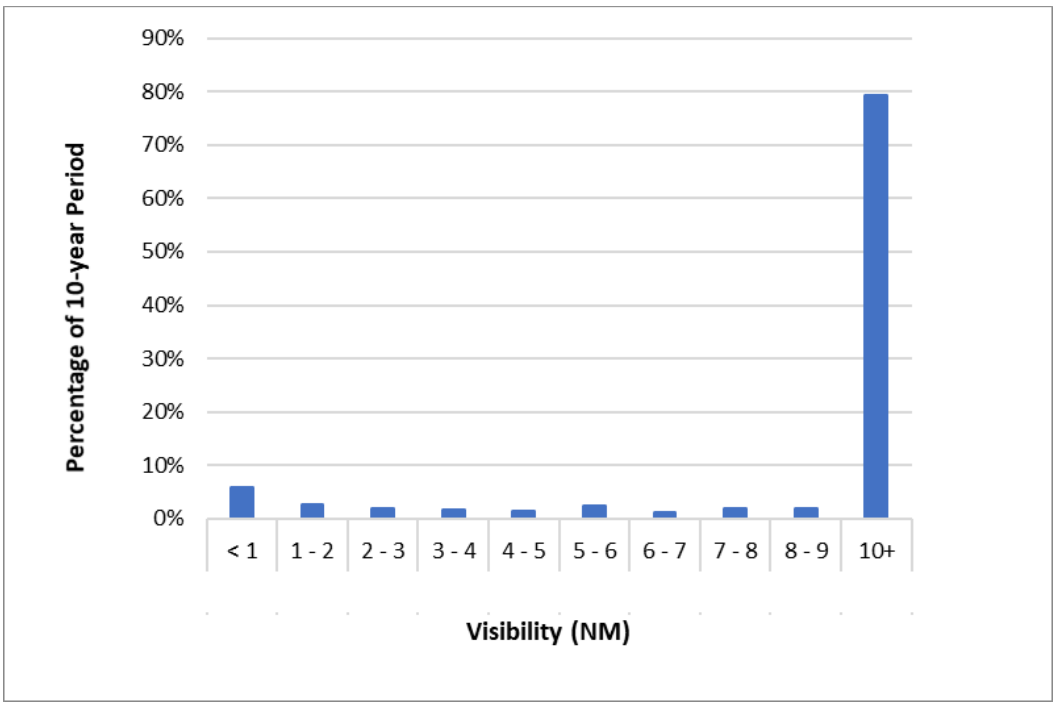


Figure 7-6 Summary of visibility measurements at Block Island State Airport (2009-2019) (NOAA, 2019b)

7.4 Ice

Ice can impact navigation around offshore WTGs in two ways: floating ice can cause treacherous conditions for vessels, and ice can accumulate on a WTG structure causing potentially hazardous conditions for any people or vessels beneath should ice fall from the WTG.

Floating ice

Coast Pilot 2 (NOAA, 2018) discusses ice within the waters of Narragansett Bay, Providence River, and Mount Hope Bay and other inland waterways. There is no discussion of ice accumulation near the Project site or in the traffic separation scheme in Coast Pilot 2. Admiralty Sailing Directions Volume 2 (UK Hydrographic Office, 2017) also describes floating ice as being extremely rare even during severe winter seasons. Pack ice usually lies well north of 40°N latitude and pack ice that does drift south is always well east of the Project Area. This assessment has found no other information to suggest that floating ice is present or poses a risk to navigation near the Project.

Falling ice

The term “ice drop” is used to describe ice falling from a structure such that it lands in the immediate vicinity of the structure. In contrast, the term “ice throw” describes ice being flung from a rotating WTG blade such that pieces of ice land some distance from the foundation.

No anticipated hazard to structural integrity is anticipated from ice accumulation on the structure because when ice builds up on WTG blades, the weight and center of mass of the blades changes, causing an imbalance in the rotor. Should the rotor continue to rotate, it will vibrate, and vibration sensors installed in the WTG would automatically trigger the WTG to shut down. As a result of the widespread use of this control strategy, ice throw occurs rarely, if ever, on modern WTGs; most ice drops to the base of the WTG.

Therefore, the greatest relative risk from ice shedding a Project structure is to a vessel or person in the immediate vicinity of the WTG. This includes maintenance, fishing, and recreational crews and vessels.

An effective and planned risk mitigation measure if icing is detected is automatic shutdown of turbines and issuance of a Notice to Mariners.

An ice hazard protocol is standard wind industry practice to reduce risk for the safety of maintenance/Project crew and vessels during conditions when icing could occur.

Risk to fishing and recreational vessels is expected to be low. Qualitatively, there is about a 1 in 100 years likelihood of ice throw, and even lower likelihood that a fishing or recreational vessel will be nearby and hit by a piece of ice. In addition, recreational vessel activity is reduced in the winter months.

As an additional precaution, DNV GL recommends that the wind farm owner publish and/or broadcast notices to mariners when icing conditions are present, when the WTGs are automatically shut down due to icing, or when ice build-up is observed.

8 CONFIGURATION AND COLLISION AVOIDANCE

Wind turbine layouts are traditionally designed to balance tradeoffs considering many factors.

Geology of the seabed, water depth, and selected foundation type for the WTGs may limit where WTGs can be installed. Some areas may not allow installation of the preferred foundations, so the layout must be modified accordingly. Significant habitat, species, or cultural/historical values may be present and need to be avoided.

Wind direction and speed determine the maximum delivered power from a wind farm. The location of each turbine relative to others given the prevalent wind direction is a key design aspect. Models are run to identify layout options that meet expectations and requirements. Straight rows or columns are less ideal than offset/curved patterns because wind turbine efficiency is higher when there is less influence on the wind flow from upwind turbines and more turbines can be effectively placed in a smaller footprint.

Greater distance between WTGs might:

- Increase delivered power from downwind turbines due to decreased wake effects. A general rule of thumb is a separation distance of eight rotor diameters, yielding spacings of slightly less than 1 NM (almost 2 km) for 12 MW WTGs with diameters of 220 m.
- Increase the cost of array cable installation and maintenance.
- Limit the number of WTGs that can be located in the Lease Area, and therefore the potential maximum delivered power from a given lease area.
- Decrease risk to vessels or low flying aircraft in the area, particularly in bad weather/visibility.

This assessment and other information are provided to assist the Coast Guard with its own site-specific evaluation of the safety of Search and Rescue (SAR) services in and around the Project.

Project risk mitigations most relevant to collision avoidance include:

- The WTG layout will be in linear rows and columns oriented both north-south and east-west. This will provide alternative routes for vessels or aircraft transiting the wind farm and provide multiple options in case of high winds or seas.
- Orsted has proposed development of additional wind farms in adjacent areas. The WTGs in adjacent/contiguous farms will have a congruent alignment.

9 VISUAL NAVIGATION

This section presents an evaluation of the extent to which Project structures could:

- Block or hinder the view of other vessels underway
- Block or hinder the view of the coastline or of any other navigation feature
- Limit the ability of vessels to maneuver in order to avoid collisions

View of other vessels underway

A geometric approach was used to determine potential visual obstruction caused by Project WTGs or OSS, with a focus on a mariner's ability to see another vessel. A monopile foundation is used in this discussion because a jacket foundation is a tubular structure with substantial open space between the supporting elements, and therefore it does not significantly obstruct the view at the water level.

The proposed north-south and east-west layout minimizes visual impedance caused by WTGs. This aligned layout, as opposed to a staggered layout, maximizes visual distances and uninterrupted lines of sight when passing near and through the wind farm. The potential length of visual obstruction for a WTG is estimated based on typical WTG dimensions plus a buffer.

A monopile foundation for a 12 MW turbine is assumed to impede visibility for its diameter plus 1 m on either side for ancillary equipment. The diameter at the sea bed (8 m) was used as a proxy for the diameter at the sea bed as a conservative input. In addition, a safety buffer of 32.3 ft (10 m) is added to account for the uncertainty in the distance between the unseen vessel and the WTG impeding line of sight to it. The resulting effective diameter is 65.6 ft (20 m) representing a WTGs potential for visual obstruction.

The OSS will have jacket foundations and present less obstruction than the WTGs because jackets are comprised of many smaller support components.

For a vessel travelling at 5 kt, the maximum amount of time that a WTG could potentially limit visibility of an object centered directly opposite the WTG is 7.8 seconds based on the minimum spacing between two WTGs layout. This calculation in based on the assumption that a single tower could obstruct visibility of an object at a fixed location centered between the obstructing WTG and the next one in line with it.

This is a conservative approach since the WTG spacing is so far apart, both vessels would need to be transiting on specific routes to lose sight of each other for very long. For a 65 ft fishing vessel, the Project layout evaluated in this assessment provides for more than 50 vessel lengths between WTGs. Table 9-1 summarizes the potential time of limited visibility for vessels transiting at various speeds.

Table 9-1 Time (in seconds) of potential visual obstruction based on vessel speed

Speed of vessel (kt)	Maximum time of potentially obstructed visibility of a fixed object (seconds)
5	7.8
10	3.9
15	2.6

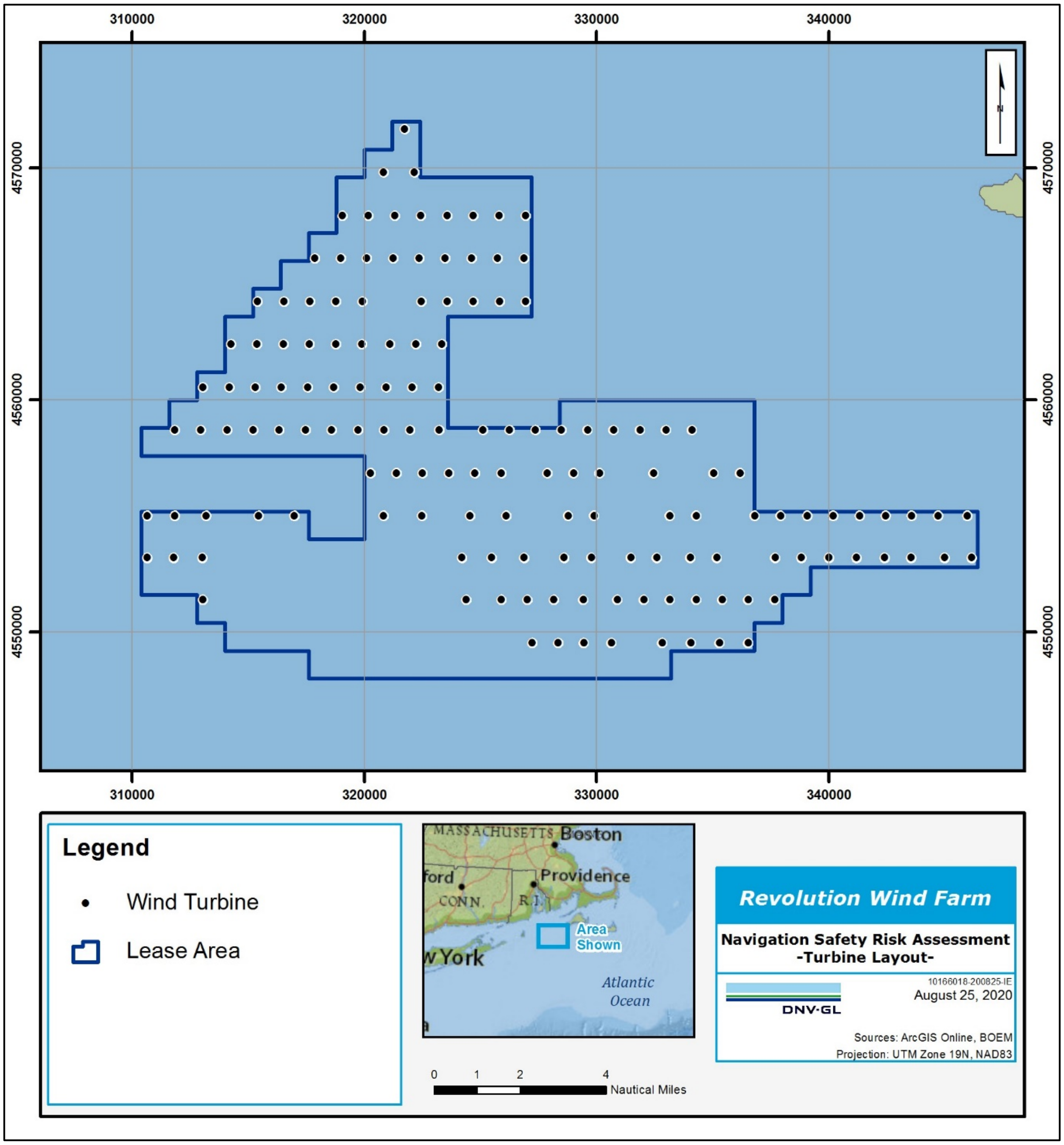


Figure 9-1 Revolution Wind Farm WTG representative layout (WTGs larger than scale)

A more detailed discussion of navigation within the boundaries of the Project is included in Section 11.

The Project will not affect a mariner's ability to use marked ATON or the coastline as reference for navigation due to the Project Area's relative location to marked aids and the coastline. To evaluate whether the Project will affect the ability of mariners to utilize ATON for navigation, a geospatial plot of current ATON, the coastline, and the Project was reviewed (Figure 9-2). No significant obstruction was noted.

During operation, each WTG foundation will serve as an ATON for mariners as they are large structures that will be lighted and marked as required by applicable law and regulation, and as included in any/all conditions the Coast Guard may impose in conjunction with its PATON permits. The marking scheme for Project structures is described in Section 13. The Project structures and seaward components will be clearly marked on applicable NOAA nautical charts, including Chart No. 13218 (NOAA, 2019c). The Project will work closely with the Coast Guard and NOAA to chart all elements of the Project (Orsted, 2020).

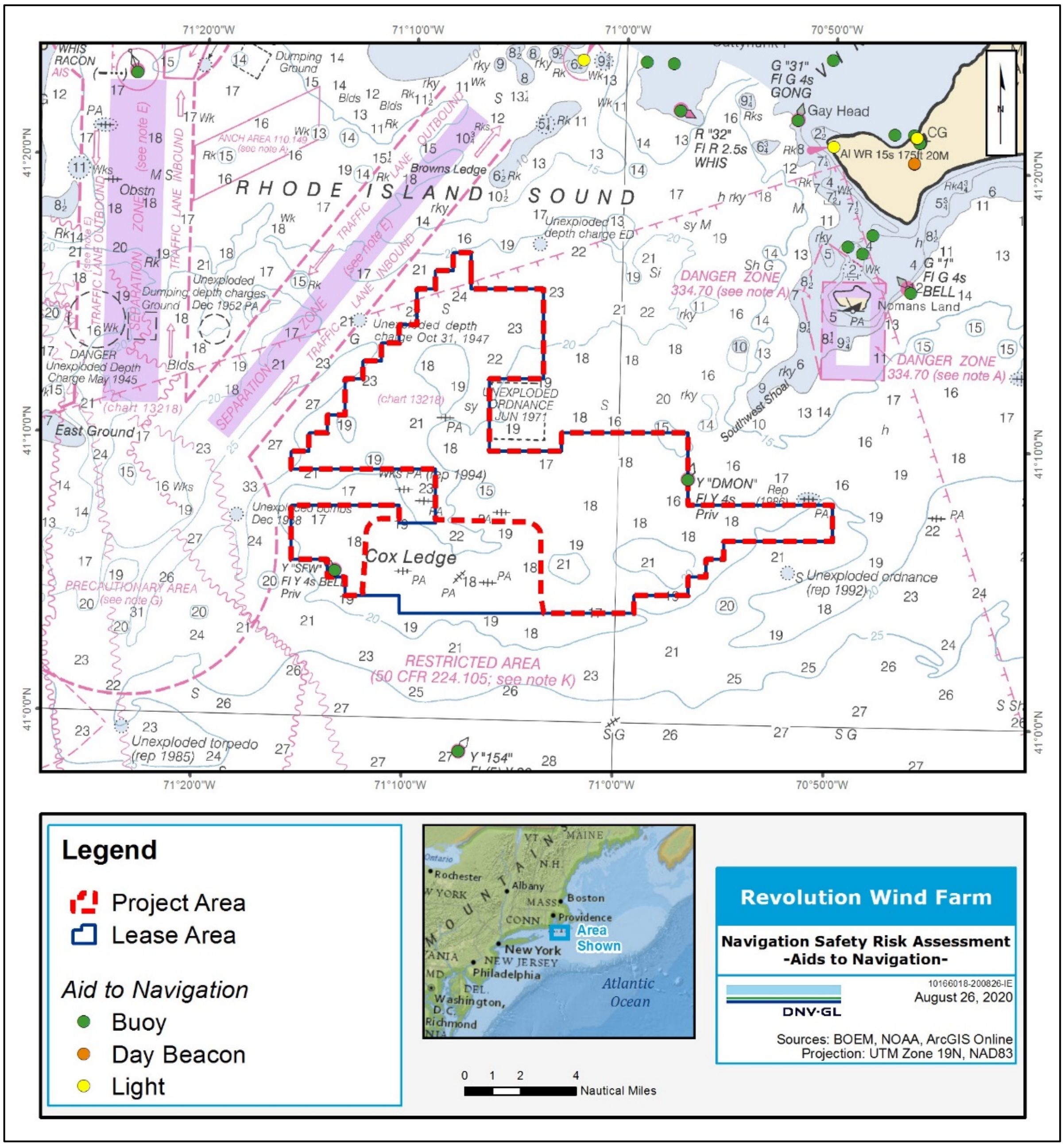


Figure 9-2 Map showing ATON

10 COMMUNICATIONS, RADAR, AND POSITIONING SYSTEMS

WTGs and the movement of turbine blades can potentially interfere with communication signals from radio and radar transmitters by either blocking or reflecting the signals. Radar and radio systems send out pulses of electromagnetic energy and measure the signals that reflect back to the receiver. The relative speed of a radar target can be determined by a shift in the returned frequency.

Publicly-available literature and project-specific studies were reviewed concerning potential impacts of offshore WTGs on communication and navigation systems.

No risks to the health of vessel crews are anticipated from the power and noise generated by Project structures. The Project will comply with applicable law and regulation concerning electromagnetic interference and human health and safety (Orsted, 2020).

10.1 Effect on communications

The scope of this section includes marine communications systems, including ship-to-ship and ship-to-shore communications systems. The research included evaluations of High Frequency (HF), Very High Frequency (VHF), and Ultra High Frequency (UHF) radio systems. In general, the effects of offshore WTGs on marine communications are minor or not discernable.

Rescue 21, Digital Selective Calling (DSC)*, and AIS are all based on VHF radio communications. The characteristics of VHF radio wave prorogation lends itself to quick recovery from structural interference due to its inherent wavelength (~1.8m). The signal recovers within a few hundred yards. Based on general information about VHF interference, the Coast Guard's advanced command, control and direction-finding system, "Rescue 21," is unlikely to experience any degradation from the Project. The Rescue 21 architecture and VHF propagation characteristics overcome interference associated with fixed structures such as wind turbines.

The following sections summarize the relevant studies.

U.S. Department of Energy

The U.S. Department of Energy conducted a generic study in 2013 to evaluate the effects of offshore wind farms on sea surface, subsurface, and airborne electronics systems (DOE, 2013). With respect to sea surface electronics, the study concluded that "Communications systems in the marine environments are unlikely to experience interference as the result of typical wind farm configurations, except under extreme proximity of operating conditions."

Horns Rev Wind Farm

In 2004, studies were performed of the Horns Rev Wind Farm in Denmark to measure the effects on marine radar, communications, and positioning systems. The studies were performed by QinetiQ and the MCA (Howard and Brown, 2004). The studies showed that the effect of wind farms on communications and positioning systems is minor.

North Hoyle Wind Farm

The effects of the North Hoyle Wind Farm in the UK on shipboard communications was studied in 2004 (Howard and Brown). The evaluation studied both ship-to-ship and ship-to-shore communications systems, as well as hand-held VHF transceivers. The wind farm had no noticeable effects on any voice communications systems.

10.2 Effect on radar

The potential impacts on marine radar are variable, with the most likely effect being some signal degradation. Proximity to the WTGs is the primary factor that determines the degree of radar signal degradation. Due primarily to the quality of radars and the proficiency of professionally licensed crew, radar operations on commercial ships are not anticipated to be affected. Smaller vessels operating in or near the Project may experience radar clutter and shadowing.

Vessel operators in or near the wind farm will be informed of the potential for radar interference from wind farms (Orsted, 2020). Most instances of interference can be mitigated through the proper use of radar gain controls. Further risk reduction can be achieved by regular communications and safety broadcasts from vessels operating in or near the wind farm. Placement of radar antennas to a favorable position on a vessel such as a commercial fishing vessel, has also be found be to an effective mitigation to adverse radar impacts (BWEA, 2007).

Below are summaries of project-specific radar studies of layouts for wind farms in the U.S. and UK.

10.2.1 Block Island Wind Farm

The Block Island Wind Farm is the first operational offshore wind farm in the United States. It consists of five wind turbines which powered up in December 2016 and were connected to the mainland energy grid in May 2017.

Pre- and post-construction radar impact studies have been conducted at the Block Island Wind Farm, and no significant permanent radar interference was detected.

10.2.2 Skipjack Wind Farm

In 2019, QinetiQ performed an assessment of the Skipjack Wind Farm, modelling two different marine radar types that are typical for the vessels transiting within the vicinity of the Project Area. QinetiQ modeled X-Band and S-Band radar systems. X-Band systems operate within a frequency range of 8.0 GHz to 12.0 GHz and are generally installed on smaller vessels. S-Band systems operate within a frequency range of 2.0 GHz to 4.0 GHz and are generally installed on large vessels.

The study evaluated nine different scenarios with each of the radar types, for a total of eighteen scenarios. Three separate assessments were performed; radar clutter assessment, saturation assessment, and shadowing assessment (Qinetiq, 2019).

Radar clutter assessment

Radar clutter assessments were conducted for nine different scenarios. For each scenario, radar display simulations were shown at three locations illustrating the likely appearance of wind turbine clutter. Both direct clutter and multipath clutter were modeled. Two reference vessels were included in all modelling results.

Initial modelling without any form of gain control (GC) showed many of the expected, typical clutter impacts, including side lobe breakthrough and multipath clutter. For the majority of scenarios considered, multipath clutter is likely to be intermittent, and did not appear on every scan. In all examples considered, the severity of the turbine direct and multipath clutter could be reduced using GC desensitization. However, the radar desensitization also resulted in the loss of detection of the reference targets in some cases.

Saturation assessment

A saturation assessment showed that when no GC is applied, X-Band radar saturation is possible when the turbine is approximately 0.29 NM (0.54 km) or closer to the radar. The corresponding value for the S-Band radar is approximately 0.48 NM (0.89 km). For both radars, saturation in these cases can easily be avoided when the sensitivity is reduced using some form of GC. This is the same as normal radar use in the vicinity of large reflective objects such as port infrastructure and large flat-sided vessels.

Shadowing assessment

Shadowing estimates were made of the jacket foundation and tower. Significant shadowing zones were limited to narrow strips behind the turbines relative to the radar position. The likelihood of detection of vessels in the shadow zone can be reduced. The impact is likely to be largest for small targets at long range. In the scenarios considered, the width of shadow zones in the traffic separation scheme ranges from 400 ft (122 m) to 3,230 ft (1,000 m). The width of the zones in the vicinity of the turbines is much smaller. Shadowing impacts will not be persistent due to the motion of the radar vessel and other vessels. The impact of the monopile foundation has not been modeled but is likely to be greater than the jacket option.

10.2.3 Horns Rev 1 Wind Farm

The Horns Rev 1 Wind Farm is an 80-WTG wind farm located in the North Sea off the coast of Denmark (Vattenfall, 2017). Observations of radar interference were made during construction and during operations of the wind farm, which used monopile foundations. No shadowing was observed and vessels operating within the wind farm were able to detect all 80 WTG towers on radar (Elsam Engineering, 2004).

10.2.4 Kentish Flats Wind Farm

The Kentish Flats Wind Farm is situated between 4.6 and 7.0 NM (8.5 and 13 km) north of Herne Bay and Whitstable in Kent, UK (Vattenfall, 2017b). The wind farm consists of 30 WTGs on monopile foundations, with a combined capacity of 90 MW (MARICO Marine, 2017).

In 2006, independent research was conducted by MARICO Marine on behalf of the British Wind Energy Association to assess the effects of the wind farm on marine radar. The research was conducted in the actual wind farm environment using a wide range of vessel types, radar systems, and operators, including commercial ships, professional mariners and marine pilots, Vessel Traffic Service and small recreational craft.

The MARICO findings concluded that trained mariners can identify the effects of wind farms on radar displays and can make necessary adjustments to mitigate their impacts. Many of the radar echoes were produced by ship structures and fittings. This is not uncommon for marine radar and mariners can adjust gain and sensitivity to account for the echoes. Echoes produced by WTGs are similar and, similarly, operators can adjust onboard radar systems to account for such interference.

In the study, mariners could track other large vessels within the wind farm as well as from behind the wind farm. Small craft in and near the wind farm were detectable by radar on ships passing nearby. But, radar signals from small craft within the wind farm were often lost within the stronger echoes from the WTGs when the small craft passed close to the WTGs. The effect was temporary until the small vessel moved away from the WTG. Small vessels operating within the wind farm were less detectable by all radar types evaluated, because of the WTGs. Adjustments to radar gain control could mitigate the effect but required some skill on the part of the radar operators.

The study evaluated the detection of floating ATON, specifically, a navigation buoy. Radar detection of the reference buoy was unobstructed from the opposite side of the wind farm.

Marine pilots were aware of the potential for radar interference caused by the wind farm. However, they were “relatively unconcerned” with the presence of the wind farm and its impact on shipboard radar. They did express that if wind farms were situated closer to shipping lanes, it could be cause of some concern and require further evaluation (MARICO Marine, 2017).

10.2.5 North Hoyle Wind Farm

The North Hoyle Wind Farm is located 3.7-4.3 NM (7-8 km) off the coast of North Wales. It consists of 30 WTGs on monopile foundations in an area of approximately 3 NM^2 (10 km^2) (Yelenic, 2016). QinetiQ partnered with the MCA to evaluate the impacts of the North Hoyle Wind Farm on shipboard radar systems. The study evaluated shipboard and shore-based radar systems (Howard and Brown, 2004).

The study found that the effects of radar shadowing prevented detection of small vessels behind the WTG towers when the subject vessel was stationary. At an observation angle of 4 degrees, at a range of 3 NM (5.5 km), vessels within the wind farm were detectable and not obscured by shadowing. Clutter caused by WTG towers was also observed but could be sufficiently reduced by the radar operator’s reduction of the gain setting.

It should be noted that adjusting the amplification of a radar receiver (i.e., gain adjustments) also adjusts the return strength of vessel targets. It is possible to reduce the gain to a point that prohibits display of vessel targets. Sea state and precipitation can also impact radar performance and signal strength. Close attention to radar gain and sensitivity settings should be paid while transiting near an offshore wind farm.

10.3 Effect on positioning systems

Global Positioning Systems (GPS) are commonly used by mariners to track their position in real-time. The available literature is limited concerning measured effects of wind farm structures on marine GPS. The potential concern is that electromagnetic energy from the WTGs may interfere with satellite-based systems like GPS (The University of Texas, 2013).

Measurements were taken in the North Hoyle Wind Farm (Howard and Brown, 2004), with a finding that, “No problems with basic GPS reception or positional accuracy were reported during the trials.”

10.4 Potential mitigation measures for radar effects

In general, mitigation measures can reduce the impacts of the wind farm on radar and communications. Potential measures identified by this study include the following, in no particular order:

- Positioning of radar scanner/antenna on the vessel, particularly in relation to ship structures and fittings
- Experience with radar setting coupled with use of a reference target when adjusting radar settings, particularly gain
- Reducing the radar cross-section of the turbines, such as by design changes or through use of special coatings

11 COLLISION, ALLISION, AND GROUNDING ASSESSMENT

This section presents the results of a quantitative assessment of collision, allision, and grounding (i.e., a marine accident) in the vicinity of the Lease Area from operation of the Project. The risk assessment consists of a "what if" consequence analysis and estimates of frequency or probability of each accident for each vessel type.

The change in frequency is estimated by modeling how often a marine accident is estimated to happen with and without the Project. Risk models are generally more conservative and by design, predict higher numbers of events than come to fruition. Much of the value from a model is its future use to evaluate potential risk controls.

The consequence analysis discusses how severe an accident could be if it were to happen.

The results are presented accident type and per vessel type. For most vessel types, risk change from the Project is estimated in terms of the difference in frequencies of marine events based on multiple data inputs into the MARCS tool. MARCS has been utilized globally to assess navigation risk of more than 16 wind farms. The tool is used to calculate the spill frequency and locations for collision between vessels, allision with Project structures, and grounding because of the establishment of Project structures.

Note, the Project model does not include anchoring as a save mechanism for drift allision nor does it include tugs of opportunity or similar towing ships, so the drift grounding and drift allision results are certainly conservative.

The historical accident record for offshore wind farms is sparse. Offshore wind farms have been in operation in the UK for 28 years (Wind Europe, 2019). This study was able to identify two documented allisions in UK wind farms involving non-project vessels:

- A distracted fishing vessel
- A container ship that lost steerage because of a power failure (BOEM, 2018)

11.1 Frequencies of marine accidents

This section presents the estimated changes in frequencies and probabilities of marine accidents due to the Project. The supplementary traffic added to the AIS data is summarized in Table 11-1 and is detailed in Section 2.3 and Appendix E.

Table 11-1 Transits added to AIS data for modeling

Vessel type	Activity	Included in base case model (each way)	Included in future case model (each way)
Recreational Vessels without AIS (similar to "Pleasure" AIS vessel type) (see Section 2.1.1.4)	Fishing	386	386
	Other pleasure activities	374	374
Commercial Fishing Vessels without AIS (see Section 2.1.1.2)	Fishing in Project Area	13,324	13,324
	Transiting through Project Area	6,288	6,288
Passenger (see Section 2.3)	Sightseeing	-	100

The MARCS model is a set of risk parameters and calculation tools that have been developed to quantify marine risk.

MARCS calculates the frequency per grid cell for marine accidents accounting for a wide range of factors identified over decades of studies into causal and mitigating factors for maritime accidents, including the following:

- Vessel speed
- Vessel direction/route
- Distance traveled on the route
- Probability of steering and / or propulsion failure
- Probability of error in navigation
- Distribution of wind direction and effect on sea state
- Probability of visibility greater than 2 NM
- Whether another vessel or object is within 0.5 NM (in a critical situation or on a dangerous course)
- Conditional probability that the crew will successfully take actions to recover from a dangerous situation

These inputs account for distances from existing traffic in TSS, displacement of traffic, deep draft routes, density of traffic, and crossing/converging routes.

The MARCS model estimates frequencies for marine accidents accounting for Project- and location-specific environmental, traffic, and operational parameters. The model estimated the average annual frequency of occurrence for each accident type in each grid cell.

The general MARCS model is described in Appendix D to this NSRA. A detailed description of the Project-specific model for collision, grounding (drift and powered) and allision (drift and powered) is in Appendix E to this NSRA.

The risk model accounted for risk control measures that are implemented today such as modern navigation equipment on vessels in international trade, electronic charts, and Port State Control. The model did not account for other risk controls that are widely regarded as beneficial:

- PATON to be installed by the Project, including marking, lighting, sound signals, AIS, and other measures. Insufficient data are available to support quantifying the effects of these measures in the model.
- Tug capability and availability to intervene and prevent a drift allision by a vessel that has lost power. Accounting for this measure would require a detailed evaluation of tug availabilities and capabilities in the region. Not accounting for it is a conservative approach to the modeling, resulting in higher risk estimates for drift allision than would be estimated with a model that included this measure.
- The potential for some vessels, if they have lost power, to prevent an allision by dropping anchor. Not accounting for it is a conservative approach to the modeling, resulting in higher risk estimates for drift allision than would be estimated with a model that included this measure.

Table 11-2 provides a summary of the incremental risk results for Revolution Wind, reported as increases in the frequency of accidents summed for all sub-areas defined in Figure 11-1.

Table 11-2 Modeled incremental change in accident frequencies from the Project

Vessel type	Increase in frequency of any accident (number per year)
Cargo/Carrier	0.015
Fishing	1.253
Other/Undefined	0.022
Passenger	0.006
Pleasure	0.026
Tanker	0.001
Tanker - Oil Product	0.006
Tug/Service	0.029
Total	1.358

Overall, the model shows that the frequency of marine accidents increases by 1.4 accidents per year. Marine accidents involving fishing vessels represent 92% of the increase.

Table 11-3 shows the same results summarized per accident type.

Table 11-3 Modeled incremental change in accident frequencies from the Project for each accident type

Accident type	Increase in frequency of any accident (number per year)
Collision	0.004
Powered grounding	0
Drift grounding	0
Powered allision	0.603
Drift allision	0.750
Total	1.358

Allision accidents of any severity are predicted to occur 1.4 times annually and comprise 99% of the increase in risk. The minor increases in collision accidents are due to the 100 additional pleasure vessel transits assumed to be taken to the wind farm. Grounding frequencies are exactly 0.0 because there is no land within the sub-areas shown in Figure 11-1.

The remainder of this section presents the risk for each sub-area shown in Figure 11-1. The sub-areas were selected to provide clarity on where risks change and where they do not. Based on initial modeling, it was noted that nearly all of the risk increase is in the Lease Area, and nearly all of the remainder is within about 3 NM of the Lease Area. The sub-areas adjacent to the Lease Area were then defined as simple polygons extending to 6 NM from the Lease Area, using a safety margin of two x 3 NM.

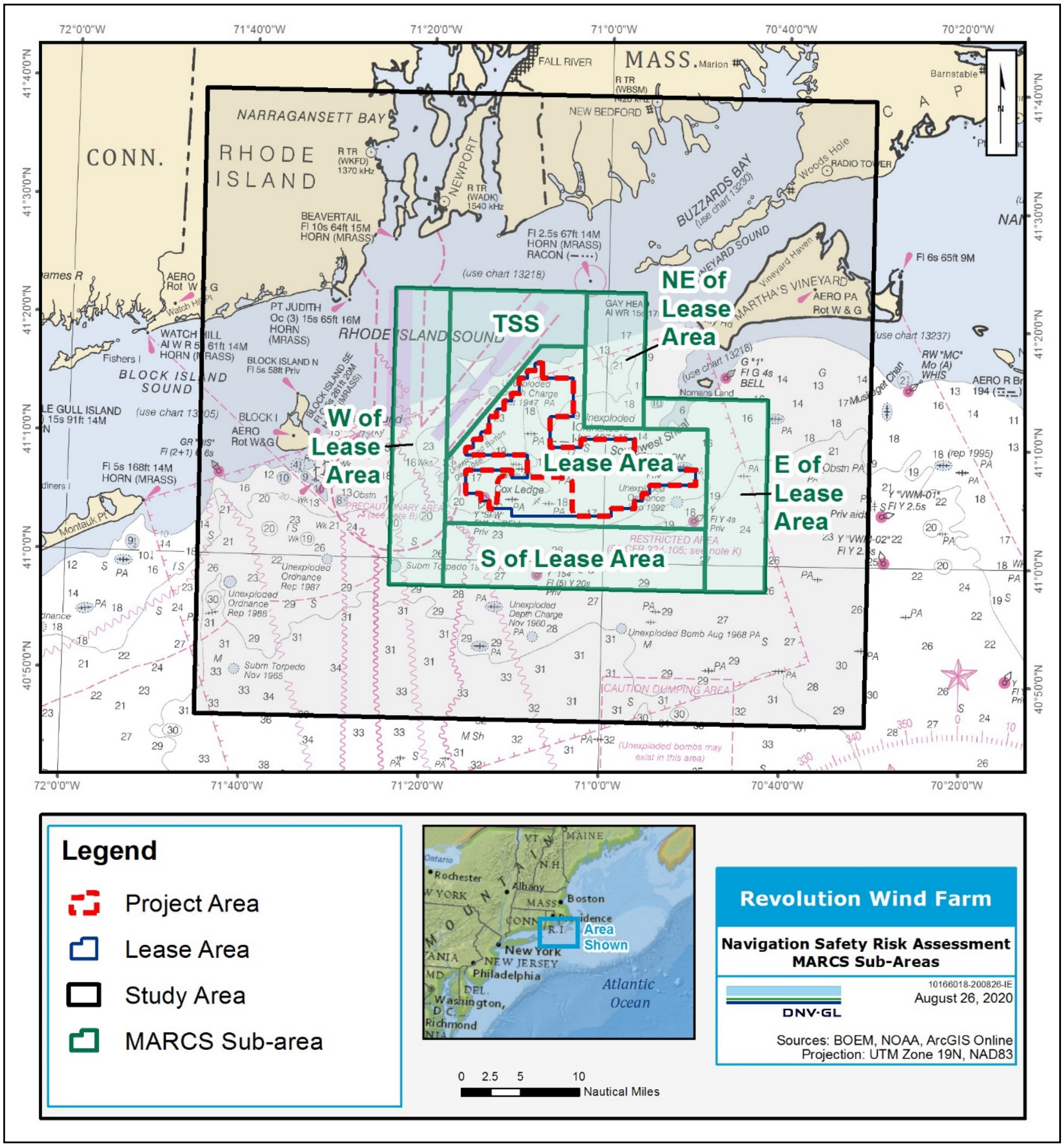


Figure 11-1 Definition of Sub Areas within the Study Area

11.1.1 Lease Area

Table 11-4 shows the modeled difference in risk from the Project. The Lease Area contains all the Project structures and hence it contains all the powered allision and all the drift allision accidents. There is zero frequency of powered grounding and drift grounding in this sub-area because there is no land or shallow water. Differences in frequency less than 0.001 per year are highlighted in grey.

Table 11-4 Risk difference: Lease Area (annual accident frequencies)

Vessel Type	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.001	-	-	<0.001	0.014	0.015
Fishing	<0.001	-	-	0.590	0.661	1.251
Other & Undefined	<0.001	-	-	0.006	0.016	0.022
Passenger	<0.001	-	-	0.001	0.005	0.006
Pleasure	<0.001	-	-	0.005	0.020	0.025
Tanker	<0.001	-	-	<0.001	<0.001	<0.001
Tanker – Oil	<0.001	-	-	<0.001	0.005	0.005
Tug & Service	<0.001	-	-	<0.001	0.028	0.028
Total	<0.001	-	-	0.603	0.750	1.354

There is a quantifiable increase in risk of allision within the Lease Area. The risk of allision for the types of vessels required to transit the TSS, cargo/carrier, tanker, and tanker-oil, is 0.02 per year, equivalent to a recurrence interval of 1 in 50 years.

11.1.2 Adjacent Sub-areas

Table 11-5 shows the modeled difference in accident frequency from the Project in the Buzzards Bay TSS. The frequency increases 0.003 accidents per year. Fishing vessels collisions contribute about 50% of this frequency increase. Based on the model results, the Project does not significantly increase the risk of collision for deep draft vessels in the TSS or routes around the Lease Area. The model accounts for the following risk factors discussed in Section 5.2 regarding operations phase risks:

- Distance from TSS, port approaches, and TSS terminations
- Anticipated changes to coastal shipping routes
- Mixing of vessel types

Risk factors that are represented by relatively few vessel tracks or they are too far from the Project to be influenced by the Project are discussed in Section 5.1, and include:

- Coastal Shipping inshore corridors
- Displacement of coastal traffic routes further offshore
- Offshore deep draft routes (Ambrose-to-Nantucket Safety Fairway and Nantucket-to-Ambrose Safety Fairway)
- Factors associated with tug traffic

Cumulative and cascading risks are discussed in Section 11.4.

There is zero frequency of grounding or allision with Project structures in the TSS sub-area because it contains no land and there are no Project structures. The estimated increase in collision risk is 3 in 1000 years (0.003 collisions of any severity per year), equivalent to a recurrence interval of 1 in 333 years, with fishing vessels contributing the most to the risk increase.

Table 11-5 Risk difference: TSS (annual accident frequencies)

Vessel Type	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.001	-	-	-	-	<0.001
Fishing	0.001	-	-	-	-	0.001
Other & Undefined	<0.001	-	-	-	-	<0.001
Passenger	<0.001	-	-	-	-	<0.001
Pleasure	<0.001	-	-	-	-	<0.001
Tanker	<0.001	-	-	-	-	<0.001
Tanker – Oil	<0.001	-	-	-	-	<0.001
Tug & Service	<0.001	-	-	-	-	<0.001
Total	0.003	-	-	-	-	0.003

Table 11-6 shows the modeled difference in accident frequency from the Project northeast of the Lease Area. There is essentially no risk increase from the Project in this sub-area.

There is zero frequency of grounding or allision with Project structures in this sub-area because it contains no land and there are no Project structures.

Table 11-6 Risk difference: Northeast of the Lease Area (annual accident frequencies)

Vessel Type	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.001	-	-	-	-	<0.001
Fishing	<0.001	-	-	-	-	<0.001
Other & Undefined	<0.001	-	-	-	-	<0.001
Passenger	<0.001	-	-	-	-	<0.001
Pleasure	<0.001	-	-	-	-	<0.001
Tanker	<0.001	-	-	-	-	<0.001
Tanker – Oil	<0.001	-	-	-	-	<0.001
Tug & Service	<0.001	-	-	-	-	<0.001
Total	<0.001	-	-	-	-	<0.001

Table 11-7 shows the modeled increase in risk east of the Lease Area. There is essentially no risk increase from the Project in this sub-area.

There is zero frequency of grounding or allision with Project structures in this sub-area because it contains no land and there are no Project structures.

Table 11-7 Risk difference: East of the Lease Area (annual accident frequencies)

Vessel Type	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.001	-	-	-	-	<0.001
Fishing	<0.001	-	-	-	-	<0.001
Other & Undefined	<0.001	-	-	-	-	<0.001
Passenger	<0.001	-	-	-	-	<0.001
Pleasure	<0.001	-	-	-	-	<0.001
Tanker	<0.001	-	-	-	-	<0.001
Tanker – Oil	<0.001	-	-	-	-	<0.001
Tug & Service	<0.001	-	-	-	-	<0.001
Total	<0.001	-	-	-	-	<0.001

Table 11-8 shows the modeled difference in accident frequency from the Project south of the Lease Area. There is essentially no risk increase from the Project in this sub-area.

There is zero frequency of grounding or allision with Project structures in this sub-area because it contains no land and there are no Project structures.

Table 11-8 Risk difference: South of the Lease Area (annual accident frequencies)

Vessel Type	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.001	-	-	-	-	<0.001
Fishing	<0.001	-	-	-	-	<0.001
Other & Undefined	<0.001	-	-	-	-	<0.001
Passenger	<0.001	-	-	-	-	<0.001
Pleasure	<0.001	-	-	-	-	<0.001
Tanker	<0.001	-	-	-	-	<0.001
Tanker – Oil	<0.001	-	-	-	-	<0.001
Tug & Service	<0.001	-	-	-	-	<0.001
Total	<0.001	-	-	-	-	<0.001

Table 11-9 shows the modeled difference in accident frequency from the Project west of the Lease Area. The frequency increases 0.001 accidents per year, which is considered negligible.

There is zero frequency of grounding or allision with Project structures in this sub-area because it contains no land and there are no Project structures.

Table 11-9 Risk difference: West of Lease Area (annual accident frequencies)

Vessel Type	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.001	-	-	-	-	<0.001
Fishing	<0.001	-	-	-	-	<0.001
Other & Undefined	<0.001	-	-	-	-	<0.001
Passenger	<0.001	-	-	-	-	<0.001
Pleasure	<0.001	-	-	-	-	<0.001
Tanker	<0.001	-	-	-	-	<0.001
Tanker – Oil	<0.001	-	-	-	-	<0.001
Tug & Service	<0.001	-	-	-	-	<0.001
Total	0.001	-	-	-	-	0.001

11.2 Consequences of marine accidents

11.2.1 Consequences from a collision

In a collision, the consequence can range from minimal (almost no consequence) to catastrophic. Collisions can result in more severe outcomes than groundings or allisions because both vessels are moving and contributing energy to the impact. The level of consequence depends on vessel speed, vessel size (DWT), collision angle, and location of contact on the vessels. The most extreme collisions in the historical data resulted in fatalities and total loss of a vessel.

11.2.2 Consequences from a grounding

The water depths near the Project are not limiting for the vessels in the Study Area, so the Project effectively poses no increase to grounding risk.

Groundings are the most common marine event near shore or on inland waters; however, consequences from groundings are not discussed further because they are not relevant to the assessment.

11.2.3 Consequences from an allision

A wide range of potential consequences exists should an allision occur. The least severe consequence is that a drifting vessel grazes a project structure. In this event, there may be minor damage to both the vessel and the WTG. It is likely that all personnel and passengers and structures would not experience any injury or damage. The severity of an allision increases with the speed of impact and size of the vessel.

