Potential Environmental, Economic, and Energy Impacts in New Hampshire from Development of Offshore Wind in the Gulf of Maine

Prepared For

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September 2023

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Acronyms and Abbreviations

AC	alternating current
ACHP	Advisory Council on Historic Preservation
AIC	Akaike information criterion
AIS	automatic identification system
AMAPPS	Atlantic Marine Assessment Program for Protected Species
ARPA	Archaeological Resources Protection Act
ARSR	air route surveillance radar
ASR	airport surveillance radar
BIA	biologically important area
BMP	best management practice
BOEM	Bureau of Ocean Energy Management
CAA	Clean Air Act
C&I	construction and installation
CELT	capacity, energy, loads, and transmission
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CFRP	carbon fiber reinforced plastic
CMECS	Coastal and Marine Ecological Classification Standard
CO2/CO_2	carbon dioxide
COA	Corresponding Onshore Area
COLREGS	International Regulations for Preventing Collisions at Sea
COP	construction and operations plan
CPUE	catch per unit effort
CT	Connecticut
CZMA	Coastal Zone Management Act
DAS	days at sea
dB	decibel
DC	direct current
DBEA	New Hampshire Department of Business and Economic Affairs
DEIS	draft environmental impact statement
DHRA	Dedicated Habitat Research Area
DOBOR	Division of Boating and Ocean Recreation
DOD	Department of Defense
DP	dynamic positioning
DPH	Division of Ports and Harbors
EA	environmental assessment
EEZ	Federal Exclusive Economic Zone
EFH	essential fish habitat
eGRID	Emissions and Generation Resource Integrated Database
EIA	Energy Information Administration
EIS	environmental impact statement

EJ	environmental justice
EM	electromagnetic
EMF	electromagnetic field
EPA	Environmental Protection Agency
EPAct	Energy Policy Act
EPSM	Electricity Policy Simulation Model
ESA	Endangered Species Act
FAA	Federal Aviation Administration
FAD	fish aggregating device
FDR	facility design report
FDS	formerly used defense site
FEIS	final environmental impact statement
FERC	Federal Energy Regulatory Commission
FIN	FAST-41 Initiation Notice
FIR	fabrication and installation report
FOWT	floating offshore wind turbine
FPISC	Federal Permitting Improvement Steering Council
ft	ft
FTE	full time equivalent
FUDS	formerly used defense site
GARFO	Greater Atlantic Regional Fisheries Office
GDP	gross domestic product
GFRP	glass fiber reinforced plastics
GHG	greenhouse gas
GIS	geographic information system
GOM	Gulf of Maine
GPS	global positioning system
GW	gigawatt
GWh	gigawatt-hours
HAB	horizontal auger boring
HAPC	Habitat Area of Particular Concern
HAPs	hazardous air pollutants
HDD	horizontal directional drilling
HF	high frequency
HI	Hawaii
HVAC	high voltage alternating current
Hz	hertz
IHA	Incidental Harassment Authorization
IOSN	Isles of Shoal North Disposal Site
IPF	impact producing factor
ISO-NE	Independent System Operator New England
IUCN	International Union for Conservation of Nature
JA	Jones Act

JATO	jet-assisted take off
JEDI	Jobs and Economic Development Impact model
K	thousand
kHz	Kilohertz
km	kilometer
km^2/sq km	square kilometer
kn	knot
kV	kilovolt
kWh	kilowatt hour
LF	low frequency
LCOE	levelized cost of energy
LLC	limited liability company
LNG	liquified natural gas
LOS	line of sight
LPUE	landings per unit effort
m	meter
m/s	meters per second
m3/m^3	cubic meter
MA	Massachusetts
MassDEP	Massachusetts Department of Environmental Protection
MBTA	Migratory Bird Treaty Act
MD	Maryland
MDAT	Marine-life Data Analysis Team
ME	Maine
ME DEP	Maine Department of Environmental Protection
MF	medium frequency
MFG	manufacturing
MMBtu	one million British Thermal Units
MMPA	Marine Mammal Protection Act
MPA	marine protected area
mph	miles per hour
MRIP	Marine Recreational Information Program
MSIR	marine site investigation report
mt	metric tons
MVR	marine vessel radar
MW	megawatt
MWhs	megawatt hours
NAAQS	National Ambient Air Quality Standards
NARW	North Atlantic Right Whale
NAVTEX	Navigational Telex
NCCOS	National Center for Coastal and Ocean Science
NCEI	National Centers for Environmental Information
NdFeB	manufacture neodymium–iron–boron

NEFSC	Northeast Fisheries Science Center
NEPA	National Environmental Policy Act
NESCOE	New England States Committee on Electricity
NEXRAD	next-generation radar
NGO	non-governmental organization
NH	New Hampshire
NHCP	New Hampshire Coastal Program
NHCSOWPD	New Hampshire Commission to Study Offshore Wind and Port Development
NHDES	New Hampshire Department of Environmental Services
NHDOE	New Hampshire Department of Energy
NHEC	New Hampshire Electric Cooperative
NHOSI	New Hampshire Office of Strategic Initiatives
NHPA	National Historic Preservation Act
NHPUC	New Hampshire Public Utilities Commission
NHSEC	New Hampshire Site Evaluation Committee
NJ	New Jersey
nm	nautical mile
NMFS	National Marine Fisheries Service
NMS	national marine sanctuary
NO_2	nitrogen dioxide
NOA	notice of availability
NOAA	National Oceanic and Atmospheric Administration
NOI	notice of intent
NO_x	nitrogen oxides
NNSR	Nonattainment New Source Review
NPS	National Parks Service
NRC	Nuclear Regulatory Commission
NRDC	Natural Resource Defense Council
NREL	National Renewable Energy Laboratory
NSB	northern sand body
NSB-E	northern sand body extension
NSR	New Source Review
NSRA	navigation safety risk assessment
NVIC	Navigation Vessel Inspection Circular
NWS	National Weather Service
NY	New York
NYS	New York State
O&M	operations and maintenance
OCS	outer continental shelf
OCSLA	Outer Continental Shelf Lands Act
ODMDS	ocean dredged material disposal site
OECC	offshore export cable corridor
OECD	Organization for Economic Co-operation and Development

OEM	original equipment manufacturer
OPAREA	operating area
OSB	offshore sand body
OSW	offshore wind
OTR	Ozone Transport Region
OWF	offshore wind farm
P&D	planning and development
PAM	passive acoustic monitoring
PAPE	preliminary area of potential effect
PDE	project design envelope
$PM_{2.5}$	particulate matter less than 2.5 microns in diameter
PM_{10}	particulate matter less than 10 microns in diameter
POI	point of interconnection
POP	Pelagic Observer Program
PPA	power purchase agreement
PTS	permanent threshold shift
RCRA	Resource Conservation and Recovery Act
REE	rare earth element
RFI	request for interest
RI	Rhode Island
RNVC	revenue net of variable costs
ROD	record of decision
RSA	Revised Statutes Annotated
RSZ	rotor swept zone
Rt	route
SAP	site assessment plan
SARA	Superfund Amendments and Reauthorization Act
SEER	Synthesis of Environmental Effects Research
SEFSC	Southeast Fishery Science Center
SO_2	sulfur dioxide
SPL	sound pressure level
SSD	southern sand deposit
STSH	Sea Turtle Sightings Hotline
TAC	total allowable catch
TLP	tension-leg platform
TNC	The Nature Conservancy
TR&C	training, research, and consulting
TTS	temporary threshold shift
U.S.	United States
UES	Unitil Energy Systems
UK	United Kingdom
ULSD	ultra-low sulfur diesel
USACE	U.S. Army Corps of Engineers

U.S.C.	United States Code
USCG	United States Coast Guard
USDOE	United States Department of Energy
USDOI	United States Department of the Interior
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UXO	unexploded ordnance
VA	Virginia
VHF	very high frequency
VIA	visual impact assessment
VMS	Vessel Monitoring System
VOCs	volatile organic compounds
VT	Vermont
WEA	wind energy area
WHBR	White House Briefing Room
WIND	Wind Integration National Dataset
WTG	wind turbine generator
WTIV	wind turbine installation vessel
%	percent

Executive Summary

The significant developments of the U.S. offshore wind industry and recent improvements to floating wind turbine technologies has led to renewed discussion on the viability of potential offshore wind deployment in the Gulf of Maine (GOM). Bureau of Ocean Energy Management (BOEM) established the Gulf of Maine Intergovernmental Renewable Energy Task Force in December 2019 to facilitate coordination and consultation related to renewable energy planning activities on the Outer Continental Shelf in the GOM. The New Hampshire Department of Energy (NHDOE) allocated funds in October 2021 to assess the potential economic, energy, and environmental impacts to the citizens and businesses of New Hampshire from development of offshore wind projects in the GOM. The Governor and Executive Council on July 12, 2022, approved the funding for the study. This assessment incorporates and builds upon the work conducted pursuant to the Governor`s Executive Orders 2019-06 and 2021-03 and by the NHCSOWPD established by House Bill 1245. The assessment focuses on providing the State of New Hampshire a high-level summary of several stakeholder input items that were categorized into five main topics:

1. Economic Impacts to Maritime Industries and Activities
2. Energy Sector and Energy-Related Economic Impacts
3. Existing Infrastructure and New Infrastructure Needs
4. Environmental and Biological Impacts
5. Permitting and Regulatory Issues

These topics are elevated for the GOM Request for Interest (RFI) Area identified by BOEM in August 2022. The RFI Area consists of 13,713,825 acres located off the coasts of Massachusetts, New Hampshire, and Maine, containing water deeper than 60 meters which is too deep for fixed-bottom wind turbine foundations. As result, offshore wind development in this area is anticipated to be based on floating offshore wind turbines, the assessment therefore focuses only on this technology.

The GOM RFI Area has steady, high winds that under normal conditions could produce enough power to fully meet the needs of the New England states for 37% of the year, or 72% with the addition of large-capacity energy storage. Although the U.S. domestic offshore wind industry is still in the early stages of development, significant growth is expected in the coming years with a U.S. national target of 30 gigawatts (GW) of offshore wind energy by 2030. The goal of this assessment is to provide elected officials, policymakers, stakeholders, and the public with the information necessary to evaluate: 1) economic development opportunities; 2) potential environmental impacts; 3) and offshore wind impacts to New Hampshire's future energy needs.

Economic Impacts to Maritime Industries and Activities

A wide range of commercial and recreational maritime activities may be affected directly or indirectly and positively and/or negatively by offshore wind development in the GOM. Such activities include commercial fishing, supply chain operations, port utilization opportunities, workforce opportunities, recreational marine uses, insurance, shipping, navigation, aviation, and radar assets. Commercial fishing, for example, may experience a direct, negative effect if sites become unavailable for fishing under certain conditions (such as high winds). An example of both a positive and negative effect is that floating wind turbines and their associated structures could act as artificial reefs, thereby attracting more and/or different game fish, while conversely, cables could introduce a negative potential for gear entanglement for recreational anglers targeting pelagic species.