A powered allision (i.e., occurring at speed) would likely result in the most severe consequences for both the vessel and the Project structure. The maximum design case scenario for a powered allision could result in the following:

- Personnel/passenger injury or fatality
- Major damage to the vessel. The damage could potentially be so severe that vessel sinking is possible. Damage could also result in a release of cargo or fuel.
- Major damage to a WTG. The severity of the damage is dependent on the design specifications and the specific nature of the strike.

Powered allision has a higher energy than drift allision; however, a drifting ship is likely to drift with its highest point away from the wind. As a result, a drifting oil tanker might contact a turbine on its stern quarter, which would increase the chance of a cargo spill, as there are no cargo tanks in the bow of most ships.

11.3 Risk mitigation of marine accidents

This section provides an overview of existing maritime and offshore wind industry practices that control risks. Risk controls are most readily identified and implemented during early concept phases. Selection of location and completion of early phase design place additional constraints on the availability and costs of some controls.

Aspects that affect the risk level for Revolution Wind include:

- Generally low traffic density
- Predominantly smaller vessels in the traffic
- Sufficient distance from ports, coastlines, and shoaling water
- Availability of ATON. Enhanced navigation aids may assist vessels in more accurately determining vessel position as well as identifying potential hazards.

Risk controls – Maritime

In the larger view of history, safe marine transit of crew, passengers, and cargo has been a focus area for a wide range of parties, including mariners, shippers, fishermen, owners of shipped goods, insurers, nations, and international bodies. Some of the first international requirements related to vessel design and construction, resulting in the creation of ship classification societies in the mid-1800s.

The primary governance for every ship is its flag state, the country in which the ship is registered. The government of the flag state adopts standards of design, construction, maintenance, and operation.

In addition, the port state, the government of the ports or anchorages at which a ship calls, may enforce international standards and its own regulations.

To facilitate general adoption of the highest practicable standards in matters concerning maritime safety and related purposes, the United Nations created the IMO in 1948 (IMO, 2019b). Because of the global nature of shipping, many requirements relating to maritime safety in U.S. waters have their foundations in IMO conventions and codes. Today, these are considered industry standard practices and are accounted for in the risk assessment. The U.S. has promulgated regulations in line with the key IMO conventions that include:

- SOLAS – The International Convention for the Safety of Life at Sea requires certain equipment and practices to increase the safety of people on board (various parts of 46 CFR)
- COLREGs -Convention on the International Regulations for Preventing Collisions at Sea. Requirements include vessel-to-vessel communication and safe transit speeds (primarily 33 CFR 80 et. seq.)
- STCW - International Convention on Standards of Training, Certification and Watchkeeping for Seafarers and International Convention on the Standards of Training, Certification and Watchkeeping for Fishing Vessel Personnel (46 CFR 11 et. seq.)

The IMO also establishes routing measures to increase the safety of vessels on approach to and departure from major ports. Routing measures are particularly effective in congested port waterways:

> "Traffic separation schemes and other ship routing systems have now been established in most of the major congested, shipping areas of the world, and the number of collisions and groundings has often been dramatically reduced." (IMO, 2019a)

As noted in Section 2, routing measures have been established by the Coast Guard, which has the primary responsibility to ensure safety of life and property at sea. The Coast Guard administers navigation and vessel inspection laws and regulations governing marine safety and environmental protection. The Coast Guard accomplishes this by prescribing regulations published in CFR Titles 33, 46, and 49. These regulations incorporate international laws to which the United States is a signatory, as well as various classification society and industry technical standards.

The Coast Guard also manages ATON in the Study Area, including an array of audio, visual, radar, and radio aid to navigation, such as lights, buoys, sound signals, range markers, and radio beacons. The Coast Guard conducts studies and consults with federal agencies, state representatives, waterway users, and the general public, to study waterways for safety and efficiency.

One type of study conducted by the Coast Guard is a Port Access and Route Study (PARS), which reviews potential traffic density and the need for safe access routes for vessels. A primary purpose of this study is to reconcile the need for safe access routes with other waterway uses. A PARS study is typically conducted before the Coast Guard establishes or changes Regulated Navigation Areas or Traffic Separation Schemes.

The most recent completed PARS studies relevant to this assessment are:

- Atlantic Coast Port Access Route Study (Coast Guard, 2015)
- Buzzards Bay Port Access Route Study (Coast Guard, 2004)

Two ongoing studies relevant to traffic off New England are:

- Atlantic Coast: Port Approach and International Entry and Departure Areas, which was announced in March 2019 (84 FR 9541)
- Areas Offshore of Massachusetts and Rhode Island, which was announced in March 2019 (84 FR 11314)

Results in PARS reports, including recommendations, “help program managers establish traffic routing measures, fairways, TSS, limited access areas, recommended routes and regulated navigation areas. They may provide justification for regulatory projects or submissions to the IMO. If the PARS recommends vessel routing measures, Commandant (CG-NAV) will validate the recommendations and initiate the Federal rulemaking process and/or IMO’s ships routing measures process.” (Coast Guard, 2019c)

NOAA also plays an important role in marine safety, providing weather reports, forecasts, warnings, nautical charts and navigational information, and other data. Two NOAA offices, the National Ocean Service and the National Weather Service, offer data and services that directly support safe navigation.

The National Ocean Service provides real-time oceanographic data, mapping, charting, and water level information. The National Weather Service provides weather, water, and climate data, forecasts and warnings and operates the National Data Buoy Center buoys.

Risk controls – Offshore wind farms

Offshore wind farms have been operation since 1991. Standard industry practices have developed, and like the above maritime safety practices, continue to evolve and improve over time.

During the design and construction stages of a wind farm, a set of design and construction standards lay out minimum requirements. An independent Certified Verification Agent checks and confirms that the design and all aspects of construction conform to the agreed set of standards (30 CFR 585).

In the operational stage of a wind farm, some risk controls have become standard practice but others are still in development.

Good industry operational practices include:

- Marking of structures such as lighting, sound signals, structure identification, air gap
- Providing timely notices to mariners regarding construction, operation, and decommissioning
- Remotely-activated locking of turbine blades in rotation and in yaw / feathering the blades

Spacing of WTGs is generally guided by energy production targets, turbine size, available area, wind distributions, and other factors. Regularly spaced turbines can facilitate use of helicopters for SAR and radar-assisted search. Additional analysis of the Project's effects on SAR is in Section 12.

Management of risk due to adjacent location of several large wind farms is a nascent challenge in the industry, and many options are being evaluated (see Section 11.4). Adjacent leaseholders (Bay State Wind, Deepwater Wind, Vineyard Wind, Equinor, and Mayflower Wind) have established a Marine Affairs Working Group to address navigation, emergency response, and other safety issues common to all.

Vessel safety for shallow draft vessels (i.e., all vessels that are not defined as deep draft) is a potential concern. Within a wind farm, this is particularly true in poor visibility or high sea states. Advance warnings to mariners and education initiatives could reduce the likelihood of a vessel in peril in the wind farm under such conditions.

The Coast Guard MARI PARS report (2020a) recommends that mariners desiring to transit the area should use extra caution, ensure proper watch, and assess risk prior to entering an offshore wind farm.

Smaller vessels operating in or near the WTGs may experience radar clutter and shadowing. Most instances of interference can be mitigated through use of radar gain controls. Increasing the spacing between WTGs generally decreases its effects on radar.

The four countries with the highest energy production from offshore wind take two different approaches to regulating maritime safety. In Belgium, Germany, and The Netherlands fishing and transiting are restricted in wind farms, although this is not related to the towers being a hazard to navigation. This reduces the frequency of SAR operations in the wind farm and damage to wind farm structures from allision. In contrast, the UK and Denmark allow commercial and recreational vessels to transit and fish in wind farms; however, they implement additional risk mitigation measures such as monitoring of vessels in the wind farm and safety zones around each WTG.

Historically, The Netherlands has used risk-based reviews to inform policies and project approval decisions. The Dutch government is currently considering allowing fishing and vessel transit in proposed wind farms. A quantitative risk assessment identified risks and first-estimates of costs and benefits of mitigation measures (MIeM-RWS, 2015). Further refinement of costs and benefits is in progress to support ALARP-informed decision-making by the Dutch government.

In general, risk controls fall into three categories:

1. Avoidance, such as:
    - Exclusion zone around a wind farm
    - Not allowing deep draft vessels to transit a wind farm
    - Not allowing fishing in a wind farm using bottom-type gear
2. Reducing likelihood, such as:
    - Vessel design and equipment maintenance
    - Routing measures
    - Sea state / visibility restrictions
    - Training
    - Safety zones around WTG
    - Additional AIS requirements
    - Enhanced radar and traffic control, warning systems
    - Real-time cable location monitoring
3. Preventing or reducing consequences, such as:
    - Highly robust subsea cable protection
    - Life safety equipment onboard all vessels
    - Standby tug near the wind farm

11.3.1 ALARP evaluation of risk mitigation measures

The general goals of risk assessment are to:

- Identify and prioritize any significant risks and recommend appropriate mitigation strategies
- Enable risk reduction by identifying, understanding and appropriately managing all major threats
- Inform decisions related to optimization of costs and benefits (ALARP process)
- Enhancing alignment between varying interests concerning residual risks

A demonstration of ALARP requires weighing the potential benefits of a measure with the costs of implementing the measure. For most scenarios not involving risk to human life, this is a straightforward cost-benefit calculation.

The challenges include:

- Estimating the all-in cost to all parties and quantifying the change in risk from the mitigation
- Balancing costs and benefits across multiple stakeholders. If one party bears all the costs and another all the benefits, then acceptance is less likely.

- Practicality. A control that can be implemented by a single party is easier to agree than one that needs the consensus of many stakeholders to be effective.

The ALARP process need not be fully rigorous and comprehensive in scope, fully evaluating every potential option. Instead, an initial list of mitigations can be developed and assigned qualitative measures of benefit and cost. The list can then be filtered into “meets ALARP criteria”, “does not meet ALARP criteria”, and “further study is needed”. Some rules of thumb are:

- Any mitigation that is “industry good practice” is considered ALARP
- Any mitigation with measurable benefit and negligible cost immediately meets the ALARP criteria
- Any mitigation with a cost greater than the benefit does not meet the ALARP criteria

11.3.2 Potential mitigation measures

This assessment provides risk information to enable the Coast Guard to evaluate whether Project risks are reduced to meet ALARP criteria. Any risk control that is standard industry practice or is good industry practice, by definition, should be implemented per ALARP principles. In the U.S., such practices are still being developed.

This assessment identified the following general list of risk control or mitigation measures (in no particular order):

- Additional ATON associated with the Project
- Pilotage of deep draft vessels near the Project
- Tug on standby
- Vessel traffic services
- Vessel design and equipment maintenance requirements for all vessels in the Project Area
- Highly robust subsea cable protection
- Life safety equipment onboard all vessels
- Larger or additional precautionary areas
- Designation of areas to be avoided or limited access areas
- Designation of additional anchorages
- Designation of additional routing measures
- Project structures along perimeter equipped with radar beacon to allow clear identification via radar
- Alternate cable protection measures, such as armored ducting, rock placement, or concrete mattresses
- Only specified designs/kinds of commercial fishing gear can be used in the wind farm
- A safety zone of 50 m around turbines
- 500-m safety zones around offshore substations
- Real-time vessel monitoring in the wind farm
- Designation of routes for additional vessel types, such as fishing and tug/tow
- WTG platforms are accessible and can be used as a potential place of refuge
- Fishing / transits limited to daytime
- Transit or fishing only with a functioning and active VHF and AIS installation
- No seabed disturbing activities
- Limitation for ships exceeding a certain length
- Ice hazard protocol
- Offshore cameras (to facilitate SAR)

The Project has committed to specific measures that are listed in Section 17.

11.4 Cumulative effects

Cumulative effects on navigation were evaluated on a qualitative basis for the four Orsted-proposed wind farms in the Study Area (Figure 11-2):

- Revolution Wind Farm
- South Fork Wind Farm
- Bay State Wind Farm
- Sunrise Wind Farm

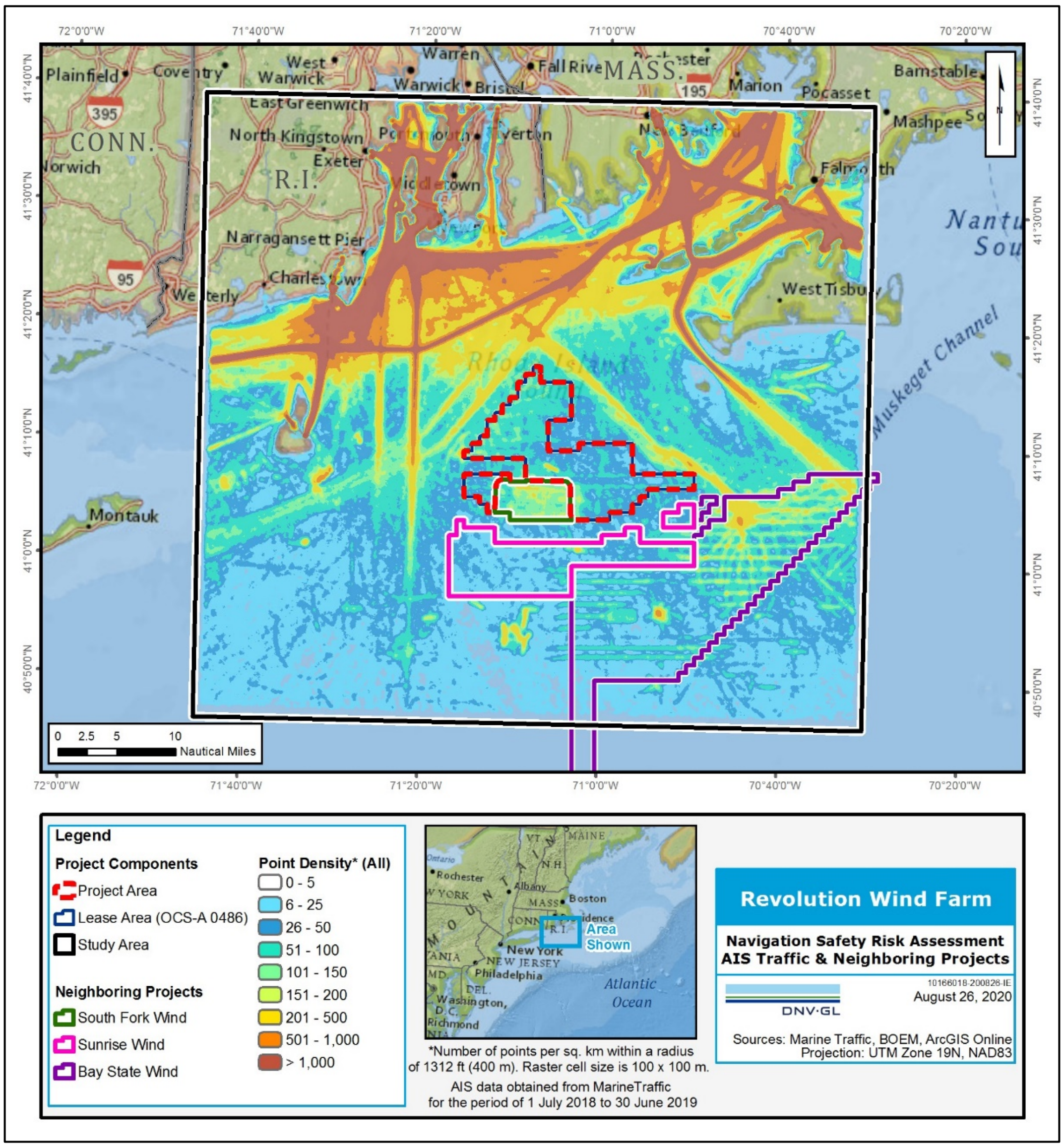


Figure 11-2 AIS traffic with Revolution, South Fork, Bay State, and Sunrise Wind Farm Lease Areas[1]

Potential effects related to navigation safety resulting from the four projects in combination may include:

1. Commercial fishing traffic that currently transits through the lease areas may instead decide to take routes to the east or west around the lease areas.
    - These vessels generally avoid TSS, per Coast Pilot guidance (NOAA, 2018). Deep draft vessels generally follow only the TSS, so a result would be an increase in interaction among the various users, which may pose a potential safety risk.
    - An increase in distance sailed and resultant increase in vessel transit time. The preliminary identified effects are:
        - Use of additional fuel / increased fuel cost and additional emissions
        - Longer exposure time for the potential failure of propulsion and steerage equipment, which increases the risk of being adrift approximately in proportion to the additional amount of time spent transiting
        - Increase in the number of fishing vessel transits in the Buzzards Bay traffic lanes, and therefore increased interactions with tugs. This effect is likely very minor because the lane does not have very dense traffic considering temporal distance between vessels. As recorded in the year of AIS data (MarineTraffic, 2019), 1,083 vessels per year transited inbound or outbound lanes - an average of 3 vessels per day. These were primarily of fishing and tug vessels. The highest traffic level in the AIS data in this lane was in the summer months consisting of 376 transits, an average of 4.1 transits per day. Many additional fishing vessels could take this lane, a credible maximum of 760 annual additional fishing and pleasure transits per year were estimated based on data for the year 2012 (see Section 2.3). The pleasure vessels are likely to sail in the summer, but the fishing vessels are likely more distributed throughout the year. Even if all 760 occurred in the summer in these two traffic lanes, the three-month total would be 763 transits, an average of 9 per day.
2. Changes to commercial and recreational fishing patterns, which are largely unpredictable at this time.
3. SAR efforts may be more challenging. A discussion of the Coast Guard's assessment of the cumulative effects of the adjacent leases is in Section 12.

    The Coast Guard's MARI PARS report (2020a) examined navigation safety and potential impacts to Coast Guard SAR throughout the WEA, which includes the following OREIs, all in various stages of development:

    - Revolution Wind Farm
    - South Fork Wind Farm
    - Bay State Wind Farm
    - Sunrise Wind Farm
    - Vineyard Wind 1
    - Vineyard Wind 2

- Beacon Wind
- Mayflower Wind

These OREI's propose a uniform 1 NM x 1NM layout in a north/south/east/west grid pattern (Orsted et.al, 2019).

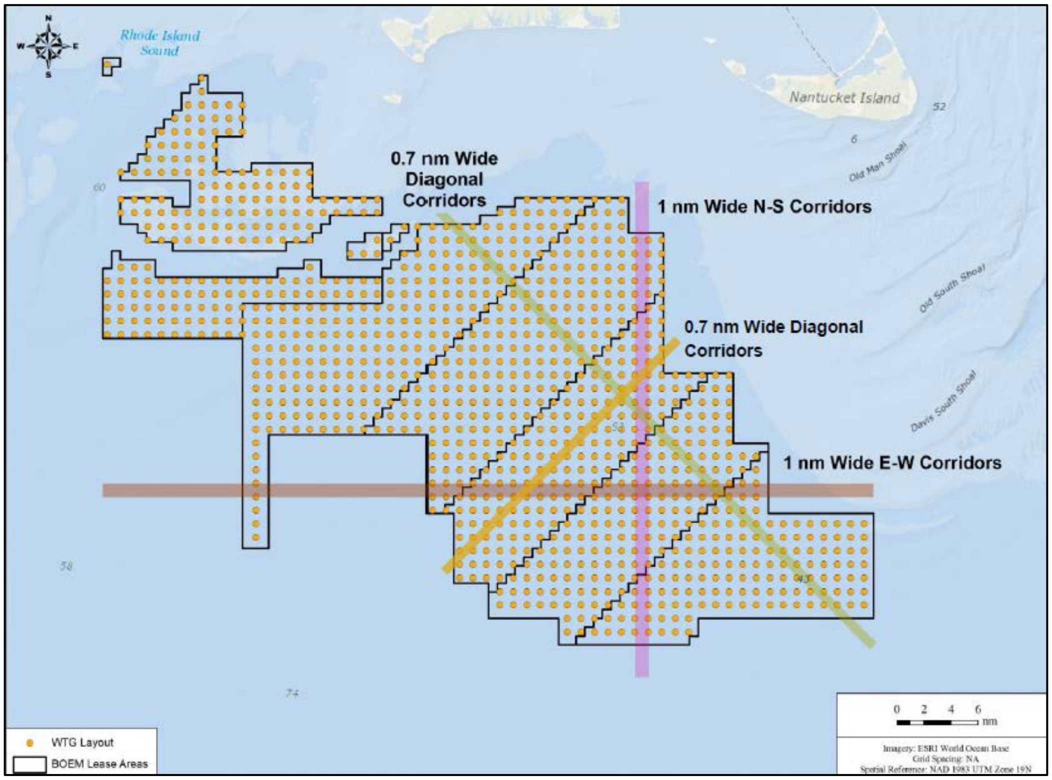


Figure 11-3 Proposed layout of OREIs in the WEA (Orsted et. al., 2019)

The MARI PARS (Coast Guard, 2020a) report found that such a layout would preserve navigation safety for vessels that routinely frequent that area and provide for search and rescue.

Additionally, BOEM, in its "Vineyard Wind 1 Offshore Wind Energy Project Supplement to the Draft Environmental Impact Statement" examined the potential cumulative impacts to navigation safety and vessel traffic that could result from the layout proposed for Revolution Wind and the entire MA/RI WEA as described above. BOEM assessed the cumulative impacts to be "Moderate," which BOEM defines as:

- Mitigation would reduce adverse impacts substantially during the life of the proposed Project, including decommissioning;
- The affected activity or community would have to adjust somewhat to account for disruptions due to notable and measurable adverse impacts of the project;

The risk control measures described here and in the COP, and/or imposed as permit conditions (such as a comprehensive aids-to-navigation plan, operations center design requirements) will reduce adverse impacts and disruptions to mariners.

12 EMERGENCY RESPONSE CONSIDERATIONS

To determine the impact on Coast Guard and other emergency responder missions, SAR and marine environmental protection/response were assessed. Recent Coast Guard mission data specific to the Project has been requested but has not been received as of the date of this report. However, the Coast Guard previously provided data for missions that occurred in or near the adjacent South Fork Lease Area during the ten-year period 2006-2016 (Figure 12-1). A cluster of missions took place west of the Project in the Precautionary Area for the Buzzards Bay TSS.

Over that ten-year period, the Coast Guard executed 5 missions in the southern portion of the Lease Area[6]. This could equate to about 15 missions over the entire Lease Area, assuming uniform distribution over the portion of the Lease Area that appears to have been excluded from the South Fork data search. This represents an estimated average of 1.5 SAR missions per year in the Revolution Wind Farm.

Information about the SAR missions in the southern portion of the Project Area is provided in Table 12-1.

Table 12-1 Summary of SAR cases

Situation	Number of occurrences 2006 - 2016
SAR cases conducted by Coast Guard in the proposed Project Area over a ten-year period	15 (extrapolated)
Cases involving helicopter hoists	Not specified in the available data
Cases at night or in poor visibility/low ceiling	3 at night (undet. visibility) 1 in the day with poor visibility
Cases involving aircraft (helicopter, fixed-wing) searches	Not specified in the available data
Number of times commercial salvors (for example, BOAT US, SEATOW, commercial tugs) responded to assist vessels in the proposed structure region over the last ten years	Not specified in the available data
Additional SAR cases estimated by modeling due to allision with the Project structures	1.4 allisions per year, with the vast majority not requiring CG assistance. (conservative maximum estimate)

Concerning the safety of SAR missions, the Coast Guard MARI PARS report (2020a) concluded,

> "After considering all options and the vessel traffic patterns within the MA/RI WEA, a standard and uniform grid pattern with at least three lines of orientation throughout the MA/RI WEA would allow for safe navigation and continuity of USCG missions through seven adjacent wind farm lease areas over more than 1400 square miles of ocean."

[6] In addition, there was one law enforcement case involving a deceased whale.

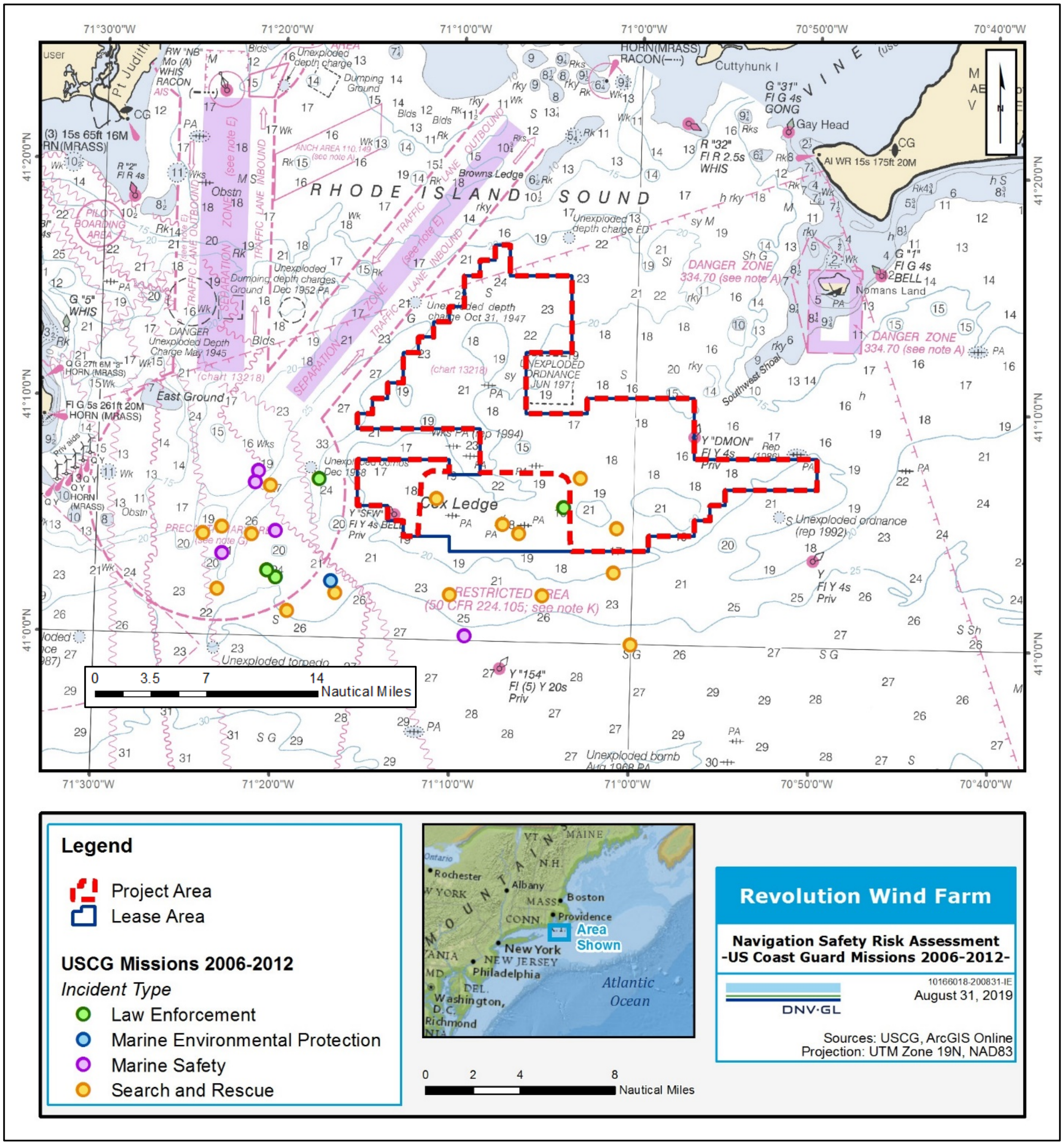


Figure 12-1 Coast Guard mission data provided for South Fork Wind Farm (2006 to 2016)

Turbines will have easily identifiable markings that could be used to aid SAR. One or more OSS within the Project or adjacent projects may provide helicopter refuge to facilitate SAR.

Table 12-2 Marine environmental protection / response

Situation	Number of occurrences 2006 - 2016
Marine environmental/pollution response cases conducted by Coast Guard in the proposed structure region over the last ten years	0
What type of pollution cases were they	N/A
What type and how many assets responded	N/A
Additional pollution cases estimated by modeling due to allision with the structures?	About 1 per 10 years[7]

[7] Multiplication of 1.4 allision frequency, 0.2 conditional probability of a severe impact, and 0.5 conditional probability that a severe impact results in a spill.

13 FACILITY CHARACTERISTICS

In general, marking of offshore wind farm structures is specified in international standards and U.S. Coast Guard guidance. The most relevant standards include:

- IALA Recommendation O-139 on the Marking of Man-Made Offshore Structures released by the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA, 2013)
- The Convention on International Civil Aviation Annex 14 (ICAO, 2013), released by the International Civil Aviation Organisation for marking of wind turbines with regard to safety of aviation
- First Coast Guard District Local Notice to Mariners 33-20, “ME, NH, MA, RI, CT, NY, NJ-ATLANTIC OCEAN-OFFSHORE STRUCTURE PATON MARKING GUIDANCE” (Coast Guard, 2020b)

A published list of international standards and guidelines is available in the DNV GL specification for certification of navigation and aviation aids of offshore wind farms (DNV GL, 2017).

Marking and lighting of the structures will conform to Coast Guard guidance at the time of Project approval. This includes any/all requirements that may be imposed in conjunction with BOEM’s anticipated permit conditions requiring the Project to submit to the Coast Guard for review and approval a comprehensive ATON plan for marking and lighting of all structures, to include:

- Identification marking
- Lighting
- Sound signals
- Automated Information System (AIS) transponder signals
- Other appropriate aids to navigation.

The Bureau of Ocean Energy Management recently published Draft Proposed Guidelines for Providing Information on Lighting and Marking of Structures Supporting Renewable Energy Development (2019). Should BOEM finalize these guidelines by the time of COP approval the Project will comply.

A decommissioning plan will be developed and submitted to relevant agencies. It is industry practice to remove wind turbine foundations at or just below the seabed during decommissioning. No marking or lighting requirements for offshore structures post-decommissioning are foreseen at this time.

Aviation lights will be controlled by an Aircraft Detection Light System (ADLS) and AIS to assure they are lit when triggered in any lighting condition (ICAO, 2013). As far as practicable, aviation lights will not be visible below the horizontal plane of the lights.

Any PATON will be maintained to meet the Coast Guard’s availability standards. Procedures will be put into place to respond to and correct any deficiencies within required timeframes.

No effects are anticipated to existing Federal ATON near the Project, shown in previous Figure 2-2 Navigation chart. The luminous intensity of WTG lights are expected to be clearly distinguishable from lights ashore. No adverse effects on visual navigation are expected due to interactions of lights, backscatter, geographic versus visible horizon, or turbine spacing.

A conceptual lighting scheme for the Project is shown in Figure 13-1.

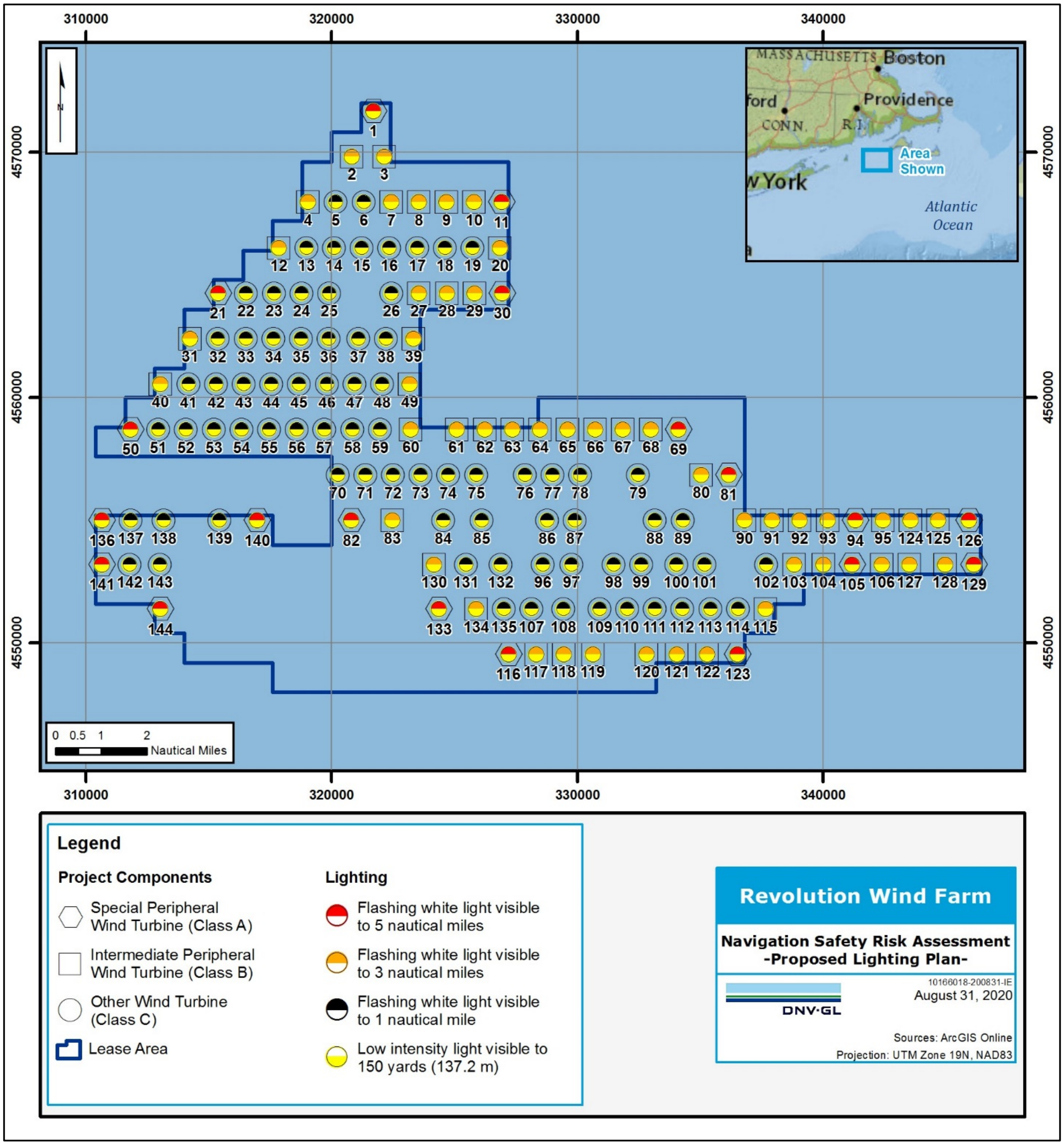


Figure 13-1 Conceptual lighting scheme for the Project

14 DESIGN REQUIREMENTS

All Project structures will be marked with clearly visible unique identification characters (for example, alpha-numeric labels). The identification characters will be illuminated by a low-intensity light visible from a vessel or be coated with a phosphorescent material. They will be designed and installed to be clearly readable at a distance of at least 150 yards, and if lighted, will be baffled to avoid misperception as ATON (Orsted, 2020).

The Project will have a 24-hour operational monitoring center to verify safe operating conditions are being maintained. The monitoring center will have the ability to remotely operate and shut down WTGs and OSS and fix/maintain the position of the turbine blades and hub in an emergency situation (Orsted, 2020).

Emergency operating procedures for the monitoring center will be agreed in consultation with the Coast Guard and other emergency support services. Offshore enclosed spaces will be capable of being opened from the outside to allow emergency access when they are occupied (Orsted, 2020).

15 OPERATIONAL REQUIREMENTS

The operations center will be manned 24 hours per day and have an electronic chart indicating the position and identification numbers of each of the offshore Project structures. Figure 15-1 shows a display from the Orsted Marine Coordination Centre in Grimsby, England. (Orsted, 2020)

Figure 15-1 Display at Orsted Marine Coordination Center in Grimsby, England

The Project operator will ensure that all applicable Coast Guard command centers (District and Sector) are advised of the contact telephone number of the operations center and that correct positions and identifiers of offshore Project structures have been provided to NOAA to include on navigation charts.

16 OPERATIONAL PROCEDURES

Orsted anticipates that the Coast Guard will recommend, and BOEM will include, a condition in its Revolution Wind Farm permit (if issued) to require Orsted to submit to the Coast Guard an acceptable emergency shutdown procedure/plan similar to requirements in the Block Island Wind Farm permit.

Additionally, Orsted will work in conjunction with the Coast Guard to develop an acceptable emergency shutdown procedure and emergency response plan that draw on the lesson learned from joint Orsted-Coast Guard emergency shutdown exercises conducted at the Block Island Wind Farm. See COP Section 1.8 and COP Appendix D for additional information on emergency response preparedness.

Emergency procedures for the Project / Project operations center will incorporate the following elements:

- Upon receiving a distress call or other emergency alert from a vessel that is concerned about a possible allision with a structure or is already close to or within the installation, the Coast Guard Search and Rescue Mission Coordinator (SMC) will establish the position of the vessel and the identification numbers of any structures visible to the vessel. The position of the vessel and identification numbers of the structures will be passed immediately to the operations center by the SMC.
- On receipt of a Coast Guard SMC request to shut down WTGs , the operations center will shut down the WTGs and maintain that status until receipt of notification from the SMC that it is safe to restart.
- Emergency communication protocols and shut down procedures will be tested at least twice per year.

17 CONCLUSIONS AND PROJECT RISK MITIGATIONS

The primary conclusions of this study are as follows:

1. Site location and coordinates
   - 0.6 NM is the evaluated minimum spacing between WTGs.[8]

2. Traffic survey
   - Vessel traffic near shore can be dense in the summer, particularly in areas close to the coastline.
   - Vessel traffic in and near the Project is light.
   - Among the vessel types, recreational/pleasure vessels represented the greatest proportion of the AIS-recorded vessel tracks in the Study Area, 26.5%.
   - Fishing, tugs / service vessels, other / undefined vessels, and passenger vessels each comprised 15-19% of the AIS-recorded vessel tracks in the Study Area.
   - Much of the passenger and other / undefined vessel traffic in or near the Project appears to be related to studies of potential offshore wind farms. These are not anticipated to continue as steady-state after the wind farms are either in operation or are cancelled. As a result, the risk estimates are likely to be higher than the reality in the future.
   - Deep draft vessels are not expected to enter the wind farm, except in emergency circumstances. The one year of AIS data shows deep draft vessel tracks crossing the southeastern corner of the Lease Area. If instead, these deep draft vessels routed around the wind farm, an additional 1000 NM (less than 1%) would be sailed per year in aggregate.

3. Offshore above water structures
   - Project structures will pose an allision and height hazard to vessels passing close by, and vessels will pose a hazard to the structures. Allision risk is specifically discussed in (11) below. Typical good practice is to mark any structure that constrains the air gap over a waterway; the air gap will be indicated on each Project structure.
   - Risk related to some types of fishing gear suggests that risk to vessels/crew and the Project can be controlled by assuring the cable is buried at sufficient depth and/or has sufficient cable protection for any gear type and/or using gear that has limited penetration depth when fishing in the wind farm.

[8] Ørsted and four other New England offshore wind leaseholders proposed 1 NM spacing between WTGs in fixed east-to-west rows and north-to-south columns to create a 1 NM by 1 NM grid arrangement in November 2019 (Ørsted et. al, 2019). The risk estimated in this report is greater than or equal to the risk estimated specifically for the proposed spacing, given all WTGs in the proposed grid layout lie within the Project Area defined in Section 1 of this report.

	• Spacing between WTGs in the evaluated layout provides sufficient sea room for maneuvering for vessel types expected to transit and fish in the wind farm. • Emergency rescue procedures will likely be adjusted to account for the Project structures once they are in place. In particular, helicopter-aided SAR will be a higher-risk activity in poor visibility, particularly within the Project Area. • Noise from construction activities or operation of WTGs is not anticipated to have negative effects on safe navigation or on the health of crew/personnel. • In general, Project WTGs with monopile foundations could sustain significant damage from an allision by a deep draft vessel at speed, and immediate collapse is not anticipated. This will be similar for the Project WTGs or the OSS if the final foundation design is also a monopile. A jacket foundation is a weaker structure relative to horizontal loads. If the final foundation design for the OSS is a jacket, structural collapse from allision by a deep draft vessel at speed cannot be ruled out.
4. Offshore under water structures	• The Project components will not affect underkeel clearance for vessels transiting in the Project Area. No Project structures will lie above the seabed except those that rise above sea level.
5. Navigation within or close to a structure	• In general, as a vessel approaches a structure, the risk increases. During construction, global good industry practice is a safety zone implemented around construction activity. • During operations, the safety of vessels and crews will rely on the enhanced ATON and on good seamanship to control the risk. • Standard industry practice is that anchoring in a wind farm is a potentially hazardous activity and should be undertaken only by Project-related vessels or in emergency situations. To control this risk, Project cables will be buried and / or protected on the seabed, marked on charts, and their location will be monitored periodically to detect any movement.
6. Effect of tides, tidal streams, and currents	• Tides, tidal streams and currents in the Project Area have a low level of influence on navigation risk related to the Project.
7. Weather	• Weather, and in particular visibility, has a significant effect on navigation risk in a wind farm. Based on ten years of data at the Block Island Airport, visibility is less than 2 NM about 8.6% of a given year.
8. Configuration and collision avoidance	Wind farm layout can have a significant influence on operational and navigation risks experienced during operations. An optimal configuration of offshore wind

	farm structures is sought through balancing many factors, including physical, environmental, technical, economic, and political aspects. Concerning configuration and collision / allision risk, the risk controls most relevant to risk avoidance include: • The WTG layout will be in linear rows and columns oriented both north-south and east-west. This will allow alternative routes by vessels or aircraft transiting the wind farm and provide options in case of high winds or seas. • The WTGs in adjacent/contiguous wind farms proposed by Orsted will align with WTGs in the Revolution Wind Farm.
9. Visual navigation	• Project structures are not anticipated to significantly obscure view of other vessels, ATON, or the coastline. • Project structures may serve as information navigation aids for mariners, particularly at night because they will be lit and marked on navigation charts.
10. Communications, radar, and positioning systems	• The impacts on marine radar are variable, with the most likely effect being some signal degradation. Proximity to the WTGs is the primary factor that determines the degree of radar signal degradation. • The Coast Guard's advanced command, control and direction-finding system, "Rescue 21," is unlikely to experience any degradation from the Project. • Due primarily to the quality of radars and the proficiency of professionally licensed crew, radar operations on commercial ships are not anticipated to be adversely affected. • Smaller vessels operating in or near the Project may experience radar clutter and shadowing. Risk controls relevant to this effect are: vessel operator awareness and competence regarding radar effects and corrections, placement of radar antenna at a favorable position on a vessel, regular communications regarding changes and activities in the wind farm, and safety broadcasts from vessels operating in or near the wind farm.

11. Risk of collision, allision, or grounding	• In this assessment, the modeled increase in risk is 1.4 accidents per year. It is DNV GL's best estimate of the additional risk that results from the presence of the Project assuming all non-AIS commercial fishing vessel transit to or through the Project Area using the most reasonably conservative approach to the estimate. • The modeling shows that the Project has no significant effect on grounding risk or collision risk. The minimal increase in estimated risk relates to allision. • The Project poses very little risk outside the Lease Area: 98% of the estimated risk increase occurs within the Lease Area. • A list of risk controls and risk mitigations which the Project is considering is provided below.
12. Emergency response considerations	• An estimated average of 1.5 SAR missions are anticipated per year in the Revolution Wind Farm, extrapolated from 10 years of Coast Guard mission data provided for South Fork Wind Farm. • About 1 pollution case per 10 years is anticipated from allision with Project structures.
13. Facility characteristics	• Marking and lighting of the WTGs and OSS will conform to U.S. requirements at the time of approval of such by relevant agencies. • No effects are anticipated to existing Federal ATON near the Project. • PATON will be maintained to meet the Coast Guard's availability standards.
14. Design requirements	• Industry good practices will be utilized concerning visible markings, lighting, and safe emergency shutdown (fixing blade and hub positions), emergency access to structures, and emergency preparedness involving relevant agencies.
15. Operational requirements	• Project operations will be monitored 24 hours per day every day and its emergency contact channels will be provided to the Coast Guard and other relevant agencies. • Offshore enclosed spaces will be capable of being opened from the outside to allow emergency access if required. • Information on project structures and their locations will be provided to NOAA to include on navigation charts.
16. Operational procedures	• Emergency procedures will be developed and reviewed with relevant agencies, including the Coast Guard, to ensure that response plans are adequate and properly resourced.

Potential Project mitigation measures

Table 17-1 summarizes the navigation risk mitigation measures that the Project may implement (Orsted, 2020). The "Type" and "Threat or Hazard" columns are intended to provide context; however, nearly all of the mitigation measures would reduce risks from several threats. The complex interrelationships between risk mitigation benefits can be taken into account during the ALARP review.

Because the Project is still in planning / design phases, these measures will be modified to align with the final Construction and Operations Plan.

Table 17-1 Summary of potential Project mitigation measures

Type *	Threat or hazard	Primary mitigation
D	Allision of a vessel with a WTG	Uniform minimum spacing between Project structures; N-S/E-W alignment of structures, and alignment with adjacent wind farm structures.
D	Vessel anchor or fishing gear snag on Project subsea cable	To reduce the risks associated with these hazards, the cable target burial depth is one meter (3.28 ft) and includes at least a single armor layer. Where possible, the cable will be buried to a depth of four to six feet deep. Cable protection measures will be employed where cable burial depth is not adequate. To ensure the risk is sufficiently mitigated, a separate cable burial risk assessment will be conducted for the Project, and the results of that study will inform the depth of burial as well as cable protection measures for the Project.
E	Vessel less certain of its location; Coast Guard locating a vessel	Lighting and marking of project structures according to U.S. requirements.
E	Vessel less certain of its course or location relative to the wind farm	Additional ATON associated with the Project.
E	Vessel less certain of its course or location relative to the wind farm	Project structures equipped with AIS technology.
P	Vessel close to Project construction activity	Safety zones around Project construction activities.
P	Vessel not aware of high level of activity in the Project Area	Notices to Mariners during construction, operation, and decommissioning activities. These may be published on and broadcasted though regular radio communications, online information for mariners, and Notices to Mariners from the Coast Guard.
P	Project construction activities in unsafe conditions	A Project construction guideline will define a window related to wind, sea state, and other constraints under which construction activities will start/continue or will stop/be discontinued. Conditions and forecasts will be monitored to enable proactive planning and early warning of future unsafe conditions.

Type *	Threat or hazard	Primary mitigation
P	Unsafe operation of the wind farm or continued operation of the wind farm during emergency conditions	A 24-hour operational monitoring center is planned to verify safe conditions are being maintained. The monitoring center will have the ability to remotely operate and shut down WTGs if required.
P	Vessel not aware of Project-related hazards	Locations and details of offshore Project components will be provided to NOAA so they can be included on nautical charts. The Project intends to work closely with Coast Guard and NOAA to chart all elements of the Project and have frequent communication with local mariners on location and status of Project activities, vessels, and components.
P	Fishing vessel not aware of Project-related hazards	Frequent updates on offshore activities to fishermen will be provided via: • Project fisheries liaisons and local fisheries representatives based in regional ports • Online updates for mariners • Twice-daily updates on VHF channels.
O	Fishing gear snag on Project component	Project process for gear-loss/damage claims.
O	Ineffective emergency procedures	Emergency communication protocols and shut-down procedures will be exercised.
O	Delay in reaching injured worker in a WTG	Offshore enclosed spaces will be capable of being opened from the outside to allow emergency access.

* (D) Design; (E) Equipment; (P) Procedures and Communication; (O) Other.

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APPENDIX A – AIS MAPS

This appendix contains maps of marine traffic showing AIS tracks, AIS density, and vessel speed.

AIS data analysis

The marine patterns and traffic statistics in the Study Area were determined utilizing AIS data. One year of AIS data typically provides a quantifiable and reliable set of data to determine the primary traffic patterns and analyze the size, speed, and movements of vessels in a region. For the Study Area, AIS data were purchased from Marine Traffic for the most recent available full-year period (MarineTraffic, 2019).

AIS data are converted into vessel tracks and vessel densities.

The AIS treatment methodology is schematically represented in Figure A-1.

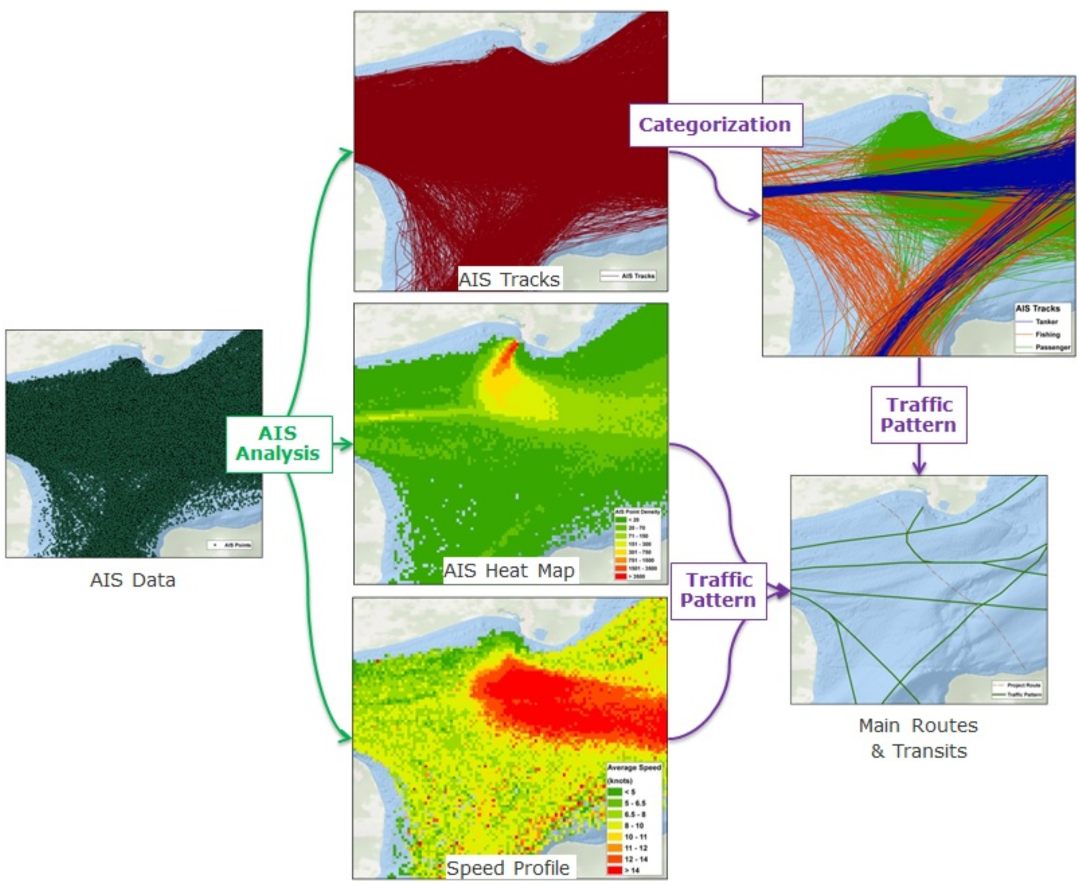
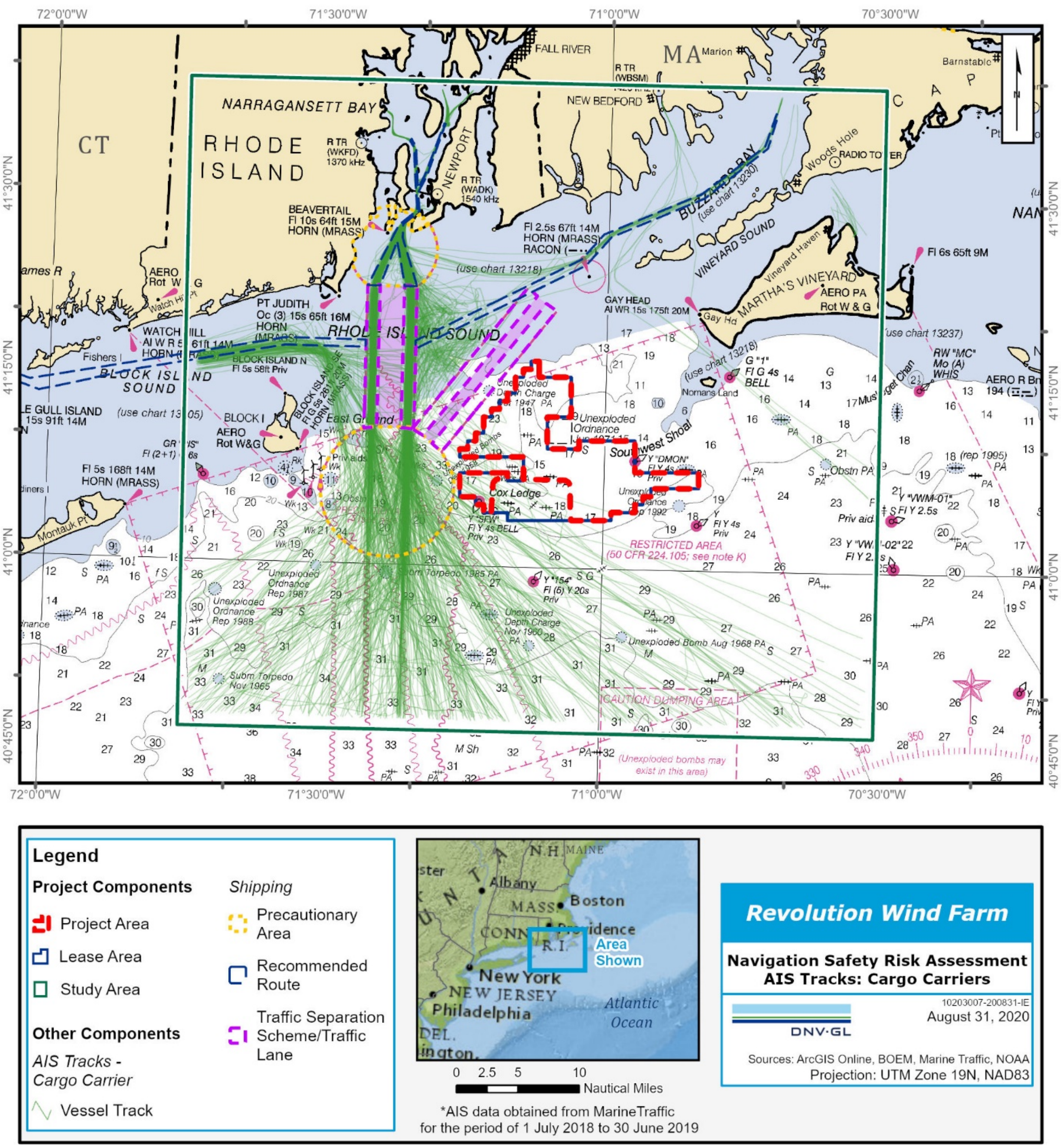
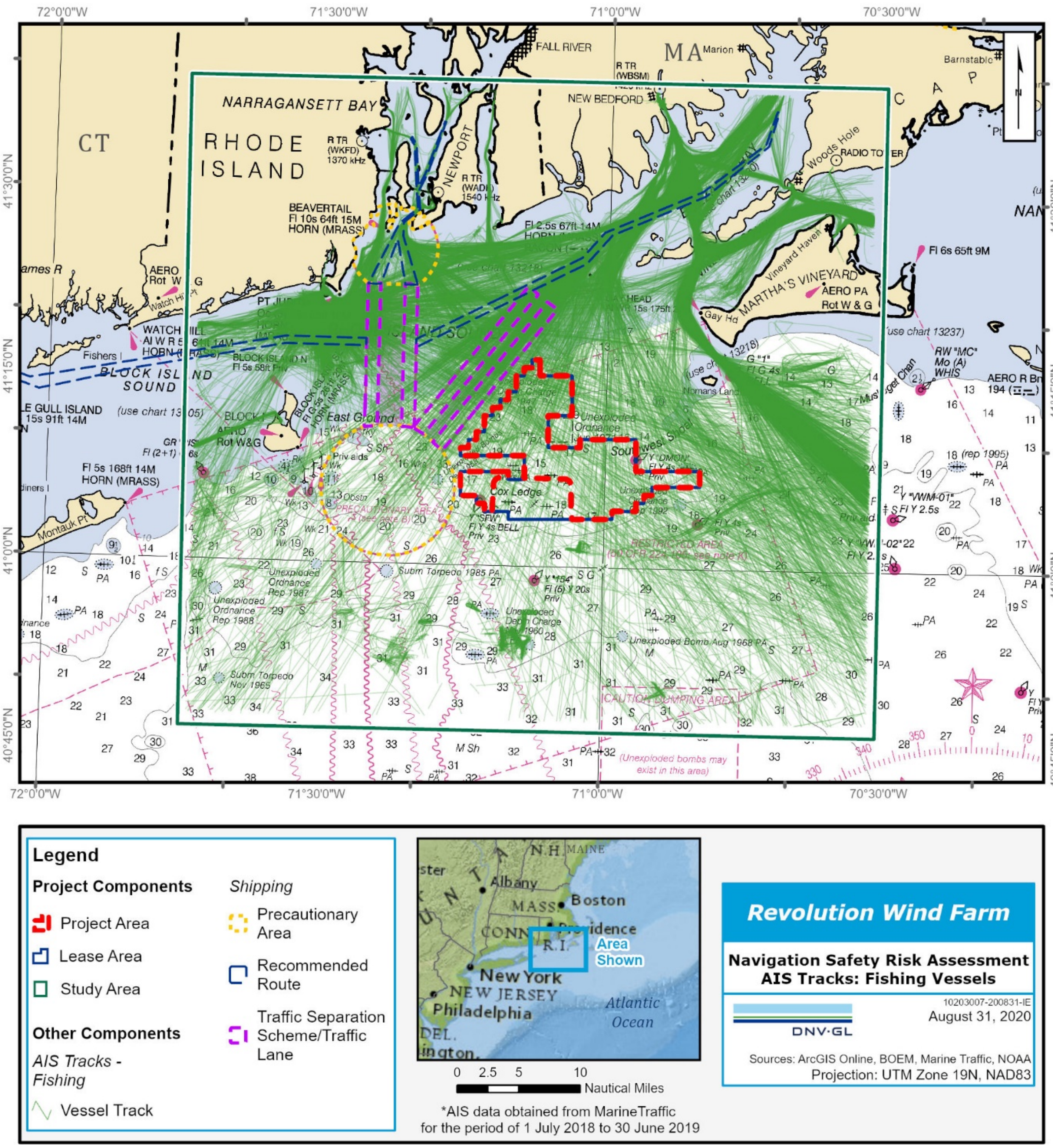


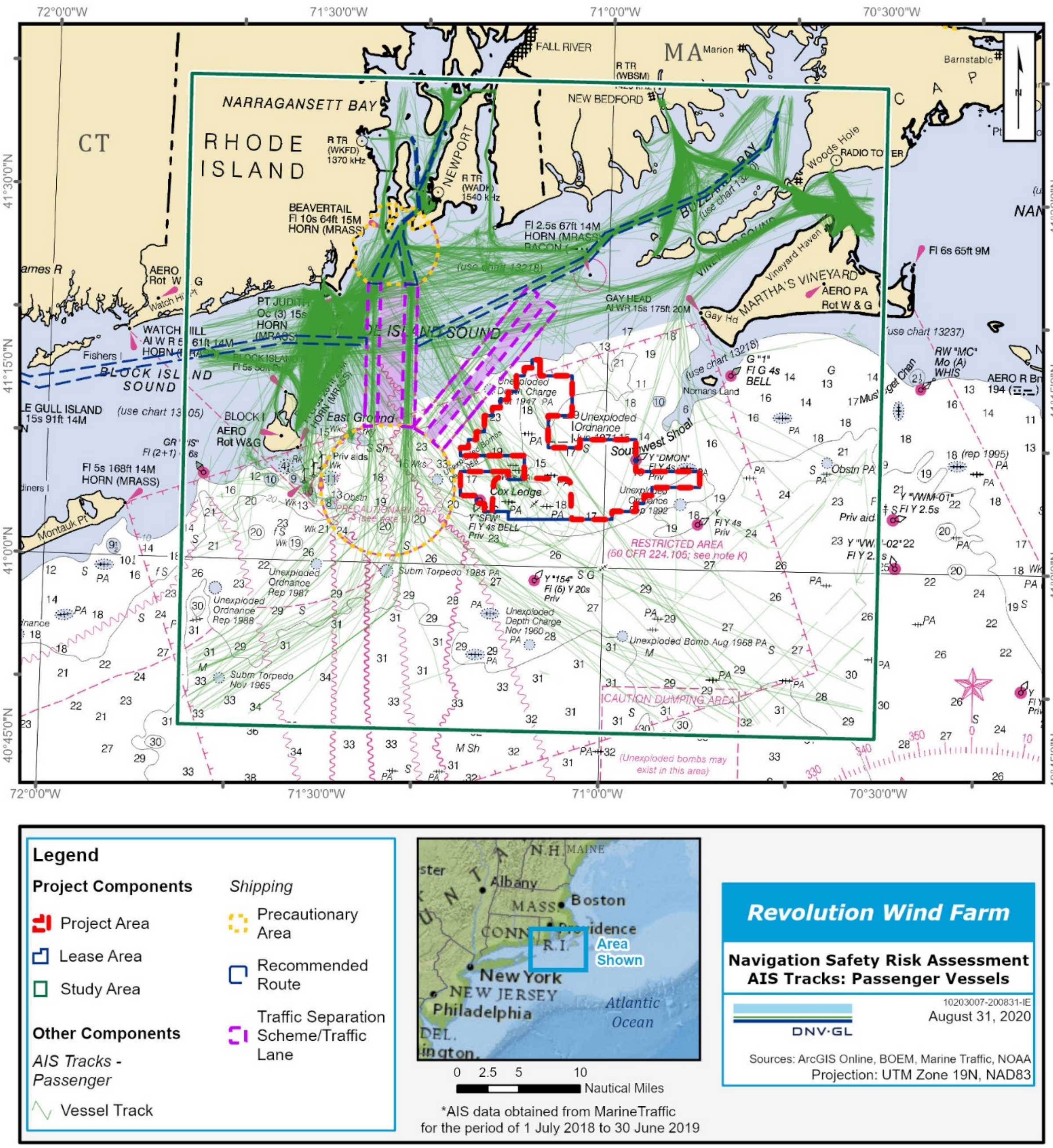
Figure A-1 AIS treatment methodology

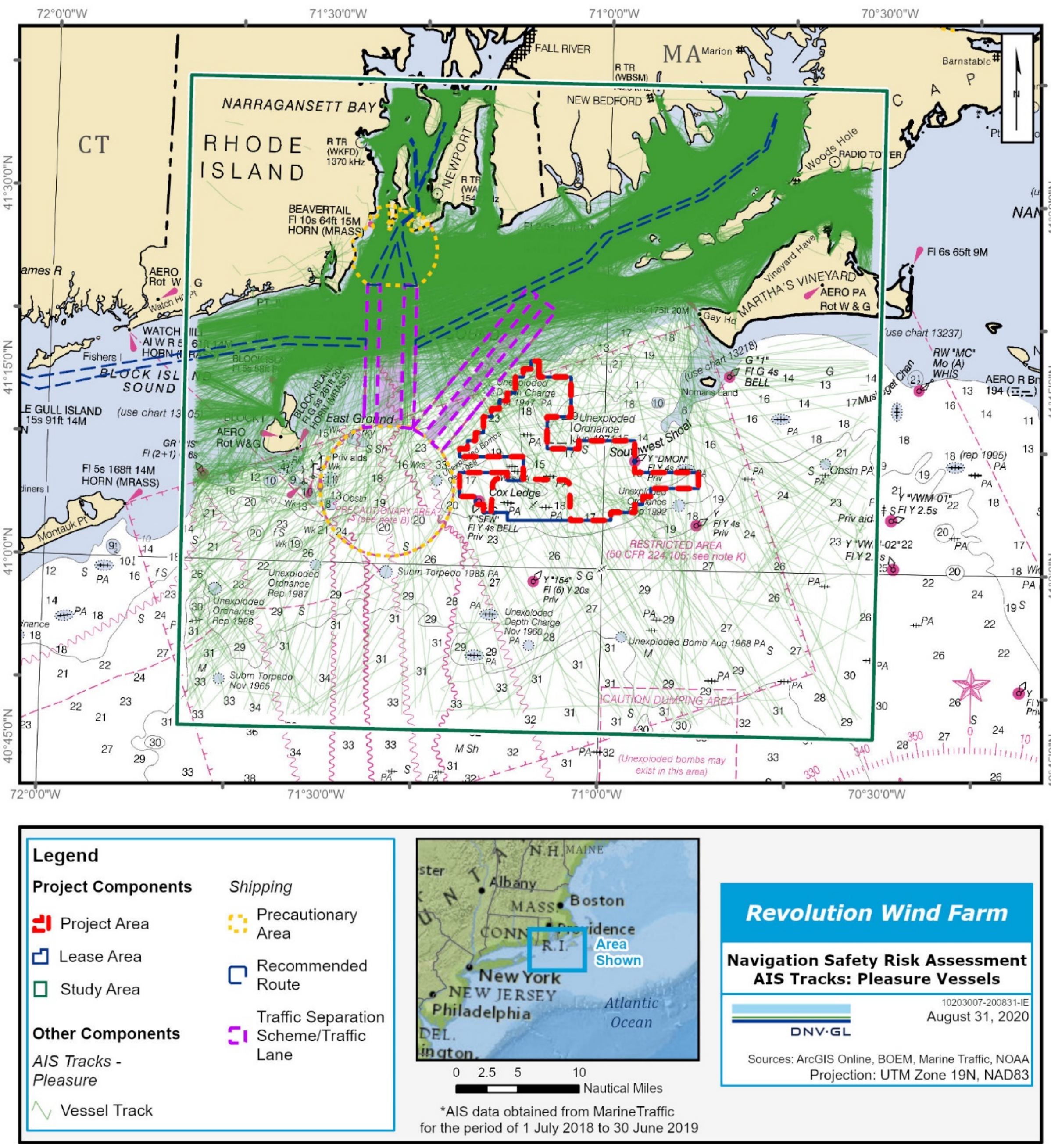
A.1 AIS track maps by vessel type

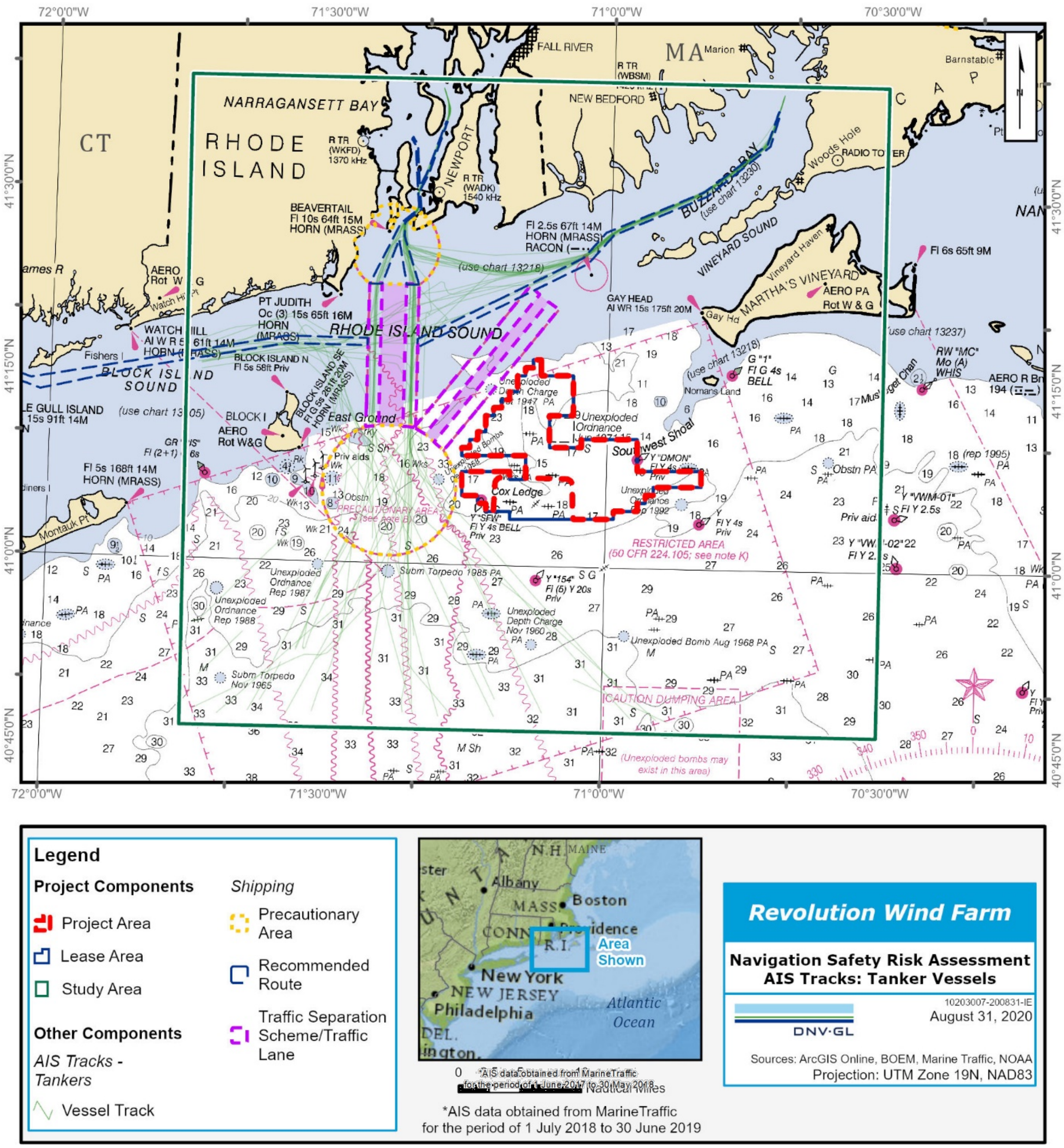
The data were spatially analyzed based on timestamp and proximity to create vessel tracks. Each vessel track represents a transit of a single vessel in the Study Area.



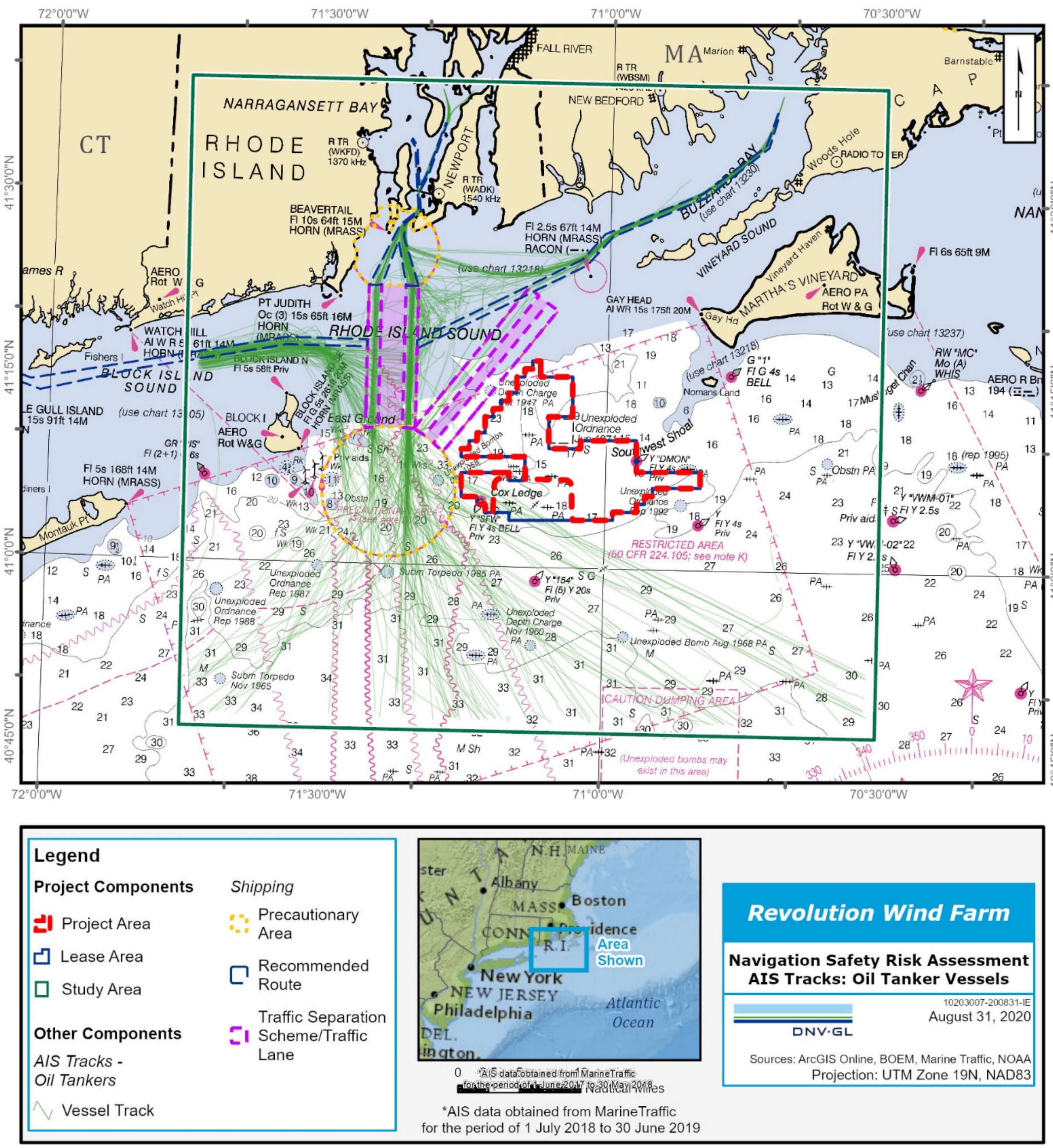

72°0'0"W
71°30'0"W
71°0'0"W
70°30'0"W
41°30'0"N
41°15'0"N
41°0'0"N
40°45'0"N
CT
RHODE ISLAND
NARRAGANSETT BAY
MA
NEWPORT
NEW BEDFORD
FALL RIVER
BLOCK ISLAND SOUND
MARTHA'S VINEYARD
Nomans Land
Cox Ledge
East Ground
PRECAUTIONARY AREA
CAUTION DUMPING AREA
(Unexploded bombs may exist in this area)
Legend
Project Components
Project Area
Lease Area
Study Area
Other Components
AIS Tracks - Fishing
Vessel Track
Shipping
Precautionary Area
Recommended Route
Traffic Separation Scheme/Traffic Lane
Boston
Albany
New York
Philadelphia
Atlantic Ocean
Area Shown
0 2.5 5 10
Nautical Miles
*AIS data obtained from MarineTraffic for the period of 1 July 2018 to 30 June 2019
Revolution Wind Farm
Navigation Safety Risk Assessment
AIS Tracks: Fishing Vessels
10203007-200831-IE
August 31, 2020
DNV·GL
Sources: ArcGIS Online, BOEM, Marine Traffic, NOAA
Projection: UTM Zone 19N, NAD83

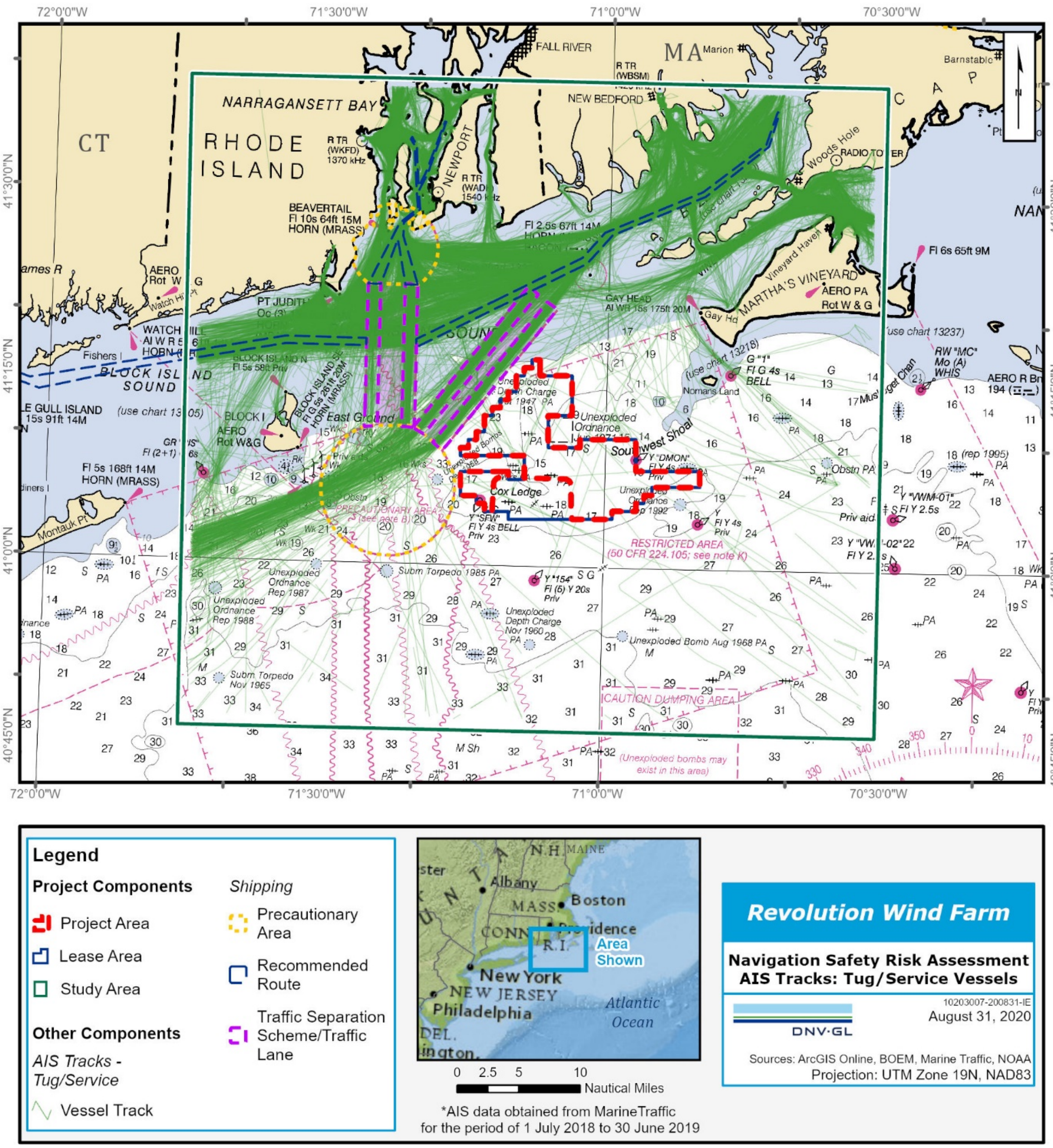

Legend
Project Components
Project Area
Lease Area
Study Area
Other Components
AIS Tracks - Passenger
Vessel Track
Shipping
Precautionary Area
Recommended Route
Traffic Separation Scheme/Traffic Lane
Area Shown
0 2.5 5 10 Nautical Miles
*AIS data obtained from MarineTraffic for the period of 1 July 2018 to 30 June 2019
Revolution Wind Farm
Navigation Safety Risk Assessment
AIS Tracks: Passenger Vessels
10203007-200831-IE
August 31, 2020
DNV·GL
Sources: ArcGIS Online, BOEM, Marine Traffic, NOAA
Projection: UTM Zone 19N, NAD83
RHODE ISLAND
NARRAGANSETT BAY
CT
MA
MARTHA'S VINEYARD
RHODE ISLAND SOUND
BLOCK ISLAND SOUND
Cox Ledge
Southwest Shoal
72°0'0"W
71°30'0"W
71°0'0"W
70°30'0"W
41°30'0"N
41°15'0"N
41°0'0"N
40°45'0"N


Legend
Project Components
Project Area
Lease Area
Study Area
Other Components
AIS Tracks - Pleasure
Vessel Track
Shipping
Precautionary Area
Recommended Route
Traffic Separation Scheme/Traffic Lane
Area Shown
0 2.5 5 10 Nautical Miles
*AIS data obtained from MarineTraffic for the period of 1 July 2018 to 30 June 2019
Revolution Wind Farm
Navigation Safety Risk Assessment
AIS Tracks: Pleasure Vessels
10203007-200831-IE
August 31, 2020
DNV·GL
Sources: ArcGIS Online, BOEM, Marine Traffic, NOAA
Projection: UTM Zone 19N, NAD83



72°0'0"W
71°30'0"W
71°0'0"W
70°30'0"W
41°30'0"N
41°15'0"N
41°0'0"N
40°45'0"N
CT
RHODE ISLAND
MA
NARRAGANSETT BAY
RHODE ISLAND SOUND
BLOCK ISLAND SOUND
BUZZARDS BAY
VINEYARD SOUND
MARTHA'S VINEYARD
NEW BEDFORD
FALL RIVER
NEWPORT
Cox Ledge
Southwest Shoal
PRECAUTIONARY AREA
RESTRICTED AREA
(50 CFR 224.105; see note K)
CAUTION DUMPING AREA
Legend
Project Components
Project Area
Lease Area
Study Area
Other Components
AIS Tracks - Tankers
Vessel Track
Shipping
Precautionary Area
Recommended Route
Traffic Separation Scheme/Traffic Lane
Albany
Boston
Providence
New York
NEW JERSEY
Philadelphia
Atlantic Ocean
Area Shown
*AIS data obtained from MarineTraffic for the period of 1 July 2018 to 30 June 2019
Revolution Wind Farm
Navigation Safety Risk Assessment
AIS Tracks: Tanker Vessels
10203007-200831-IE
August 31, 2020
DNV·GL
Sources: ArcGIS Online, BOEM, Marine Traffic, NOAA
Projection: UTM Zone 19N, NAD83


Legend
Project Components
Project Area
Lease Area
Study Area
Other Components
AIS Tracks - Oil Tankers
Vessel Track
Shipping
Precautionary Area
Recommended Route
Traffic Separation Scheme/Traffic Lane
Area Shown
*AIS data obtained from MarineTraffic for the period of 1 July 2018 to 30 June 2019
Revolution Wind Farm
Navigation Safety Risk Assessment
AIS Tracks: Oil Tanker Vessels
10203007-200831-IE
August 31, 2020
DNV·GL
Sources: ArcGIS Online, BOEM, Marine Traffic, NOAA
Projection: UTM Zone 19N, NAD83
RHODE ISLAND
NARRAGANSETT BAY
RHODE ISLAND SOUND
BLOCK ISLAND SOUND
VINEYARD SOUND
MARTHA'S VINEYARD
BUZZARDS BAY
Cox Ledge
RESTRICTED AREA
CAUTION DUMPING AREA



Legend
Project Components
Project Area
Lease Area
Study Area
Other Components
AIS Tracks - Tug/Service
Vessel Track
Shipping
Precautionary Area
Recommended Route
Traffic Separation Scheme/Traffic Lane
Area Shown
0 2.5 5 10 Nautical Miles
*AIS data obtained from MarineTraffic for the period of 1 July 2018 to 30 June 2019
Revolution Wind Farm
Navigation Safety Risk Assessment
AIS Tracks: Tug/Service Vessels
10203007-200831-IE
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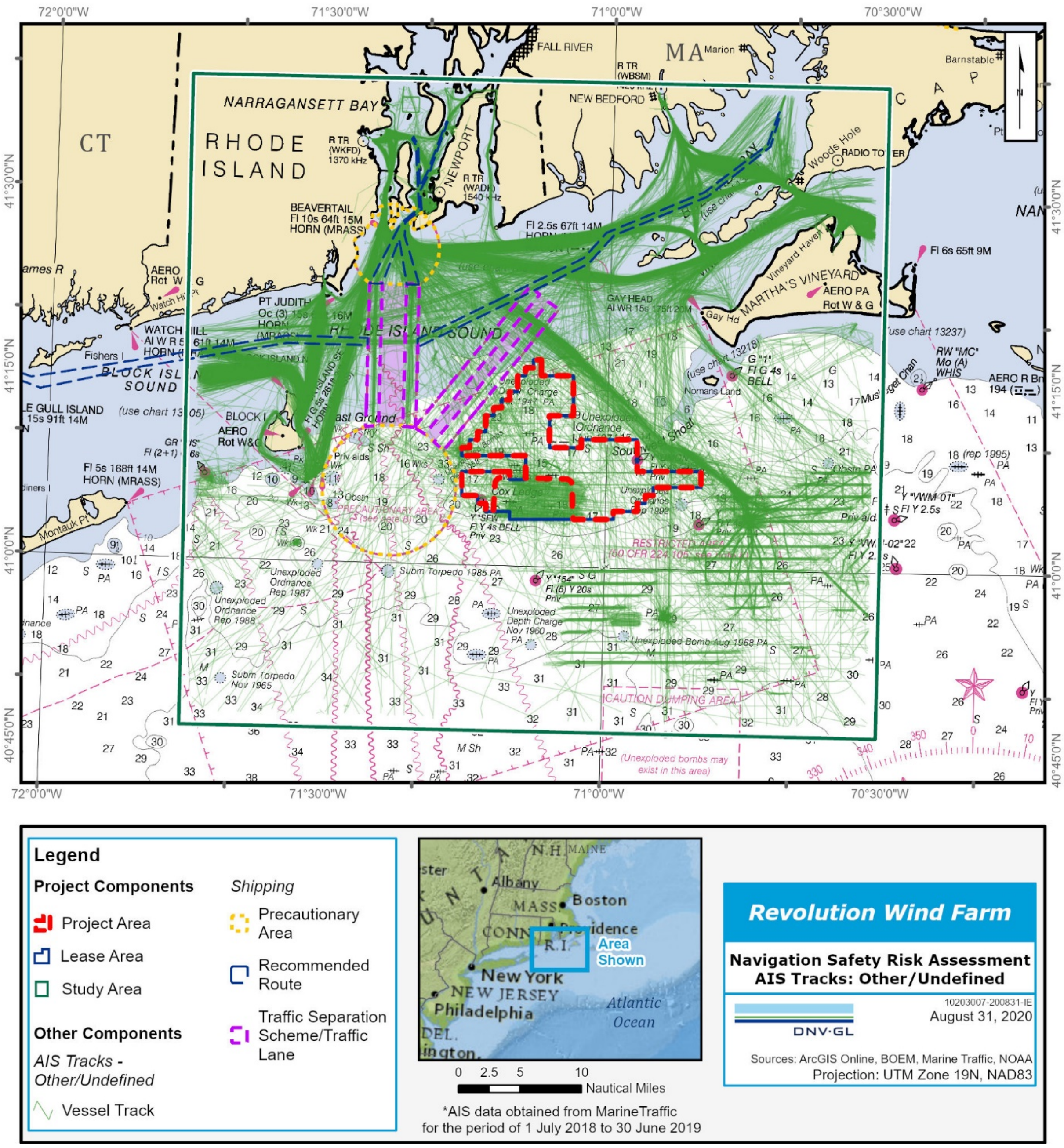
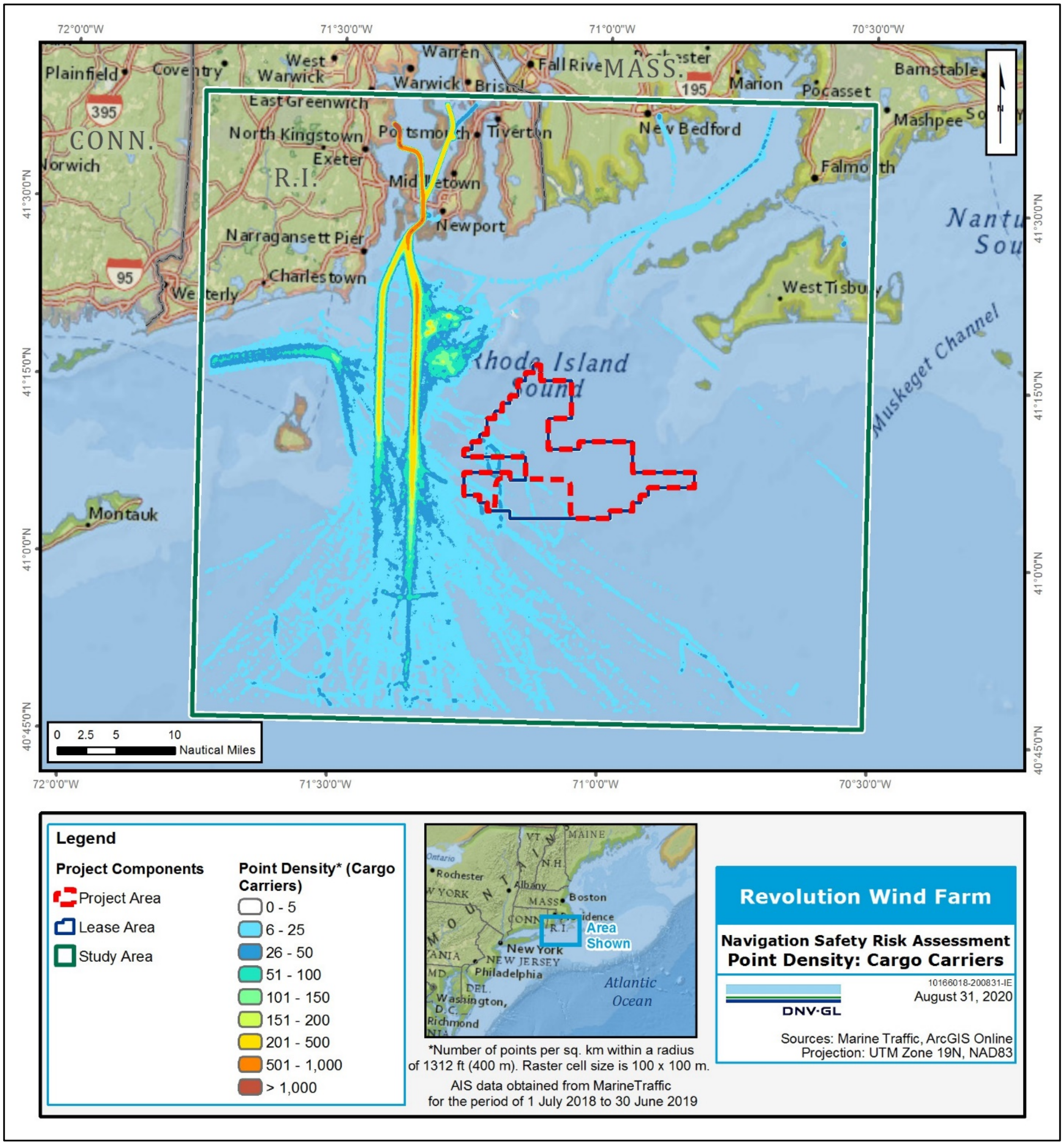
Sources: ArcGIS Online, BOEM, Marine Traffic, NOAA
Projection: UTM Zone 19N, NAD83
72°0'0"W
71°30'0"W
71°0'0"W
70°30'0"W
41°30'0"N
41°15'0"N
41°0'0"N
40°45'0"N
CT
RHODE ISLAND
NARRAGANSETT BAY
MA
MARTHA'S VINEYARD
NEW BEDFORD
FALL RIVER
BLOCK ISLAND SOUND
Cox Ledge
Southwest Shoal
RESTRICTED AREA
CAUTION DUMPING AREA
PRECAUTIONARY AREA