Economic modelling for commercial fishing using baseline and counterfactual techniques based on the lobster fishery resulted in two potential scenarios ranging from no change in revenues or profits for New Hampshire lobstermen to a maximum reduction of nearly $2 million in annual revenues and nearly $3.3 million in annual profits. In cases where the second scenario applies, developers are expected to mitigate and compensate commercial fishermen for impacts from offshore wind development by implementing the best management practices presented in BOEM's 2014 Report *Development of Mitigation Measures to Address Potential Use Conflicts Between Commercial Wind Energy Lessees and Commercial Fishermen.*

One of the largest economic impacts of offshore wind development is likely to result from the development and use of port facilities. This development may also directly benefit commercial fishing by adding berth capacity. Development and operation of an offshore wind farm requires a workforce in all stages of the wind farm life cycle. This workforce is composed of 74 different occupational fields and will create employment opportunities in the following categories: construction, manufacturing, operations and maintenance, supply chain management, environmental oversight, and onshore administration. Economic implications specific to New Hampshire are presented for the Port of New Hampshire in Portsmouth. It is the only significant port in New Hampshire and the only port in the state that is likely to support offshore wind. The Port of New Hampshire could be used as a maintenance port during the operational life of the wind farm. Modeling results of a hypothetical offshore wind project are estimated to produce 3,640 jobs in New Hampshire with job-related earnings totaling $268.9 million.

Insurance implications for fishing in offshore wind farms were evaluated in this assessment in the context of additional financial risk. The largest risk to offshore wind farm operators would likely be from damaged electrical cables requiring repair and replacement which can take months, and result in loss of revenue during downtime. Cable failures in the open ocean are caused by fishing gears, anchor strikes, and erosion. It is presumed that developers will bear responsibility for electric cables and that the primary risk faced by insurers of fishing vessels is from collisions between vessels and turbines. Information about how insurers will manage wind farm risks to fishing vessels has not been identified. The implications of offshore wind in the Gulf of Maine for insuring fishing vessels are currently unknown. Commercial vessels are expected to be the most affected, but the degree of the effect is difficult to determine ahead of time.

Offshore wind development also has the potential to affect shipping, navigation, land-based, marine, and aviation radar, and communications in the GOM. Wind turbine generators with blade lengths exceeding 100 meters may impact radar operations supporting air traffic control, maritime commerce, homeland security, national defense, weather forecasting, and other activities relying on this technology for navigation, situational awareness, and surveillance. A particular concern is the impact on marine vessel radar, which is a widely used, critical instrument for navigation, collision avoidance, and other specialized purposes including small target detection and tracking, especially in low visibility conditions. However, several mitigation measures including siting and location of the turbines can minimize conflicting impacts.

Energy Sector and Energy-related Economics Impacts

Potential impacts to the energy sector and energy-related economics were modelled to reflect cumulative projected activities of ME, MA, RI, CT, NY, and NJ; clean energy requirements of ME and MA; and licensing status of the Seabrook Station Nuclear Power Plant. If power is generated from an offshore wind farm near New Hampshire, any resulting grid-tied electricity would come ashore, and interconnect to the New England grid in either Maine, New Hampshire, or Massachusetts. These states plus Connecticut and Rhode Island are part of a regional transmission organization known as the Independent System Operator New England, Inc. (ISO-NE).

The introduction of offshore wind will have substantial implications for the operation of ISO-NE. The potential power system effects of offshore wind development for New Hampshire were evaluated using the Electricity Policy Simulation Model (EPSM) in baseline and counterfactual conditions. Modeling results indicate that planned offshore wind development and carbon dioxide (CO_2) reduction goals may result in substantial electricity shortfalls. Even with the most sophisticated algorithms and wind farm siting that considers correlations in wind speeds, a de-carbonized New England grid will still require a significant amount of emission-free dispatchable generation. There are several technologies that can be described as emission-free and dispatchable, including energy storage using Canadian hydropower resources, hydrogen powered thermal plants and fuel cells, and batteries. The most practical and cost-effective approach for storing energy to generate electricity is hydroelectric systems. However, because as New England states do not have significant available hydroelectric storage capacity, an interface with Hydro-Québec Quebec Hydro may be a solution.

As New Hampshire is part of the same ISO-NE, as Maine and Massachusetts, its electricity supply will be affected by changes these other states such as Maine and Massachusetts are encouraging, and electricity from offshore wind coming ashore in any New England state could potentially flow into New Hampshire. It is also possible that offshore wind could come ashore and interconnect to the New England grid in New Hampshire, as several potential interconnection points have been identified in this assessment. This indicates that New Hampshire is well positioned to receive and distribute power from offshore wind development.

Existing Infrastructure and New Infrastructure Needs

This section provides a discussion on existing New Hampshire electrical infrastructure and new infrastructure that may be needed to bring offshore wind energy from the GOM to New

Hampshire interconnection points. The discussion includes an overview of the existing transmission cables, characterization of potential new transmission grid interconnection points and cable routes, considerations for routing of offshore wind transmission cables along with existing cables, pipelines, and other infrastructure found in the GOM RFI Area. The decommissioning process for offshore wind turbines is also reviewed to provide insight into the full life cycle of offshore wind farms and associated expectations and impacts.

One of the challenges associated with delivering offshore wind energy is moving the large amount of energy to load centers. The Seacoast area of southern New Hampshire has several possible transmission grid interconnection points available. The search for interconnection points involves looking for high voltage substations, power generation stations, de-commissioned power stations, or even green space near major existing 345-kV lines for new substations. The delivery of offshore wind energy from a hypothetical lease area located anywhere within the Gulf of Maine RFI Area in federal waters could be delivered in two separate ways, High-Voltage Alternating-Current (HVAC) submarine cables or High-Voltage Direct Current (HVDC) submarine cables. Each of these delivery methods has pros and cons.

Potential landfalls, landfall sites, and onshore cable route options in New Hampshire are discussed. The crossing of an offshore wind transmission cable with any existing cables, pipelines, or other seabed infrastructure will require coordination with the owner of the existing asset to ensure the locations and crossing methods can be agreed upon, so that operations and maintenance for both systems is not encumbered. Numerous federal, state, and municipal permits and approvals are required for the siting, construction, operation, and decommissioning of an offshore wind project and associated infrastructure. Federal permits and approval from BOEM are required to ensure that any activities it authorizes will consider the protection of the environment and the conservation of natural resources. A landfall in New Hampshire would trigger permit requirements under state and local jurisdictions.

Environmental and Biological Impacts

The GOM is an ecologically and biologically diverse body of water with unique habitats and resources to other areas on the East Coast of the United States. It is semi-enclosed and roughly rectangular bounded to the northeast by Nova Scotia, Canada and to the west by the northeast U.S. coast (Massachusetts, New Hampshire, and Maine). The Gulf consists of three major basins and many smaller ones separated by numerous ridges and ledges including Georges and Browns Banks that separate the GOM from the Atlantic Ocean. The seafloor is highly diverse, with undersea valleys reaching depths of over 1,500 ft and undersea mountains rising from the seafloor to 800 ft.

Biological and Physical Resources

The GOM RFI Area contains numerous environmentally sensitive habitats including deep-sea corals; Habitat Management Areas (HMAs); fisheries closed areas; critical habitat for North Atlantic right whales; essential fish habitat (EFH); habitat areas of particular concern (HAPC); complex bathymetric features supporting high biodiversity, nursery habitat, calving grounds;

and near-shore nesting sites for fish, mammals, birds, and bats; and kelp forests. These environmentally sensitive habitats can be fragile and highly susceptible to a multitude of disturbances and thus must be considered for further surveying and delineation, protection, or exclusion from potential lease areas.

The GOM supports a wide variety of finfish and invertebrate species. As many as 578 finfish species from at least 118 families occur in the GOM, including threatened and endangered species, species of special concern, and species that are commercially and/or recreationally important. Invertebrates species groups including 186 cnidarians, 489 annelids, 762 crustaceans, 504 mollusks, and 110 echinoderms have been recorded in the GOM RFI Area. There are 11 federally- and/or state-listed threatened and endangered species, species of special concern, and candidate fish species that occur in the RFI Area. A total of 54 commercially and recreationally harvested fish species and 14 species of commercially and recreationally harvested invertebrate species have been reported by New Hampshire fishermen over the past several years.

Information of potential impacts to finfish and invertebrates specific to from floating offshore wind turbines (FOWT) is not currently available due to the limited number of FOWT in operation. However, based on information from fixed-bottom turbines, FOWT may have less of a direct effect on fish species and habitats due to the limited vertical profile of the floating foundation and smaller footprint associated with mooring and anchoring than fixed-bottom turbines. Impacts associated with FOWT on fish may include entanglement, noise effects, electromagnetic fields (EMF) effects, habitat displacement, habitat alteration or destruction, and vessel collision.

The Gulf of Maine supports historically and culturally significant and high value commercial and recreational fisheries including American lobster, Northeast Multispecies (groundfish), Atlantic sea scallop, Atlantic Herring, Monkfish, skates, and Bluefin Tuna. The lobster fishery (worth $725 million), groundfish ($40.6 million), and herring fisheries are the largest fisheries by volume and value in the RFI Area. Fishing vessels from Maine to North Carolina operate in the Gulf of Maine and many are dependent on this area for a significant portion (50-100%) of their annual fishing revenue. Additionally, Boston, MA, Portland ME, and Rockland, ME average between $9 and $11 million in annual fishing revenues from trips in the RFI Area. New Hampshire commercial fisheries are the third largest by both landings and revenue in the RFI Area with cumulative landings within the area from 2008 through 2020 of 81.5 million pounds worth $196.7 million. New Hampshire recreational fishermen harvested a cumulative total of 14.7 million pounds of fish from 2015 through 2021 with an annual average of 2.1 million pounds.

Currently, all U.S. leased areas are partially or completely opened to commercial and recreational fishing and are expected to remain accessible to fishing after construction of offshore wind farms. However, commercial and recreational fisheries will most likely be affected by offshore wind development, despite efforts to minimize conflict and reduce overlap of Wind Energy Areas (WEAs) with other users. Direct impacts to commercial fishermen and their communities include the potential increased risk of collision with wind farm infrastructure and other vessels, interruption of fishing by wind farm development and construction activities, and loss of fishing areas and/or changes in fishing locations. Potential impacts associated with changes through regional fishery management could include changes to fishing regulations, management measures at specific areas or new management areas, and impacts to the scientific fishery resource surveys used for stock assessments. Offshore wind facilities could also directly benefit the recreational fishing community by providing new fishing locations and opportunities to catch different species than those available from shore or nearshore areas.

There are 21 species of cetaceans (whales, dolphins, and porpoises), 4 species of seals, and 4 species of sea turtles that inhabit the GOM and RFI Area. Among the 21 species of cetaceans, 5 whales (blue, fin, North Atlantic right (NARW), sei, and sperm) are designated as endangered under the ESA. NARW is considered critically endangered due to a declining population since 2010, increased mortality rate, and larger interval between calving. NARW critical foraging habitat encompasses the entire RFI Area footprint. Green and loggerhead sea turtles are listed as threatened, and Kemp's ridley and leatherback sea turtles are listed as endangered under the ESA. Marine mammals and sea turtles utilize the habitat in the GOM for many purposes including foraging, migrating, resting, mating, socializing, and for some species including NARW as a nursery area. Biologically Important Areas (BIA) have been delineated in the GOM and RFI Area for cetacean habitat use including foraging and/or migration for the following species: harbor porpoise, humpback whale, minke whale, sei whale, fin whale, and NARW.

Recent warming due to climate change has caused a decline in the abundance of the cold-water species of copepods, *C. finmarchicus,* that NARW mainly feed on. The decline in their primary forage species has resulted in a shift in NARW historical distribution both spatially and temporally. Recent and rapid changes in the quality of foraging habitat for NARW have prompted researchers to attempt to predict where suitable habitat will be in the future, which is vitally important information needed for resource management planning. Monthly models into the year 2050 indicate a decrease in foraging habitat across the GOM except for the area along the Scotian Shelf. However, in any given year, historical foraging grounds could still be important habitat. Due to the recent shifts in *C. finmarchicus* and NARW distribution, historical seasonal migratory patterns should not be used alone to assess their presence and potential impacts from floating offshore wind farms. Development and management of resources in the GOM should be adapted and reevaluated continually in relation to NWRW's' use of the area.

Potential impacts to marine mammals and sea turtles during site characterization surveys, construction, and operation of floating offshore wind farms in the RFI include noise; increased vessel traffic and risk of vessel strike; allision with turbine platforms, ESP foundations, and array cables; entanglement; turbidity; electromagnetic field (EMF); secondary impacts from potential reduction of wind speed (e.g., less mixing of the water column, lower current speeds, and higher surface water temperatures); and displacement or avoidance of the habitat.

Bird species and species groups with potential exposure to offshore wind development activities include waterfowl, nightjars, chimney swift, shorebirds, phalaropes, skuas, jaegers, auks, gulls, terns, black skimmers, tropicbirds, seabirds, loons, storm-petrels, fulmars, shearwaters, the magnificent frigatebird, brown booby, northern gannet, cormorants, pelicans, vultures, raptors, owls, belted kingfisher, and passerines. The federally endangered and threatened bird species likely to occur in the RFI Area include roseate tern, red knot, and piping plover. There is no critical habitat designated for roseate tern and no critical habitat for piping plovers that overlap the RFI Area.

Direct effects that may occur to birds due to offshore wind development include injury or mortality from turbine collisions and displacement or attraction due to visible infrastructure, lighting, noise, and vessel traffic. Indirect effects may occur after project activity and influence adjacent or larger areas than the project site alone, this could include displacement associated with avoidance of visible infrastructure.

There are eight bat species known to occur in NH. Among these species, four have been recorded on offshore structures or boats in the GOM (Eastern red bat, Hoary bat, Silver-haired bat, and Little brown bat), one was recorded on small and medium GOM islands (Big brown bat), and another (Tricolored bat) was recorded at buoys up to 26 kilometer (km) from shore in the GOM. As "ground zero" for the spread of the fungal pathogen causing white nose syndrome in North America, bat populations of most New England species have suffered drastic declines over the past 10-15 years, leading to many of them being state or federally listed.

Wind turbines are recognized as a major cause of excess bat mortality worldwide and in the US that may lead to significant population declines and risk of extinction. The GOM RFI is located within flight distance from the nearest shore of all species found in NH. Moreover, three of these species are migratory tree-dwelling bats – Eastern red bat, Hoary bat, and Silver-haired bat. These species are deemed especially at risk for wind energy-related mortality and together comprise up to 79% of the mortalities reported in wind energy facilities. Studies indicate that the mere presence of a wind turbine (or multi-turbine facility) can alter bat behavior in the area in ways that can either increase collision risk due to attraction or increase energetic costs due to avoidance. For that reason, pre-construction risk assessments are often not sufficient and post-construction assessments are necessary to reveal the full impact of wind energy on bat populations.

Other Environmental Topics of Concern

Federal agencies are responsible to ensure that environmental justice is part of their projects' goals and that all disproportionate environmental or human health effects on minority and low-income populations are addressed to the most precise degree legally possible (59 FR 7629). Several new environmental justice initiatives were established under Executive Order 14008 in 2021 (86 FR 7619) and include agency-specific strategies to strengthen environmental justice policies. Environmental justice practices are in place not only to protect the health of individuals in impacted communities but also their livelihoods and traditions. Environmental justice is becoming an increasing concern for coastal communities and fisheries stakeholders. Development of the offshore wind industry in the United States has the potential for direct and indirect socioeconomic benefits for coastal communities, however, the delivery of such benefits to environmental justice communities needs to be tracked throughout the life of a project to determine if benefits are realized. Environmental justice concerns should be considered early in the project planning stage.

Fossil fuels would be required to operate marine vessels and other combustion equipment needed for construction, operations, and maintenance of an offshore wind project. The majority of the marine vessels would be equipped with either Category 1 or Category 2 engines and use only ultra-low sulfur diesel fuel. Many of the larger installation vessels would be equipped with Category 3 main engines and would likely use marine diesel oil with a sulfur content of 0.1 percent by weight. Oils, greases, and fuels would be used for lubrication, cooling, and hydraulic transmission for the wind turbines and offshore substations. However, since materials are not burned, they would not have a significant contribution to a project's total greenhouse gas emissions or criteria pollutants. The wind turbine would be designed to minimize the potential for spills through containment measures.

Renewable energy sources such as offshore wind generation create substantially lower GHG indirect emissions across a project life cycle when compared to the direct GHG emissions associated with conventional fossil fuel generation facilities. Primary emission sources of GHG and criteria pollutants (carbon monoxide [CO], lead, nitrogen dioxide [NO_2], ozone, particulate matter, and sulfur dioxide [SO_2] for an offshore wind project would include marine vessel engines and other equipment used during construction, commissioning, operation, and maintenance of the project. Construction project-related air emissions could have short-term impacts to air quality. Most of the project-related construction emissions are expected to occur offshore, within the Lease Area and along the submarine export cable routes. Estimated air emissions from operations and maintenance activities are not expected to have a significant impact on regional air quality over the operational life of a project and are generally expected to be smaller compared to the impacts anticipated during construction activities.

The construction and operation of an offshore wind farm would generate sound in the lease area and along the transmission cable route that would be regulated by NOAA and BOEM. Both agencies have published guidelines that specify sound thresholds for marine species. Sound created by the onshore portion of the projects would be regulated by state and local agencies. The section discusses the sounds that may be produced by various equipment and components used during both in-water and onshore construction and operation.

Rare earth elements comprise a group of chemical elements with similar properties that are used in a range of high-tech applications and are crucial to accomplishing global renewable energy targets, including offshore wind energy. Current supply chains are mainly fulfilled by the Chinese rare earth industry. Rare earth element concentrates produced in the U.S. are currently exported to China to carry out the final separation and purification processes. This has resulted in price volatility, supply chain uncertainties, and trade disputes. A 2021 supply chain assessment found the U.S. was over-reliant on foreign sources and adversarial nations for critical minerals and materials which posed national and economic security threats. The report recommended expanding domestic mining, production, processing, and recycling of critical minerals and materials.

Offshore wind projects have the potential to affect the existing visual character and scenic resources of the coastal New Hampshire landscape. The potential for and magnitude of effects to scenic resources from depends on many factors including distance, scale, prominence, patterns of atmospheric conditions, and viewer expectations and values. Visibility toward the GOM from shorefront areas varies widely through the seasons and would directly influence whether and how offshore wind developments could be seen from a given location. The level of change perceived by viewers is dependent upon distance between the viewer and the structure, the height of the structure, the elevation of the viewer, earth curvature, atmospheric conditions, and individual viewer activities and expectations. Potential offshore wind development projects within the GOM could be observed by viewers from a variety of locations along the New Hampshire shoreline particularly during the summer months when atmospheric conditions would favor higher visibility in combination with higher numbers of total viewers enjoying the shoreline. However, given the small proportion of area within the GOM RFI Area that falls within 40 miles of the New Hampshire shoreline, it is anticipated that most potential offshore wind developments would be located beyond the distance that could cause adverse visual effects.

Permitting and Regulatory Issues

BOEM oversees the leasing for offshore wind energy on the U.S. Outer Continental Shelf (OCS) and the permitting of offshore wind projects in leases areas. The offshore wind development process comprises four phases (1. Planning and Analysis, 2. Leasing, 3. Site Assessment, and 4. Lessee development and submission of construction and operations plan [COP]) and three rounds of NEPA reviews and consultations. Permitting for the potential wind developer is limited to Phase 3 and Phase 4. The COP must include information on the following resources, conditions, and activities that may be affected by the proposed activity including: hazard information, water quality, biological resources, archaeological resources, social and economic resources, coastal and marine uses, and consistency certifications, among others. Due to logistical issues, BOEM has proposed a revised process for a partial COP submission, referred to as the “NOI Checklist” providing minimum information and deadlines BOEM requires to adequately continue or complete the COP review.

If the COP is approved or approved with modification, the lessee must submit a Fabrication and Installation Report (FIR) and Facility Design Report (FDR) for BOEM’s review and then proceed through the regulatory process prior to fabricating and installing the proposed project elements. In addition, and simultaneous to BOEM’s review process, the lessee is required to comply with environmental consultations under the following regulations: National Historic Preservation Act (NHPA), Migratory Bird Treaty Act (MBTA), Endangered Species Act (ESA), Magnuson-Stevens Fishery Conservation and Management Act (Essential Fish Habitat [EFH]), Marine Mammal Protection Act (MMPA), and Coastal Zone Management Act (CZMA).

In addition, the Merchant Marine Act of 1920, better known as the Jones Act (JA), requires that any cargo travelling by sea between two U.S. ports must sail on a ship both built and registered in the U.S; be owned by a U.S. citizen or permanent resident; or owned by a U.S.-based company with over 75% of the ownership stake held by U.S. citizens; and have a crew consisting of a majority of U.S. citizens. However, vessels necessary for the installation and upkeep of offshore wind turbines are often non-JA compliant and critical wind turbine installation vessels (WTIV) are exclusively foreign-made. As of 2021, a development program was initiated to upgrade current port infrastructure to accommodate larger installation vessels and Dominion Energy has commissioned the first U.S. WTIV to be built domestically scheduled to be completed in 2023. However, construction of US-made WTIV and the current lack of ports capable of docking WTIV are limiting factors for the 30GW by 2030 goal, a combination of JA-compliant supporting vessels with noncompliant WTIVs may provide a short-term solution. A long-term solution may involve avoidance for the need for WTIVs in exchange for other vessel types including "feeder" vessels. There are several potential workaround solutions to the JA regarding FOWT, each with its own set of advantages and disadvantages.