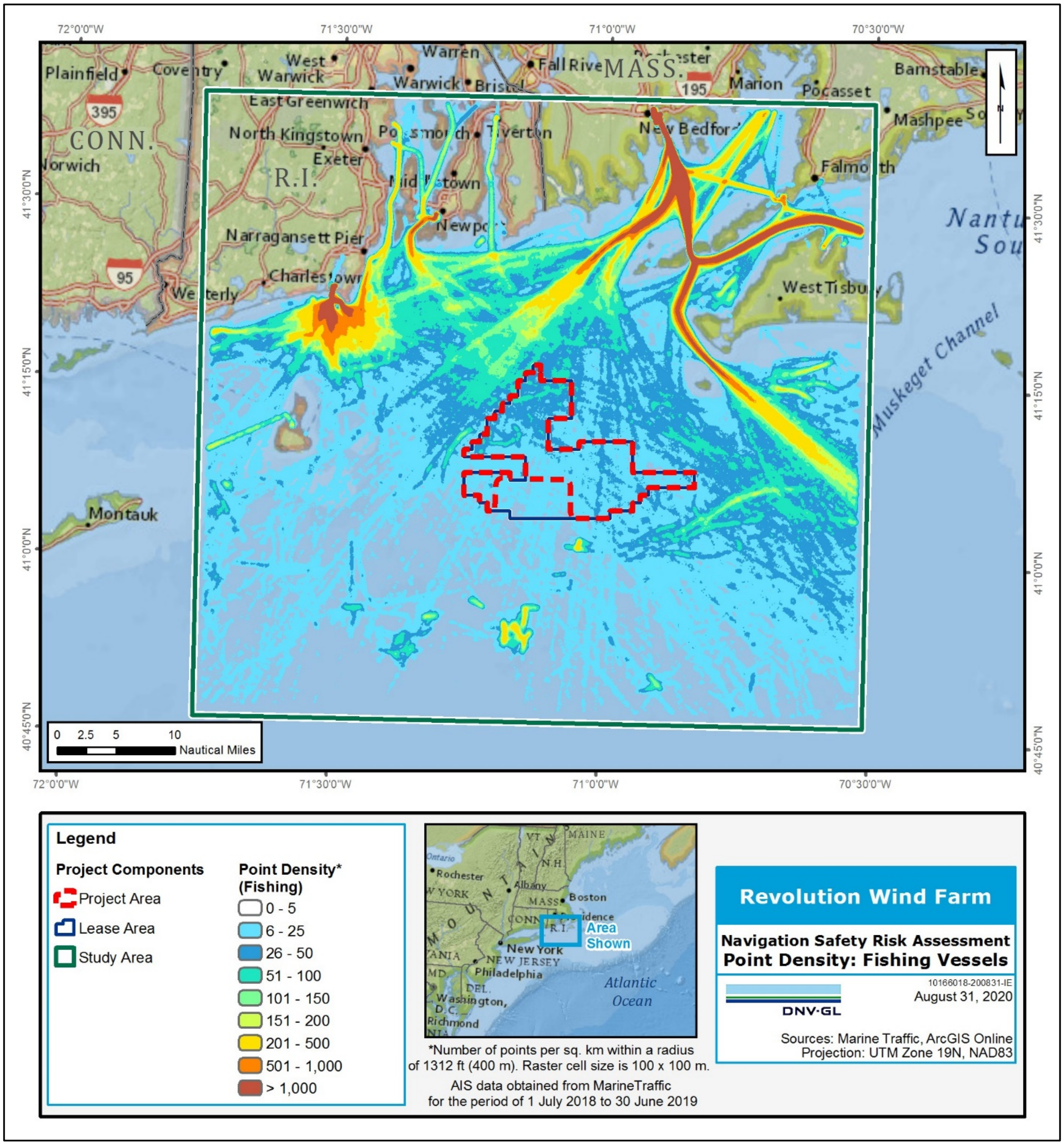


A.2 AIS point density maps by vessel type

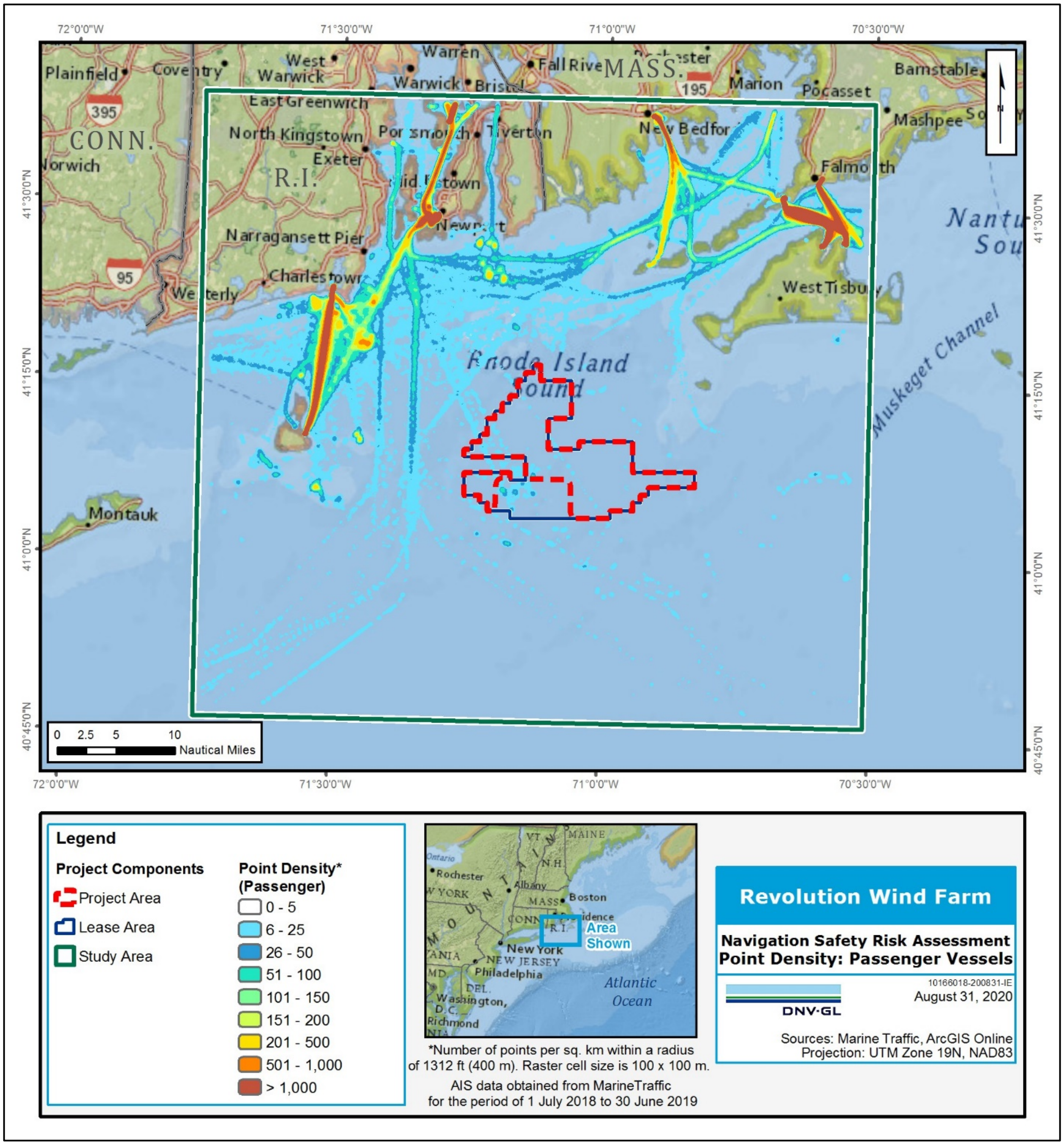
The figures in this section present density heat maps for all AIS points in the Study Area. The density is calculated by determining the number of AIS data points within a square kilometer grid cell.



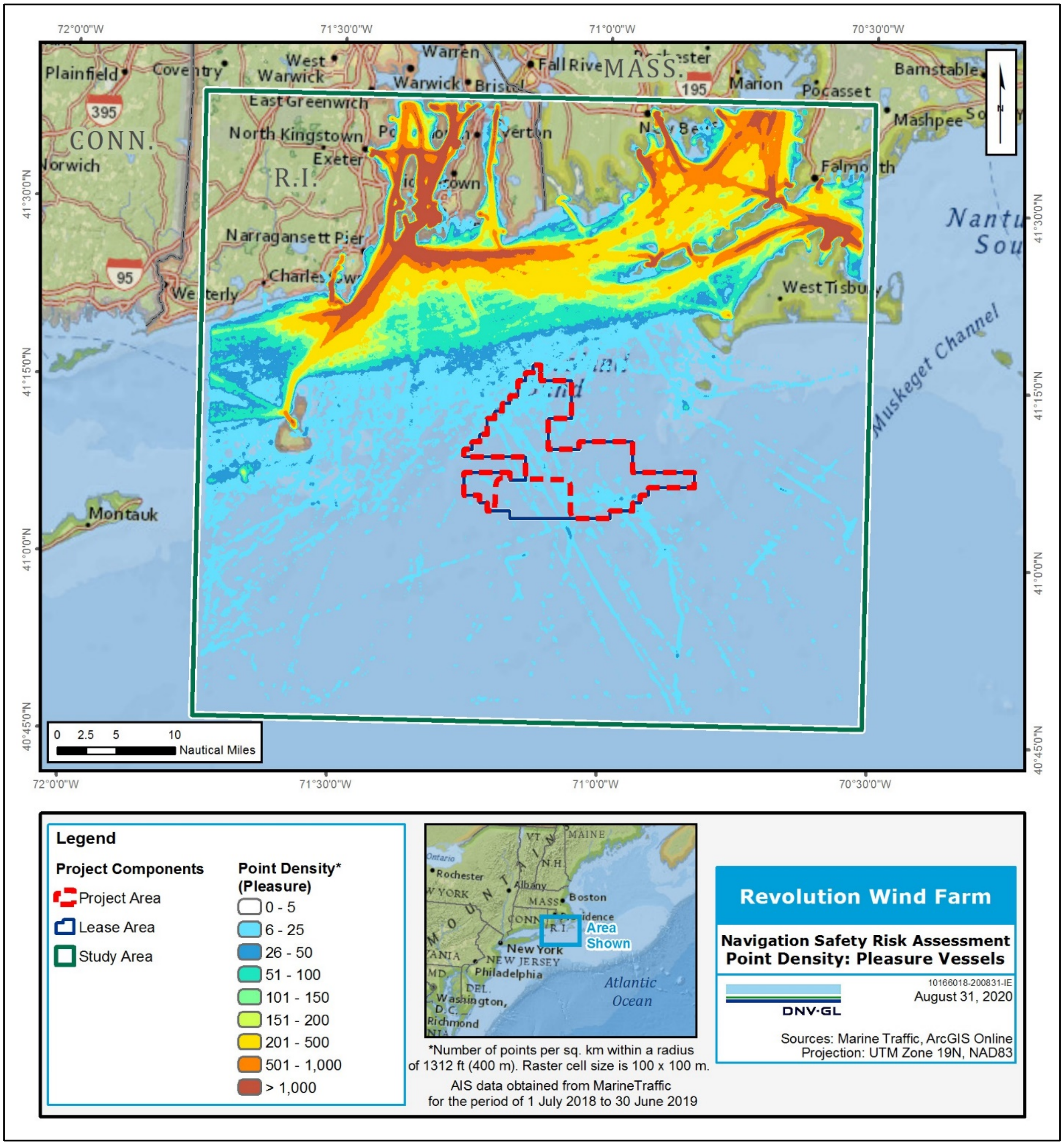
Legend
Project Components
Project Area
Lease Area
Study Area
Point Density* (Cargo Carriers)
0 - 5
6 - 25
26 - 50
51 - 100
101 - 150
151 - 200
201 - 500
501 - 1,000
> 1,000
Area Shown
*Number of points per sq. km within a radius of 1312 ft (400 m). Raster cell size is 100 x 100 m.
AIS data obtained from MarineTraffic for the period of 1 July 2018 to 30 June 2019
Revolution Wind Farm
Navigation Safety Risk Assessment
Point Density: Cargo Carriers
10166018-200831-IE
August 31, 2020
DNV·GL
Sources: Marine Traffic, ArcGIS Online
Projection: UTM Zone 19N, NAD83



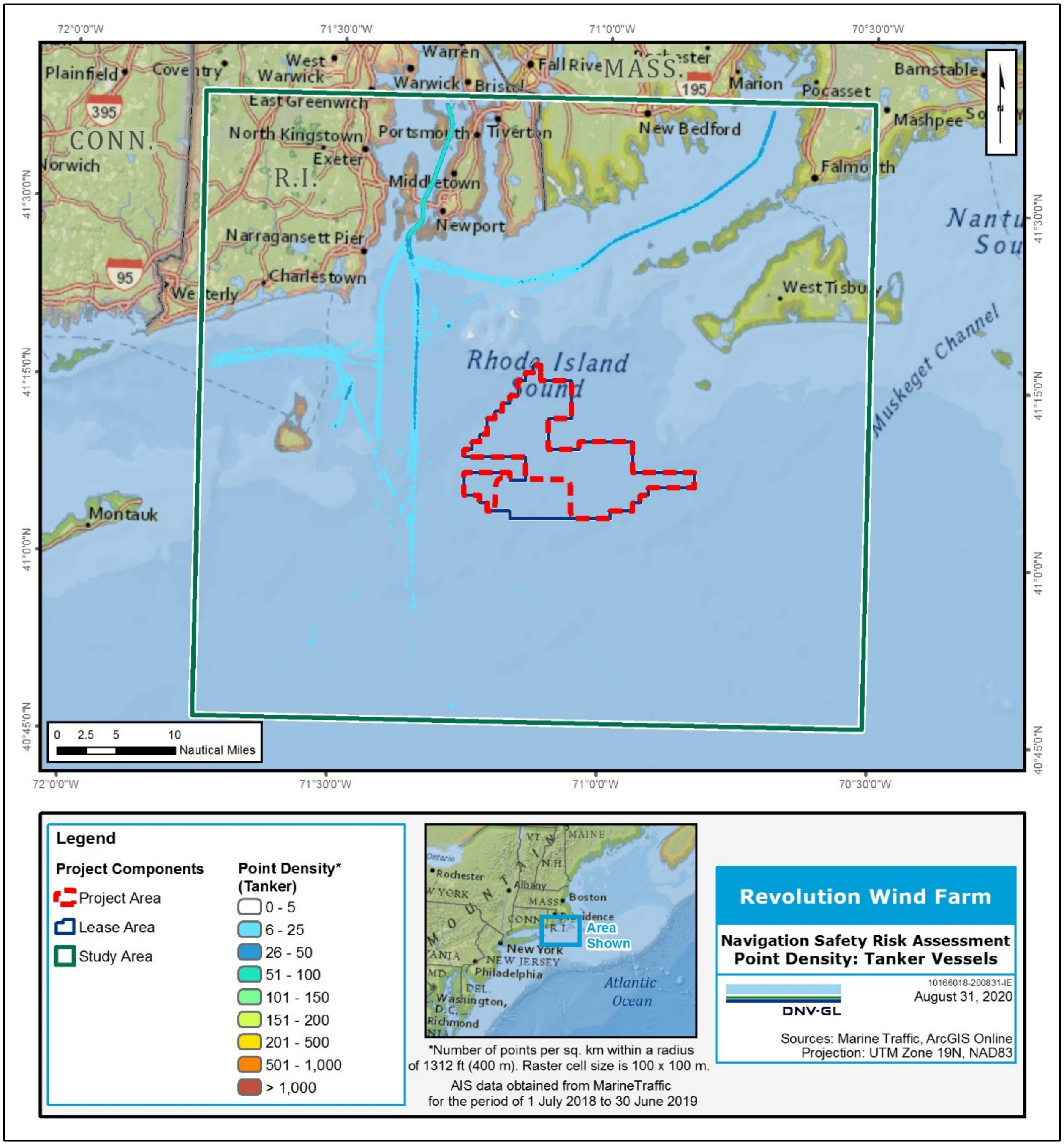
72°0'0"W
71°30'0"W
71°0'0"W
70°30'0"W
41°30'0"N
41°15'0"N
41°0'0"N
40°45'0"N
Plainfield
Coventry
West Warwick
Warren
Fall River
MASS.
Marion
Barnstable
Pocasset
Mashpee
Warwick
Bristol
East Greenwich
North Kingstown
Tiverton
Falmouth
CONN.
Norwich
Exeter
R.I.
Newport
Narragansett Pier
Charlestown
Westerly
West Tisbury
Muskeget Channel
Montauk
0 2.5 5 10 Nautical Miles
Legend
Project Components
Project Area
Lease Area
Study Area
Point Density* (Fishing)
0 - 5
6 - 25
26 - 50
51 - 100
101 - 150
151 - 200
201 - 500
501 - 1,000
> 1,000
MAINE
Rochester
Albany
Boston
NEW YORK
MASS
R.I.
Area Shown
New York
NEW JERSEY
Philadelphia
Washington, D.C.
Richmond
Atlantic Ocean
*Number of points per sq. km within a radius of 1312 ft (400 m). Raster cell size is 100 x 100 m.
AIS data obtained from MarineTraffic for the period of 1 July 2018 to 30 June 2019
Revolution Wind Farm
Navigation Safety Risk Assessment
Point Density: Fishing Vessels
10166018-200831-IE
August 31, 2020
DNV·GL
Sources: Marine Traffic, ArcGIS Online
Projection: UTM Zone 19N, NAD83



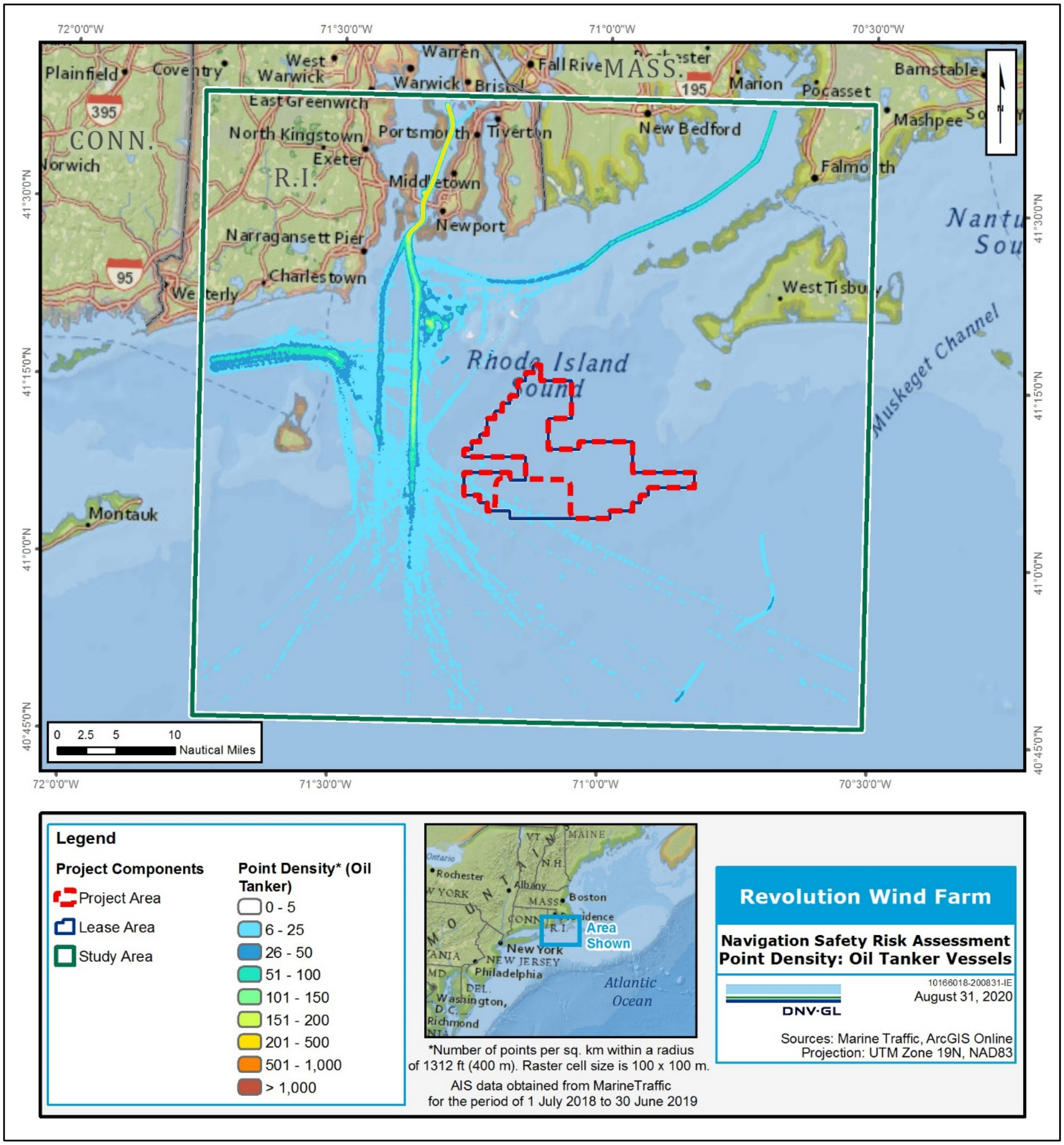
72°0'0"W
71°30'0"W
71°0'0"W
70°30'0"W
41°30'0"N
41°15'0"N
41°0'0"N
40°45'0"N
Plainfield
Coventry
West Warwick
Warren
Warwick
Bristol
Fall River
MASS.
Marion
Barnstable
Pocasset
Mashpee
East Greenwich
North Kingstown
Portsmouth
Tiverton
New Bedford
CONN.
Norwich
Exeter
R.I.
Falmouth
Newport
Narragansett Pier
Charlestown
Westerly
West Tisbury
Nantu
Sou
Muskeget Channel
Rhode Island Sound
Montauk
0 2.5 5 10
Nautical Miles
Legend
Project Components
Project Area
Lease Area
Study Area
Point Density* (Passenger)
0 - 5
6 - 25
26 - 50
51 - 100
101 - 150
151 - 200
201 - 500
501 - 1,000
> 1,000
MAINE
N.H.
Rochester
Albany
Boston
MASS.
R.I.
Area Shown
New York
NEW JERSEY
Philadelphia
Washington, D.C.
Richmond
Atlantic Ocean
*Number of points per sq. km within a radius of 1312 ft (400 m). Raster cell size is 100 x 100 m.
AIS data obtained from MarineTraffic for the period of 1 July 2018 to 30 June 2019
Revolution Wind Farm
Navigation Safety Risk Assessment
Point Density: Passenger Vessels
10166018-200831-IE
August 31, 2020
DNV·GL
Sources: Marine Traffic, ArcGIS Online
Projection: UTM Zone 19N, NAD83



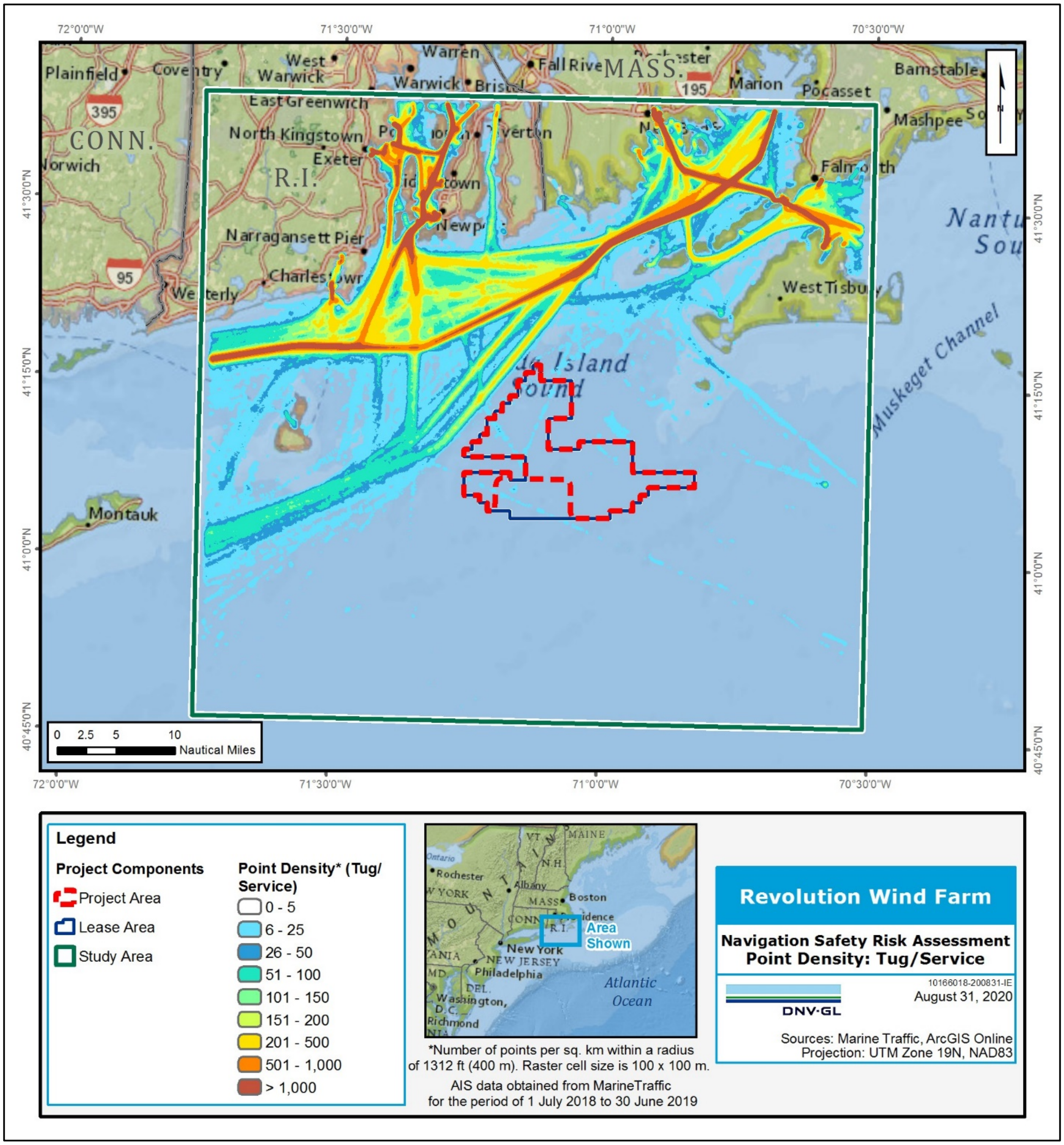
Legend
Project Components
Project Area
Lease Area
Study Area
Point Density* (Pleasure)
0 - 5
6 - 25
26 - 50
51 - 100
101 - 150
151 - 200
201 - 500
501 - 1,000
> 1,000
*Number of points per sq. km within a radius of 1312 ft (400 m). Raster cell size is 100 x 100 m.
AIS data obtained from MarineTraffic for the period of 1 July 2018 to 30 June 2019
Revolution Wind Farm
Navigation Safety Risk Assessment
Point Density: Pleasure Vessels
10166018-200831-IE
August 31, 2020
DNV·GL
Sources: Marine Traffic, ArcGIS Online
Projection: UTM Zone 19N, NAD83
0 2.5 5 10 Nautical Miles

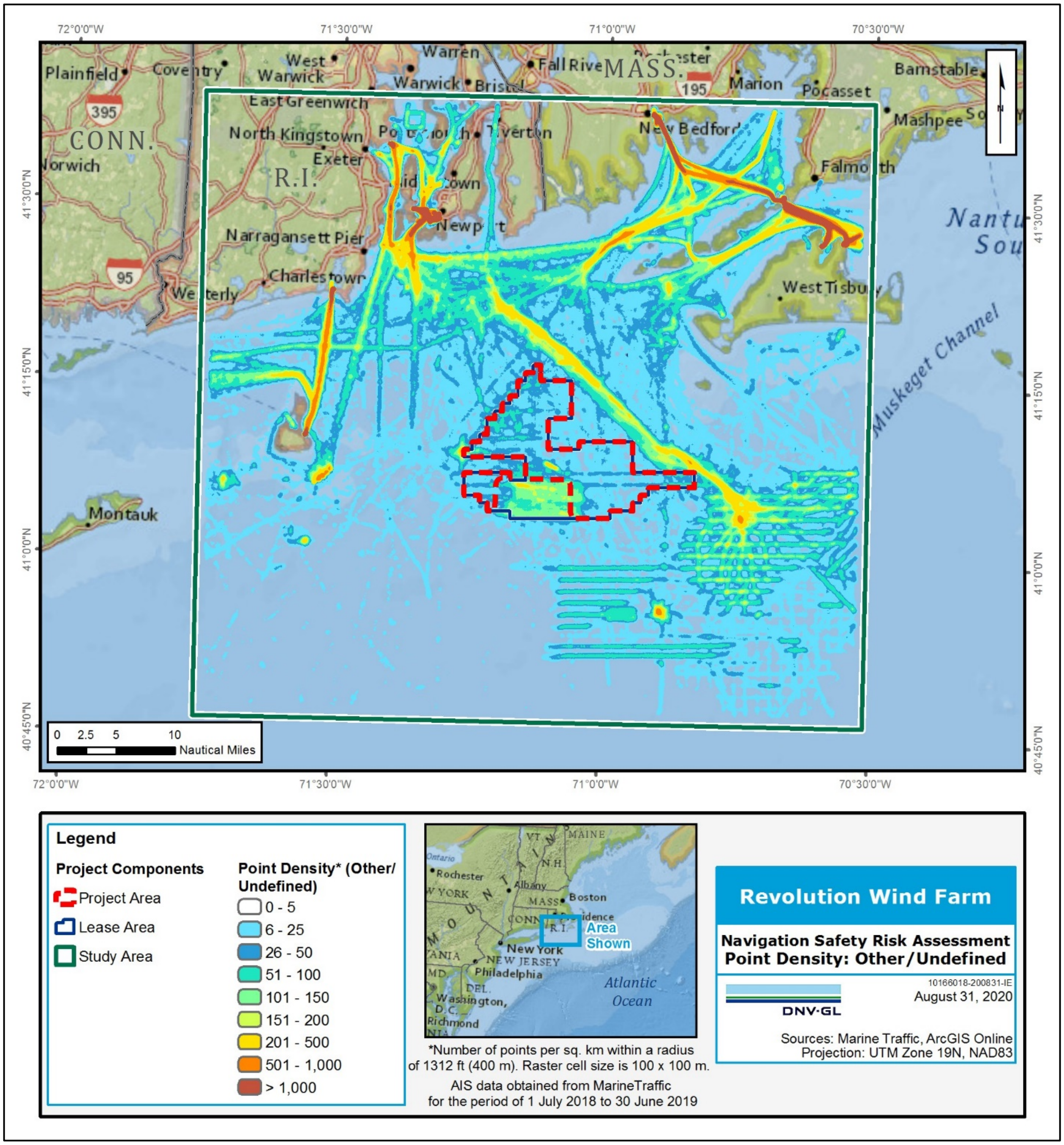


Legend
Project Components
Project Area
Lease Area
Study Area
Point Density* (Tanker)
0 - 5
6 - 25
26 - 50
51 - 100
101 - 150
151 - 200
201 - 500
501 - 1,000
> 1,000
*Number of points per sq. km within a radius of 1312 ft (400 m). Raster cell size is 100 x 100 m.
AIS data obtained from MarineTraffic for the period of 1 July 2018 to 30 June 2019
Revolution Wind Farm
Navigation Safety Risk Assessment
Point Density: Tanker Vessels
10166018-200831-IE
August 31, 2020
DNV·GL
Sources: Marine Traffic, ArcGIS Online
Projection: UTM Zone 19N, NAD83
Rhode Island Sound
Muskeget Channel
Nautical Miles



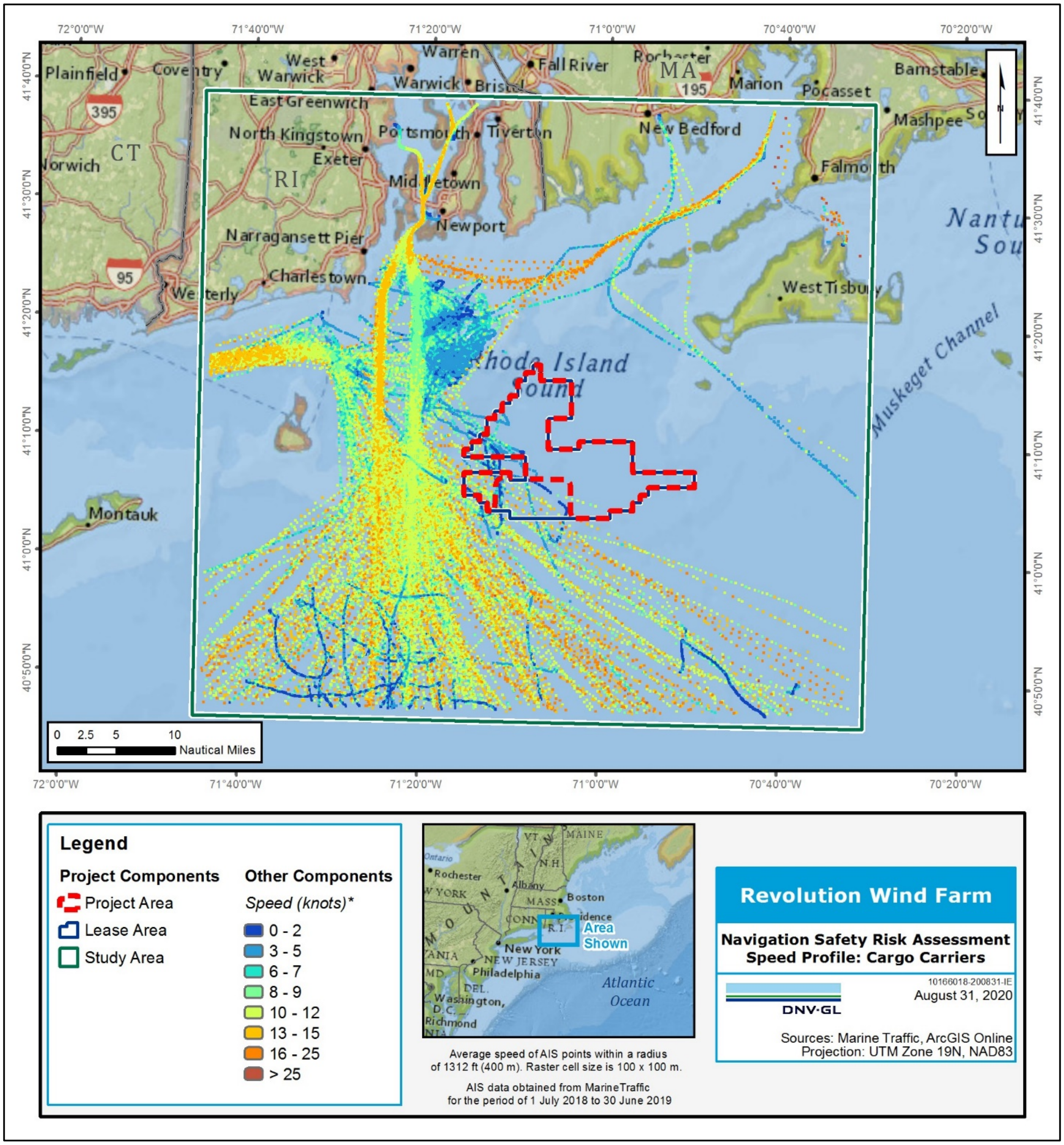
Revolution Wind Farm
Navigation Safety Risk Assessment
Point Density: Oil Tanker Vessels
10166018-200831-IE
August 31, 2020
DNV·GL
Sources: Marine Traffic, ArcGIS Online
Projection: UTM Zone 19N, NAD83
Legend
Project Components
Project Area
Lease Area
Study Area
Point Density* (Oil Tanker)
0 - 5
6 - 25
26 - 50
51 - 100
101 - 150
151 - 200
201 - 500
501 - 1,000
> 1,000
*Number of points per sq. km within a radius of 1312 ft (400 m). Raster cell size is 100 x 100 m.
AIS data obtained from MarineTraffic for the period of 1 July 2018 to 30 June 2019
Area Shown
Rhode Island Sound
Muskeget Channel
0 2.5 5 10 Nautical Miles

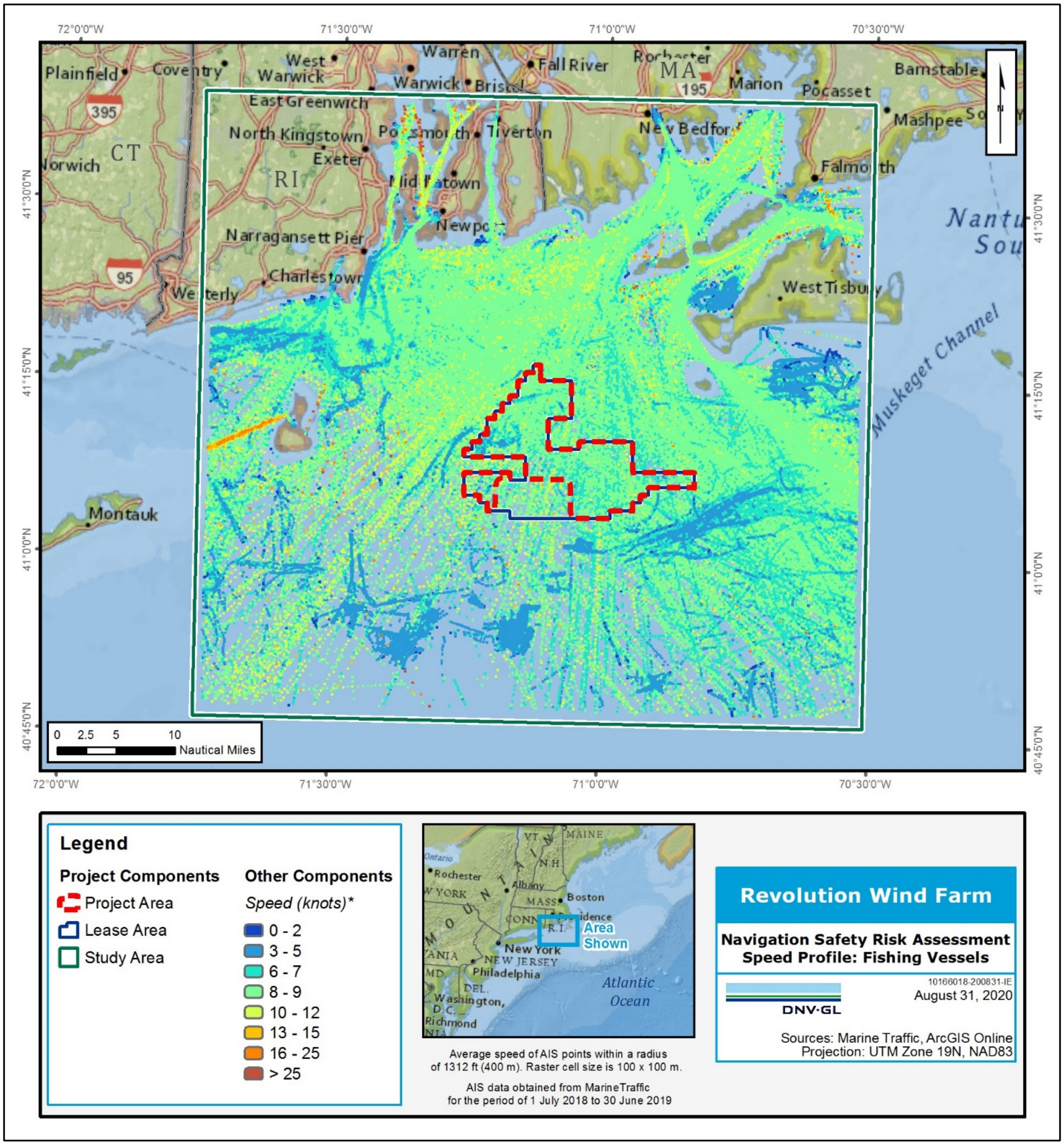

72°0'0"W
71°30'0"W
71°0'0"W
70°30'0"W
41°30'0"N
41°15'0"N
41°0'0"N
40°45'0"N
Plainfield
Coventry
West Warwick
Warren
Fall River
MASS.
Marion
Pocasset
Barnstable
Mashpee
Warwick
Bristol
East Greenwich
North Kingstown
Exeter
CONN.
Norwich
R.I.
Falmouth
Narragansett Pier
Newport
Charlestown
Westerly
West Tisbury
Nantucket Sound
Muskeget Channel
Montauk
395
95
195
0 2.5 5 10
Nautical Miles
Legend
Project Components
Project Area
Lease Area
Study Area
Point Density* (Tug/ Service)
0 - 5
6 - 25
26 - 50
51 - 100
101 - 150
151 - 200
201 - 500
501 - 1,000
> 1,000
Rochester
NEW YORK
Albany
MAINE
N.H.
VT
MASS
Boston
Providence
CONN
R.I.
Area Shown
New York
NEW JERSEY
Philadelphia
DEL.
MD.
Washington, D.C.
Richmond
Atlantic Ocean
*Number of points per sq. km within a radius of 1312 ft (400 m). Raster cell size is 100 x 100 m.
AIS data obtained from MarineTraffic for the period of 1 July 2018 to 30 June 2019
Revolution Wind Farm
Navigation Safety Risk Assessment
Point Density: Tug/Service
10166018-200831-IE
August 31, 2020
DNV·GL
Sources: Marine Traffic, ArcGIS Online
Projection: UTM Zone 19N, NAD83