Stakeholders have raised concerns and made recommendations associated with offshore wind development in the GOM. These stakeholders include, but are not limited to, federal and state government agencies, non-governmental organizations (NGOs), and representatives from development and manufacturing groups, indigenous nations, and fisheries associations as well as individuals. Stakeholder concerns have been grouped into three main topics (environmental concerns, lease process concerns, and ocean user conflicts and food security concerns) and have been presented in a variety of formats and settings including in written publics comments submitted to BOEM on the GOM RFI Area. Bulleted lists of recommendations from stakeholders regarding the three main topics and other general recommendations are provided herein.

The final section of this report includes a summary of the pros and cons of the various areas of the GOM Call Area under consideration from potential offshore wind developers. The areas of interest have been grouped into eight sections based on a combination of location and overall interest level. The pros and cons are based on available knowledge at the time of this assessment and are intended as a high-level general review.

1 Introduction

The viability of offshore wind deployment in the Gulf of Maine (GOM) has been discussed for many years. Recently, as floating wind turbine technologies have improved and the industry has matured, there has been a motivation to explore the potential of offshore wind as 1) a clean and renewable energy source which could reduce regional greenhouse gas emissions, 2) a way to increase the regional energy supply, and 3) the potential for economic benefits through investment and the creation of well-paying jobs that would boost the State's economy.

In January 2019, the State of New Hampshire requested the United States Department of the Interior Bureau of Ocean Energy Management (BOEM) establish an offshore renewable energy task force for the GOM that would include representation from New Hampshire (NH), Massachusetts (MA), and Maine (ME). The BOEM Gulf of Maine Intergovernmental Renewable Energy Task Force was form in December 2019 and chartered to facilitate coordination and consultation related to renewable energy planning activities on the Outer Continental Shelf (OCS) in the GOM.

On December 3, 2019, the Governor issued Executive Order 2019-06 that created four advisory boards to be chaired by State agency department heads and required Office of Strategic Initiatives (NHOSI), Department of Environmental Services (NHDES), and Department of Business and Economic Affairs (DBEA) to issue reports on the greenhouse gas reduction potential of offshore wind, and the status of New Hampshire's existing port infrastructure, coastal transmission infrastructure, and opportunities for New Hampshire to attract offshore wind supply chain operations to New Hampshire. On March 1, 2021, the Governor issued Executive Order 2021-03 extending the deadline for the state agencies to issue the requested reports due to the challenges of COVID-19 pandemic. The advisory board completed and publicly released the report on greenhouse gas reduction potential of offshore wind in February 2022[1].

During the 2020 Session of the NH General Court, House Bill 1245 was passed by the State Legislature and signed by the Governor establishing the New Hampshire Commission to Study Offshore Wind and Port Development (NHCSOWPD). The Commission is made up of representatives from government, the business community including representatives from New Hampshire's commercial fishing industry, and labor unions, and is tasked with many of the same activities as those assigned to the four advisory boards created by Executive Order 2019-06.

In October 2021, the New Hampshire Department of Energy (NHDOE) allocated funds from the American Rescue Plan Act of 2021 to assess the potential economic, energy, and environmental

[1] New Hampshire Departments of Energy, Environmental Services, and Business and Economic Affairs. 2022. Report on Greenhouse Gas Emissions, and Infrastructure and Supply Chain Opportunities as it Relates to the Deployment of Offshore Wind in the Gulf of Maine. 29 pp + appendices. Available at https://www.des.nh.gov/news-and-media/nh-releases-report-greenhouse-gas-emissions-and-infrastructure-and-supply-chain

impacts to the citizens and businesses of New Hampshire from development of offshore wind projects in the GOM and issued a Request for Proposals. On July 12, 2022, the Governor and Executive Council approved the winning bid, and this federally funded study was approved to move forward. The assessment incorporates and builds upon the work conducted pursuant to the Governor`s Executive Orders 2019-06 and 2021-03 and by the NHCSOWPD established by House Bill 1245.

This assessment focuses on providing the State of New Hampshire a high-level summary of several stakeholder input items related to the development and deployment of offshore wind in the GOM. These items were categorized into five main topics outlined below:

1. Economic Impacts to Maritime Industries and Activities
2. Energy Sector and Energy-Related Economic Impacts
3. Existing Infrastructure and New Infrastructure Needs
4. Environmental and Biological Impacts
5. Permitting and Regulatory Issues

These five topics are elevated for the GOM Request for Interest (RFI) Area identified by BOEM in August 2022 (Figure 1.2.1; See Section 1.2). The RFI Area contains water deeper than 60 meters (m; 197 feet [ft]) which is too deep for “fixed-bottom” wind turbine foundations that are secured to the seafloor. Offshore wind development in this area is anticipated to be based on floating offshore wind turbines: turbines mounted to a floating foundation or platform that is anchored to the seafloor with mooring lines (See Section 1.4.2, Appendix A). Therefore, the assessment focuses only on this type of wind turbine and its potential effects. The goal of the assessment is to provide elected officials, policymakers, stakeholders, and the public with the information necessary to evaluate:

1. Economic development opportunities;
2. Potential environmental impacts; and
3. Offshore wind impacts to New Hampshire’s future energy needs.

The information assembled and the findings outlined in this assessment will be used to facilitate further discussion, objective policy development, and provide the basis for future studies.

1.1 Offshore Wind Industry

The offshore wind industry is now recognized as a leading source for renewable energy worldwide (Musial et al. 2022). The first offshore wind project was developed off the coast of Denmark in 1991 (Ramirez et al. 2020). This project, Vindeby, had a total generation capacity of 5 megawatts (MW) from 11 turbines. In the decades since the development of Vindeby, Europe emerged as an early leader in the industry. As of 2019, the total installed capacity of offshore wind across 12 European countries was approximately 22,000 MW (Ramirez et al. 2020). Offshore wind development is increasing rapidly across the world. China, Vietnam, and Taiwan built projects in 2021. During 2021 alone, China commissioned 13,790 MW of offshore wind. As of 2021, the cumulative global installed capacity of offshore wind was 50,623 MW from 257 operating projects (Musial et al. 2022).

Although the U.S. domestic offshore wind industry is still in the early stages of development, significant growth is expected in the coming years (Musial et al. 2022). A U.S. national target of 30 GW of offshore wind energy by 2030 was established in March 2021. Strong state-level offshore wind energy procurement activities and policies, along with the 30 GW-by-2030 national target, have been seen as driving factors behind recent offshore wind development activities in the U.S. (Musial et al. 2022). These factors have contributed to rapid growth in U.S. offshore wind, especially in the North Atlantic and mid-Atlantic regions as evident in the record-setting prices for offshore wind area leases in the February 2022 New York Bight auction (Musial et al. 2022). National leasing plans in conjunction with technological advancements, such as floating wind turbine technology, will contribute to further industry growth and allow commercial development in the GOM as early as 2030 (Musial et al. 2022). These recent developments have increased the likelihood that offshore wind will become a viable option in the GOM, with potential environmental, economic, and energy impacts to New Hampshire.

1.2 Gulf of Maine Request for Interest (RFI) Area

On October 13, 2021, Secretary Haaland, U.S. Department of the Interior, announced the offshore wind leasing strategy for 2021-2025, which includes the goal of holding a commercial lease sale within the GOM in 2024 (BOEM 2021, BOEM 2023a). On August 19, 2022, BOEM published a Request for Interest (RFI) in commercial leasing for wind energy development for the GOM Outer Continental Shelf (OCS) in the Federal Register (87 FR 51129). The RFI was the first step to identify the offshore locations that appear most suitable for wind energy development in the BOEM commercial planning and leasing process, while taking into consideration potential impacts to resources and ocean users. BOEM sought feedback from stakeholders, industry, Native American Tribal Governments, and others regarding the location and size of specific areas they wish to be included in or excluded from a future offshore wind energy lease sale, along with other planning considerations including competitive interest to develop renewable energy on the OCS, understanding ocean uses, and to identify potential conflicts (87 FR 51129). This information will be used to narrow the area to be considered for offshore wind development as BOEM moves forward with the GOM planning and leasing process.

The GOM RFI Area consists of 13,713,825 acres located off the coasts of Massachusetts, New Hampshire, and Maine (Figure 1.2.1; 87 FR 51129). BOEM delineated the outer perimeter of the RFI Area roughly to the north, east, and west by the boundaries of BOEM's jurisdiction over renewable energy activities on the OCS and the southern boundary by looking at the oceanographic and ecological features that uniquely define the GOM (87 FR 51129). Areas excluded from the RFI Area that were incompatible with offshore wind energy development and met the following criteria:

- A unit within the National Park System, National Wildlife Refuge System, or National Marine Sanctuary System, and any National Monument (30 CFR § 585.204),
- Existing Traffic Separation Schemes, fairways, and other internationally recognized navigation measures, and
- The Request for Competitive Interest (RFCI) area encompassing the State of Maine's lease request (87 FR 51134).

In response to the RFI, BOEM received nominations of areas of interest from five developers that have been found to be legally, technically, and financially qualified (submission period ended October 3, 2022). The interest and qualification of these developers does not guarantee participation in any future lease auctions, and BOEM reserves the right to not offer for lease areas nominated as a result of the RFI (87 FR 51134). The five developers are Avangrid Renewables, LLC, Hexicon USA, LLC, Pine Tree Offshore Wind, LLC, TotalEnergies SBE US, LLC, and U.S. Mainstream Renewable Power Inc. (BOEM 2023a). The areas of interest indicated by the developers are shown in Figure 1.2.2. BOEM received over 50 public comments from federal and state agencies, commercial fishermen associations, businesses and business organizations, worker unions, environmental organizations, and private citizens (BOEM 2023a).

In January 2023, BOEM released a draft Call Area that reduced the original RFI area by 9.9 million acres (approximately 27%), based on the information received through industry nominations and public comment on the RFI, and a spatial analysis in partnership with the National Oceanic and Atmospheric Administration (NOAA) National Center for Coastal and Ocean Science (NCCOS; Figure 1.2.3; 88 FR 25427). BOEM identified key themes and focused on areas where a considerable number of comments and supporting information indicated overlapping conflicts and recommendations for area exclusions where established boundaries protect against existing ocean activities. Areas removed from the draft Call Area include:

- Areas within 20 nautical miles (nm) of the coastline (not including islands)
- Groundfish closure areas
- Closed Area I North
- Gulf of Maine cod spawning protection area
- Habitat management areas
- Coral protection areas
- Traffic separation schemes (2 nm setback from the sides; 5 nm setback from the entry and exit)
- Jeffreys Ledge (depths shallower than 120 m)
- Jordan Basin Dedicated Habitat Research Area
- Areas identified as ‘‘critical’’ and ‘‘high’’ impact zones for next generation and terminal doppler weather radar systems (0–35 km from radar installations identified by NOAA National Weather Service)
- Environmental Protection Agency designated ocean disposal sites
- Environmental sensors and buoys identified by NOAA’s Marine Environmental Buoy Database
- Liquid natural gas installations and pipelines
- An OCS maritime area claimed by both Canada and the United States (88 FR 25427).