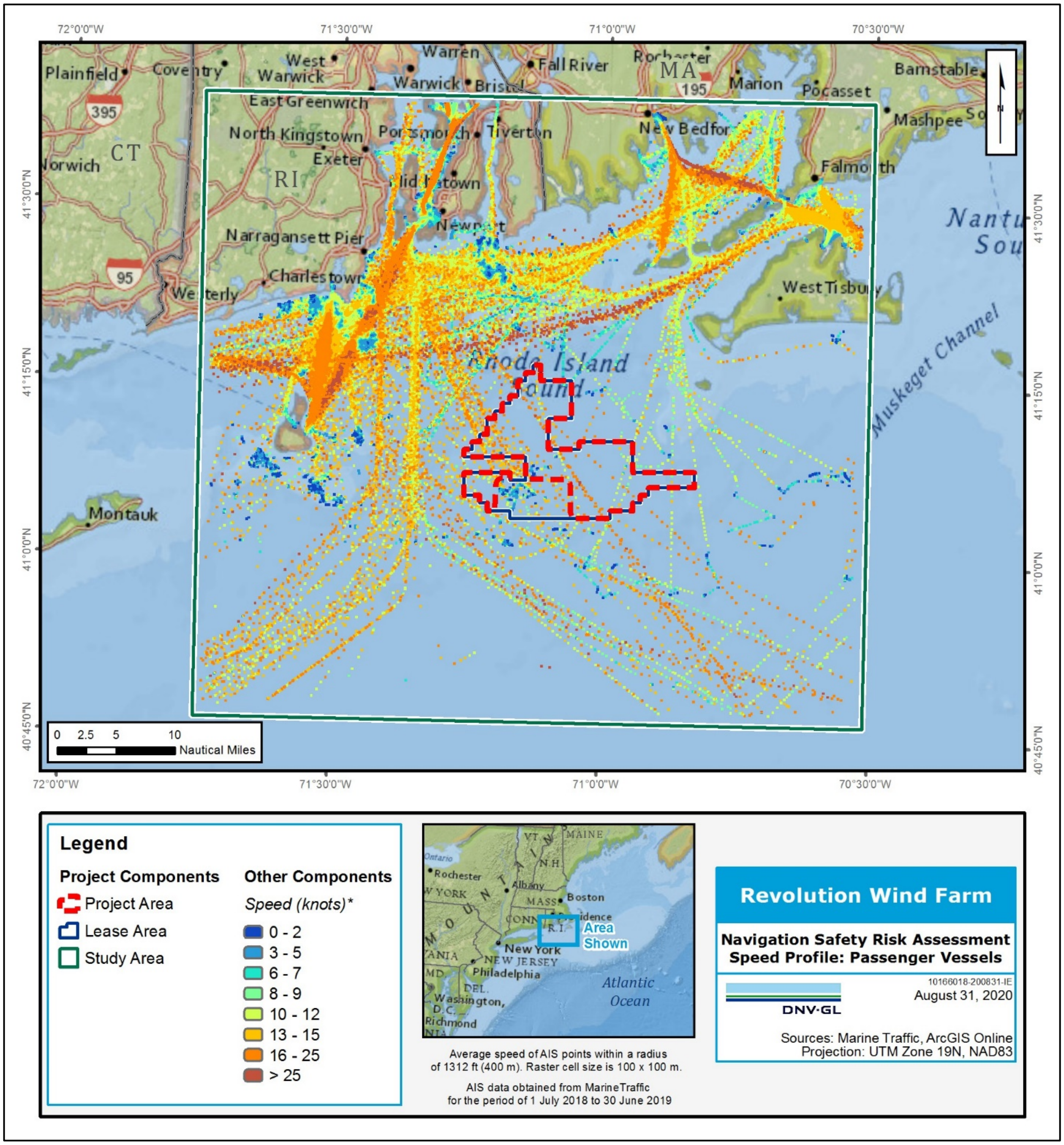
72°0'0"W
71°30'0"W
71°0'0"W
70°30'0"W
41°30'0"N
41°15'0"N
41°0'0"N
40°45'0"N
Plainfield
Coventry
West Warwick
Warren
Warwick
Bristol
Fall River
MASS.
Marion
Pocasset
Barnstable
Mashpee
CONN.
Norwich
East Greenwich
North Kingstown
Exeter
R.I.
Tiverton
New Bedford
Falmouth
Middletown
Newport
Narragansett Pier
Charlestown
Westerly
West Tisbury
Muskeget Channel
Montauk
395
95
195
0 2.5 5 10
Nautical Miles
Legend
Project Components
Project Area
Lease Area
Study Area
Point Density* (Other/ Undefined)
0 - 5
6 - 25
26 - 50
51 - 100
101 - 150
151 - 200
201 - 500
501 - 1,000
> 1,000
Rochester
Albany
Boston
MASS.
R.I.
Area Shown
New York
NEW JERSEY
Philadelphia
Washington, D.C.
Richmond
Atlantic Ocean
*Number of points per sq. km within a radius of 1312 ft (400 m). Raster cell size is 100 x 100 m.
AIS data obtained from MarineTraffic for the period of 1 July 2018 to 30 June 2019
Revolution Wind Farm
Navigation Safety Risk Assessment
Point Density: Other/Undefined
10166018-200831-IE
August 31, 2020
DNV·GL
Sources: Marine Traffic, ArcGIS Online
Projection: UTM Zone 19N, NAD83

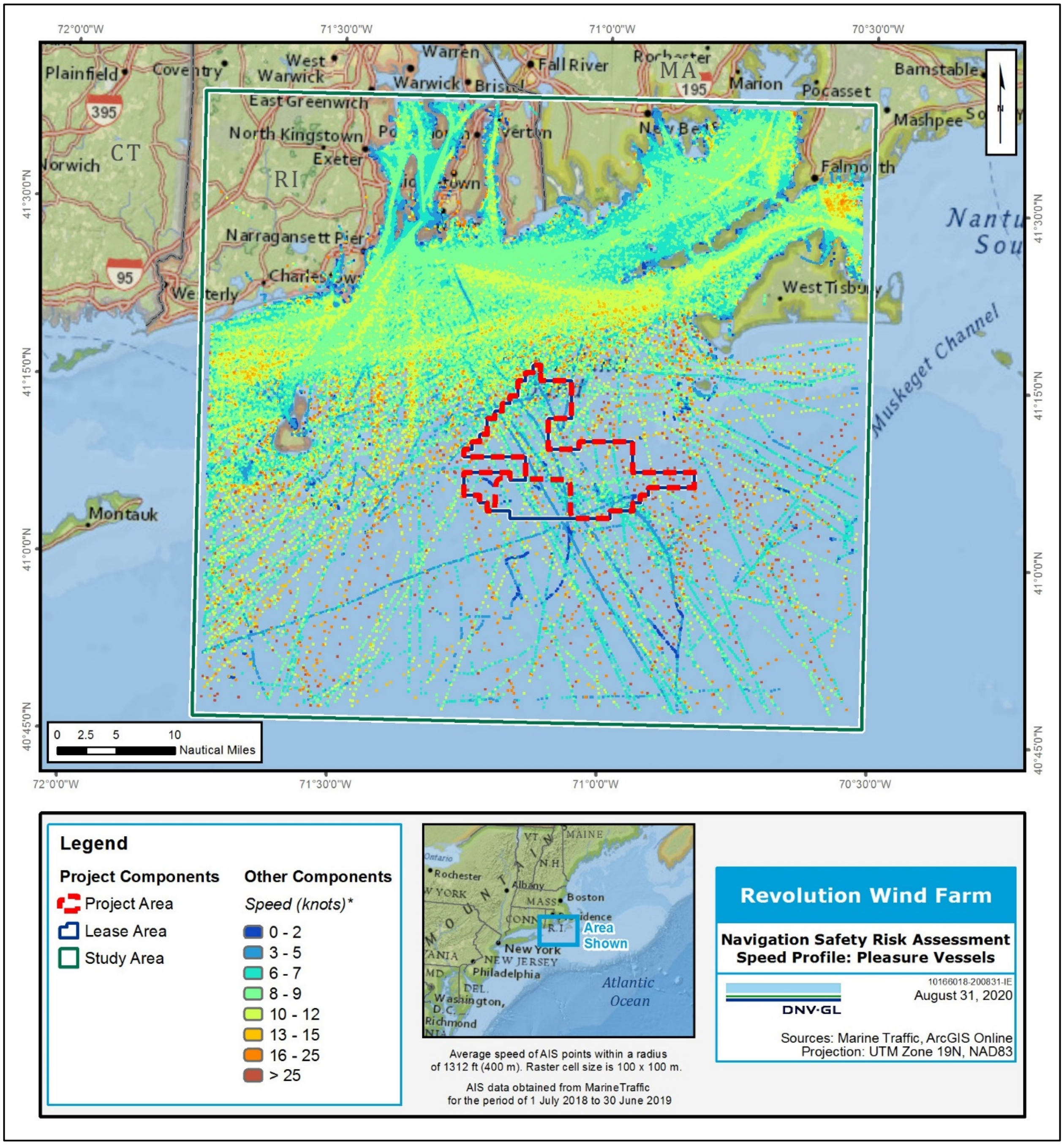
A.3 AIS speed profile by vessel type



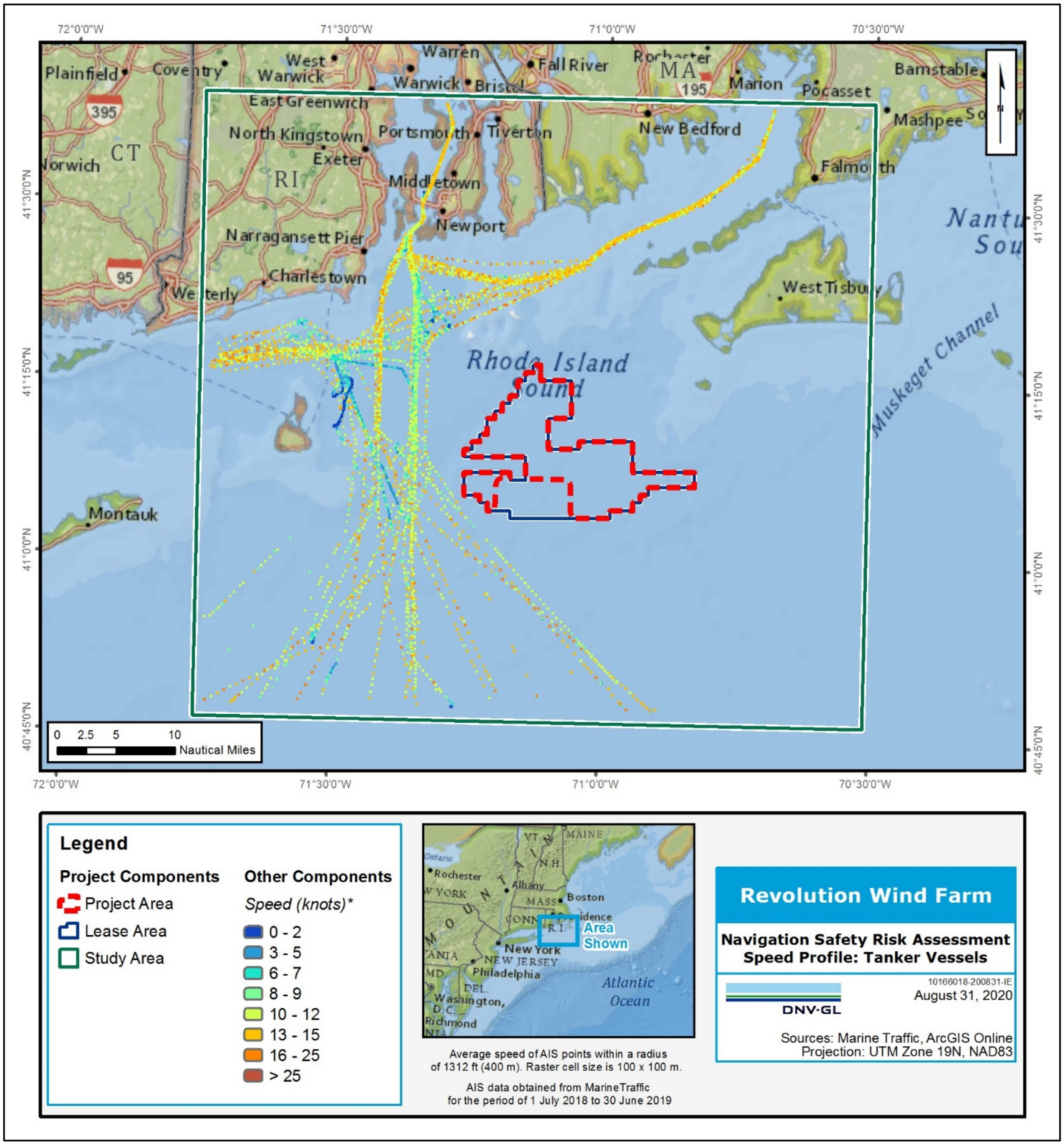


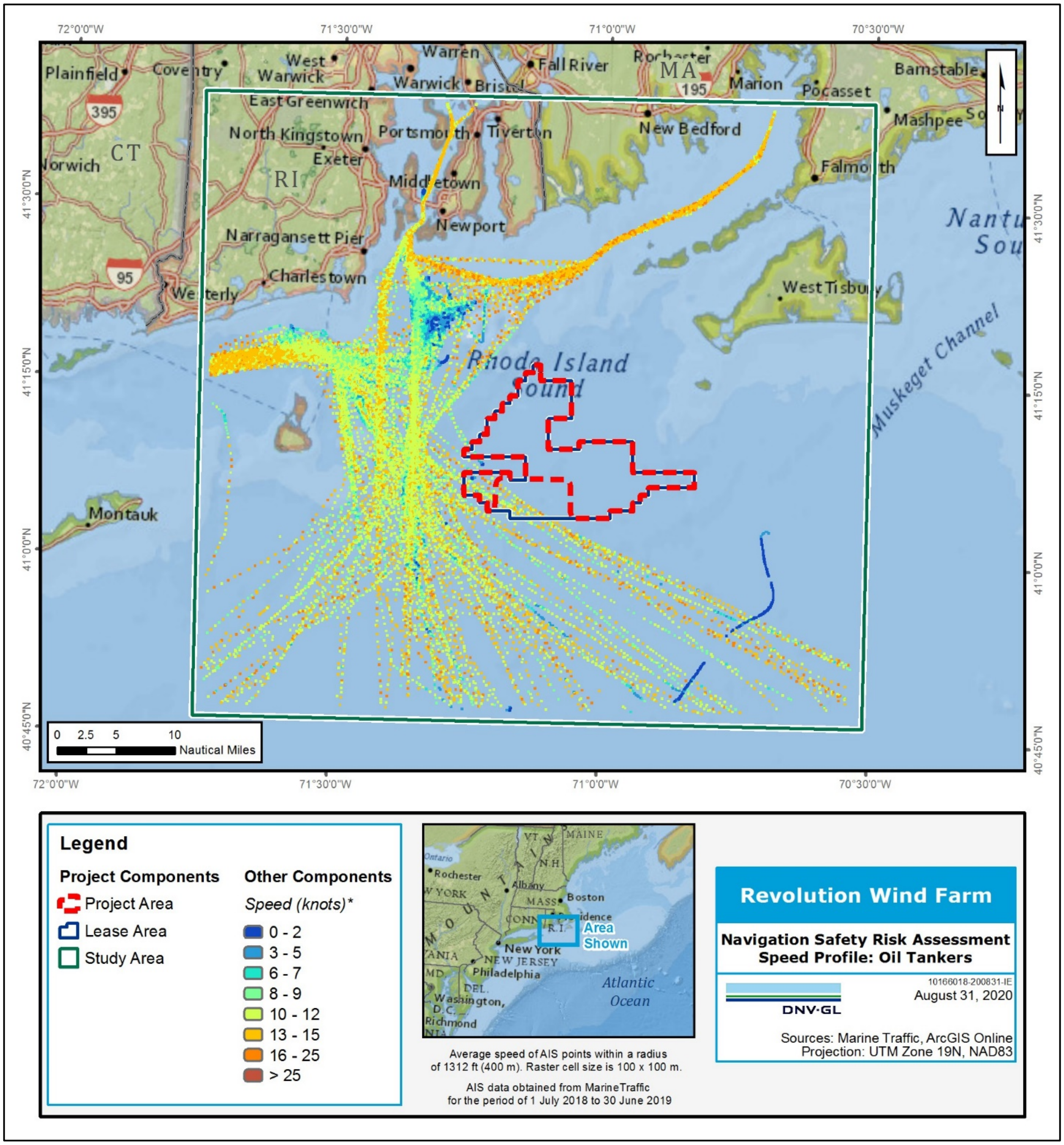
Legend
Project Components
Project Area
Lease Area
Study Area
Other Components
Speed (knots)*
0 - 2
3 - 5
6 - 7
8 - 9
10 - 12
13 - 15
16 - 25
> 25
Average speed of AIS points within a radius of 1312 ft (400 m). Raster cell size is 100 x 100 m.
AIS data obtained from MarineTraffic for the period of 1 July 2018 to 30 June 2019
Revolution Wind Farm
Navigation Safety Risk Assessment
Speed Profile: Fishing Vessels
10166018-200831-IE
August 31, 2020
DNV·GL
Sources: Marine Traffic, ArcGIS Online
Projection: UTM Zone 19N, NAD83
0 2.5 5 10 Nautical Miles
Area Shown


Legend
Project Components
Project Area
Lease Area
Study Area
Other Components
Speed (knots)*
0 - 2
3 - 5
6 - 7
8 - 9
10 - 12
13 - 15
16 - 25
> 25
Average speed of AIS points within a radius of 1312 ft (400 m). Raster cell size is 100 x 100 m.
AIS data obtained from MarineTraffic for the period of 1 July 2018 to 30 June 2019
Revolution Wind Farm
Navigation Safety Risk Assessment
Speed Profile: Passenger Vessels
10166018-200831-IE
August 31, 2020
DNV·GL
Sources: Marine Traffic, ArcGIS Online
Projection: UTM Zone 19N, NAD83
Rhode Island Sound
Muskeget Channel
Nautical Miles

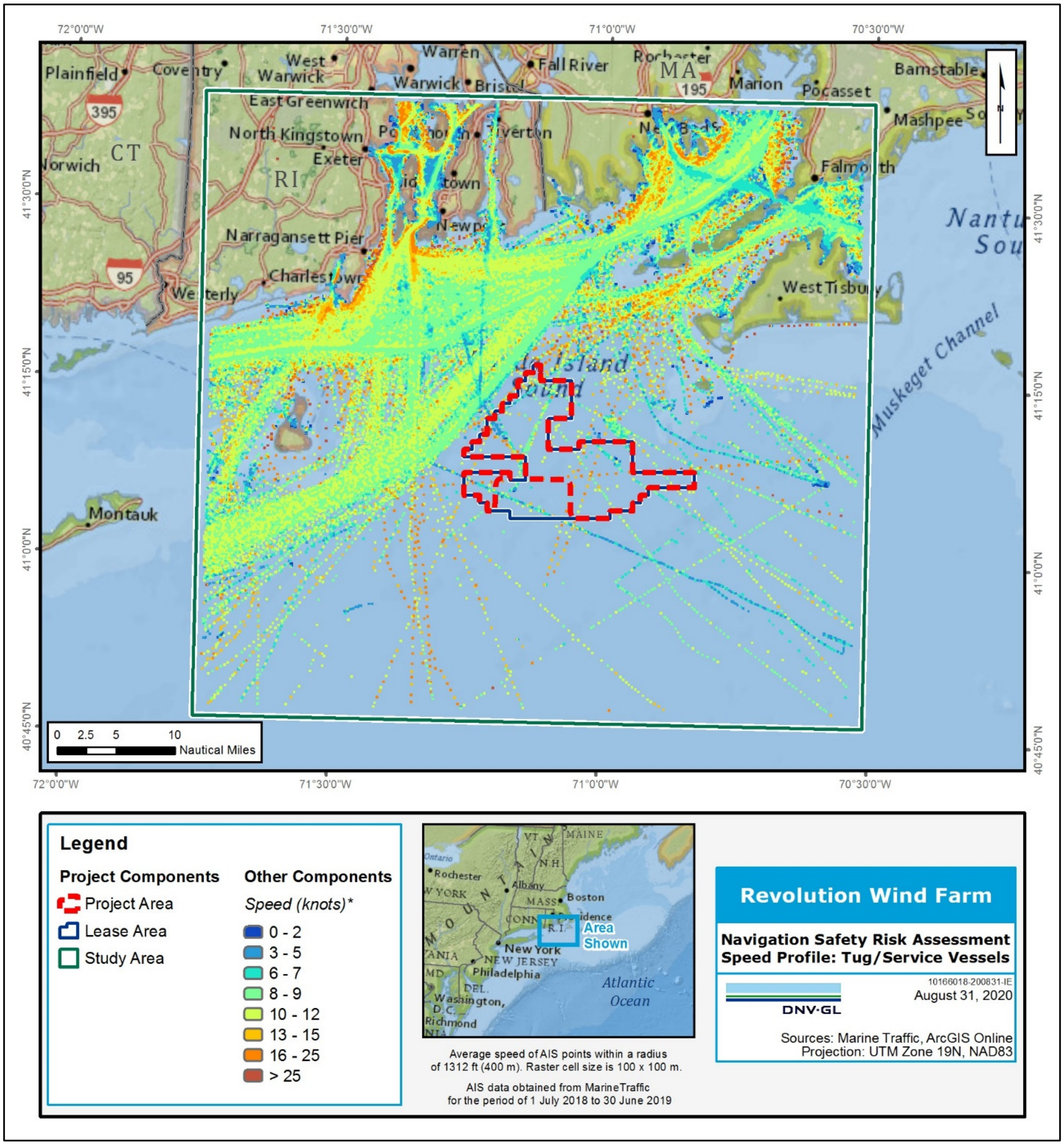


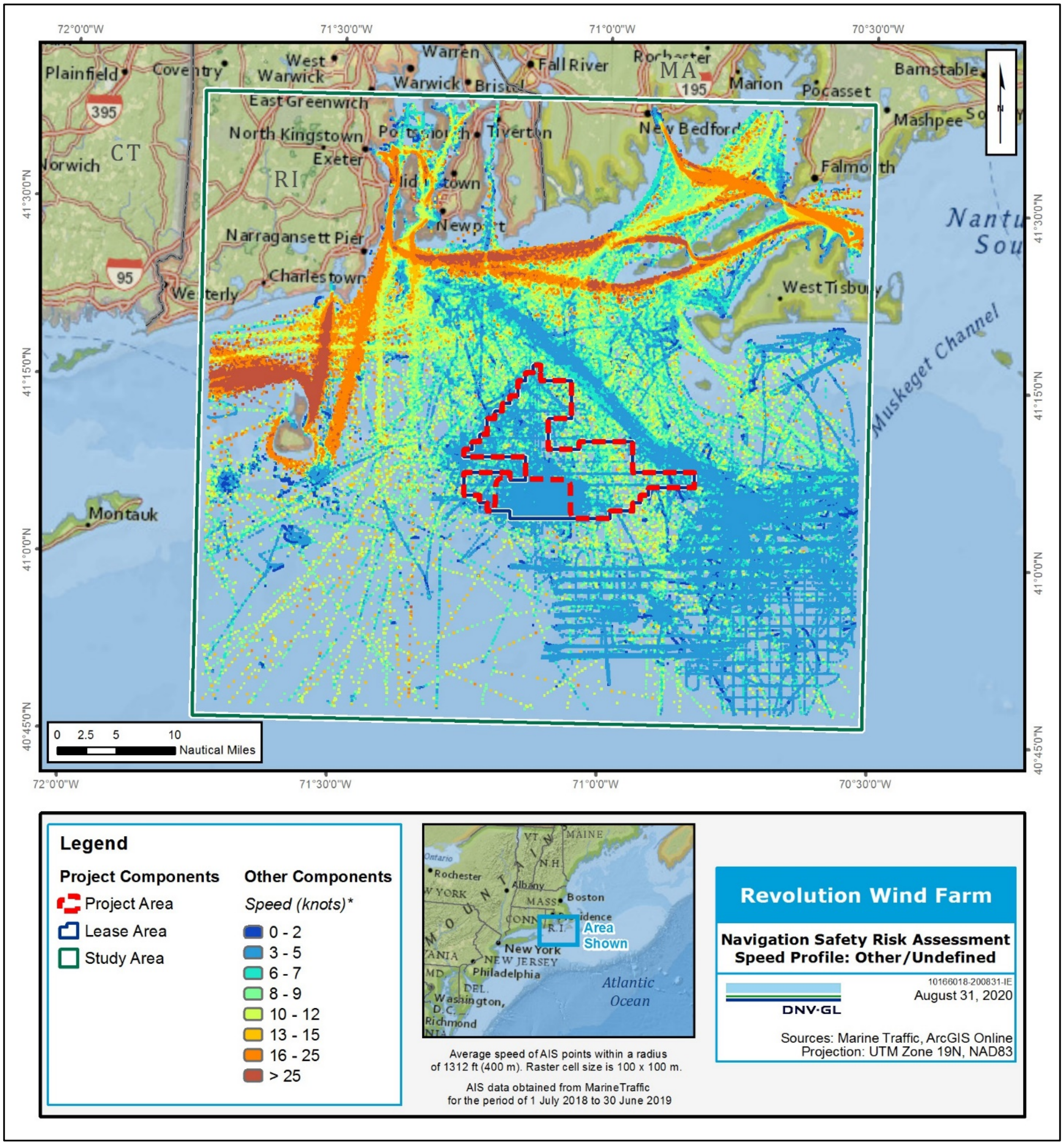
Legend
Project Components
Project Area
Lease Area
Study Area
Other Components
Speed (knots)*
0 - 2
3 - 5
6 - 7
8 - 9
10 - 12
13 - 15
16 - 25
> 25
Average speed of AIS points within a radius of 1312 ft (400 m). Raster cell size is 100 x 100 m.
AIS data obtained from MarineTraffic for the period of 1 July 2018 to 30 June 2019
Revolution Wind Farm
Navigation Safety Risk Assessment
Speed Profile: Pleasure Vessels
10166018-200831-IE
August 31, 2020
DNV·GL
Sources: Marine Traffic, ArcGIS Online
Projection: UTM Zone 19N, NAD83
0 2.5 5 10 Nautical Miles
Muskeget Channel
Area Shown


72°0'0"W
71°30'0"W
71°0'0"W
70°30'0"W
41°30'0"N
41°15'0"N
41°0'0"N
40°45'0"N
Plainfield
Coventry
West Warwick
Warren
Warwick
Bristol
Fall River
Rochester
MA
Marion
Barnstable
Pocasset
Mashpee
East Greenwich
North Kingstown
Portsmouth
Tiverton
New Bedford
Falmouth
Norwich
CT
RI
Exeter
Middletown
Newport
Narragansett Pier
Charlestown
Westerly
West Tisbury
Rhode Island Sound
Muskeget Channel
Montauk
395
95
195
0 2.5 5 10
Nautical Miles
Legend
Project Components
Project Area
Lease Area
Study Area
Other Components
Speed (knots)*
0 - 2
3 - 5
6 - 7
8 - 9
10 - 12
13 - 15
16 - 25
> 25
MAINE
N.H.
VT
Rochester
Albany
Boston
MASS
CONN
R.I.
Area Shown
New York
NEW JERSEY
Philadelphia
DEL.
MD.
Washington, D.C.
Richmond
Atlantic Ocean
Average speed of AIS points within a radius of 1312 ft (400 m). Raster cell size is 100 x 100 m.
AIS data obtained from MarineTraffic for the period of 1 July 2018 to 30 June 2019
Revolution Wind Farm
Navigation Safety Risk Assessment
Speed Profile: Tanker Vessels
10166018-200831-IE
August 31, 2020
DNV·GL
Sources: Marine Traffic, ArcGIS Online
Projection: UTM Zone 19N, NAD83



Legend
Project Components
Project Area
Lease Area
Study Area
Other Components
Speed (knots)*
0 - 2
3 - 5
6 - 7
8 - 9
10 - 12
13 - 15
16 - 25
> 25
Average speed of AIS points within a radius of 1312 ft (400 m). Raster cell size is 100 x 100 m.
AIS data obtained from MarineTraffic for the period of 1 July 2018 to 30 June 2019
Revolution Wind Farm
Navigation Safety Risk Assessment
Speed Profile: Oil Tankers
10166018-200831-IE
August 31, 2020
DNV·GL
Sources: Marine Traffic, ArcGIS Online
Projection: UTM Zone 19N, NAD83
0 2.5 5 10 Nautical Miles
Rhode Island Sound
Muskeget Channel


Legend
Project Components
Project Area
Lease Area
Study Area
Other Components
Speed (knots)*
0 - 2
3 - 5
6 - 7
8 - 9
10 - 12
13 - 15
16 - 25
> 25
Area Shown
Average speed of AIS points within a radius of 1312 ft (400 m). Raster cell size is 100 x 100 m.
AIS data obtained from MarineTraffic for the period of 1 July 2018 to 30 June 2019
Revolution Wind Farm
Navigation Safety Risk Assessment
Speed Profile: Tug/Service Vessels
10166018-200831-IE
August 31, 2020
DNV·GL
Sources: Marine Traffic, ArcGIS Online
Projection: UTM Zone 19N, NAD83
0 2.5 5 10 Nautical Miles
Muskeget Channel



Legend
Project Components
Project Area
Lease Area
Study Area
Other Components
Speed (knots)*
0 - 2
3 - 5
6 - 7
8 - 9
10 - 12
13 - 15
16 - 25
> 25
Average speed of AIS points within a radius of 1312 ft (400 m). Raster cell size is 100 x 100 m.
AIS data obtained from MarineTraffic for the period of 1 July 2018 to 30 June 2019
Revolution Wind Farm
Navigation Safety Risk Assessment
Speed Profile: Other/Undefined
10166018-200831-IE
August 31, 2020
DNV·GL
Sources: Marine Traffic, ArcGIS Online
Projection: UTM Zone 19N, NAD83
0 2.5 5 10 Nautical Miles
Nantucket Sound
Muskeget Channel

A.4 References

1. MarineTraffic (2019), Automatic Identification System data acquired from MarineTraffic, Historical AIS-T data (vessel positions) for TIMESTAMP between '2018-07-01 00:00' and '2019-06-30 23:59' UTC, LAT between 40.79041 and 41.64521 and LON between -71.73783 and -70.52470.

APPENDIX B   STAKEHOLDER ENGAGEMENT

Stakeholder engagement is an important aspect of assuring navigation safety. Stakeholder engagement includes myriad interactions with a wide spectrum of interested parties, including but not limited to:

- General meetings (both in-person and virtual) hosted or sponsored by Orsted with the express purpose of discussing stakeholder concerns;
- Meetings hosted by others in which Orsted was a panelist or featured speaker with the express purpose of discussing stakeholder concerns;
- One-on-one meetings with individual stakeholders to discuss their specific concerns, such as routine “port hours” hosted by Orsted;
- Correspondence with various stakeholders or stakeholder representative groups;
- Postings and solicitations for feedback on Orsted’s Mariners’ website.

Orsted has engaged the stakeholders below regarding navigation issues (Orsted, 2020):

1. Atlantic Clam Farm
2. Atlantic Offshore Lobstermen's Association
3. Atlantic State Marine Fisheries Commission
4. Cape Cod Fishermen's Alliance
5. Commercial Fisheries Center of Rhode Island
6. Commercial Fisheries Research Foundation
7. Connecticut Fisheries Advisory Council
8. Connecticut Lobsterman's Association
9. Eastern New England Scallop Association
10. Fisheries Survival Fund
11. Long Island Commercial Fishing Association
12. Martha's Vineyard Shellfish Group
13. Massachusetts Division of Marine Fisheries
14. Massachusetts Fishermen's Partnership
15. Massachusetts Lobstermen's Association
16. Narragansett Bay Propeller Club
17. National Marine Fisheries Services
18. New Bedford Port Authority
19. New Bedford Seafood Consulting

20. New England Fisheries Management Council

21. Northeast Marine Pilots

22. Responsible Offshore Development Alliance (RODA)

23. Rhode Island Coastal Resources Management Council

24. Rhode Island Department of Environmental Management

25. Rhode Island Fisheries Advisory Board

26. Rhode Island Fishermen's Alliance

27. Rhode Island Lobstermen’s Association

APPENDIX C MARINERS' PERSPECTIVES OF PROJECT IMPACT

The Project has engaged and continues to engage numerous stakeholders regarding the potential impacts—both positive and negative—that the proposed Revolution Wind project may have on their particular waterway uses (Orsted, 2020).

Appendix B lists major stakeholder organizations with which the Project regularly engages. The list is not all-inclusive. Additionally, the Project has conversed with nearly 200 individual stakeholders, mostly from the commercial fishing industry, to receive their input.

The combined stakeholder group (organizations and individuals) represents a comprehensive cross-section of waterway users in the Project Area, including representatives from the recreational boating and fishing, commercial fishing, commercial vessel operators and pilot organizations, and port authorities.

Anecdotal feedback from stakeholders falls generally into one or more of the following categories:

Recreational boating: Recreational boaters are expected to visit the Project Area to view the novelty of an offshore wind farm. After an initial uptick of recreational vessel traffic to the Project Area, it is expected that little recreational traffic would regularly operate in the vicinity.

Recreational fishing: Recreational fishing is expected to increase as fish congregate around the artificial reef associated with each turbine and OSS.

Commercial fishing: Commercial fishing stakeholders expressed concerns about lines of orientation (rows and columns) and spacing between turbines. Based on feedback received from this constituency, the Project plans an array with two lines of orientation, east/west and north/south, and a minimum of one nautical mile separation between towers.

Commercial vessel operators/pilots: Commercial vessels will make slight adjustments to their intended courses to avoid the Project Area completely.

Port Authorities: Port authorities are supportive of the Project and have not expressed concerns about potential impacts the Project may have on port operations.

APPENDIX D DESCRIPTION OF MARCS MODEL

D.1 Introduction

The Marine Accident Risk Calculation System (MARCS) is a set of risk parameters and calculation tools that have been developed to support DNV GL's marine risk services. MARCS calculates the frequency and consequence of accidents due to the following "standard" navigation hazards:

- Collision between two ships both underway
- Powered grounding, where a ship strikes the grounding line due to human error (steering and propulsion not impaired)
- Drift grounding, where a ship strikes the grounding line due to mechanical failure (steering and/or propulsion failed)
- Powered impact, where a ship strikes a man-made structure (e.g., platform or wind turbine) due to human error (steering and propulsion not impaired)
- Drift impact, where a ship strikes a man-made structure (e.g., platform or wind turbine) due to mechanical failure (steering and/ or propulsion failed)

The frequency of each hazard is calculated by MARCS as a function of geographical position, for each accident type, and for each ship type included in the input data. The marine accident frequency assessment for marine transport or turbine/platform installation can be performed by assessing the frequency of the above accident types in a defined study area. The analysis results can then be assessed to determine if the estimated accident frequencies are acceptable or if mitigation measures are justified or required.

D.2 Overview of MARCS

The MARCS accident frequency model provides an estimate of the frequency of accidents that may occur at sea. A block diagram of the model is shown in Figure D-1.

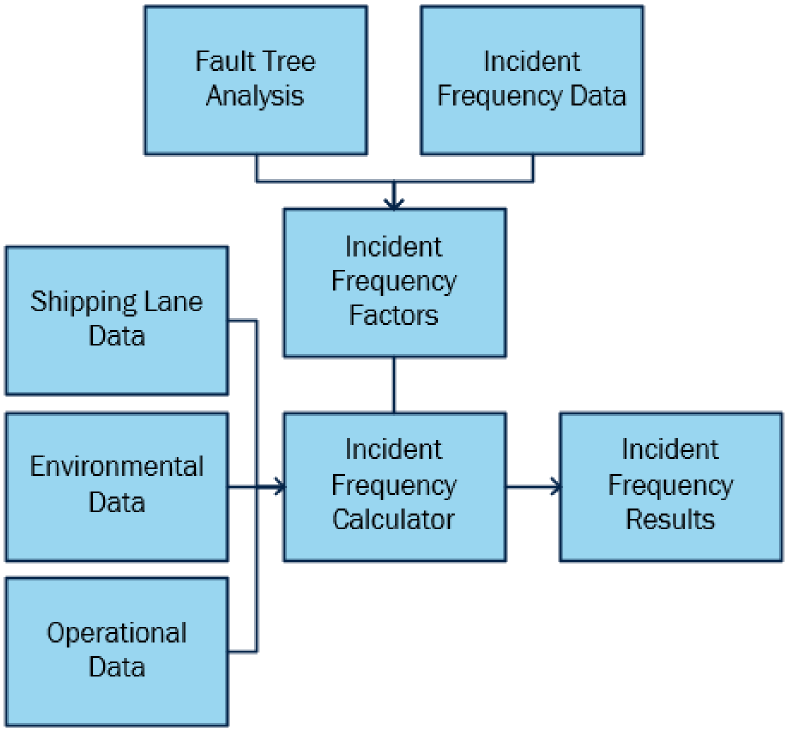


Figure D-1 Block diagram of MARCS incident frequency model

The MARCS model classifies data into four main types:

- Shipping lane data describes the movements of different marine traffic types within the study area.
- Environmental data describes the conditions within the calculation area, including the location of geographical features (land, offshore structures, offshore wind farms, etc.) and meteorological data (visibility, wind rose, water currents, and sea state).
- Operational data represents how shipping operations are performed. This includes ship speed data, use of pilots, use of Vessel Traffic Services, etc.

A MARCS calculation is performed in a study area. The study area is a rectangle defined by the coordinates of the northwest and southeast corners. Marine accident risks are calculated within the study area, as shown in Figure D-2.

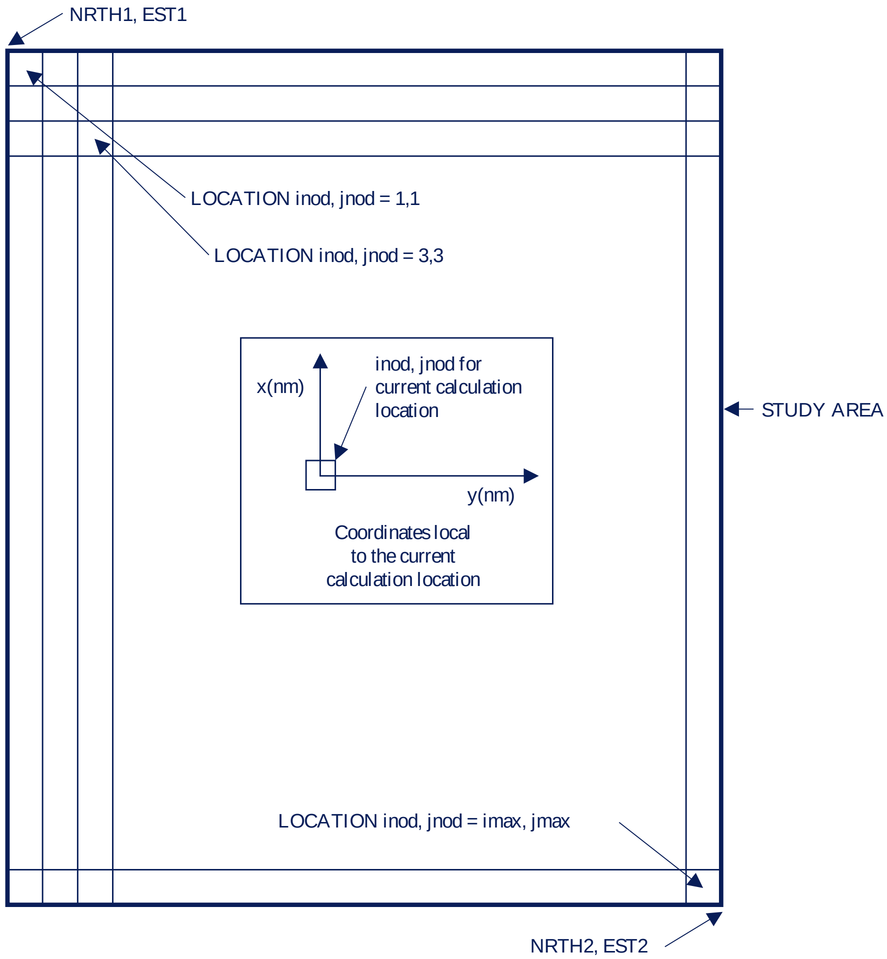


Figure D-2 Basic definitions and coordinate sets

The study area is divided into a large number of small locations (or pixels). The marine accident risk is calculated at each location in sequence. The study area and the calculation resolution (how many locations to put into the study area – the values of imax, jmax) is usually one of the first decisions made on starting a new project.

Three coordinate systems are used by MARCS:

- Absolute coordinates are specified in decimal degrees east of Greenwich, England and decimal degrees north of the equator.
- Calculation locations are specified in terms of their row number (inod [1.imax]) and column number (jnod [1.jmax]), where location (1,1) is at the top left hand corner of the study area. Calculation locations are equally spaced in terms of decimal degrees.
- Local distance coordinates are defined in terms of pseudo x,y Cartesians relative to the calculation location (Ninod, Ejnod).

D.2.1 Critical situations

To calculate the incident frequency, MARCS first identifies critical situations. The definition of a critical situation varies with the incident type. It first calculates the location dependent frequency of critical situations (the number of situations which could result in an incident – "potential incidents" – at a location per year; a location is defined as a small part of the study area, typically about one nautical mile square, but dependent on the chosen calculation resolution). The definition of a critical situation varies with the incident type).

Fault tree analysis[9,10] can be described as an analytical technique, whereby an undesired state of a system is specified, and the system is then analyzed in the context of its environment and operation to find all credible ways in which the undesired event can occur. This undesired state is referred to as the top event of the fault tree. It expresses the frequency or probability for the occurrence of this event or incident.

The basic events of a fault tree are those events that make up the bottom line of the fault tree structure. To perform calculations of the top frequency or probability of a fault tree, these basic events need to be quantified. The fault tree structure is built up by basic events and logical combinations of these events that are expressed by AND and OR gates. The outputs of these gates are new events, which again may be combined with other events / basic events in new gates. The logic finally results in the top event of the fault tree.

The different symbols in the fault tree are defined in Figure D-3.

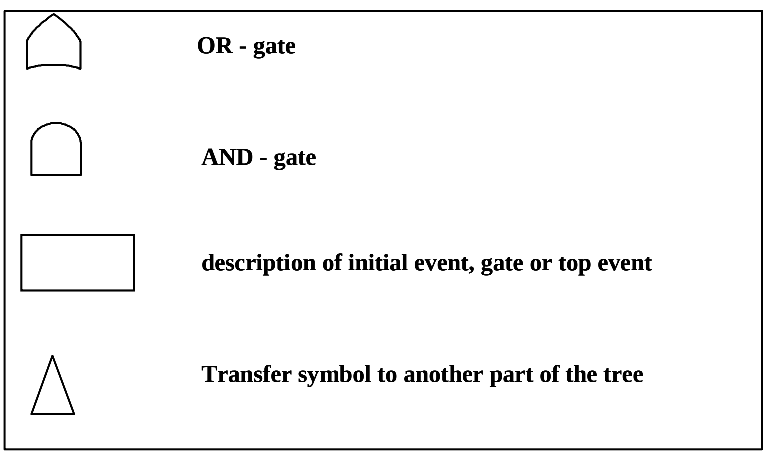


Figure D-3 Fault tree symbols

The OR gate (Figure D-4) expresses the probability of occurrence of Event 1 or Event 2, and is calculated as the sum minus the intersection of the two events:

$$P(\text{Event 1 OR Event 2}) = P1 + P2 - P1 * P2$$

[9] E. J. Henley and H. Kumamoto, "Reliability Engineering and Risk Assessment," Prentice-Hall Inc., 1981.
[10] R. M. Cooke, "Methods and Code for Uncertainty Analysis", UNICORN, AE Technology, TUDelft, 1995.

Usually the intersection probability can be neglected, as it will be a very small number (if P1 = P2 = 10^{-2}, then P1*P2 = 10^{-4}).

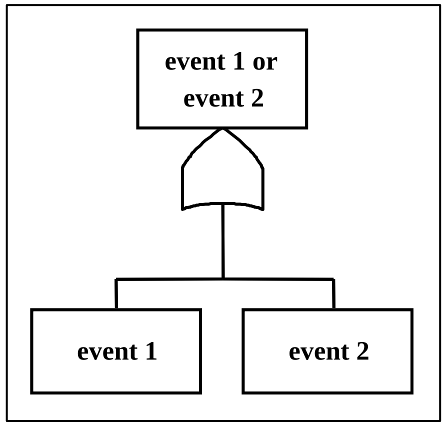


Figure D-4 OR gate

The AND gate (Figure D-5) expresses the probability that Event 1 and Event 2 occur simultaneously, and is calculated as the product of the two events:

P(Event 1 AND Event 2)= P1*P2

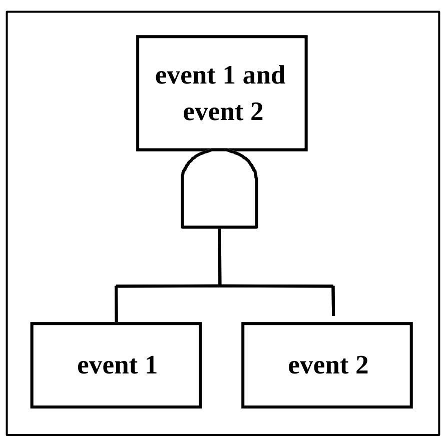


Figure D-5 AND gate

It should be emphasized that the quality of the results produced by fault tree analysis is dependent on how realistically and comprehensively the fault tree model reflects the causes leading to the top event. Of course, it is never possible to fully represent reality, and therefore the models will always only represent a simplified picture of the situation of interest. The top event frequencies will generally be indicative, and hence relative trends are more reliable than the absolute values.

Fault tree models have been constructed to assess a number of parameters within MARCS, including collision probabilities per encounter (collision model) and failure probabilities to avoid a powered grounding given a critical situation (powered grounding model) (Det Norske Veritas, 1998b and 1999b).