BOEM issued a final Call Area in April 2023 after receiving comments and feedback from Native American tribes, states, existing ocean users, and the general public, reducing the RFI area by additional 160,000 acres to avoid Georges Bank (BOEM 2023a). BOEM received nominations of areas of interest from seven developers that were found to be legally, technically, and financially qualified during the draft Call Area comment period (submission period ended June 12, 2023). These developers are Avangrid Renewables, LLC, Corio USA ProjectCo LLC, Diamond Wind North America, LLC, Maine Offshore Wind Development LLC, OW Gulf of Maine LLC, Repsol Renewables North America, Inc. and TotalEnergies SBE US, LLC (BOEM 2023a). The areas of interest in the Call Area indicated by the seven developers are shown in Figure 1.2.4.

The next step in the BOEM process for commercial offshore wind development in the GOM would be the release of draft GOM Wind Energy Areas (WEAs). WEAs are areas within the Call

Area that BOEM in consultation with federal, state, local, and tribal partners identify as appearing to be the most suitable for commercial wind energy activities, while presenting the fewest apparent environmental and user conflicts. BOEM and NCCOS are developing a GOM Offshore Wind Suitability Model using a team of expert spatial planners, marine and fisheries scientists, environmental policy analysts, project coordinators, and others to identify the best areas for wind energy sites (BOEM 2023b). BOEM anticipates announcing a GOM WEA designation in the third or fourth quarter of 2023. BOEM plans to hold a GOM commercial lease sale in 2024 (BOEM 2021).

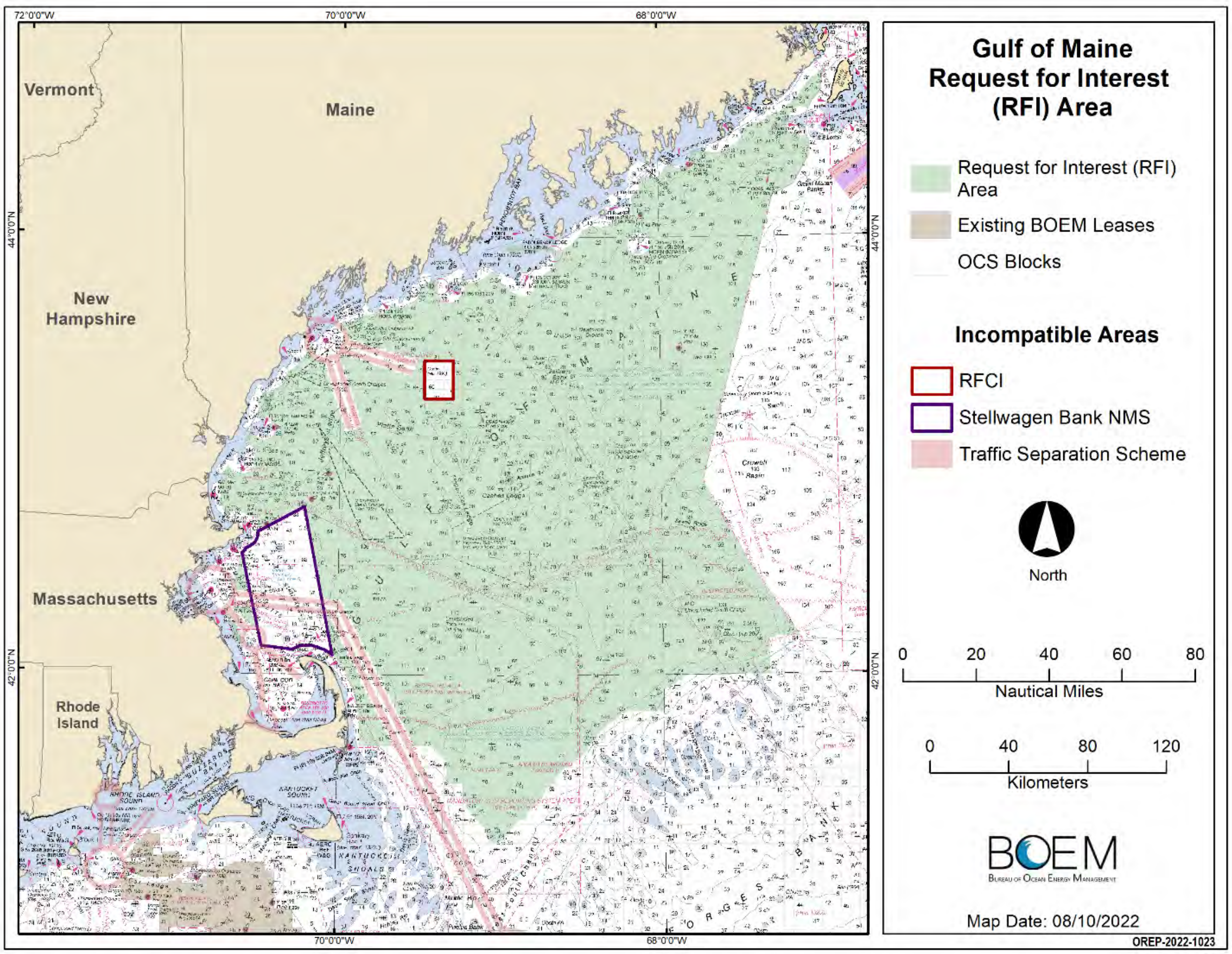

Figure 1.2.1. Map of Gulf of Maine Request for Interest (RFI) Area (BOEM 2023a).

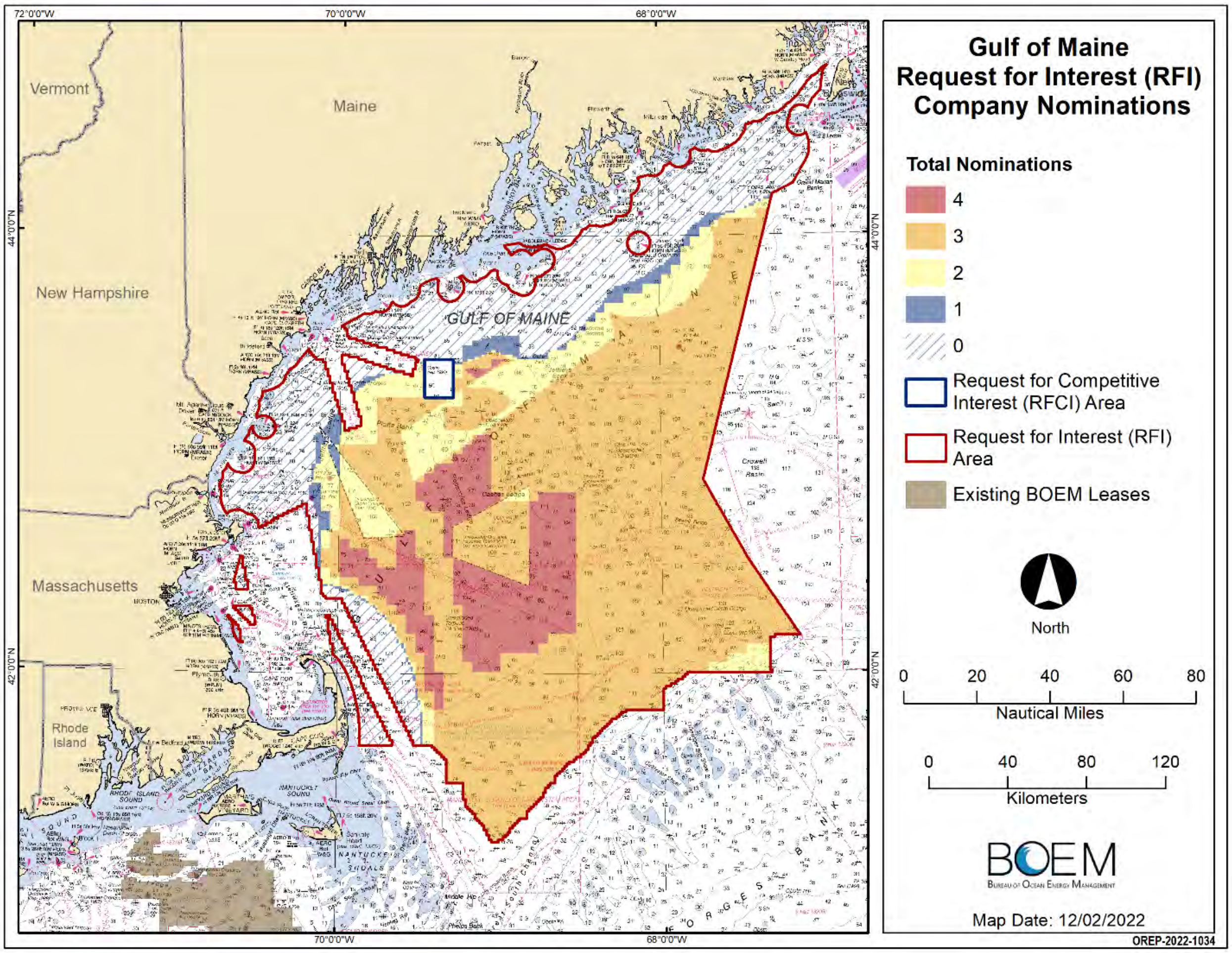

Figure 1.2.2. Map of Gulf of Maine Request for Interest (RFI) company nominations (BOEM 2023a).

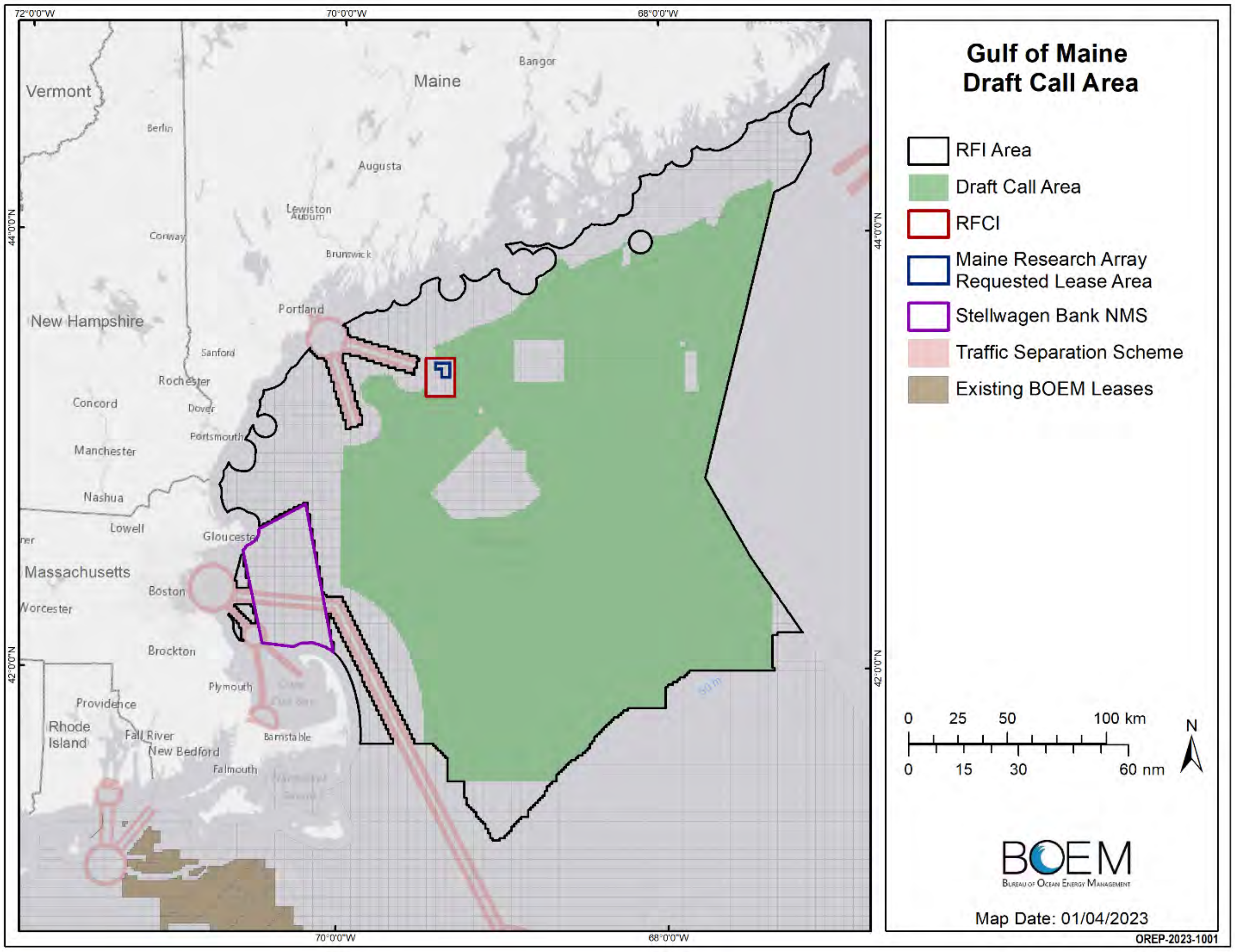

Figure 1.2.3. Map of Gulf of Maine Draft Call Area company nominations (BOEM 2023a).

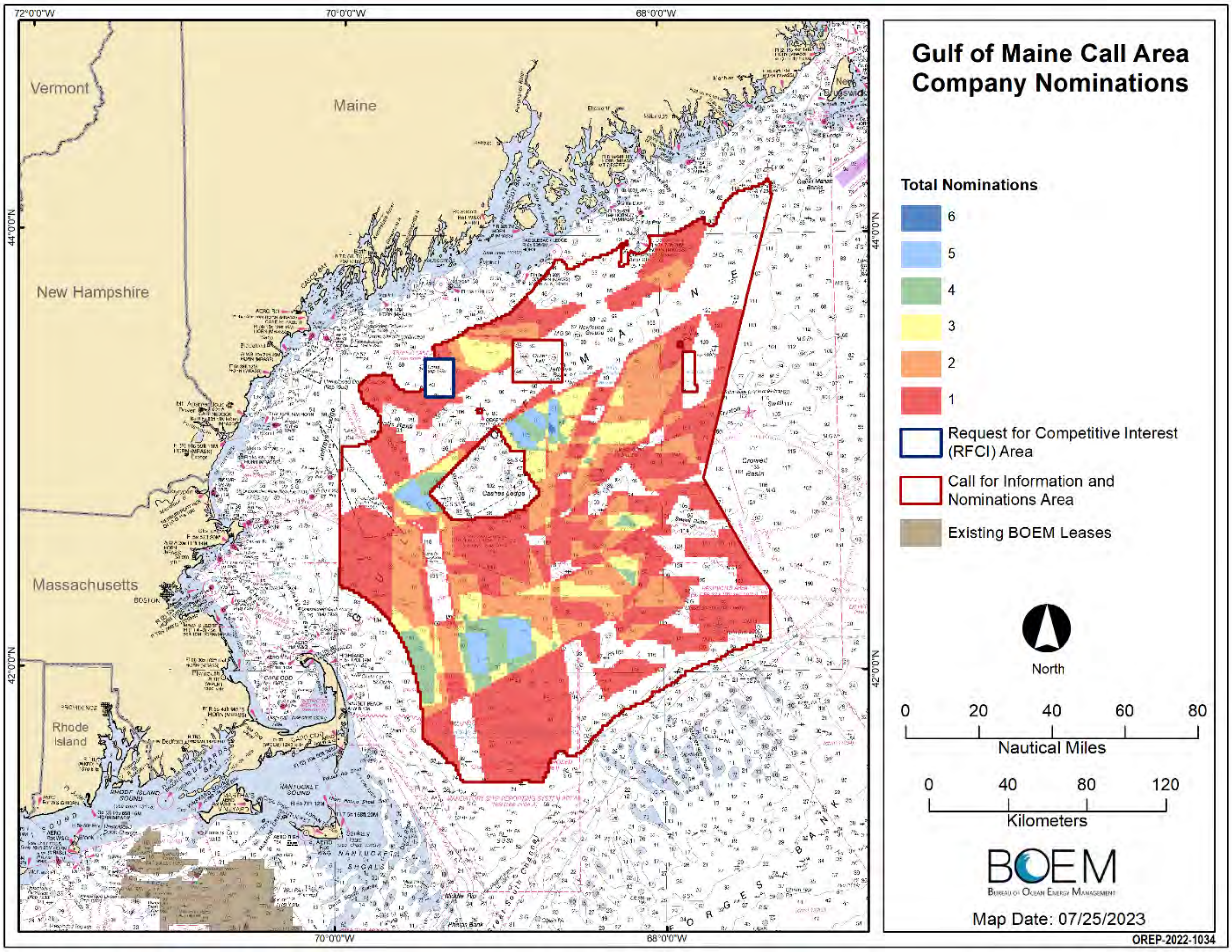

Figure 1.2.4. Map of Gulf of Maine Call Area company nominations (BOEM 2023a).

1.3 Offshore Wind Resources

The U.S. has abundant and widely distributed offshore wind resources, with 30 U.S. states bordering an ocean or Great Lake. The usage of offshore wind as a resource has multiple advantages. The wind at sea tends to be stronger and more uniform than on land, meaning more electricity generation per turbine and less wear from variable strain on the components (AECOM 2017). Wind speed increases rapidly with distance from the shore, so many of the most promising sites for the utilization and storage of wind energy may not require long-distance power transmission, mitigating associated logistical and environmental concerns. Many of the sites demonstrating the most promising offshore wind resource are situated near major urban load centers which pay the highest electricity rates in the U.S. (University of Massachusetts 2014). Furthermore, in many coastal areas of the country, the land-based wind resource is negligible in comparison to their offshore resource (AECOM 2017, Schwartz et al. 2010).

U.S. offshore wind resources are less well understood or quantified than U.S. land-based wind resource since data accurately describing the overall wind resource of an offshore region can be difficult to produce. Meteorological towers with the capability of measuring wind speeds at a turbine's hub height are logistically challenging and expensive (Sheridan et al. 2012). Therefore, estimates have often been modelled or extrapolated from surface buoys, marine automated stations, satellites, or land-based instruments (Schwartz et al. 2010, Sheridan et al. 2012, Livingston and Lundquist 2020). Despite the difficulty, wind speed remains the most important factor for site selection for development of offshore wind power (Gil-Garcia et al. 2022). An increasing number of studies have used advanced modelling to map the offshore resource as interest and publications exploring this renewable energy source increased dramatically in the mid- to late-2000s (Gil-Garcia et al. 2019).

In 2010, the National Renewable Energy Laboratory (NREL) released a comprehensive assessment of the U.S. offshore resource which used a variety of modelling techniques to estimate the average wind speeds at 90 m above the surface out to 50 nautical miles (nm) from the shore (Schwartz et al. 2010). Based on these and other similar assessments, the Atlantic coast was found to boast an excellent offshore resource, with some of the highest wind speeds found in U.S. waters and a potential estimated capacity of 156 GW (Schwartz et al. 2010, Draxl et al. 2015a, Livingston and Lundquist 2020, Gil-Garcia et al. 2022). Preliminary evaluations estimated that the offshore wind there would likely produce enough to supply the energy needs of most, if not all, of the northeastern coastal states (Kempton et al. 2007, Dvorak et al. 2013, Kempton et al. 2016, AECOM 2017). In addition, many of these areas have strong winds that often correspond to peak load hours (Dvorak et al. 2012, Kempton et al. 2016). The diurnal pattern of offshore winds along the East Coast normally peak in the afternoon and evening, closely resembling hours of peak electricity demand, i.e., when the majority of residents return home, turn on lights, and begin to cook dinner or watch television (Bailey and Wilson 2016, AECOM 2017). The NREL Wind Integration National Dataset Toolkit provides updated wind profiles for the continuous United States including offshore areas at various heights (10 m to 200 m) above surface level (Figure 1.3.1).