D.3 Data used by MARCS

This section describes the various data inputs used by MARCS.

D.3.1 Traffic image data

The marine traffic image data used by MARCS is a representation of the actual flows of traffic within the calculation area. Marine traffic data is represented using lane data structures.

A typical shipping traffic lane is shown in Figure D-6. The following data items are defined for all lanes:

- The lane number (a unique identifier used as a label for the lane)
- The lane width distribution function (e.g., Gaussian or truncated Gaussian)
- The lane directionality (one-way or two-way)
- The annual frequency of ship movements along the lane
- A list of waypoints, and an associated lane width parameter at each waypoint
- The vessel size distribution on the lane

Additional data may be attached to the lane, such as: the hull type distribution (single hull, double hull, etc.) for tankers; the loading type (full loading, hydrostatic loading) for tankers; ship type, etc.

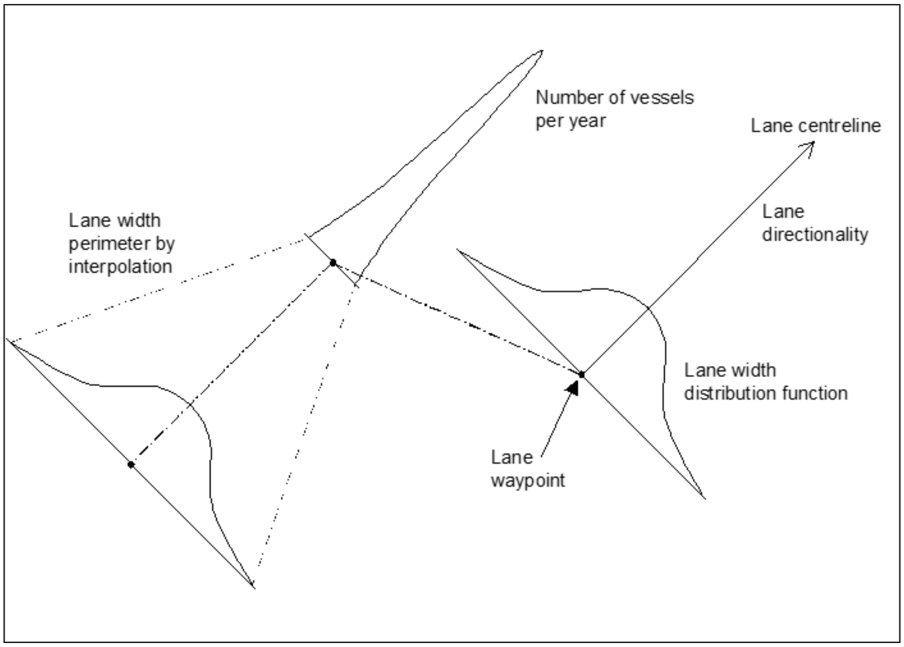


Figure D-6 Shipping lane representation used in MARCS

Detailed surveys of marine traffic in UK waters in the mid-1980s[11] concluded that commercial shipping follows fairly well-defined shipping lanes, as opposed to mainly random tracks of individual ships. Further detailed analysis of the lanes showed that the lateral distribution across the lane width was approximately Gaussian or truncated Gaussian for traffic arriving in coastal waters from long haul voyages (e.g., from Europe or Asia). The shipping lane distributions used in MARCS are shown in Figure D-7.

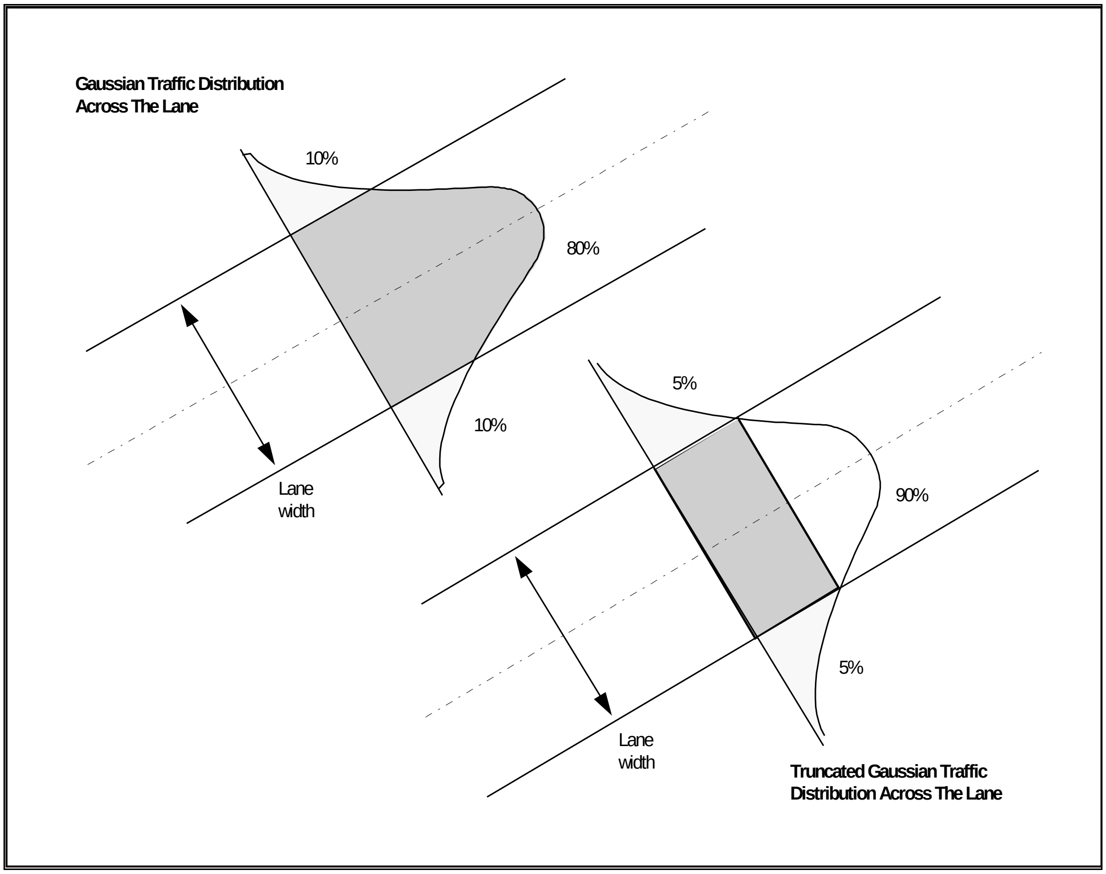


Figure D-7 Shipping lane width distribution functions used in MARCS

The marine traffic description used by MARCS is completed by the definition of four additional parameters for each type of traffic:

- Average vessel speed
- Speed fraction applied to faster and slower than average vessels (generally ± 20 percent)
- Fraction of vessels travelling faster and slower than the average speed (generally ± 20 percent)

[11] HMSO, "Shipping routes in the area of the UK continental shelf: Offshore technology report," OTH 85 213, HMSO, March 1985.

- Fraction of vessels that exhibit "rogue" behavior (generally set to 0 percent, though historical incident data in many geographical areas shows a small proportion of (usually) smaller vessels undergo incidents through lack of watchkeeping (bridge personnel absent or incapacitated)

A rogue vessel is defined as one that fails to adhere (fully or partially) to the Collision Avoidance Rules.[12] Such vessels are assumed to represent an enhanced collision hazard. These four parameters can be specified as a function of location within the study area for each traffic type.

The marine traffic image is made up by the superposition of the defined traffic for each contributing traffic type.

D.3.2 Operational data

Internal operational data is represented within MARCS using either worldwide data or frequency factors obtained from fault tree analysis or location specific survey data. Fault tree parameters take into consideration factors such as crew watchkeeping competence and internal vigilance (where a second crew member, or a monitoring device, checks that the navigating officer is not incapacitated). Examples of internal operational data include:

- The probability of a collision given an encounter
- The probability of a powered grounding given a ship's course close to the shoreline
- The frequency (per hour at risk) of fires or explosions

Internal operational data may be defined for different traffic types and / or the same traffic type on a location-specific basis.

External operational data generally represent controls external to the traffic image, which affect marine risk. In MARCS, it relates mainly to the location of Vessel Traffic Service zones (which influence the collision and powered grounding frequencies by external vigilance, where external vigilance means that an observer external to the ship may alert the ship to prevent an incident) and the presence and performance of emergency towing vessels (tugs) which can save a ship from drift grounding or allision.

D.3.3 Environmental data

The environmental data describes the location of geographical features (land, turbines, offshore structures, etc.) and meteorological data (visibility, wind rose, sea currents, and sea state).

Poor visibility arises when fog, snow, rain, or other phenomena restrict visibility. In the MARCS model, poor visibility is defined as less than 2 NM. It should be noted that night-time is categorized as visibility greater than 2 NM unless any phenomenon restricting visibility is present.

Wind rose data is defined within 8 compass points (north, northeast, east, etc.) in four wind speed categories: calm (0 to 20 kt, Beaufort 0 to 4); fresh (20 to 30 kt, Beaufort 5 to 6); gale (30 to 45 kt, Beaufort 7 to 9); and storm (greater than 45 kt, Beaufort 10 to 12). Sea state (wave height) within MARCS is inferred from the wind speed and the nature of the sea area (classified as sheltered, semi-sheltered, or open water).

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[12] A. N. Cockcroft and J. N. F. Lameijar, "A guide to the collision avoidance rules," Stanford Maritime, 1982.

In order to avoid over-prediction of grounding or impact frequencies MARCS needs to know if a line of sight (LOS) exists between the location of a ship and the grounding or impact location. This is achieved by assigning every calculation location one of three types:

- Clear water location. Here ships can always pass through. Groundings or impacts cannot occur in clear water locations.
- Coastal location. Here groundings occur and ships cannot pass through.
- Clear water location plus man-made object (e.g., offshore platform or wind turbine). Here ships can always pass through the location but some ships may impact on the man-made object.

For “clear water locations plus a man-made object” data describing the size of the object enables MARCS to calculate the size of the object relative to the size of the location.

To determine if a LOS exists, MARCS calculates all the locations through which a ship must move in order to impact a specified object (or ground at a specified coastal location). If any one of these locations is another coastal location, then a LOS does not exist and the impact (or grounding) accident frequency is set to zero. If one of more of these locations is a “clear water locations plus a man-made object” location, then the accident frequency is multiplied by the proportion of clear water in the location ((size of the location – size of the man-made object)/size of the location). In this way, the accident frequency for turbines at the edge of a large array is higher than that for turbines in the center of the array. This mechanism is sometimes called the “shadow effect”.

D.4 Description of incident frequency models

This section describes how MARCS uses the input data (traffic image, internal operational data, external operational data and environment data) to calculate the frequency of serious incidents in the study area.

D.4.1 The collision model

The collision model calculates the frequency of serious inter-ship powered collisions at a given geographical location in two stages. The model first estimates the frequency of encounters (critical situations for collision - when two vessels pass within 0.5 nautical miles of each other) from the traffic image data using a pair-wise summation technique, assuming no collision-avoiding actions are taken. This enables the calculation of either total encounter frequencies, or encounter frequencies involving specific vessel types.

The model then applies a probability of a collision for each encounter, obtained from fault tree analysis, to give the collision frequency. The collision probability value depends on a number of factors including, for example, the visibility or the presence of a Pilot.

Figure D-8 shows a graphical representation of the way in which the collision model operates.

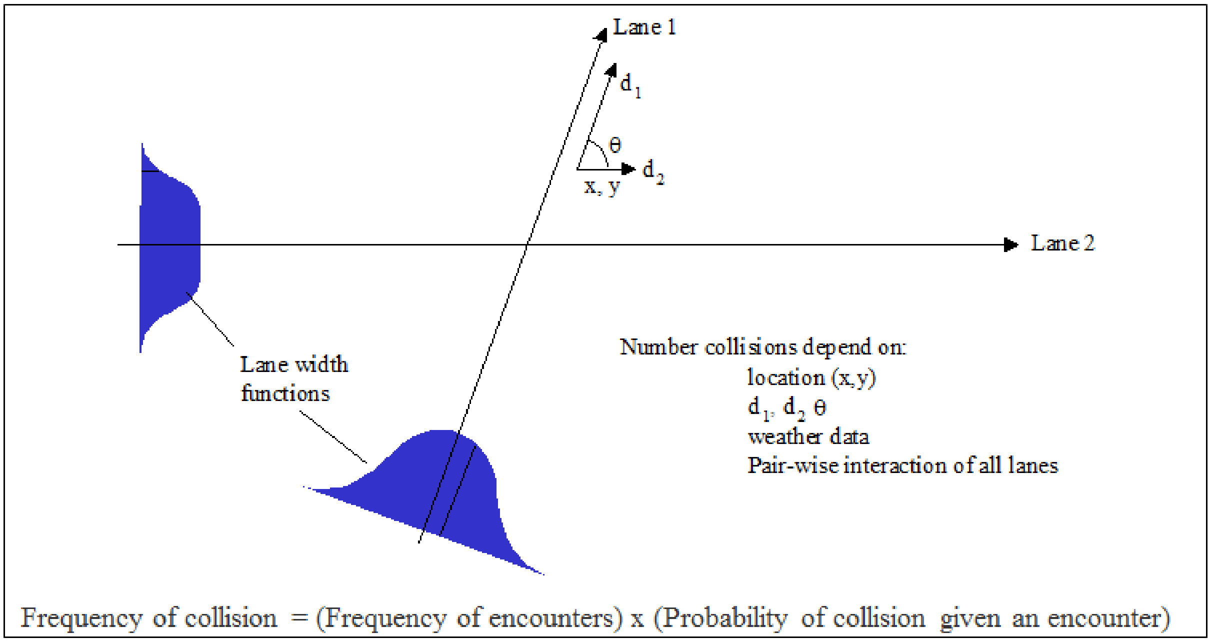

Figure D-8 Graphical representation of the collision model

In Figure D-8, d_1 refers to the density of traffic associated with Lane 1 at the location (x, y). The frequency of encounters at location (x, y) through the interaction of Lanes 1 and 2 is proportional to the product of d_1, d_2 and the relative velocity between the lane densities.

D.4.2 The powered grounding model

The powered grounding frequency model calculates the frequency of serious powered grounding incidents in two stages. The model first calculates the frequency of critical situations (sometimes called "dangerous courses" for powered grounding incidents). Two types of critical situations are defined as illustrated in Figure D-9. The first critical situation arises when a course change point (waypoint) is located such that failure to make the course change would result in grounding within 20 minutes' navigation from the planned course change point if the course change is not made successfully. The second critical situation results when a grounding location is within 20 minutes' navigation of the course centerline. In this case, crew inattention combined with wind, current, or other factors could result in a powered grounding.

The frequency of serious powered groundings is calculated as the frequency of critical situations multiplied by the probability of failure to avoid grounding.

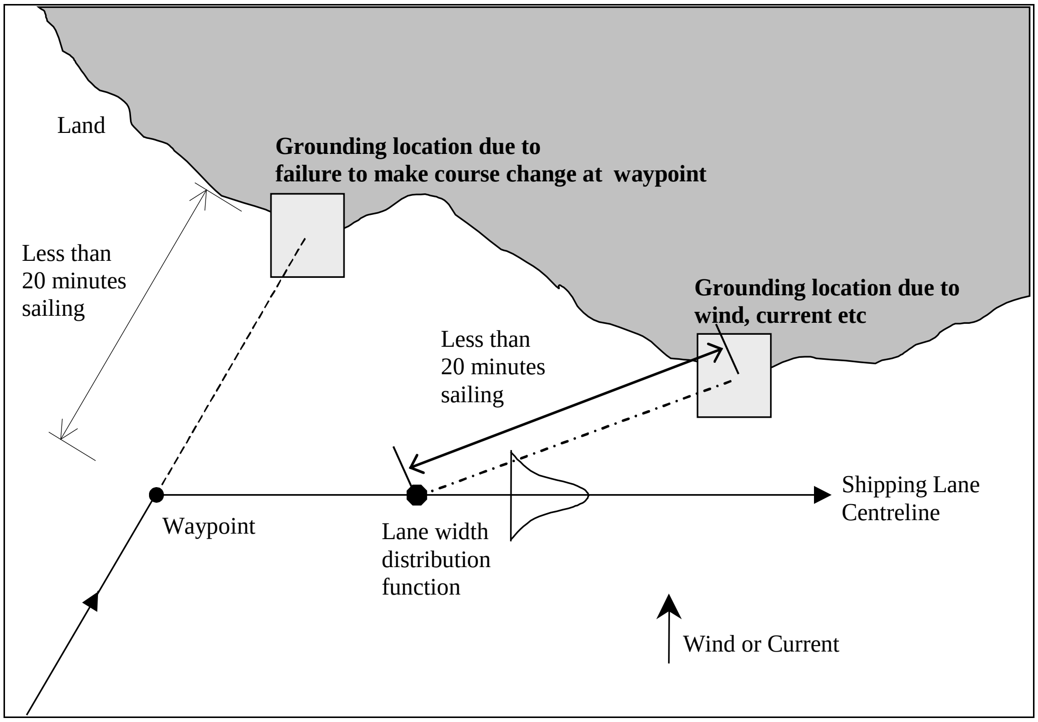

Figure D-9 Graphical representation of the powered grounding model

The powered grounding probabilities are derived from the fault tree analysis of powered grounding. The powered grounding fault tree contains two main branches:

- Powered grounding through failure to make a course change whilst on a dangerous course. A dangerous course is defined as one that would ground the vessel within 20 minutes if the course change were not made.
- Powered grounding caused by crew inattention and wind or current from the side when the ship lane runs parallel to a shore within 20 minutes sailing.

Both these branches are illustrated in Figure D-9. The powered grounding frequency model takes into account internal and external vigilance, visibility, and the presence of navigational aids in deducing failure parameters.

D.4.3 The drift grounding model

The drift grounding frequency model consists of two main elements: first, the ship traffic image is combined with the ship breakdown frequency factor to generate the location and frequency of vessel breakdowns; second, the recovery of control of drifting ships can be regained by one of three mechanisms:

- Repair
- Emergency tow vessel assistance
- Anchoring

Those drifting ships that are not saved by one of these three mechanisms (and do not drift out into the open sea) contribute to the serious drift grounding incident frequency results.

The number and size distribution of ships which start to drift is determined from the ship breakdown frequency, the annual number of transits along the lane and the size distribution of vessels using the lane. The proportion of drifting vessels that are saved (fail to ground) is determined from the vessel recovery models. The drift grounding frequency model is illustrated in Figure D-10.

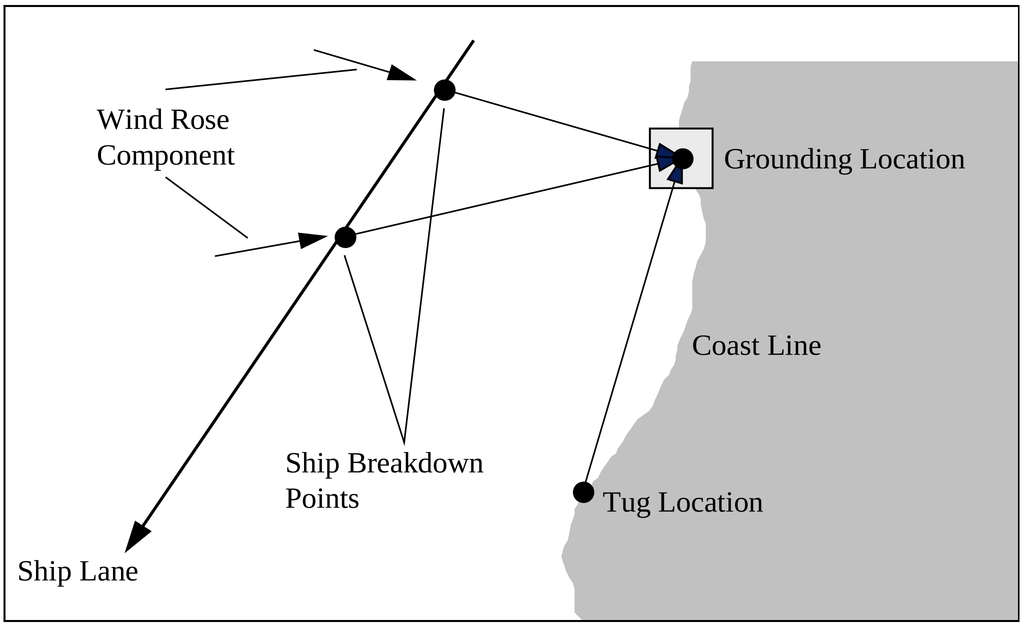

Figure D-10 Graphical representation of the drift grounding model

Implicit in Figure D-10 is the importance of the time taken for the ship to drift aground. When this time is lengthy (because the distance to the shore is large and/or because the drift velocity is small) then the probability that the ship will recover control before grounding (via repair or tug assistance) will be increased.

D.4.3.1 The repair recovery model

Vessels that start to drift may recover control by effecting repairs. For a given vessel breakdown location, grounding location, and drift speed, there is a characteristic drift time to the grounding point. The proportion of drifting vessels that have recovered control by self-repair is determined from this characteristic drift time and the distribution of repair times.

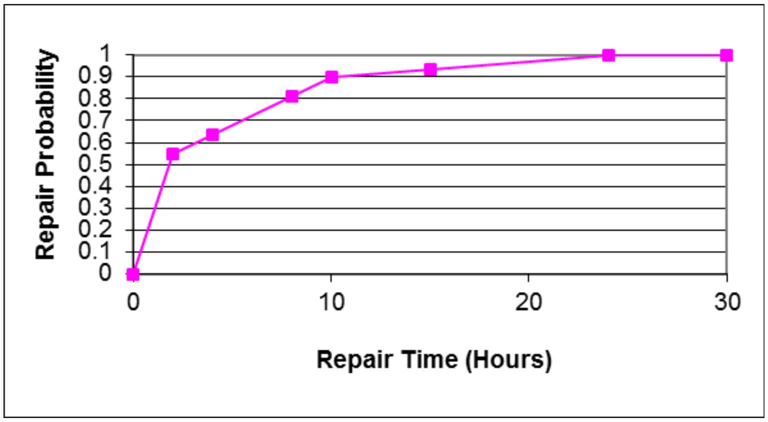

Figure D-11 Graphical representation of the self-repair save mechanism

D.4.3.2 Recovery of control by anchoring

The anchor save model is derived with reference to the following:

- Anchoring is only possible if there is a sufficient length of suitable water to prevent the ship running aground. Suitable water is defined as a depth between 30 fathoms (about 60 m - maximum for deployment of anchor) and 10 fathoms (about 20 m - minimum for ship to avoid grounding). Sufficient length is calculated as 100 m for the anchor to take a firm hold of the seabed + 300 m to stop the ship + 300 m for the length of ship + 100 m for clearance = 800 m, or 0.5 nautical miles (to be slightly conservative).
- If such a track exists, then the probability that the anchor holds is calculated as a function of the wind speed and the sea bottom type (soft seabeds consist predominantly of sands, silts, and muds). If the anchor holds, then an anchor save is made.

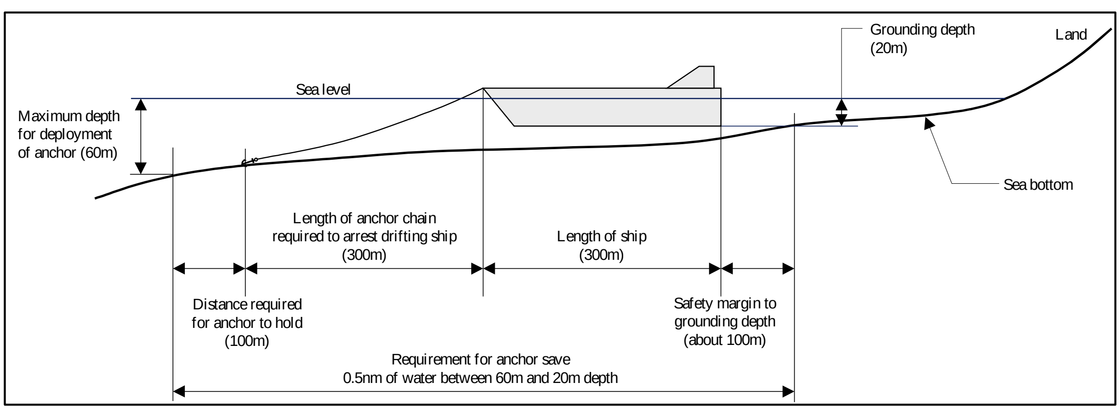

Figure D-12 Graphical representation of the anchor save mechanism

The anchor save model is conservative in that it under-predicts the effectiveness of this save mechanism for average and smaller ships.

D.4.4 The powered impact model

The powered impact frequency model calculates the frequency of serious powered impact accidents in two stages. The model first calculates the frequency of critical situations (sometimes called “dangerous courses” for powered impact accidents). Two types of critical situation are defined as illustrated in Figure D-13. The first critical situation arises when a course change point (waypoint) is located such that failure to make the course change would result in impact within 20 minutes’ navigation from the planned course change point if the course change is not made correctly. The second critical situation results when an impact object is within the lane width distribution. In each case the overlap integral of the lane width distribution aligned with the size of the impact object is calculated.

The frequency of serious powered impacts is calculated as the frequency of critical situations multiplied by the probability of failure to avoid impact. This probability may be similar to that used for powered grounding, or it may be modified to take account of wind farm specific risk controls, such as guard ships or fired pyrotechnics should a dangerous course be detected by the wind farm.

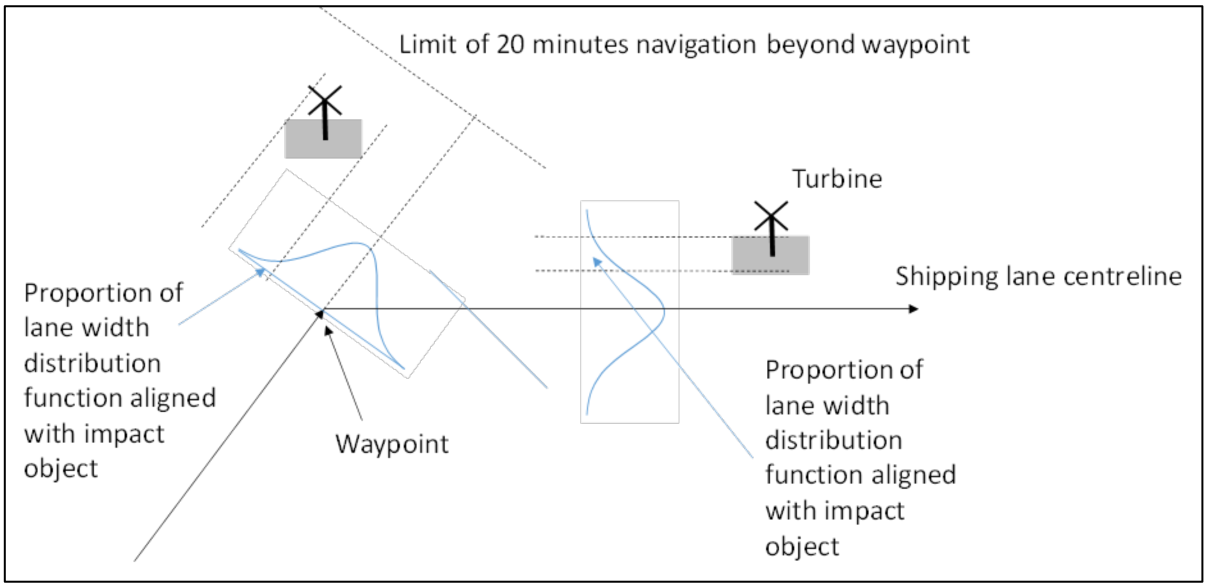

Figure D-13 Graphical representation of powered impact model

D.4.5 The drift impact frequency model for offshore wind turbines or offshore platforms

The drift impact frequency model consists of two main elements as follows: first, the ship traffic image is combined with the ship breakdown frequency to generate the location and frequency of vessel breakdowns; second, the recovery of control of drifting ships can be regained by one of three mechanisms:

- Repair
- Emergency tow vessel assistance
- Anchoring

Those drifting ships that are not saved by one of these three mechanisms (and do not drift out into open water) contribute to the serious drift impact accident frequency results.

The number and size distribution of ships which start to drift is determined from the ship breakdown frequency, the annual number of transits along the lane, and the size distribution of vessels using the lane. The proportion of drifting vessels which are saved (fail to impact) is determined from the vessel recovery models. The drift impact frequency model is illustrated in Figure D-14.

In order to avoid over prediction of grounding or impact frequencies MARCS needs to know if a LOS[13] exists between the location of a ship and the grounding or impact location. This is achieved by assigning every calculation location one of three types:

- Clear water location. Here ships can always pass through. Groundings or impacts cannot occur in clear water locations.
- Coastal location. Here groundings occur and ships cannot pass through.
- Clear water location plus man-made object (e.g., offshore platform or wind turbine). Here ships can always pass through the location but in addition some ships may impact on the man-made object.

For “clear water locations plus a man-made object” data describing the size of the object enables MARCS to calculate the size of the object relative to the size of the location.

To determine if a LOS exists, MARCS calculates all the locations through which a ship must move in order to impact a specified object (or ground at a specified coastal location). If any one of these locations is another coastal location, then a line of sight does not exist and the impact (or grounding) accident frequency is set to zero. If one of more of these locations is a “clear water locations plus a man-made object” location, then the accident frequency is multiplied by the proportion of clear water in the location ((size of the location – size of the man-made object)/size of the location). In this way, the accident frequency for turbines at the edge of a large array is higher than that for turbines in the center of the array. This mechanism is sometimes called the “shadow effect.”

[13] “Line of sight” is defined as a straight line of clear water through which a ship can navigate or drift to a grounding or impact location.

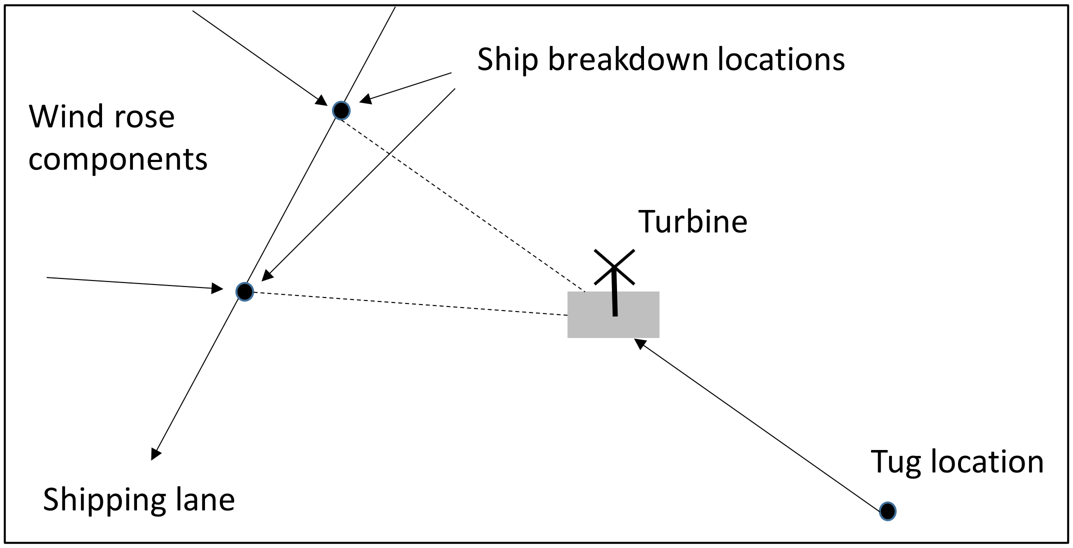

Figure D-14 Graphical representation of the drift impact model

Implicit in Figure D-14 is the importance of the time taken for the ship to drift to the impact object. When this time is large (because the distance to the object is large and/ or because the drift velocity is small) then the probability that the ship will recover control before impacting (via repair or tug assistance) will be increased.

Recovery methods described in the Drift Grounding Frequency Model are applicable to the Drift Impact Frequency Model.

D.5 Risk control quantification

All risk controls reduce the frequency of critical situations and/or reduce the probability of an incident given a critical situation (e.g., pilotage will reduce the probability of collision given a critical situation). The performance parameters, such as the probability of human error leading to a collision, were derived in previous work by DNV GL in research projects for the European Union (EU) on Safety of Shipping in Coastal Waters (SSPA Sweden, 2012 and IMO, 2007). This was done by reference to historical incident rates. The effect of different risk controls on the performance parameters was derived by a mixture of methods; including historical data, where available, in addition to fault trees and expert judgment. The following sections describe the effect of risk controls applied in this study.

D.5.1 Coastal Vessel Traffic Service

Vessel traffic service is expected to reduce the frequency of collision and of powered grounding. Several studies have assessed its effectiveness with relative risk for collision and groundings estimated to be 0.8 to 0.33 (i.e., risk reduction of 20 to 67 percent, respectively).[14,15,16,17]

Under the SAFECO program, through a review of numerous studies with differing results, the default relative risk for a vessel traffic service was concluded to be 0.8 (Det Norske Veritas, 1999a). According to the references mentioned above, some studies showed vessel traffic service to be more effective in some circumstances, but 0.8 was and continues to be a sound basis for risk assessment. Based on this, DNV GL's MARCS model conservatively uses a relative risk factor for external vigilance of 0.8 with respect to human performance and incapacitation, which give an overall relative risk of 0.8 (i.e., a 20 percent reduction) for collisions assuming both ships in the encounter participate in the vessel traffic service and for powered grounding.

D.5.2 Pilotage

The use of pilots has two main benefits:

- Their navigational expertise and familiarity with local conditions reduces the chance of error due to unfamiliarity with the navigation or poor performance by the officer of the watch.
- Their presence increases the number of people on the bridge, so reducing the chance of incidents due to omission or incapacitation.

Several factors are considered that might modify the benefits of pilotage:

- The navigational complexity and uniqueness of the route. In the open sea, a pilot would have smaller benefit, as local familiarity would have little value. Most areas with mandatory pilotage are assumed to have significant navigational complexity.
- The navigational expertise and local knowledge of the ship's crew. If the bridge team is already well managed and knowledgeable, the pilot's expertise would have relatively less benefit. This is acknowledged by pilotage exemptions for some ship's masters.
- The navigational expertise and local knowledge of the pilot.

A pilot's Portable Pilot Unit (PPU) is an auxiliary device brought aboard and used by pilots to support safe navigation of vessels the pilots assist. A PPU is a support tool that may enhance the pilot's navigational performance, due to their familiarity with their own equipment. The PPU also provides some additional redundancy against ship navigational equipment failure or incorrect calibration and in some cases a greater degree of accuracy than from the ship's own equipment.

The effect of pilotage on the collision and grounding risk has been evaluated in several studies (Larsen, 1993; Det Norske Veritas, 1998a; Det Norske Veritas 1999a; SSPA Sweden, 2012). Reviewing the estimates

[14] Commission of the European Communities (CEC), Cost-301, Shore-Based marine Navigation Aid System, The Directorate General, Transportation, CEC, Luxemburg, 1988.
[15] G.R.G. Lewison, "The Estimation of Collision Risk for Marine Traffic in UK Waters," Journal of Navigation, September 1980.
[16] O.D. Larsen, "Ship Collision with Bridges," IABSE Structural Engineering documents, 1993.
[17] Det Norske Veritas, "Demonstration of Risk Analysis Technique for Ship Transportation in European Waters," Safety of Shipping in Coastal Waters (SAFECO), Det Norske Veritas Project 98-2021, July 1998.

from these studies, a conservative consensus was reached for the relative risk estimates for vessels with pilotage due to human error and incapacitation are 0.5 and 0.25, respectively. No credit was given for reducing drift grounding incidents with pilotage. In addition, the MARCS model uses relative risk factor for internal vigilance of 0.5 with respect to human performance and 0.24 with respect to incapacitation.

A PPU is only effective in prevention of powered grounding incidents that result from human error. In the absence of any data, it is provisionally assumed that a PPU will improve the pilot's human error performance with respect to powered groundings by another 10 percent. The effect on collisions is assumed to be negligible. The effect of a PPU is modeled by an additional relative risk factor of 0.90 (i.e., a 10 percent reduction) applied to human performance errors in powered groundings and allisions when at least one pilot is present.

D.5.3 Aids to navigation

D.5.3.1 Electronic chart display and information system

A formal safety assessment (FSA) was submitted to IMO MSC in 2006 in connection with a proposal for ECDIS carriage requirements (IMO, 2007). The assessment investigated three cargo ship types using a Bayesian network model. It concluded that ECDIS reduced grounding risk by approximately 36 percent. This was due to a combination of more time available on the bridge for situational awareness, more efficient plotting of the ship's position and more efficient updating routines. ECDIS is assumed to have the same effect on allision risk in the modeling.

D.5.3.2 Conventional aids to navigation

Causal data on groundings provide some indication of the potential benefit of improving conventional ATON. In the absence of recent data, the relative risk factors in Table D-1 are used over the entire length of the route studied. Causes that might be prevented by improved conventional ATON are represented by "fault/deficiency of lights/marks" and amounted to 6.4 percent of incidents. Improving conventional ATON would not necessarily prevent all such incidents, but might have indirect benefits on other navigational errors. Therefore, this study uses a reduction in groundings and allisions by 6 percent, which is justified by this data.

The relative risk factors applied in MARCS for ATON are shown in Table D-1.

Table D-1 Relative risk factors for aids to navigation

Incident	cATON
Powered grounding or powered allision – human error	0.94
Powered grounding or powered allision- incapacitation	1.00

D.6 Additional background on MARCS

The Marine Accident Risk Calculation System (MARCS) was first developed by DNV GL during the mid-1990s. Since then it has been further developed and applied to different types of projects worldwide. The number of distinct projects performed probably exceeds 40. This section lists and summarizes the more significant projects relevant to wind farm navigation safety assessments.

D.6.1 Selected wind farm projects

All wind farm navigation safety assessments follow a similar pattern. The risk level prior to the wind farm installation is evaluated as the base case and the risks are re-evaluated after the addition of the proposed wind farm array.

2018	Skipjack
2017	South Fork
2015	Baltic Eagle in the Baltic Sea
2013	Iberdrola in the Baltic Sea
2013	Kriegers Flak in the Baltic Sea
2012	Baltic Eagle in the Baltic Sea
2011	Iberdrola in the Baltic Sea
2010	Iberdrola in the Baltic Sea
2010	Arcadis in the Baltic Sea
2009	Arcadis In the Baltic Sea
2009	Aldlergrund in the Baltic Sea
2008	Frederic Haven in the Baltic Sea
2008	Stignaes in the Baltic Sea
2007	Aldlergrund in the Baltic Sea
2006	Arcadis in the Baltic Sea
2006	Roedsand in the Baltic Sea
2005	Horns Rev in the Baltic Sea
2003	Adlergrund and Pommersche Bucht in the Baltic Sea
2003	Arkona in the Baltic Sea

D.6.2 Selected navigation risk projects

North East Shipping Risk Assessment, PP042653, 2012-2013

AMSA is the Australian government agency with prime responsibility for the safety of shipping in Australian waters and for the protection of the marine environment from ship-sourced pollution. The Great Barrier Reef (GBR) is a World Heritage Area located off the North East coast of Australia. In order to support its responsibilities to protect the GBR area while at the same time promoting safe and efficient shipping operations, AMSA commissioned DNV to perform a risk assessment of navigational accidents due to shipping traffic in the area.

The risk assessment entailed: the derivation of ship movement frequency data from AIS data; the assessment of the effectiveness of currently applied risk controls and more than 12 possible risk reduction options; the prediction of shipping traffic levels in 2020 and 2032; and the analysis of 12 distinct cases to estimate the relative effectiveness of the proposed risk reduction options for the NE area of Australia. The results will be used to guide AMSA's decision making processes.

Aleutian Islands Marine Risk Assessment, EP007543, 2009-2011

The Aleutian Island chain to the south west of Alaska is located on the major great circle marine trade route between the west coast of North America and the Far East. The region contains rich and diverse marine resources, including highly significant commercial fisheries.

In 2004 the M/V Selendang Ayu went aground off the Aleutians. The resulting fine established funding for a risk assessment managed by the U.S. National Fish and Wildlife Foundation, Alaska Department of Environmental Conservation and the U.S. Coast Guard. A team from Environmental Resources Management and Det Norske Veritas was awarded the risk assessment contract.

The risk assessment involved a detailed ship traffic study to establish the ship trading patterns used in 2008/09 and estimated in 2034. This information included: routes used (waypoints, lane widths); the annual frequency, size and type of ships on each route; cargoes carried; ship speeds; etc. For 2008/09, this information was obtained from AIS data where this was available and was estimated where no information existed. Future traffic in 2034 was estimated from the traffic pattern today and estimates of economic growth.

The traffic study was combined with DNV's marine risk model MARCS (Marine Accident Risk Calculation System) to calculate cargo and bunker fuel oil spill risks. ERM's spill trajectory model was then used to assess detailed accident consequences for a small group of agreed spill scenarios. Risk Reduction Options (RROs) were identified and subjected to an assessment of their risk reduction effectiveness, practicality and cost effectiveness by an expert judgement process at a DNV-led 4-day workshop in Anchorage. The outputs from the study were published in a 60-page summary report in August 2011.

The entire risk assessment process was subjected to and validated by a peer review process by 6 marine risk experts appointed through the U.S. National Academy of Science.

Prince William Sound Risk Assessment, 1995-1997

Prince William Sound in Alaska is famous as the location of the most expensive oil spill in history; the crude oil tanker Exxon Valdez went aground on Bligh Reef in March 1989. The Prince William Sound Risk Assessment project was performed by a group of contractors headed by DNV for a client consortium of oil shippers and citizens action groups along with state and federal regulators. The project mission statement was, "To improve the safety of oil transportation in Prince William Sound".

The risk assessment team was committed to make the best possible scientific estimate of the absolute risk of the present-day oil transportation system, as well as evaluating the effect of over 150 proposed risk reduction measures. Since the goal was to make the system safer, the majority of these risk reduction measures were prevention-based. That is, they were aimed at preventing accidents rather than responding to oil spills once they occur.

The project was subject to peer review by the American National Academy of Sciences to ensure that results of the highest quality were achieved. This was important, since the results of the study were used as the basis of a fully costed Risk Management Plan for Prince William Sound which involved a multi-million-dollar investment program.

The risk assessment project had an unstated but important subsidiary objective. Since the *Exxon Valdez* accident an atmosphere of distrust and confrontation had arisen between the major stakeholders in Prince William Sound. One result of this was that it was nearly impossible to gain consensus regarding how to modify the marine oil transportation system to reduce risk levels; each party favored a different approach. Each of these stakeholder groups was represented on the Risk Assessment Steering Committee. The process of managing the risk assessment, which entailed being actively involved in data gathering and validation, as well as examining risk assessment methods and results, improved mutual understanding of different group's positions, promoted co-operation and, to some extent, trust. The contract team, headed by DNV, facilitated this process by providing clear explanations of the technical field of risk assessment with tact and without bias.

The Prince William Sound Risk Assessment Project had a total budget of about $2m, comprising $1m for DNV's contributions with the remainder shared by the 2 sub-contracting organizations. The project was completed at the start of 1997 at which time a full, public domain report was issued.

D.6.3 Selected model development projects

Safety of Shipping in Coastal Waters (SAFECO II), 1998-1999

The Safety of Shipping in Coastal Waters (SAFECO II) project was performed for the Transport Directorate (DGVII) of the European Union under the Fourth Framework programme by a consortium of 10 European organisations with complimentary maritime expertise and was managed by DNV. The objectives of SAFECO II were:

- To assess the marine risk reduction potential of risk reduction measures based around the theme of improved ship-to-ship and ship-to-shore communication (measures explicitly evaluated were: ship transponders; standard maritime communication phrases; and an expert system providing advice on collision avoidance maneuvers);
- To develop improved ship accident consequence models, in terms of lives lost, bunker and crude oil outflow and financial impacts;
- To demonstrate the application of marine risk assessment methods in two case study areas (the North Sea and Rotterdam Port Approach) by performing a cost-benefit analysis of possible risk reduction measures.

The overall objective of the SAFECO programme was to develop marine risk assessment methods such that they form a solid basis for marine transport regulation. This aim was achieved by SAFECO II.

Safety of Shipping in Coastal Waters (SAFECO), 1997-1998

The SAFECO project was performed for the Transport Directorate (DGVII) of the European Union under the Fourth Framework programme. The objective of SAFECO was to improve the safety of shipping in coastal waters. The project aimed to establish robust methodologies capable of delivering secure risk assessment parameters to quantitative risk assessment tools. The ultimate aim of SAFECO was to use risk assessment results as the basis for marine transport regulation.

The project was performed by a consortium of 10 organizations headed and managed by DNV. Each project partner was an expert in one or more factors crucial to safe navigation (e.g. training of mariners, reliability of machinery, strength of ship hulls etc.) and developed a program of research to quantify the effect of these different factors on safety levels. However, in order to compare the relative effect of each factor, it was necessary to draw the results of each research program into a comprehensive marine risk model. DNV built an interface to each of the project partner research programs to allow the inter-comparison of the effects of each factor investigated by the project partners. This enabled the determination of those factors which had the greatest influence on the overall risk levels.

The SAFECO I project concluded with an evaluation of 8 risk reduction measures via 3 case studies (English Channel, North Sea and Rotterdam Port Approach).

D.6.4 Additional documents in the public domain

The following is a selection of papers and reports that are in the public domain:

- OVERVIEW OF PRINCE WILLIAM SOUND RISK ASSESSMENT PROJECT. Presented at, “Marine Risk Assessment - A better way to manage your business”, Institute of Marine Engineers, London, 7-8 May 1997
- SAFECO I Summary Report. DNV Report 98-2038
- SAFECO II Summary Report. DNV Report 99-2032
- Modelling Ship Transportation Risk, Risk Analysis, Vol 20, No. 2, 2000, pages 225-244
- Aleutian Islands Risk Assessment, Project Overview https://www.slideserve.com/aristotle-farley/aleutian-islands-risk-assessment-project-overview-powerpoint-ppt-presentation

APPENDIX E REVOLUTION WIND FARM MARINE ACCIDENT MODELING

E.1 Introduction

This appendix documents evaluation of the frequency and description of (1) collision between vessels, (2) allision with structures, and (3) grounding because of the establishment of a structure:

- Likely frequency of collision (vessel to vessel)
- Likely location of collision
- Likely type of collision
- Likely vessel type involved in collision
- Likely frequency of allision (vessel to structure)
- Likely location of allision
- Likely vessel type involved in allision
- Likely frequency of grounding
- Likely location of grounding
- Likely vessel type involved in grounding

The consequences of the modeled events are described in the main report.

The MARCS model is a set of risk parameters and calculation tools that have been developed to quantify marine risk. MARCS calculates the frequency of accidents due to the following navigation hazards:

- Collision between two ships underway
- Powered grounding, where a ship grounds due to human error (steering and propulsion not impaired)
- Drift grounding, where a ship strikes the grounding line due to mechanical failure (steering and/ or propulsion failed)
- Powered allision, where a ship strikes a man-made structure (e.g., WTG) due to human error (steering and propulsion not impaired)
- Drift allision, where a ship strikes a man-made structure (e.g., WTG) due to mechanical failure (steering and/ or propulsion failed)

The frequency of each accident type is calculated for each grid cell for each accident type and each ship type.

MARCS was used to calculate the frequency of collision, grounding, and allision for each cell defined by a grid covering the Study Area. The model provides the average annual frequency of occurrence for each accident type in each grid cell. These results are reported in this appendix. A detailed description of the collision, grounding (drift and powered), and allision (drift and powered) models is included in Appendix D.

Three cases are reported here:

1. The Base Case (or Case 0). This includes the un-modified shipping traffic as transiting the area today prior to the installation of the wind turbines.
2. The Base Case Plus (or Case 1). This includes the un-modified shipping traffic as transiting the area today prior to the installation of the wind turbines. In addition, the wind turbine locations are also included in Case 1 to provide an estimate of the extra risk introduced by the presence of the wind farm, in the absence of any modification to the traffic pattern.
3. The Future Case (or Case 2). This is similar to Case 1 but includes additional traffic caused by the presence of the wind farm and includes modified traffic routes assuming some ships will navigate around the wind farm once it is installed.

The differences in risk between these three cases provide an estimate of the changed risk introduced by the construction of the wind farm.

E.2 Model inputs

E.2.1 Study area

This is a quantitative assessment of collision, allision, and grounding in the modeled Study Area during operation of the Project. The Study Area utilized in the MARCS modelling of Revolution Wind Farm (the Project) is shown in Figure E-1 Note the distinctions between the Project Area, Lease Area and Study Area.

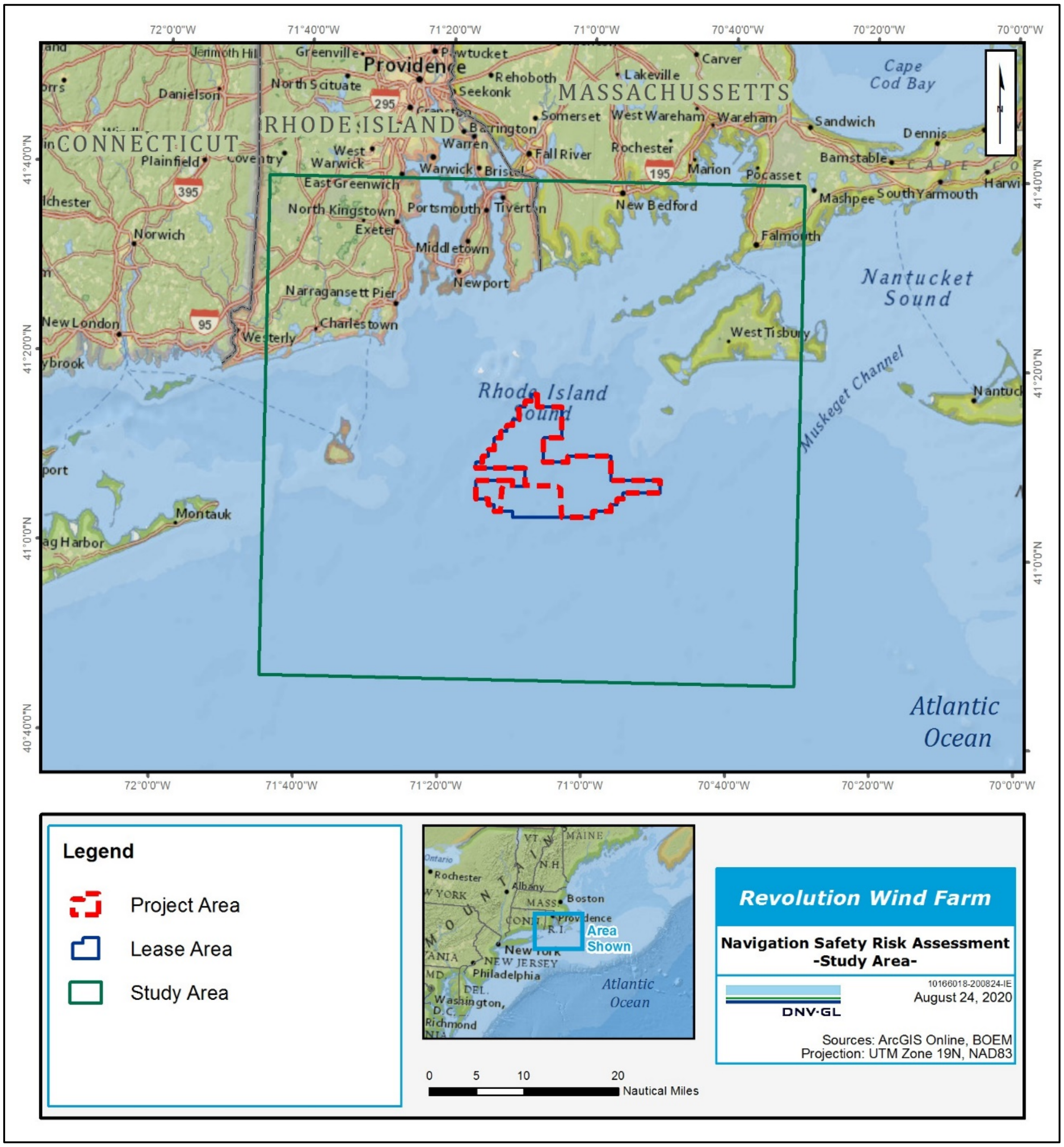

Figure E-1 Quantified risk Study Area

Accident frequency results are presented below for each sub-area as defined in Figure E-2.

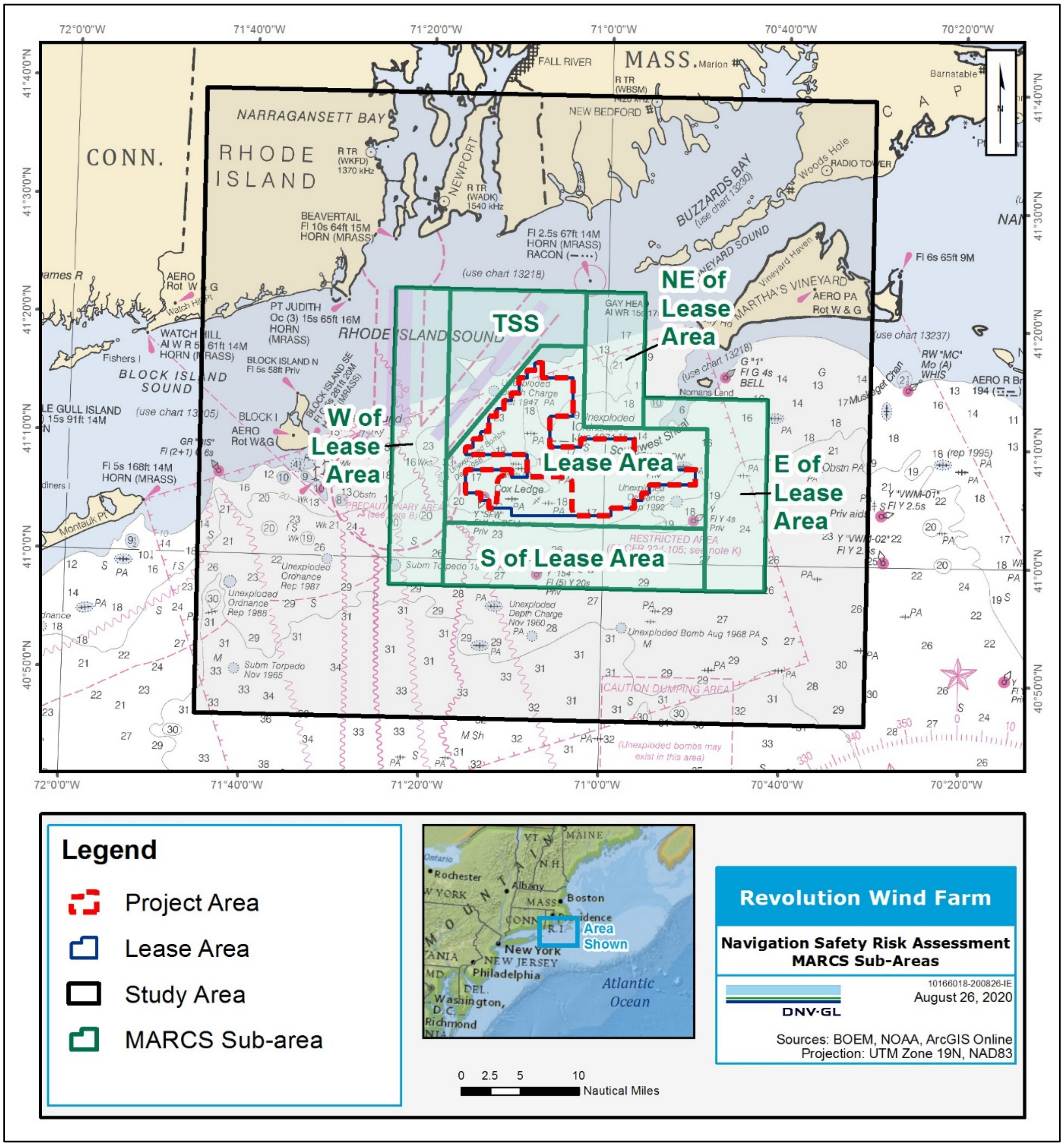

Figure E-2 Definition of Sub Areas within the Study Area

E.2.2 Wind Farm

The Project is modeled as 144 Project structures. The Project structures are separated by a minimum distance of 0.6 NM and each has a diameter of 10 m at and near sea level (i.e., the collision cross section is 10 m).

E.2.3 Metocean inputs

The metocean inputs utilized in MARCS are consistent with the weather described in Section 7 of the main report and are described below.

Wind

MARCS uses the wind speed and direction as a modelling input. Table E-1 shows the wind data described in Section 7.1 of the main report, formatted for MARCS: eight directions (North, Northeast, East, Southeast, South, Southwest, West, and Northwest) and four speed categories (Calm, Fresh, Gale, and Storm). The probabilities presented below are based on a virtual model of 17.5 years of hourly wind speed and direction data.

Table E-1 Annual wind direction and wind speed probabilities

Wind Speed in knots	N	NE	E	SE	S	SW	W	NW	Total
< 20 (Calm)	0.0742	0.0758	0.0692	0.0635	0.1039	0.2136	0.1164	0.0976	0.8141
20 – 30 (Fresh)	0.0169	0.0193	0.0116	0.0079	0.0107	0.0237	0.0278	0.0455	0.1632
30 – 45 (Gale)	0.0034	0.0045	0.0015	0.0009	0.0005	0.0008	0.0049	0.0059	0.0224
> 45 (Storm)	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003
Total	0.0945	0.0997	0.0823	0.0722	0.1151	0.2381	0.1492	0.1490	1.0000

Visibility

The Journal of Navigation's information regarding marine traffic studies[18] defines poor visibility as beginning at 2.2 NM (4.0 km) [19]. Visibility was therefore assessed as either poor, less than 2 NM (3.7 km) or good, greater than 2 NM. Table E-2 presents the visibility data used in the MARCS model.

[18] G.R.G. Lewison, "The Estimation of Collision Risk for Marine Traffic in UK Waters," Journal of Navigation, September 1980.
[19] National Oceanic and Atmospheric Administration, National Centers for Environmental Information, Block Island State Airport, RI, U.S. (WBAN:94793), Visibility data for Start date: 2010-09-01, End date: 2019-08-31. Website: https://www.ncdc.noaa.gov/cdo-web/datatools/lcd. Accessed 9 September 2019.

Table E-2 Visibility

Visibility in NM	Frequency	Modeled visibility
< 1	5.9%	Bad visibility = 8.6% of an average year
1 – 2*	2.7%	
2 – 3	1.8%	Good visibility = 91.4% of an average year
3 – 4	1.8%	
4 – 5	1.4%	
5 - 6	2.4%	
6 - 7	1.1%	
7 - 8	1.8%	
8-9	1.9%	
9-10	79.2%	
10+	5.9%	
Total	**100.0%**	

* Visibility was not measured at 2.2 NM

Sea state

A designation of “open water” in MARCS allows a higher power transfer from the wind to the waves than “semi-sheltered” or “sheltered” waters leading to higher wave heights (also called higher sea state). This allows for the wind speed in the area to have a greater effect on sea state, with higher winds resulting in rougher seas. The entire Study Area was modeled as an “open water” area because the Lease Area is located about 10 NM from the nearest shoreline at Martha’s Vineyard and is directly open to the North Atlantic.

Shoreline

Figure E-3 illustrates the shoreline used in MARCS. The defined shoreline identifies possible grounding locations for the model.

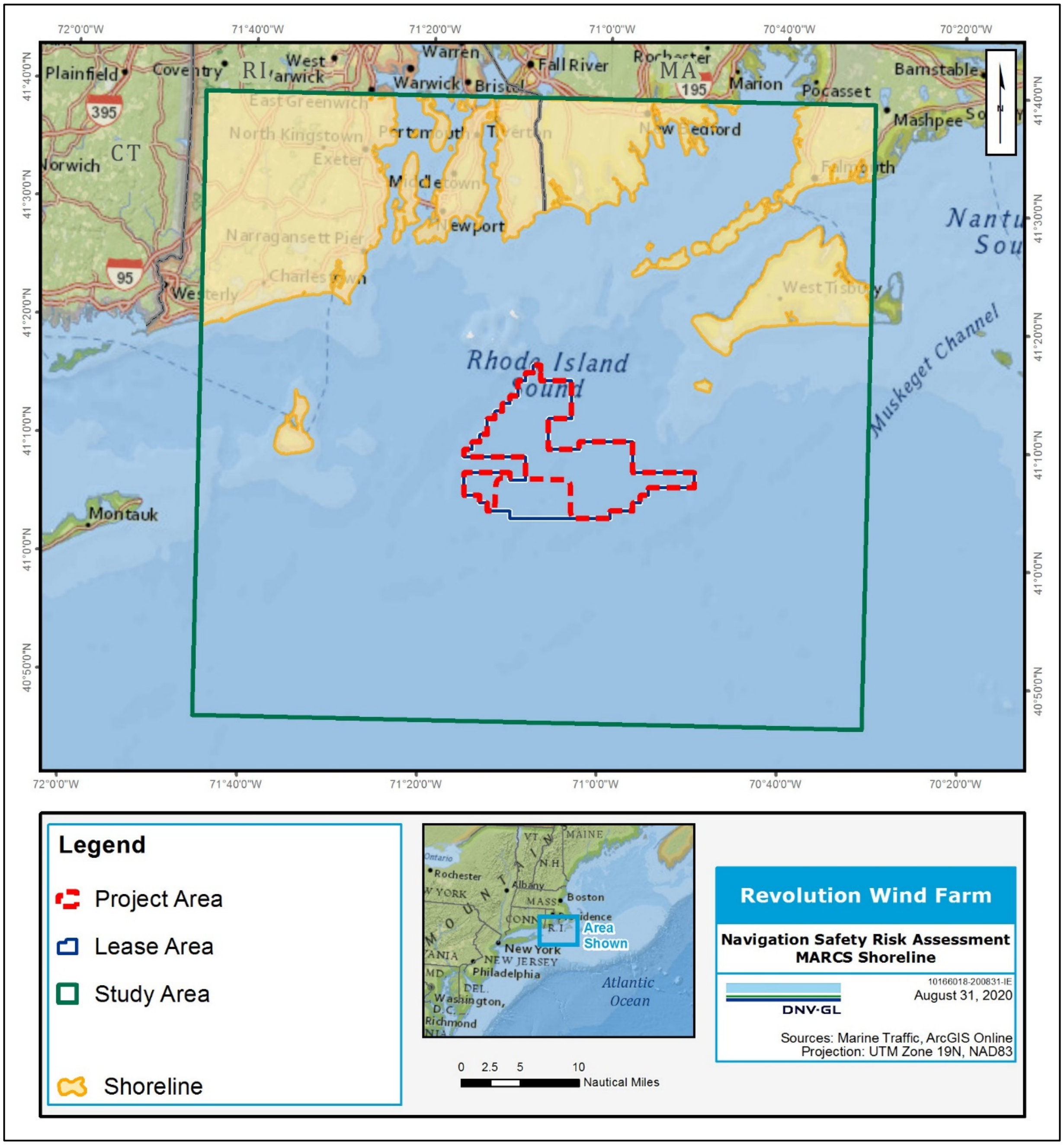

Figure E-3 Shoreline utilized in MARCS

E.2.4 Traffic data

Traffic data was derived by analysis of 3.6 million lines of Automatic Identification System (AIS) data collected between 1 July 2018 and 30 June 2019 within the Study Area. MARCS uses a statistical representation of aggregated ship tracks (Appendix D) and up to 8 distinct traffic types. The traffic types selected for this analysis are shown in Table E-3. Also shown are the average vessel speeds derived from the AIS data for each vessel type.

Table E-3 Traffic types used for MARCS analysis

Id	Traffic type name	Draft	Speed (knots)
1	Cargo/Carrier	Deep draft	9.5
2	Fishing	Not deep draft	7.5
3	Other/Undefined	Not deep draft	11.3
4	Passenger	Not deep draft	11.7
5	Pleasure	Not deep draft	7.5
6	Tanker	Deep draft	11.0
7	Tanker - Oil Product	Deep draft	10.8
8	Tug/Service	Not deep draft	8.5

The AIS dataset was analyzed in the following stages:

- Dirty or missing data were corrected or removed.
- Each AIS ship type was mapped to the most appropriate ship type category in Table E-3.
- Each AIS ship size was mapped to a MARCS ship size category for that ship type. Where no ship size data were available in the AIS data, the average ship size for that ship type category was assigned.
- Ship position reports were used to derive shipping density plots for each ship type and for all ships.
- A ship route structure was derived from the shipping density plots.
- Ship tracks were derived by linking successive ship position reports separated by a short time interval and a small distance for a specified ship.
- The ship tracks were allocated to the ship routes to derive the annual frequency of movement of each ship type and ship size along each route.

E.2.5 Traffic data adjustments

The traffic data derived from AIS data analysis were adjusted to correctly represent the data required for the three calculation cases. Three types of adjustments have been made:

1. The addition of traffic that is not correctly captured in the AIS data.
2. The addition of traffic that is projected to be generated by the presence of the wind farm.
3. The modification of traffic routes for some ship types due to the construction of the wind farm.

Each is described here.

Additional Traffic Added to all the cases (Base Case, Base Case Plus and Future Case)

The adjustments to pleasure vessels (including recreational boating) and to commercial fishing transits not in the AIS data were implemented into the MARCS model for all cases.

The AIS dataset is a reliable resource for capturing the main traffic patterns and vessels equipped with AIS transmitters. However, not all vessels are required to have AIS on board per Coast Guard regulations. To achieve the most realistic results for the Study Area, special care was placed on estimated recreational and commercial fishing vessel traffic that may not have been captured in the AIS dataset. This was done in two different ways.

First, for recreational boating, data were obtained from the Northeast Recreation Boater Activities from the Northeast Ocean Data portal. The activities are from participants in the 2012 Northeast Recreational Boater survey, conducted by SeaPlan, the Northeast Regional Ocean Council (NROC), states' coastal agencies, marine trade association of industry representatives, and the First Coast Guard District[20]. The data are from a randomly selected survey of registered boaters in the 2012 boating season.

The data contain 760 registered activities in the defined Study Area: 386 for fishing activity and 374 for other pleasure activities (such as diving and swimming). Each record was implemented in the model as an outbound and a return transit. The traffic patterns derived from the AIS analysis for fishing vessels and pleasure vessels were examined and the most densely trafficked routes closest to the wind farm were selected. The additional traffic was allocated to these routes. This represents a reasonable worst-case assessment of traffic that does not transmit AIS.

Figure E-4 shows the fishing routes that had additional recreational fishing transits added to them and Figure E-5 shows the route that had additional recreational pleasure boating transits added to it.

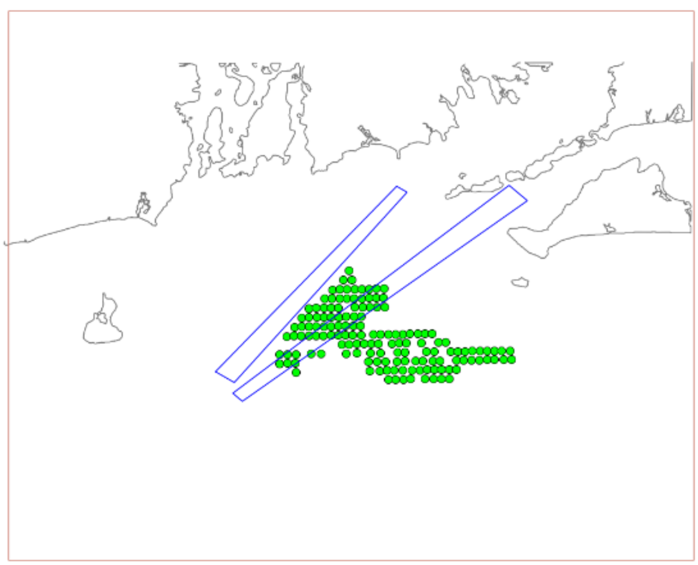

Figure E-4 Recreational boater routes that had additional transits added to them

[20] SeaPlan, "Recreational Boater Activities" http://www.northeastoceandata.org/files/metadata/Themes/Recreation/RecreationalBoaterActivities.pdf.

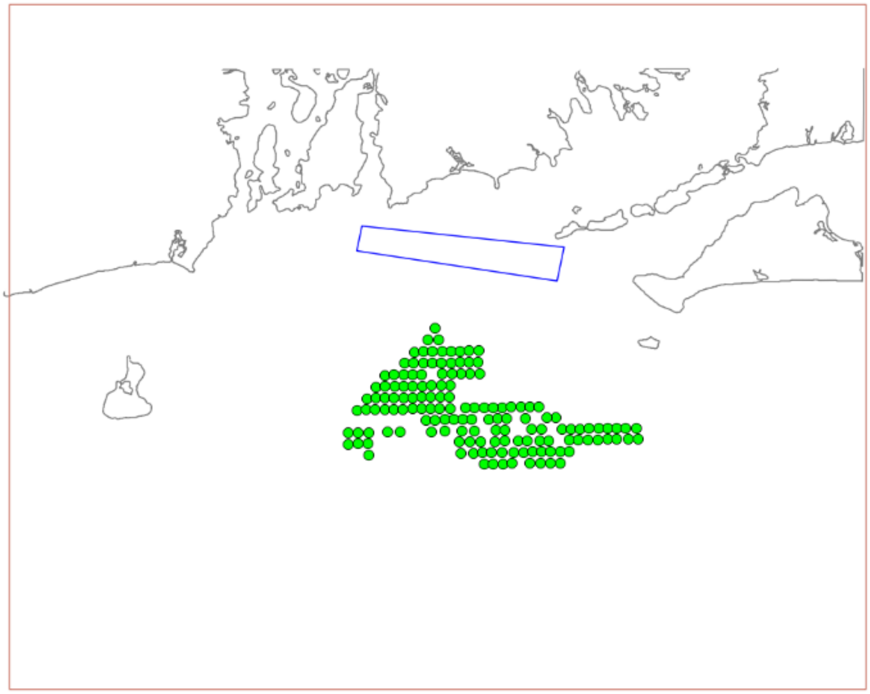

Figure E-5 Pleasure vessels' route that had additional transits added to it

Second, for commercial fishing, an analysis of fishing ship lengths for commercial fishing vessels registered in Rhode Island and Connecticut was performed. This showed that 17.5% of the registered commercial fishing vessels have lengths greater than 65 feet and hence are required to use AIS.

Key assumptions are:

- All of the longer commercial fishing boats are represented in the AIS dataset on departure from or approach to port, and the shorter boats are assumed to not be represented in the data at all. Therefore, all of transect crossings at port entries / exits by vessels indicated as commercial fishing in the AIS dataset represent all crossings made by 17.5% of the registered commercial fishing vessels. These are the vessels that must carry and turn on AIS and likely do so near shore.
- The number of transits per year taken by an average fishing vessel *longer* than 65 feet is the same as the number of transits per year taken by an average fishing vessel *shorter* than 65 feet. Regardless of vessel size, the number of transits per vessel is assumed to be the same.

The number of additional commercial fishing vessel trips for boats shorter than 65' was estimated as:

$$\text{Number of trips} = N / 0.175$$

where:

N is the number of trips for fishing vessels longer than 65' obtained from the AIS data

The resulting 19,611 additional commercial fishing vessel trips (19,611 inbound and 19,611 outbound per year) were allocated to new routes shown in Figure E-6.

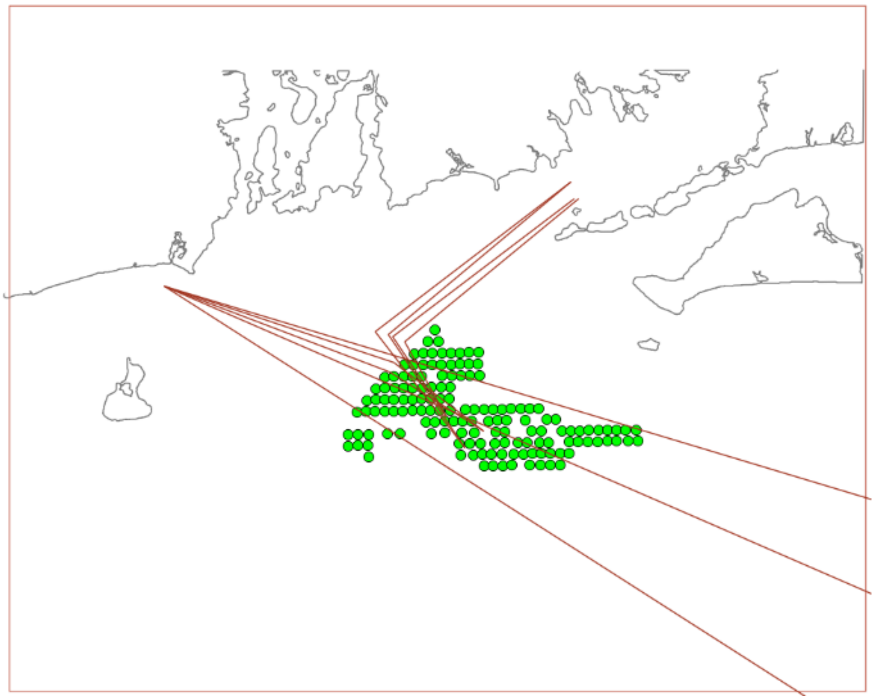

Figure E-6 New fishing vessel route centerlines that had transits added to them

Additional Traffic Added to the Future Case

The adjustments described in this section are to the Future Case (Case 2) MARCS model, with the Project.

It is anticipated that there will be public interest in the Project that could potentially lead to pleasure tours of the wind farm and a potential increase of recreational traffic (including recreational fishing). It is difficult to estimate a precise number of vessels per year that will be added to local traffic patterns. To incorporate the potential tours, excursion and recreational (including recreational fishing) traffic surrounding the Project, it is assumed that there will be 100 transits per year inbound and outbound. This is a conservatively high estimate for the first operational year of the Project. It is anticipated that as time passes, there will be less traffic due to wind farm tours and the increase in vessels may diminish. This study aims to present the conservative case with the most possible traffic, as opposed to an average traffic scheme over a longer period. This additional traffic in the Future Case is included in the Pleasure vessel category and is allocated a new route from Narragansett to the wind farm, as shown in Figure E-7.

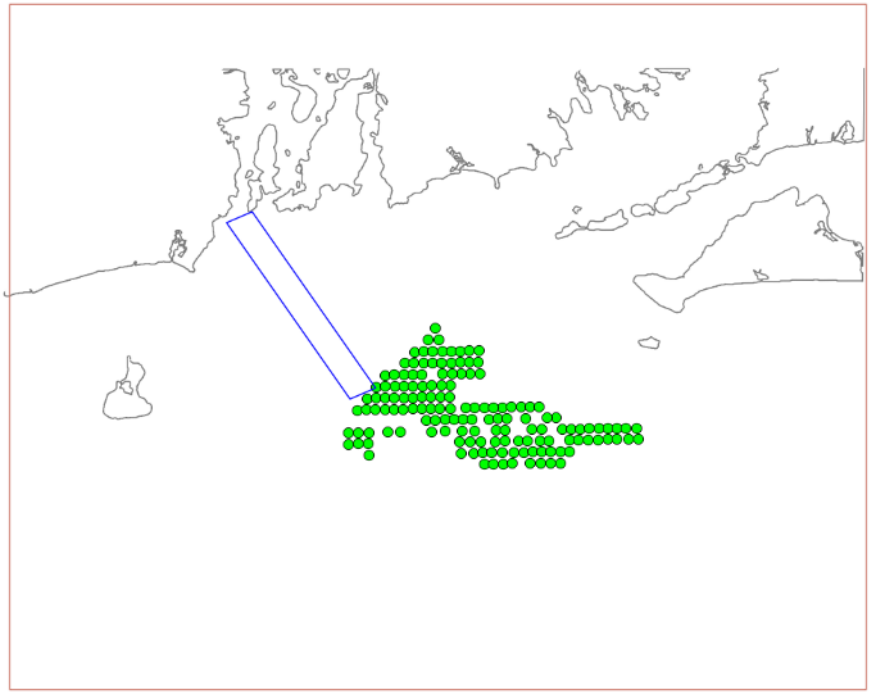

Figure E-7 New Pleasure vessel transit route added to the Future Case

Modification of Traffic Routes in the Future Case

Currently, some shipping routes traverse the area where the wind farm is to be constructed. Many ships will choose not to navigate through the wind farm. At this time, the extent to which they will adjust their course is a matter of speculation. DNV GL developed alternative routes for vessels to avoid the wind farm footprint and to minimize the additional navigation while taking account of the existing TSS.

Figure E-8 shows an example of how this modification was performed for 1 of the 5 routes that needed modification.

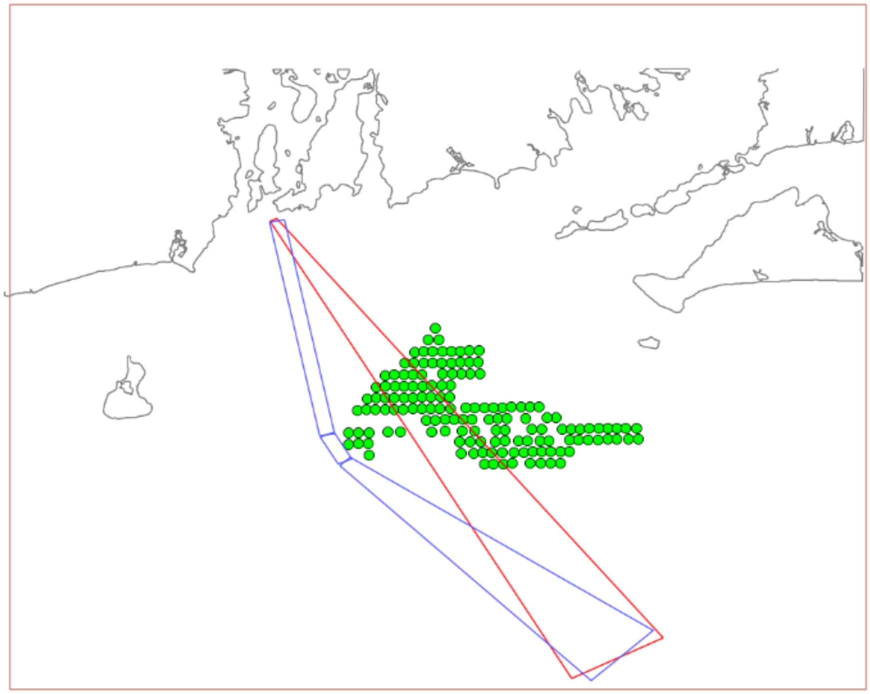

Figure E-8 Example of how one route was modified (red route was deleted, blue route was added)

Deep draft ships (Cargo, Tanker and Tanker Oil Products) as well as Tug/Service vessels that were on routes through the wind farm were re-allocated to these modified routes outside of the wind farm for the Future Case. Other traffic types (Fishing, Other, Passenger and Pleasure) continue to navigate through the wind farm in the Future Case.

E.2.6 Operational inputs

The MARCS model can apply different risk reduction options to a specific type of traffic and/or to a specified area, see Figure E-9. The risk controls applied to vessels transiting are described in Table E-4. This table show which risk controls are applied based on vessel types and areas.

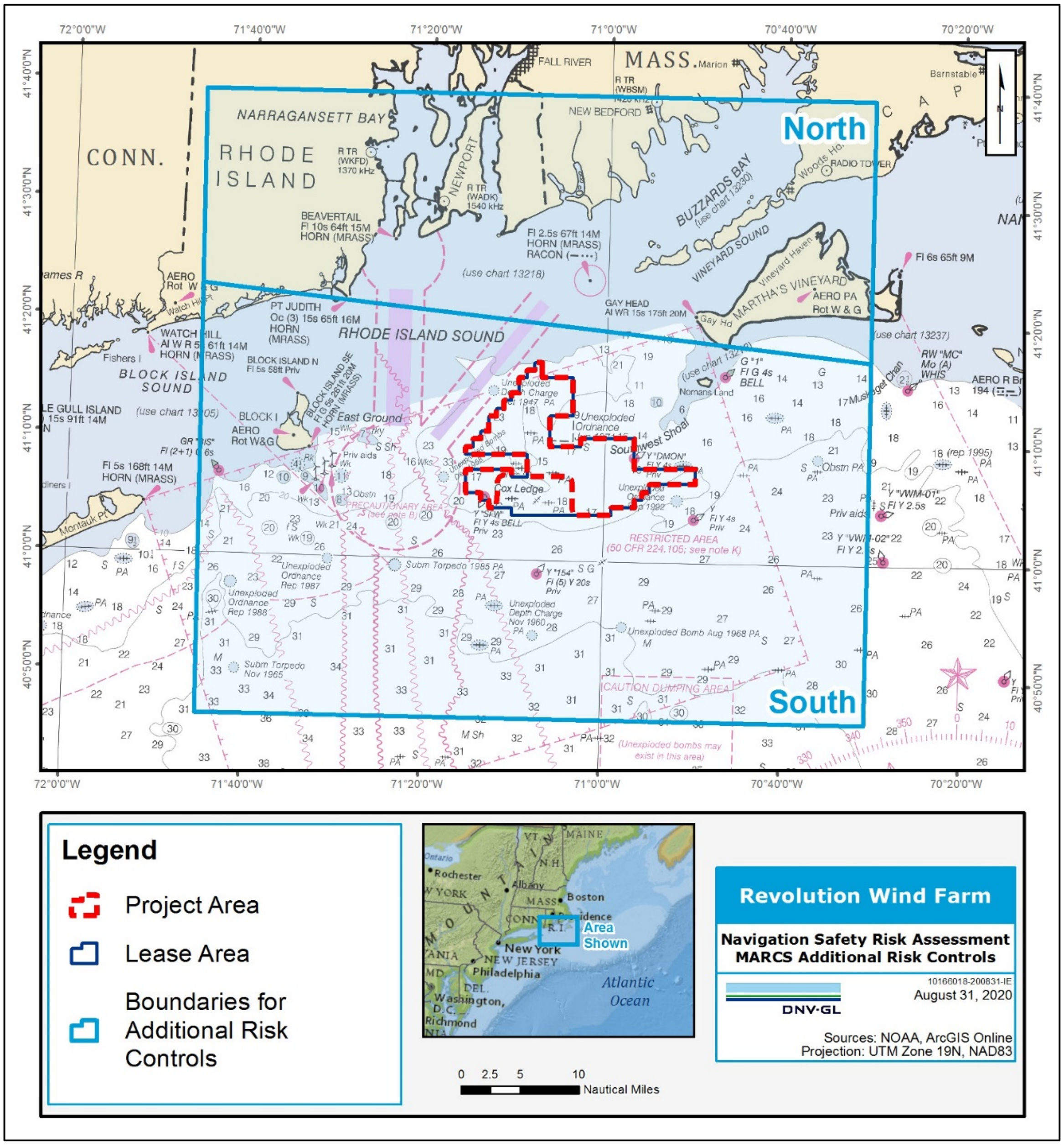

Figure E-9 Boundaries for model-specific risk controls

Table E-4 Risk controls applied in MARCS modelling for the Study Area

Risk control	Vessel type		
	Deep draft vessels		All other vessels
	Study Area North	Study Area South	Study Area North and South
Vessel traffic services	Yes	No	No (Note: some tugs yes, dep on cargo, in Zone A)
Pilotage	Yes	No	No (Note: depends on vessel, some tugs yes)
Portable pilotage unit	Yes	No	No (Note: depends on vessel, some tugs yes)
Differential global positioning systems	Yes	Yes	Yes
Conventional aids to navigation	Yes	Yes	Yes
Electronic chart display and information system	Yes	Yes	Yes
Underkeel clearance management	N/A (Note: only applied in Providence River)	N/A	N/A

Note, if a risk control is not applied to all ships of the specified type in an area then it is applied to no ships of that ship type in that area. This is a conservative assumption that tends to over-estimate the calculated risks.

In addition, Port State Control is applied to all deep draft ships as defined in Table E-3 and the National Oceanic and Atmospheric Administration PORTS® (Physical Oceanographic Real-Time System) System is applied to deep draft ships in Study Area North. The NOAA PORTS system provides real-time data to enhance safe navigation to and from the major ports in the Study Area. It provides many of the same capabilities as a Portable Pilotage Unit; however, its risks and benefits have not been quantified. As a result, PORTS is not included as a quantified risk reduction measure in the risk modeling conducted for the Project. This is a conservative assumption.

Pilotage requirements are defined in Rhode Island Code § 46-9-2 and § 46-9.1-5. DNV GL applied pilotage requirements to vessels in the method most appropriate for modelling purposes: to deep draft and passenger vessels in Rhode Island Sound and Block Island Sound.

E.3 Collision, allision, and grounding frequency results

In line with NVIC 01-19, this assessment compares the risk before the Project is built, and after it is operational:

- A Base Case (Case 0) was modeled for the current conditions in the Study Area. The results from the Base Case consist of collision, powered grounding and drift grounding accident frequencies alone since this case is an estimate of the risk levels today prior to the construction of the wind farm.
- A Base Case Plus (Case 1) was modeled for the current conditions in the Study Area plus the proposed wind farm. This provides a hypothetical estimate of the risk after construction of the wind farm but without any modifications to the traffic pattern. The Base Case Plus estimates the frequency of a collision, grounding, and allision with Project structures.

- A Future Case with the Project (Case 2). This estimates the anticipated future conditions of the Study Area. The Future Case incorporates the Project structures, traffic redistribution due to the Project, and any anticipated increases in traffic due to the Project. The Future Case estimates the frequency of a collision, grounding, and allision with Project structures.

Table E-5 summarizes these cases.

Table E-5 Summary of modeled cases

Case	Considerations
Base Case (Case 0)	- AIS data - Traffic adjustments to fishing and pleasure vessels not in the AIS data
Base Case Plus (Case 1)	- AIS data - Traffic adjustments to fishing and pleasure vessels not in the AIS data - Implementation of the Project structures
Future Case with the Project (Case 2)	- AIS data - Traffic adjustments to fishing and pleasure vessels not in the AIS data - Traffic adjustments to tour passenger vessel traffic - Re-distribution of traffic lanes for ship types Cargo, Tankers, Tanker - Oil Product, and Tugs - Implementation of Project structures

Cases 0, 1, and 2 are modeled in MARCS. The MARCS model is detailed further in Appendix D to this NSRA. It has been utilized globally by DNV GL to determine the navigation risk of more than 16 wind farms.

All results are reported for the Lease Area, the adjacent sub-areas, and the sum across them. The residual area comprises the remainder of the Study Area. The results for the residual area:

- Grounding risk exists only in the residual area, but the frequency of groundings is not significantly affected by the Project
- Collision risk in the residual area is not significantly affected by the Project (a frequency increase <0.001 per year)

E.3.1 Base Case (Case 0)

The Base Case results define the baseline average annual frequencies of marine accidents. The Base Case utilized AIS data from 1 July 2018 through 30 June 2019 plus additional transits for recreational boating and commercial fishing vessels.

Table E-6 presents the Base Case accident frequencies for each ship type and for each accident type for the Lease Area plus the 5 adjacent sub-areas. Cells in grey denote frequencies less than 1 in 10,000 per year.

Note these frequencies are for all accidents irrespective of whether the accident has significant consequences.

Table E-6 Accident frequencies (per year) for Base Case (Case 0) without the Wind Farm[21]

Base Case	Collision	Powered grounding	Drift grounding	Powered allision	Drift allision	Total
Cargo/Carrier	0.0021	0	0	0	0	0.0021
Fishing	0.7325	0	0	0	0	0.7325
Other/Undefined	0.0027	0	0	0	0	0.0027
Passenger	0.0007	0	0	0	0	0.0007
Pleasure	0.0072	0	0	0	0	0.0072
Tanker	<0.0001	0	0	0	0	<0.0001
Tanker - Oil Product	0.0006	0	0	0	0	0.0006
Tug/Service	0.0084	0	0	0	0	0.0084
Total	0.7543	0	0	0	0	0.7543

The modeled Base Case accident frequency today without the wind farm is estimated to be 0.75 per year, primarily involving commercial fishing vessels. There is zero frequency of grounding or allision with Project structures in the Lease Area or these sub-areas because they contain no land and there are no Project structures.

Table E-7 Accident return periods (in years) (on average, 1 accident expected every return period)

Base Case	Base Case Marine Accident Return Period
Cargo/Carrier	473
Fishing	1
Other/Undefined	371
Passenger	1,335
Pleasure	138
Tanker	14,172
Tanker - Oil Product	1,689
Tug/Service	120

Table E-8 through Table E-13 show the accident frequencies for Case 0 in the Lease Area and each of the sub-areas around the Project (Figure E-2).

[21] Note the number of significant figures quoted in this Table, and in similar Tables, is only to facilitate comparison of results. Up to two significant figures are reasonable to evaluate considering uncertainties in the modeling.

Table E-8 Accident frequencies (per year) for Case 0 in Lease Area

Base Case	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.0001	0	0	0	0	<0.0001
Fishing	0.3703	0	0	0	0	0.3703
Other/Undefined	0.0008	0	0	0	0	0.0008
Passenger	<0.0001	0	0	0	0	<0.0001
Pleasure	0.0012	0	0	0	0	0.0012
Tanker	0	0	0	0	0	0
Tanker - Oil Product	<0.0001	0	0	0	0	<0.0001
Tug/Service	0.0007	0	0	0	0	0.0007
Total	0.3732	0	0	0	0	0.3732

Note these frequencies are for all accidents irrespective of whether the accident has significant consequences.