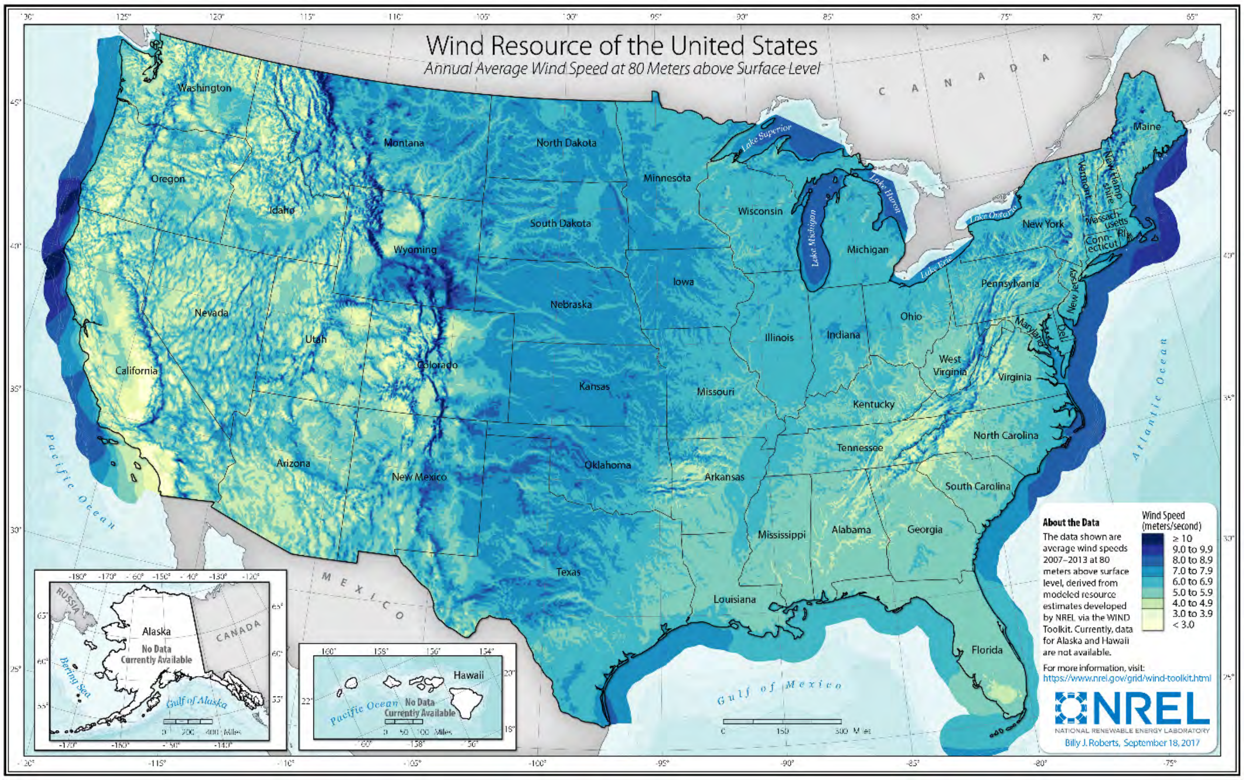

Figure 1.3.1. U.S. annual average wind resources at 80 m above the surface (Roberts 2017, Draxl et al. 2015a, b, Lieberman-Cribbin et al. 2014, King et al. 2014).

Offshore winds are generally much stronger and steadier with a more stable dominant direction than inland winds and are expected to play an important role in the future energy market (Chen and Kim 2022). A significant challenge to building offshore wind turbines in United States coastal waters is the water depths along many areas. Approximately 60% of the nation's offshore wind resources are situated in deep waters, more than 60 m (197 ft), including California, Hawaii, and Maine. Traditional fixed-bottom foundations are not economically viable in these locations (Hartman and Bittner 2017). Floating foundations allow wind turbines to operate in areas where water depths range from 60 to 1,000 m (165 to 3,281 ft; Musial et al. 2016).

In the Northeast region in particular, offshore winds at turbine heights average more than 9 meters per second (m/s) at just 50 nm from the shore as shown in Figure 1.3.2. Additionally, it has been shown that although there is some seasonal and interannual variability, ten years of data are sufficient to account for the variability in this region (Lee et al. 2018). Using ten-year averages, speeds do show a predictable seasonal dip in average speeds during the late summer months of June-October (Figure 1.3.3), however these lows generally remain above 7.5 m/s on average, a speed which is classed at minimum as 'excellent' and ranging up to 'outstanding' according to the wind power classification scheme by the NREL (Fisher et al. 2010, Livingston and Lundquist 2020).

In fact, the offshore asset in this area is so formidable and consistent that modelling with NASA's MERRA-2 dataset showed that just 2000, 10 MW wind turbines under normal coastal conditions with a standard 20% wake loss could produce enough power to fully meet the needs of the New England states (Maine, New Hampshire, Massachusetts, Rhode Island, Vermont, and Connecticut) for 37% of the year, or 72% with the addition of large-capacity energy storage (Livingston and Lundquist 2020).

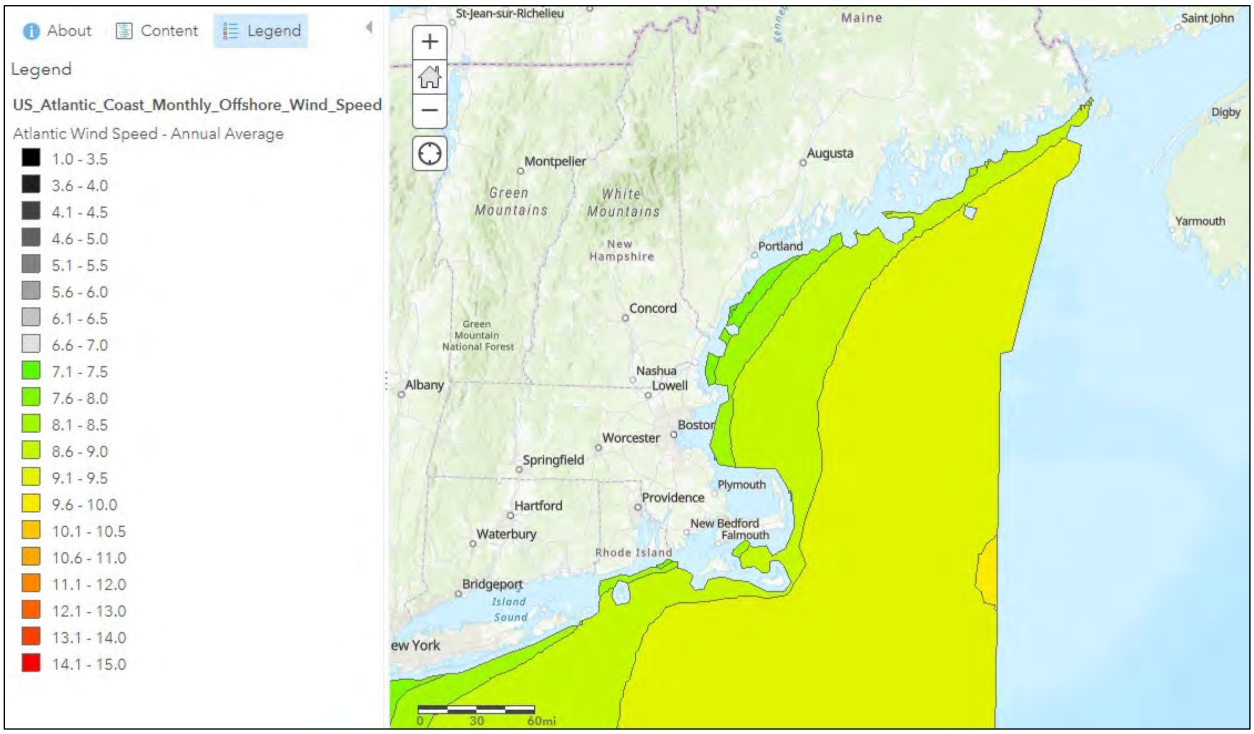

Figure 1.3.2. U.S. Northeast Atlantic coast annual average wind speed using Wind Integration National Dataset (WIND) toolkit for the years 2007-2013 (www.gis.boem.gov).

The proposed Gulf of Maine RFI Area represents a significant contribution to these statistics (Figure 1.3.4). Offshore wind resource potential values for Maine, New Hampshire, and Massachusetts, of which a considerable proportion is situated within the RFI area, are presented in Table 1.3.1, organized by available square kilometer of water for annual wind speeds greater than 7 m/s at 90 m above the surface. It has been found that over 80% of the wind potential along the Atlantic coast is situated in areas of 60 m depths or greater (Fisher et al. 2010, Gil-Garcia et al. 2022; See Appendix B). The GOM RFI Area encompasses an area of outstanding potential for the development of offshore wind using floating turbine technology due to several factors including steady, high winds that occur for the majority of the year, a sharp wind speed increase relatively near to the coast, and proximity to urban centers with a high demand during periods of peak seasonal winds. The proximity to the urban centers will result in less long-distance transmission in order to meet a significant proportion of energy demand throughout the year.

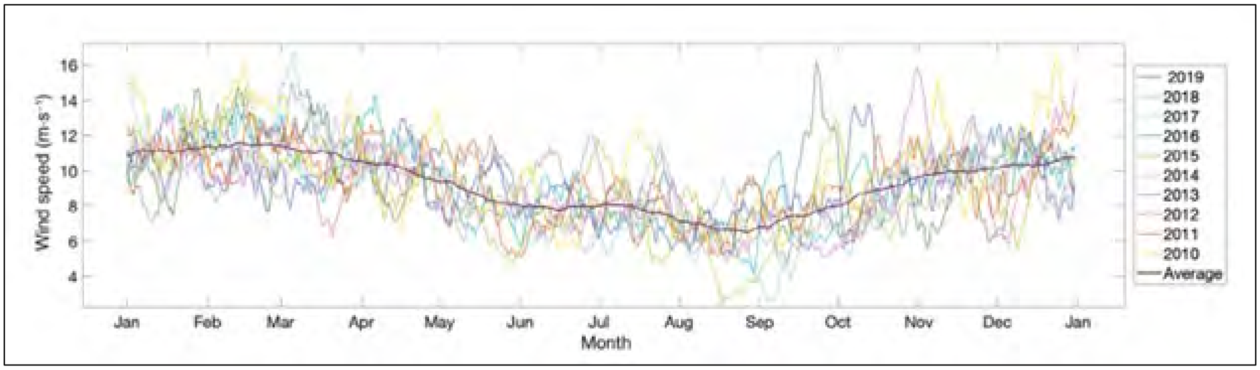

Figure 1.3.3. Ten-day moving averages of wind speeds for 10 years showing interannual variablity and overall average (Livingston and Lundquist 2020).