Table E-9 Accident frequencies (per year) for Case 0 in TSS

Base Case	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	0.0003	0	0	0	0	0.0003
Fishing	0.2051	0	0	0	0	0.2051
Other/Undefined	0.0011	0	0	0	0	0.0011
Passenger	0.0003	0	0	0	0	0.0003
Pleasure	0.0039	0	0	0	0	0.0039
Tanker	<0.0001	0	0	0	0	<0.0001
Tanker - Oil Product	<0.0001	0	0	0	0	<0.0001
Tug/Service	0.0050	0	0	0	0	0.0050
Total	0.2158	0	0	0	0	0.2158

Table E-10 Accident frequencies (per year) for Case 0 for Northeast of Lease Area

Base Case	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.0001	0	0	0	0	<0.0001
Fishing	0.0034	0	0	0	0	0.0034
Other/Undefined	0.0001	0	0	0	0	0.0001
Passenger	<0.0001	0	0	0	0	<0.0001
Pleasure	0.0007	0	0	0	0	0.0007
Tanker	<0.0001	0	0	0	0	<0.0001
Tanker - Oil Product	<0.0001	0	0	0	0	<0.0001
Tug/Service	0.0002	0	0	0	0	0.0002
Total	0.0044	0	0	0	0	0.0044

Table E-11 Accident frequencies (per year) for Case 0 for East of Lease Area

Base Case	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.0001	0	0	0	0	<0.0001
Fishing	0.0055	0	0	0	0	0.0055
Other/Undefined	0.0002	0	0	0	0	0.0002
Passenger	0	0	0	0	0	0
Pleasure	<0.0001	0	0	0	0	<0.0001
Tanker	0	0	0	0	0	0
Tanker - Oil Product	0	0	0	0	0	0
Tug/Service	<0.0001	0	0	0	0	<0.0001
Total	0.0057	0	0	0	0	0.0057

Table E-12 Accident frequencies (per year) for Case 0 for South of Lease Area

Base Case	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.0001	0	0	0	0	<0.0001
Fishing	0.0051	0	0	0	0	0.0051
Other/Undefined	0.0001	0	0	0	0	0.0001
Passenger	<0.0001	0	0	0	0	<0.0001
Pleasure	<0.0001	0	0	0	0	<0.0001
Tanker	0	0	0	0	0	0
Tanker - Oil Product	<0.0001	0	0	0	0	<0.0001
Tug/Service	<0.0001	0	0	0	0	<0.0001
Total	0.0052	0	0	0	0	0.0052

Table E-13 Arequencies (per year) for Case 0 for West of Lease Area

Base Case	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	0.0017	0	0	0	0	0.0017
Fishing	0.1430	0	0	0	0	0.1430
Other/Undefined	0.0004	0	0	0	0	0.0004
Passenger	0.0004	0	0	0	0	0.0004
Pleasure	0.0013	0	0	0	0	0.0013
Tanker	<0.0001	0	0	0	0	<0.0001
Tanker - Oil Product	0.0005	0	0	0	0	0.0005
Tug/Service	0.0025	0	0	0	0	0.0025
Total	0.1499	0	0	0	0	0.1499

E.3.2 Base Case Plus the Project (Case 1)

The Case 1 results show the average annual frequencies of marine accidents using unmodified Base Case traffic data plus including the Project structures. This case is used to verify the modeling.

Table E-14 to Table E-19 show the model results for each sub-area.

The results for Case 1 are compared with the other case results and discussed in Section E.4.

Table E-14 Accident frequencies (per year) for Case 1 in Lease Area

Base Case	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.0001	0	0	0.0009	0.0132	0.0142
Fishing	0.3703	0	0	0.5901	0.6612	1.6216
Other/Undefined	0.0008	0	0	0.0057	0.0160	0.0225
Passenger	<0.0001	0	0	0.0010	0.0052	0.0063
Pleasure	0.0012	0	0	0.0043	0.0166	0.0221
Tanker	0	0	0	0	0.0006	0.0006
Tanker - Oil Product	<0.0001	0	0	0.0005	0.0045	0.0051
Tug/Service	0.0007	0	0	0.0025	0.0299	0.0331
Total	0.3732	0	0	0.605	0.7472	1.7254

Table E-15 Accident frequencies (per year) for Case 1 in TSS

Base Case	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	0.0003	0	0	0	0	0.0003
Fishing	0.2051	0	0	0	0	0.2051
Other/Undefined	0.0011	0	0	0	0	0.0011
Passenger	0.0003	0	0	0	0	0.0003
Pleasure	0.0039	0	0	0	0	0.0039
Tanker	<0.0001	0	0	0	0	<0.0001
Tanker - Oil Product	<0.0001	0	0	0	0	<0.0001
Tug/Service	0.0050	0	0	0	0	0.0050
Total	0.2158	0	0	0	0	0.2158

Table E-16 Accident frequencies (per year) for Case 1 for Northeast of Lease Area

Base Case	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.0001	0	0	0	0	<0.0001
Fishing	0.0034	0	0	0	0	0.0034
Other/Undefined	0.0001	0	0	0	0	0.0001
Passenger	<0.0001	0	0	0	0	<0.0001
Pleasure	0.0007	0	0	0	0	0.0007
Tanker	<0.0001	0	0	0	0	<0.0001
Tanker - Oil Product	<0.0001	0	0	0	0	<0.0001
Tug/Service	0.0002	0	0	0	0	0.0002
Total	0.0044	0	0	0	0	0.0044

Table E-17 Accident frequencies (per year) for Case 1 for East of Lease Area

Base Case	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.0001	0	0	0	0	<0.0001
Fishing	0.0055	0	0	0	0	0.0055
Other/Undefined	0.0002	0	0	0	0	0.0002
Passenger	0	0	0	0	0	0
Pleasure	<0.0001	0	0	0	0	<0.0001
Tanker	0	0	0	0	0	0
Tanker - Oil Product	0	0	0	0	0	0
Tug/Service	<0.0001	0	0	0	0	<0.0001
Total	0.0057	0	0	0	0	0.0057

Table E-18 Accident frequencies (per year) for Case 1 for South of Lease Area

Base Case	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.0001	0	0	0	0	<0.0001
Fishing	0.0051	0	0	0	0	0.0051
Other/Undefined	0.0001	0	0	0	0	0.0001
Passenger	<0.0001	0	0	0	0	<0.0001
Pleasure	<0.0001	0	0	0	0	<0.0001
Tanker	0	0	0	0	0	0
Tanker - Oil Product	<0.0001	0	0	0	0	<0.0001
Tug/Service	<0.0001	0	0	0	0	<0.0001
Total	0.0052	0	0	0	0	0.0052

Table E-19 Accident frequencies (per year) for Case 1 for West of Lease Area

Base Case	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	0.0017	0	0	0	0	0.0017
Fishing	0.1436	0	0	0	0	0.1436
Other/Undefined	0.0004	0	0	0	0	0.0004
Passenger	0.0004	0	0	0	0	0.0004
Pleasure	0.0013	0	0	0	0	0.0013
Tanker	<0.0001	0	0	0	0	<0.0001
Tanker - Oil Product	0.0005	0	0	0	0	0.0005
Tug/Service	0.0025	0	0	0	0	0.0025
Total	0.1499	0	0	0	0	0.1499

E.3.3 Future Case with the Project (Case 2)

The Case 2 results show the average annual frequencies of marine accidents using modified Base Case traffic data including the Project structures.

Table E-20 presents the Future Case accident frequencies for each ship type and for each accident type in the Lease Area and adjacent sub-areas.

Table E-20 Accident frequencies (per year) for Future Case (Case 2) with the Wind Farm[22]

Base Case	Collision	Powered grounding	Drift grounding	Powered allision	Drift allision	Total
Cargo/Carrier	0.0026	0	0	0.0003	0.0145	0.0174
Fishing	0.7343	0	0	0.5901	0.6612	1.9856
Other/Undefined	0.0027	0	0	0.0057	0.0160	0.0244
Passenger	0.0008	0	0	0.0010	0.0052	0.0070
Pleasure	0.0085	0	0	0.0053	0.0198	0.0337
Tanker	<0.0001	0	0	<0.0001	0.0006	0.0007
Tanker - Oil Product	0.0009	0	0	0.0001	0.0052	0.0062
Tug/Service	0.0084	0	0	0.0006	0.0280	0.0370
Total	0.7584	0	0	0.6031	0.7504	2.1119

The modeled Future Case accident frequency today with the wind farm is estimated to be 2.1 per year. Accidents involving commercial fishing vessels are the dominant accident frequency contributor.

Table E-21 to Table E-26 show the model results for the Lease Area and the adjacent sub-areas.

The results for Case 2 are compared with the other case results and discussed in Section E.4 below.

Table E-21 Accident frequencies (per year) for Case 2 in Lease Area

Base Case	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	0.0002	0	0	0.0003	0.0145	0.015
Fishing	0.3703	0	0	0.5901	0.6612	1.6216
Other/Undefined	0.0008	0	0	0.0057	0.016	0.0225
Passenger	<0.0001	0	0	0.0010	0.0052	0.0063
Pleasure	0.0012	0	0	0.0053	0.0198	0.0263
Tanker	0	0	0	0	0.0006	0.0006
Tanker - Oil Product	0.0001	0	0	0.0001	0.0052	0.0054
Tug/Service	0.0004	0	0	0.0006	0.028	0.0290
Total	0.3731	0	0	0.6031	0.7505	1.7267

[22] Note the number of significant figures quoted in this Table, and in similar Tables, is only to facilitate comparison of results. Up to two significant figures are reasonable to evaluate considering uncertainties in the modeling.

Table E-22 Accident frequencies (per year) for Case 2 in TSS

Base Case	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	0.0006	0	0	0	0	0.0006
Fishing	0.2064	0	0	0	0	0.2064
Other/Undefined	0.0011	0	0	0	0	0.0011
Passenger	0.0003	0	0	0	0	0.0003
Pleasure	0.0046	0	0	0	0	0.0046
Tanker	<0.0001	0	0	0	0	<0.0001
Tanker - Oil Product	0.0003	0	0	0	0	0.0003
Tug/Service	0.0050	0	0	0	0	0.0050
Total	0.2183	0	0	0	0	0.2183

Table E-23 Accident frequencies (per year) for Case 2 for Northeast of Lease Area

Base Case	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.0001	0	0	0	0	<0.0001
Fishing	0.0034	0	0	0	0	0.0034
Other/Undefined	0.0001	0	0	0	0	0.0001
Passenger	<0.0001	0	0	0	0	<0.0001
Pleasure	0.0007	0	0	0	0	0.0007
Tanker	<0.0001	0	0	0	0	<0.0001
Tanker - Oil Product	<0.0001	0	0	0	0	<0.0001
Tug/Service	0.0002	0	0	0	0	0.0002
Total	0.0044	0	0	0	0	0.0044

Table E-24 Accident frequencies (per year) for Case 2 for East of Lease Area

Base Case	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.0001	0	0	0	0	<0.0001
Fishing	0.0056	0	0	0	0	0.0056
Other/Undefined	0.0002	0	0	0	0	0.0002
Passenger	<0.0001	0	0	0	0	<0.0001
Pleasure	<0.0001	0	0	0	0	<0.0001
Tanker	<0.0001	0	0	0	0	<0.0001
Tanker - Oil Product	<0.0001	0	0	0	0	<0.0001
Tug/Service	<0.0001	0	0	0	0	<0.0001
Total	0.0058	0	0	0	0	0.0058

Table E-25 Accident frequencies (per year) for Case 2 for South of Lease Area

Base Case	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.0001	0	0	0	0	<0.0001
Fishing	0.0051	0	0	0	0	0.0051
Other/Undefined	0.0001	0	0	0	0	0.0001
Passenger	<0.0001	0	0	0	0	<0.0001
Pleasure	<0.0001	0	0	0	0	<0.0001
Tanker	<0.0001	0	0	0	0	<0.0001
Tanker - Oil Product	<0.0001	0	0	0	0	<0.0001
Tug/Service	<0.0001	0	0	0	0	<0.0001
Total	0.0052	0	0	0	0	0.0052

Table E-26 Accident frequencies (per year) for Case 2 for West of Lease Area

Base Case	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	0.0018	0	0	0	0	0.0018
Fishing	0.1436	0	0	0	0	0.1436
Other/Undefined	0.0004	0	0	0	0	0.0004
Passenger	0.0004	0	0	0	0	0.0004
Pleasure	0.0019	0	0	0	0	0.0019
Tanker	<0.0001	0	0	0	0	<0.0001
Tanker - Oil Product	0.0005	0	0	0	0	0.0005
Tug/Service	0.0027	0	0	0	0	0.0027
Total	0.1514	0	0	0	0	0.1514

E.4 Model verification

Several checks and cross-checks were conducted to assure the model is self-consistent, and provides valid, credible results.

The difference between Case 1 and Case 0 provides an estimate of the maximum risk increase that could result from the presence of the Project wind farm if none of the traffic varied their routes because of the Project.

The difference between Case 2 and Case 1 provides an estimate of how risk is mitigated when some traffic types are re-routed around the wind farm footprint.

E.4.1 Comparing Case 1 to Case 0

The Base Case (Case 0) is without the Project structures and without modification of the traffic data. The Base Case Plus (Case 1) is the same as the Base Case but includes the Project structures. Comparing the two cases (using the sum of accident frequencies in all the defined sub-areas) shows that the total accident frequency increases by 1.4 accidents per year when the Project structures are present and without modification of the traffic data. It also shows that the collision accident frequency is exactly unchanged (as is the grounding frequency because there are no grounding locations in the defined sub-areas). This is because the only difference between Case 0 and Case 1 is the addition of the project turbines in Case 1.

The turbine allision accident frequencies in Case 1 are 0.605 and 0.747 for powered and drift allision respectively. The sum of the allision frequencies represent the difference in the total accident frequency between Case 1 and Case 0. Approximately 55% of the total allision frequency is due to drift allision.

Other comparisons that were made to assure model quality were miles travelled per vessel type and ratio of accident frequencies per vessel type and per accident type.

E.4.2 Comparing Case 2 to Case 1

The Future Case (Case 2) includes the Project structures and the modified traffic data. The Base Case Plus (Case 1) is the same as the Future Case but without the modifications to the traffic data.

The accident frequencies are mostly either identical or very similar for the Future Case (Case 2) compared to the Base Case Plus (Case 1). The main differences expected for the Future Case (Case 2) are:

- Powered allision is reduced for Cargo, Tanker – Oil and Tugs. This is because these ship types are re-routed around the wind farm in the Future Case. (Tankers are also re-routed around the wind farm but there is no significant Tanker traffic through the wind farm area in the Base Case (and Base Case Plus)).
- Powered allision for Pleasure ships is increased. This is because of the additional pleasure tour ships included in the Future Case (Case 2).
- Drift allision is slightly increased for Cargo and Tanker – Oil ships. This is because the prevailing wind is from the West and many of these ship types are re-routed around the western side of the wind farm. Thus, after re-routing, all these ships become up-wind of the entire wind farm array, resulting in an increased drift allision frequency.

E.5 Results and discussion

E.5.1 Project risk difference: comparing Case 2 to Case 0

The Future Case (Case 2) includes the Project structures and the modified traffic data. The Base Case (Case 0) is without the Project structures and without the modifications to the traffic data.

Table E-27 shows the predicted effect of the Project on accident frequency, that is, the difference between Case 2 and Case 0. Differences in frequency less than 0.001 per year are highlighted in grey.

The difference between the two cases for the Lease Area and adjacent sub-areas shows that the total accident frequency increases 1.4 accidents per year. This is because Case 2 includes the Project WTGs and introduces extra wind farm pleasure tour transits which are not included in Case 0.

Non-allision accident frequencies in the Future Case (Case 2) after the installation of the Project structures are very similar to those in the Base Case (Case 0).

Table E-27 Risk Difference: Future Case (Case 2) minus Base Case (Case 0) (annual accident frequency)

Vessel Type	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.001	0	0	<0.001	0.015	0.015
Fishing	0.002	0	0	0.590	0.661	1.253
Other & Undefined	<0.001	0	0	0.006	0.016	0.022
Passenger	<0.001	0	0	0.001	0.005	0.006
Pleasure	0.001	0	0	0.005	0.020	0.026
Tanker	<0.001	0	0	<0.001	<0.001	<0.001
Tanker – Oil	<0.001	0	0	<0.001	0.005	0.006
Tug & Service	<0.001	0	0	<0.001	0.028	0.029
Total	0.004	0	0	0.603	0.750	1.358

E.5.2 Discussion of the sub-area results

The sub-area accident frequency differences between Case 0 and Case 2 are discussed below. These are conservative estimates of the risk increase from the Project.

In general, the accident frequencies observed reflect the amount of shipping traffic of each ship type in each sub-area.

Table E-28 shows the modeled difference in risk from the Project. The Lease Area contains all the Project structures and hence it contains all the powered allision and all the drift allision accidents. There is zero frequency of powered grounding and drift grounding in this and all sub-areas because the sub-areas contain no land.

Table E-28 Risk difference: Lease Area (annual accident frequencies)

Vessel Type	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.001	-	-	<0.001	0.014	0.015
Fishing	<0.001	-	-	0.590	0.661	1.251
Other & Undefined	<0.001	-	-	0.006	0.016	0.022
Passenger	<0.001	-	-	0.001	0.005	0.006
Pleasure	<0.001	-	-	0.005	0.020	0.025
Tanker	<0.001	-	-	<0.001	<0.001	<0.001
Tanker – Oil	<0.001	-	-	<0.001	0.005	0.005
Tug & Service	<0.001	-	-	<0.001	0.028	0.028
Total	<0.001	-	-	0.603	0.750	1.354

Table E-29 shows the modeled difference in accident frequency from the Project in the Buzzards Bay TSS. The frequency increases 0.003 accidents per year. Fishing vessels collisions contribute about 50% of this frequency increase.

There is zero frequency of grounding or allision with Project structures in this sub-area because it contains no land and there are no Project structures.

Table E-29 Risk difference: TSS (annual accident frequencies)

Vessel Type	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.001	-	-	-	-	<0.001
Fishing	0.001	-	-	-	-	0.001
Other & Undefined	<0.001	-	-	-	-	<0.001
Passenger	<0.001	-	-	-	-	<0.001
Pleasure	<0.001	-	-	-	-	<0.001
Tanker	<0.001	-	-	-	-	<0.001
Tanker – Oil	<0.001	-	-	-	-	<0.001
Tug & Service	<0.001	-	-	-	-	<0.001
Total	0.003	-	-	-	-	0.003

Table E-30 shows the modeled difference in accident frequency from the Project northeast of the Lease Area. There is essentially no risk increase from the Project in this sub-area.

There is zero frequency of grounding or allision with Project structures in this sub-area because it contains no land and there are no Project structures.

Table E-30 Risk difference: Northeast of the Lease Area (annual accident frequencies)

Vessel Type	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.001	-	-	-	-	<0.001
Fishing	<0.001	-	-	-	-	<0.001
Other & Undefined	<0.001	-	-	-	-	<0.001
Passenger	<0.001	-	-	-	-	<0.001
Pleasure	<0.001	-	-	-	-	<0.001
Tanker	<0.001	-	-	-	-	<0.001
Tanker – Oil	<0.001	-	-	-	-	<0.001
Tug & Service	<0.001	-	-	-	-	<0.001
Total	<0.001	-	-	-	-	<0.001

Table E-31 shows the modeled difference in accident frequency from the Project east of the Lease Area. There is essentially no risk increase from the Project in this sub-area.

There is zero frequency of grounding or allision with Project structures in this sub-area because it contains no land and there are no Project structures.

Table E-31 Risk difference: East of the Lease Area (annual accident frequencies)

Vessel Type	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.001	-	-	-	-	<0.001
Fishing	<0.001	-	-	-	-	<0.001
Other & Undefined	<0.001	-	-	-	-	<0.001
Passenger	<0.001	-	-	-	-	<0.001
Pleasure	<0.001	-	-	-	-	<0.001
Tanker	<0.001	-	-	-	-	<0.001
Tanker – Oil	<0.001	-	-	-	-	<0.001
Tug & Service	<0.001	-	-	-	-	<0.001
Total	<0.001	-	-	-	-	<0.001

Table E-32 shows the modeled difference in accident frequency from the Project south of the Lease Area. There is essentially no risk increase from the Project in this sub-area.

There is zero frequency of grounding or allision with Project structures in this sub-area because it contains no land and there are no Project structures.

Table E-32 Risk difference: South of the Lease Area (annual accident frequencies)

Vessel Type	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.001	-	-	-	-	<0.001
Fishing	<0.001	-	-	-	-	<0.001
Other & Undefined	<0.001	-	-	-	-	<0.001
Passenger	<0.001	-	-	-	-	<0.001
Pleasure	<0.001	-	-	-	-	<0.001
Tanker	<0.001	-	-	-	-	<0.001
Tanker – Oil	<0.001	-	-	-	-	<0.001
Tug & Service	<0.001	-	-	-	-	<0.001
Total	<0.001	-	-	-	-	<0.001

Table E-33 shows the modeled difference in accident frequency from the Project west of the Lease Area. The frequency increases 0.001 accidents per year, which is considered negligible.

There is zero frequency of grounding or allision with Project structures in this sub-area because it contains no land and there are no Project structures.

Table E-33 Risk difference: West of Lease Area (annual accident frequencies)

Vessel Type	Collision	Powered Grounding	Drift Grounding	Powered Allision	Drift Allision	Total
Cargo/Carrier	<0.001	-	-	-	-	<0.001
Fishing	<0.001	-	-	-	-	<0.001
Other & Undefined	<0.001	-	-	-	-	<0.001
Passenger	<0.001	-	-	-	-	<0.001
Pleasure	<0.001	-	-	-	-	<0.001
Tanker	<0.001	-	-	-	-	<0.001
Tanker – Oil	<0.001	-	-	-	-	<0.001
Tug & Service	<0.001	-	-	-	-	<0.001
Total	0.001	-	-	-	-	0.001

E.6 Summary

The MARCS model calculates accident frequencies for the Base Case (Case 0), for Base Case Plus (addition of the Project to the Base Case) (Case 1), and the Future Case with the addition of the Project (and additional vessel traffic caused by the presence of the wind farm and assumes modified traffic routes) (Case 1).

Per NVIC 01-19 recommendations, the NSRA addresses the difference in collision and grounding due to the implementation of the Project, in addition to the risk of allision with Project structures. In this assessment, the difference in risk between Case 2 and Case 0, 1.4 accidents per year, is our best estimate of the extra risk that results from the presence of the Project assuming all non-AIS commercial fishing vessel transit to or through the Project Area. The Project poses very little risk outside the Lease Area: 98% of the estimated risk increase occurs in the Lease Area.

The quantified risk assessment of the navigation risk for the Project concludes there is a small risk increase due to the Project. The actual observed accident rate of fishing vessel allisions with Project structures will depend directly on how many transits fishing vessels take to / through the Project. This modeling included a maximum estimate of the number of commercial fishing vessels that will transit to and through the Project, as the current number of transits is not available in the public domain.

APPENDIX F CHECKLIST FOR NSRA DEVELOPMENT AND REVIEW

Enclosure (6) to NVIC 01-19 contains the below checklist for review and development of an NSRA. Below is the checklist, completed during development of this NSRA.

ISSUE	YES/NO	COMMENTS
1. SITE AND INSTALLATION COORDINATES		
Has the developer ensured that coordinates and subsequent variations of site perimeters and individual structures are made available, upon request, to interested parties at all, relevant project stages?	NA	Not applicable at this project stage See Section 1.3
Has the coordinate data been supplied as authoritative Geographical Information System (GIS) data, preferably in Environmental Systems Research Institute (ESRI) format? Metadata should facilitate the identification of the data creator, its date and purpose, and the geodetic datum used. For mariners' use, appropriate data should also be provided with latitude and longitude coordinates in WGS84 datum.	NA	Not applicable at this project stage See Section 1.3
2. TRAFFIC SURVEY		
Was the traffic survey conducted within 12 months of the NSRA?	Yes	See Section 2
Does the survey include all vessel types?	Yes	See Section 2 See details per vessel type in Section 2.1
Is the time period of the survey at least 28 days duration?	Yes	See Section 2
Does the survey include consultation with recreational vessel organizations?	Yes	See Section 2 and Appendix B and Appendix C
Does the survey include consultation with fishing vessel organizations?	Yes	See Appendix B
Does the survey include consultation with pilot organizations?	Yes	See Appendix B
Does the survey include consultation with commercial vessel organizations?	Yes	See Appendix B
Does the survey include consultation with port authorities?	Yes	See Appendix B
Does the survey include proposed structure location relative to areas used by any type of vessel?	Yes	See Section 2.2, including Section 2.2.1
Does the survey include numbers, types, sizes and other characteristics of vessels presently using such areas?	Yes	See Section 2.1.3
Does the survey include types of cargo carried by vessels presently using such areas?	Yes	See Section 2.1.4

ISSUE	YES/NO	COMMENTS
Does the survey identify non-transit uses of the areas (for example, fishing, day cruising of leisure craft, racing, marine regattas and parades, aggregate mining)?	Yes	See Section 2.2.1
Does the survey include whether these areas contain transit routes used by coastal or deep-draft vessels, ferry routes, and fishing vessel routes?	Yes	See Section 2.2.2.1 and Section 2.2.2.2 (refers to Section 2.1.1.2)
Does the survey include alignment and proximity of the site relative to adjacent shipping routes	Yes	See Section 2.2.2.3
Does the survey include whether the nearby area contains prescribed or recommended routing measures or precautionary areas?	Yes	See Section 2.2.2.4
Does the survey include whether the site lies on or near a prescribed or conventionally accepted separation zone between two opposing routes or traffic separation scheme?	Yes	See Section 2.2.2.4
Does the survey include the proximity of the site to anchorage grounds or areas, safe haven, port approaches, and pilot boarding or landing areas?	Yes	See Section 2.2.2.5
Does the survey include the feasibility of allowing vessels to anchor within the vicinity of the structure field?	Yes	See Section 2.2.2.5
Does the survey include the proximity of the site to existing fishing grounds, or to routes used by fishing vessels to such grounds?	Yes	See Section 2.2.3 (refers to Section 2.1.1.2)
Does the survey include whether the site lies within the limits of jurisdiction of a port and/or navigation authority?	Yes	See Section 2.2.3
Does the survey include the proximity of the site to offshore firing/bombing ranges and areas used for any marine or airborne military purposes?	Yes	See Section 2.2.3
Does the survey include the proximity of the site to existing or proposed offshore OREI/gas platform or marine aggregate mining?	Yes	See Section 2.2.3
Does the survey include the proximity of the site to existing or proposed structure developments?	Yes	See Section 2.2.3
Does the survey include the proximity of the site relative to any designated areas for the disposal of dredging material or ocean disposal site?	Yes	See Section 2.2.3
Does the survey include the proximity of the site to aids to navigation and/or Vessel Traffic Services (VTS) in or adjacent to the area and any impact thereon?	Yes	See Section 2.2.3

ISSUE	YES/NO	COMMENTS
Does the survey include a researched opinion using computer simulation techniques with respect to the displacement of traffic, mixing of vessel types that were previously segregated; changes in traffic density and resultant change in vessels encounters; and, in particular, the creation of 'choke points' in areas of high traffic density?	Yes	See Section 2.3
Does the survey include whether the site lies in or near areas that will be affected by variations in traffic patterns as a result of changes to vessel emission requirements?	Yes	See Section 2.4
Does the survey include seasonal variations in traffic?	Yes	See Section 2.5
3. OFFSHORE ABOVE WATER STRUCTURES		
Does the NSRA denote whether any features of the offshore above water structure, including auxiliary platforms outside the main generator site and cabling to the shore, could pose any type of difficulty or danger to vessels underway, performing normal operations, or anchoring? Such dangers would include clearances of wind turbine blades above the sea surface, the burial depth of cabling, and lateral movement of floating wind turbines.	Yes	See Section 3.1
Does the NSRA denote whether minimum safe (air) clearances between sea level conditions at Mean Higher High Water (MHHW) and wind turbine rotors are suitable for the vessels types identified in the traffic survey? Depths, clearances, and similar features of other structure types which might affect navigation safety and other Coast Guard missions should be determined on a case by case basis.	Yes	See Section 3.2
Does the NSRA denote whether any feature of the installation could impede emergency rescue services, including the use of lifeboats, helicopters and emergency towing vessels (ETVs)?	Yes	See Section 3.3
Does the NSRA denote how rotor blade rotation and power transmission, etc., will be controlled by the designated services when this is required in an emergency?	Yes	See Section 3.3
Does the NSRA denote whether any noise or vibrations generated by a structure above and below the water column would impact navigation safety or affect other Coast Guard missions?	Yes	See Section 3.4
Does the NSRA denote the ability of a structure to withstand collision damage by vessels without toppling for a range of vessel types, speeds, and sizes?	Yes	See Section 3.5

ISSUE	YES/NO	COMMENTS
4. OFFSHORE UNDER WATER STRUCTURES		
Does the NSRA denote whether minimum safe clearance over underwater devices has been determined for the deepest draft of vessels that could transit the area?	Yes	See Section 4
Has the developer demonstrated an evidence-based, case- by-case approach which will include dynamic draft modeling in relation to charted water depth to ascertain the safe clearance over a device?	NA	Not applicable. See Section 4
To establish a minimum clearance depth over devices, has the developer identified from the traffic survey the deepest draft of observed traffic? This will then require modeling to assess impacts of all external dynamic influences giving a calculated figure for dynamic draft. A 30% factor of safety for under keel clearance (UKC) should then be applied to the dynamic draft, giving an overall calculated safe clearance depth to be used in calculations.	NA	Not applicable. See Section 4
5. ASSESSMENT OF ACCESS TO AND NAVIGATION WITHIN, OR CLOSE TO, A STRUCTURE. Has the developer determined the extent to which navigation would be feasible within the structure site itself by assessing whether:		
Navigation within the site would be safe? • By all vessels or • By specified vessel types, operations and/or sizes? • In all directions or areas; or • In specified directions or areas? • In specified tidal, weather or other conditions; and • At any time, day or night?	Yes	See Section 5
Navigation in and/or near the site should be • Prohibited by specified vessel types, operations and/or sizes; • Prohibited in respect to specific activities; • Prohibited in all areas or directions; • Prohibited in specified areas or directions; • Prohibited in specified tidal or weather conditions; • Prohibited during certain times of the day or night; or • Recommended to be avoided?	Yes	See Section 5
Does the NSRA contain enough information for the Coast Guard to determine whether or not exclusion from the site could cause navigation, safety, or transiting problems for vessels operating in the area?	Yes	See Section 5 and supporting information in Section 2.3 and Section 11.1

ISSUE	YES/NO	COMMENTS
6. THE EFFECT OF TIDES, TIDAL STREAMS, AND CURRENTS. Does the NSRA contain enough information for the Coast Guard to determine whether or not:		
Current maritime traffic flows and operations in the general area are affected by the depth of water in which the proposed structure is situated at various states of the tide, that is, whether the installation could pose problems at high water which do not exist at low water conditions, and vice versa?	Yes	See Section 6
Current maritime traffic flows and operations in the general area are affected by existing currents in the area in which the proposed structure is situated?	Yes	See Section 6 introduction and Section 6.2
The set and rate of the tidal stream, at any state of the tide, would have a significant effect on vessels in the area of the structure site?	Yes	See Section 6 introduction and Section 6.2
Current directions/velocities might aggravate or mitigate the likelihood of allision with the structure?	Yes	See Section 6.2
The maximum rate tidal stream runs parallel to the major axis of the proposed site layout, and, if so, its effect?	Yes	See Section 6.2
The set is across the major axis of the layout at any time, and, if so, at what rate?	Yes	See Section 6.2
In general, whether engine failure or other circumstance could cause vessels to be set into danger by the tidal stream or currents?	Yes	See Section 6.2 and Section 11 for risk results
Structures themselves could cause changes in the set and rate of the tidal stream or direction and rate of the currents?	Yes	See Section 6.2
Structures in the tidal stream could produce siltation, deposition of sediment or scouring, any other suction or discharge aspects, which could affect navigable water depths in the structure area or adjacent to the area?	Yes	See Section 6.2
Structures would cause danger and/or severely affect the air column, water column, seabed and sub-seabed in the general vicinity of the structure?	Yes	See Section 6.2
7. WEATHER. Does the NSRA contain a sufficient analysis of expected weather conditions, water depths and sea states that might aggravate or mitigate the likelihood of allision with the structure, so that Coast Guard can properly assess the applicant's determinations of whether:		
The site, in all weather conditions, could present difficulties or dangers to vessels, which might pass in close proximity to the structure?	Yes	See Section 7 and Section 11 risk results
The structures could create problems in the area for vessels under sail, such as wind masking, turbulence, or sheer?	Yes	See Section 7.2
In general, taking into account the prevailing winds for the area, whether engine failure or other circumstances could cause vessels to drift into danger, particularly if in conjunction with a tidal set such as referred above?	Yes	See Section 7 and Section 11 risk results

ISSUE	YES/NO	COMMENTS
Depending on the location of the structure and the presence of cold weather, sea ice and/or icing of the structure may cause problems? A thorough analysis of how the presence of the structure would mitigate or exacerbate icing?	Yes	See Section 7.4
An analysis of the ability for structures to withstand anticipated ice flows should be conducted by the applicant?	Yes	See Section 7.4
An analysis of the likelihood that ice may form on the structure, especially those types that have rotating blades such as a Wind Turbine Generator (WTG), should be conducted by the applicant, and should include an analysis of the ability of the structure to withstand anticipated ice accumulation on the structures, and potential for ice to be thrown from the blades, and the likely consequences of that happening and possible actions to mitigate that occurrence?	Yes	See Section 7.4
8. CONFIGURATION AND COLLISION AVOIDANCE		
The Coast Guard will provide Search and Rescue (SAR) services in and around OREIs in US waters. Layout designs should allow for safe transit by SAR helicopters operating at low altitude in bad weather, and those vessels (including rescue craft) that decide to transit through them. Has the developer conducted additional site specific assessments, if necessary, to build on any previous assessments to assess the proposed locations of individual turbine devices, substations, platforms and any other structure within OREI such as a wind farm or tidal/wave array? Any assessment should include the potential impacts the site may have on navigation and SAR activities. Liaison with the USCG is encouraged as early as possible following this assessment which should aim to show that risks to vessels and/or SAR helicopters are minimized and include proposed mitigation measures.	Yes	See Section 8 and Section 10
Each OREI layout design will be assessed on a case-by-case basis.	Yes	See Section 8
Risk assessments should build on any earlier work conducted as part of the NSRA and the mitigations identified as part of that process. Where possible, an original assessment should be referenced to confirm where information or the assessment remains the same or can be further refined due to the later stages of project development. Risk assessments should present information to enable the USCG to adequately understand how the risks associated with the proposed layout have been reduced to As Low As Reasonably Practicable (ALARP).	Yes	See Section 8 and Section 11.3

ISSUE	YES/NO	COMMENTS
In order to minimize risks to surface vessels and/or SAR helicopters transiting through an OREI, structures (turbines, substations) should be aligned and in straight rows or columns. Multiple lines of orientation may provide alternative options for passage planning and for vessels and aircraft to counter the environmental effects on handling i.e. sea state, tides, currents, weather, visibility. Developers should plan for at least two lines of orientation unless they can demonstrate that fewer are acceptable.	Yes	See Section 1
Packed boundaries will be considered on a case-by-case basis as part of the risk assessment process. For opposite boundaries of adjacent sites due consideration should be given to the requirement for lines of orientation which allow a continuous passage of vessels and/or SAR helicopters through both sites. Where there are packed boundaries this will affect layout decisions for any possible future adjacent sites. The definition of 'adjacent' will be assessed on a case-by-case basis.	NA	Not applicable to the considered layouts
9. VISUAL NAVIGATION. Does the NSRA contain an assessment of the extent to which:		
Structures could block or hinder the view of other vessels underway on any route?	Yes	See Section 9
Structures could block or hinder the view of the coastline or of any other navigational feature such as aids to navigation, landmarks, promontories?	Yes	See Section 9
Structures and locations could limit the ability of vessels to maneuver in order to avoid collisions?	Yes	See Section 9 and Section 11
10. COMMUNICATIONS, RADAR AND POSITIONING SYSTEMS. Does the NSRA provide researched opinion of a generic and, where appropriate, site specific nature concerning whether or not:		
Structures could produce interference such as shadowing, reflections or phase changes, with marine positioning, navigation, or communications, including Automatic Identification Systems (AIS), whether ship borne, ashore, or fitted to any of the proposed structures?	Yes	See Section 10
Structures could produce radar reflections, blind spots, shadow areas or other adverse effects in the following interrelationships: • Vessel to vessel; • Vessel to shore; • Vessel Traffic Service radar to vessel; • Radio Beacons (RACONS) to/from vessel; and • Aircraft and Air Traffic Control?	Yes	See Section 10
Structures, in general, would comply with current recommendations concerning electromagnetic interference?	Yes	See Section 10 introduction

ISSUE	YES/NO	COMMENTS
Structures might produce acoustic noise or noise absorption or reflections which could mask or interfere with prescribed sound signals from other vessels or aids to navigation?	Yes	See Section 10.1 and Section 3.4
Structures, generators, and the seabed cabling within the site and onshore might produce electro-magnetic fields affecting compasses and other navigation systems?	Yes	See Section 10
The power and noise generated by structures above or below the water would create physical risks that would affect the health of vessel crews?	Yes	See Section 10 introduction
11. RISK OF COLLISION, ALLISION, OR GROUNDING. Does the NSRA, based on the data collected per paragraph 2 above, provide an evaluation that was conducted to determine the risk of collision between vessels, risk of allisions with structures, or grounding because of the establishment of a structure, including, but not limited to:		
• Likely frequency of collision (vessel to vessel); • Likely consequences of collision ("What if" analysis); • Likely location of collision; • Likely type of collision; • Likely vessel type involved in collision; • Likely frequency of allision (vessel to structure) • Likely consequences of allision ("What if" analysis); • Likely location of allision; • Likely vessel type involved in allision; • Likely frequency of grounding; • Likely consequences of grounding (" What if" analysis); • Likely location of grounding; and • Likely vessel type involved in grounding?	Yes	See Section 11

ISSUE	YES/NO	COMMENTS
12. EMERGENCY RESPONSE CONSIDERATIONS. In order to determine the impact on Coast Guard and other emergency responder missions, has the developer conducted assessments on the Search and Rescue and the Marine Environmental Protection emergency response missions?		
Search and Rescue (SAR): • The Coast Guard will assist in gathering and providing the following information: The number of search and rescue cases the USCG has conducted in the proposed structure region over the last ten years. • The number of cases involving helicopter hoists. • The number of cases performed at night or in poor visibility/low ceiling • The number of cases involving aircraft (helicopter, fixed-wing) searches. • The number of cases performed by commercial salvors (for example, BOAT US, SEATOW, commercial tugs) responding to assist vessels in the proposed structure region over the last ten years. • Has the developer provided an estimate of the number of additional SAR cases projected due to allisions with the structures? • Will the structure enhance SAR such as by providing a place of refuge or easily identifiable markings to direct SAR units?	Yes	See Section 12
Marine Environmental Protection/Response: • How many marine environmental/pollution response cases has the USCG conducted in the proposed structure region over the last ten years? • What type of pollution cases were they? • What type and how many assets responded? • How many additional pollution cases are projected due to allisions with the structures?	Yes	See Section 12
13. FACILITY CHARACTERISTICS. In addition to addressing the risk factors detailed above, does the developer's NSRA include a description of the following characteristics related to the proposed structure:		
Marine Navigational Marking?	Yes	See Section 13
How the overall site would be marked by day and by night, taking into account that there may be an ongoing requirement for marking on completion of decommissioning, depending on individual circumstances?	Yes	See Section 13
How individual structures on the perimeter of and within the site, both above and below the sea surface, would be marked by day and by night?	Yes	See Section 13

ISSUE	YES/NO	COMMENTS
If the site would be marked by one or more Radar Beacons (RACONS) or, an Automatic Identification System (AIS) transceiver, or both and if so, the AIS data it would transmit?	NA	Not applicable at this project stage
If the site would be fitted with a sound signal, the characteristics of the sound signal, and where the signal or signals would be sited?	Yes	See Section 13
If the structure(s) are to be fitted with aviation marks, how would they be screened from mariners or potential confusion with other navigational marks and lights be resolved?	Yes	See Section 13
Whether the proposed site and/or its individual generators would comply in general with markings for such structures, as required by the Coast Guard?	Yes	See Section 13
Whether its plans to maintain its aids to navigation are such that the Coast Guard's availability standards are met at all times. Separate detailed guidance to meet any unique characteristics of a particular structure proposal should be addressed by the respective District Waterways Management Branch?	Yes	See Section 13
The procedures that need to be put in place to respond to and correct discrepancies to the aids to navigation, within the timeframes specified by the Coast Guard?	Yes	See Section 13
How the marking of the structure will impact existing Federal aids to navigation in the vicinity of the structure?	Yes	See Section 13
14. DESIGN REQUIREMENTS. Is the structure designed and constructed to satisfy the following recommended design requirements for emergency shut-down in the event of a search and rescue, pollution response, or salvage operation in or around a structure?		
All above surface structure individual structures should be marked with clearly visible unique identification characters (for example, alpha-numeric labels such as "Al," "B2."). The identification characters should each be illuminated by a low-intensity light visible from a vessel, or be coated with a phosphorescent material, thus enabling the structure to be detected at a suitable distance to avoid a collision with it. The size of the identification characters in combination with the lighting or phosphorescence should be such that, under normal conditions of visibility and all known tidal conditions, they are clearly readable by an observer, and at a distance of at least 150 yards from the structure. It is recommended that, if lighted, the lighting for this purpose be hooded or baffled so as to avoid unnecessary light pollution or confusion with navigation aids. (Precise dimensions to be determined by the height of lights and necessary range of visibility of the identification numbers).	Yes	See Section 14
All generators and transmission systems should be equipped with control mechanisms that can be operated from an operations center of the installation.	Yes	See Section 14

ISSUE	YES/NO	COMMENTS
Throughout the design process, appropriate assessments and methods for safe shutdown should be established and agreed to through consultation with the Coast Guard and other emergency support services.	Yes	See Section 14
The control mechanisms should allow the operations center personnel to fix and maintain the position of the WTG blades, nacelles and other appropriate moving parts as determined by the applicable Coast Guard command center. Enclosed spaces such as nacelle hatches in which personnel are working should be capable of being opened from the outside. This would allow rescuers (for example, helicopter winch-man) to gain access if occupants are unable to assist or when sea-borne approach is not possible.	Yes	See Section 14
Access ladders, although designed for entry by trained personnel using specialized equipment and procedures for maintenance in calm weather, could conceivably be used in an emergency situation to provide refuge on the structure for distressed mariners. This scenario should therefore be considered when identifying the optimum position of such ladders and take into account the prevailing wind, wave, and tidal conditions.	Yes	See Section 14
15. OPERATIONAL REQUIREMENTS. Will the operations be continuously monitored by the facility's owners or operators, ostensibly in an operations center? Does the NSRA identify recommended minimum requirements for an operations center such as:		
The operations center should be manned 24 hours a day?	Yes	See Section 15
The operations center personnel should have a chart indicating the Global Positioning System (GPS) position and unique identification numbers of each of the structure?	Yes	See Section 15
All applicable Coast Guard command centers (District and Sector) will be advised of the contact telephone number of the operations center?	Yes	See Section 15
All applicable Coast Guard command centers will have a chart indicating the position and unique identification number of each of the structures?	Yes	See Section 15
16. OPERATIONAL PROCEDURES. Does the NSRA provide for the following operational procedures?		
Upon receiving a distress call or other emergency alert from a vessel that is concerned about a possible allision with a structure or is already close to or within the installation, the Coast Guard Search and Rescue Mission Coordinator (SMC) will establish the position of the vessel and the identification numbers of any structures visible to the vessel. The position of the vessel and identification numbers of the structures will be passed immediately to the operations center by the SMC.	Yes	See Section 16

ISSUE	YES/NO	COMMENTS
The operations center should immediately initiate the shut-down procedure for those structures as requested by the SMC, and maintain the structure in the appropriate shut-down position, again as requested by the SMC, until receiving notification from the SMC that it is safe to restart the structure.	Yes	See Section 16
Communication and shutdown procedures should be tested satisfactorily at least twice each year.	Yes	See Section 16
After an allision, the applicant should submit documentation that verifies the structural integrity of the structure.	NA	Not applicable at this project stage

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