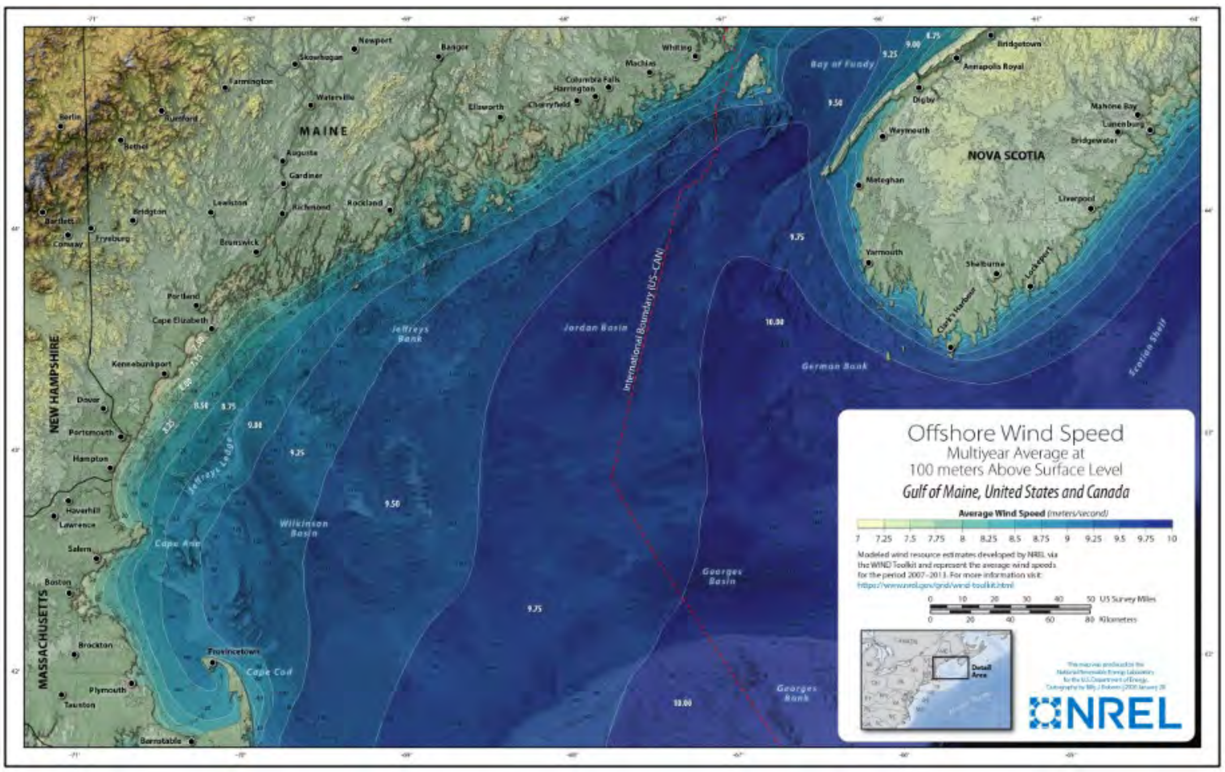

Figure 1.3.4. Gulf of Maine average multi-year wind speed map using modelled resource estimates developed using the Wind Integration National Dataset (WIND) toolkit for the years 2007-2013 (www.windexchange.energy.gov).

Table 1.3.1. Offshore Wind Resource Area and Potential by Wind Speed Interval and State Within 50 nm of Shore (Schwartz et al. 2010)

	Wind Speed at 90 m (m/s)							
State	**7.0 - 7.5**	**7.5 - 8.0**	**8.0 - 8.5**	**8.5 - 9.0**	**9.0 - 9.5**	**9.5 - 10.0**	**>10.0**	**Total >7.0**
Maine								
km^2	906	1,142	1,976	3,331	8,429	15,485	42	31,311
(GW)	*(4.5)*	*(5.7)*	*(9.9)*	*(16.7)*	*(42.1)*	*(77.4)*	*(0.2)*	*(156.6)*
New Hampshire								
km^2	19	46	171	336	102	0	0	672
(GW)	*(0.1)*	*(0.2)*	*(0.9)*	*(1.7)*	*(0.5)*	*(0.0)*	*(0.0)*	*(3.4)*
Massachusetts								
km^2	202	526	1,639	3,606	20,351	13,674	0	39,997
(GW)	*(1.0)*	*(2.6)*	*(8.2)*	*(18.0)*	*(101.8)*	*(68.4)*	*(0.0)*	*(200.0)*

Note: Potential gigawatt (GW) values are calculated uniformly using a constant of 5MW per square kilometer of water.

1.4 Offshore Wind Technologies

Offshore wind projects use turbines to capture wind energy and generate electricity. Each wind turbine within a project is connected to an offshore substation through a network of array cables (inter-array cables). The inter-array cables transport the energy generated by each of the turbines to an offshore electrical substation. At the offshore substation, the power is stabilized in preparation for transmission to shore. The offshore substation is connected to a static subsea export power cables that are used to transmit power from the offshore substation to an onshore substation, where electricity is then transferred to the existing transmission network (Rentschler et al. 2020). Offshore wind turbines are either secured directly to the ocean floor using fixed-bottom turbine technologies for shallow-water deployment, or they are anchored using floating turbine technologies, which allow for deep-water deployment. These two technologies for offshore wind turbines are discussed in the sections below. A glossary of terms used in this assessment is provided in Appendix A.

1.4.1 Fixed-bottom Offshore Wind Turbines

Fixed-bottom turbines are the primary technology that has been used for commercial scale offshore wind projects to date. These turbines are rigid structures secured directly to the ocean floor by foundations of various types, including jackets, monopiles, and gravity-based foundations. The size and generating capacity of fixed-bottom turbines has increased steadily with the advancement of offshore wind technology. Based on industry announcements, most developers of U.S. projects are planning to use offshore wind turbines in the 15-MW class for their projects under development (Musial et al. 2022). These 15-MW-class turbines will be commercially available by 2024 (Musial et al. 2022). The industry standard, fixed-bottom turbines are generally limited to areas with less than 60 m water depth. Deep water in the GOM drastically limits the potential for offshore wind projects using fixed-bottom turbines in this area.

1.4.2 Floating Offshore Wind Turbines

Access to offshore wind resources in the GOM will primarily require the use of floating wind technologies. Floating offshore wind turbines (FOWT) employ buoyant floating substructures that are anchored to the seabed with mooring lines and a variety of anchor types (Figure 1.4.1). The inter-array power cables are suspended in the water column and move with the floating platform (Rentschler et al. 2020).

Types of Platforms

There are four main design concepts for floating platforms: spar-buoy, tension-leg platform (TLP), semisubmersible, and barge (pontoon) type (Figure 1.4.1; Wang et al. 2010, Chen and Kim 2022).

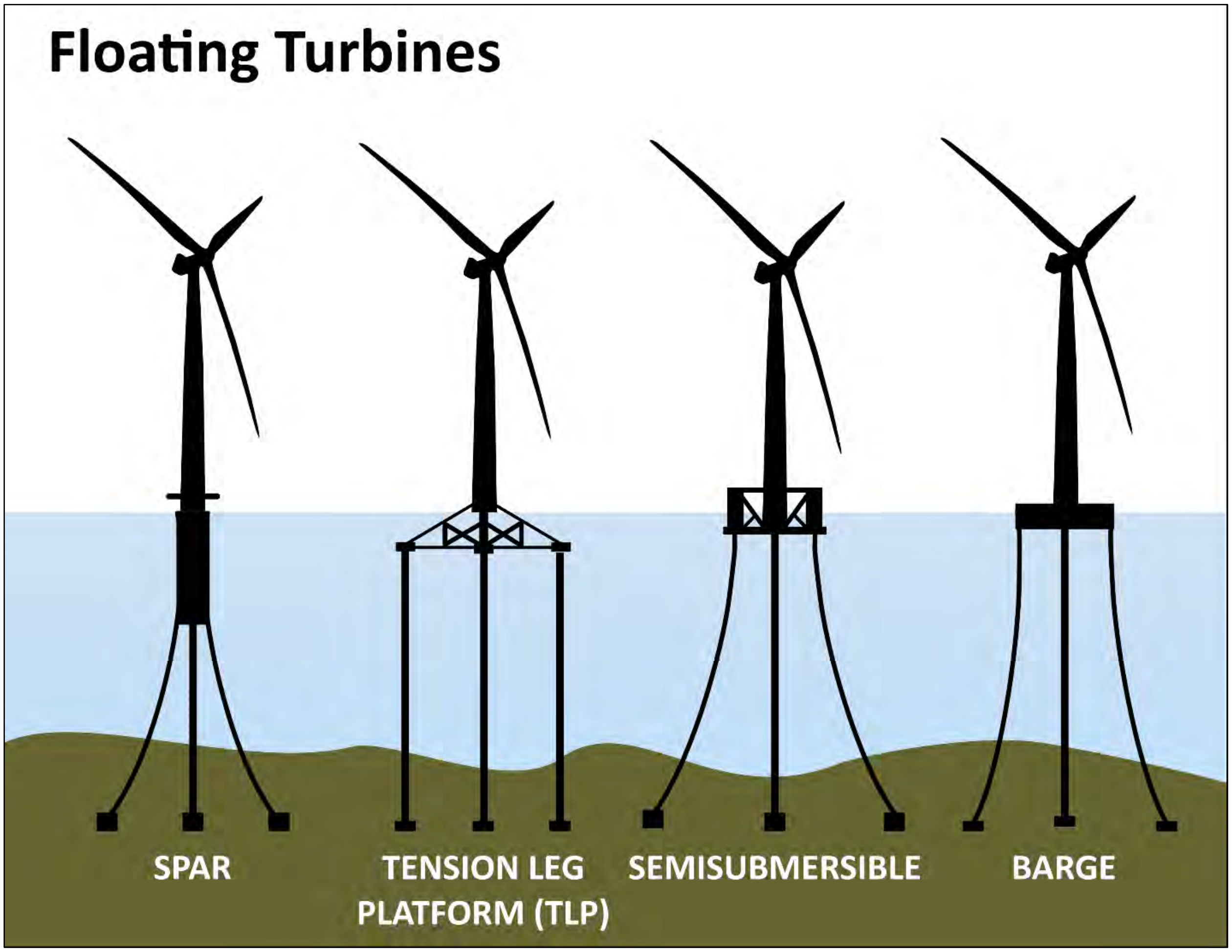

Figure 1.4.1. Types of floating offshore wind turbines.

Spar-buoy type – The spar-type platform is a deep-draft vertical cylinder composed of steel and/or concrete, which provides buoyancy with a ballast of water and gravels (Wang et al. 2010). Roll and pitch stability is maintained by placing the center of gravity sufficiently below the center of buoyancy. For station-keeping, a semi-taut or catenary (U-shaped) spread mooring system of anchor-chains, steel cables, and/or synthetic fiber ropes can be used (Wang et al. 2010, Chitteth Ramachandran et al. 2021, Chen and Kim 2022). The hull can float horizontally and be towed by tug or barge (wet-towed) to calm waters near the deployment site. The foundation is then water-ballasted into a vertical position, stabilized, and the tower and rotor-nacelle assembly mounted with a derrick crane barge before the turbine is towed to the deployment site for connection to the mooring system (Wang et al. 2010, Chen and Kim 2022). The floating spar–buoy concept is the most technically proven concept among floating wind turbines. The first commercial floating wind farm consisting of five 6 MW spar-type turbines was commissioned off the coast of Scotland by Statoil in 2020 (Chen and Kim 2022). The spar-buoy wind turbine is suitable for deployment in waters with depths greater than 150 m and is considered the most economical option at depths greater than 200 m (Chitteth Ramachandran et al. 2021, Chen and

Kim 2022). One challenge for spar-type turbines is that the platform's deep drafts limit port access (Musial 2021).

Tension-leg platform (TLP) type – TLP-type structures are used in the oil and gas industry and are traditionally comprised of a square pontoon with columns on which the topside deck rests. The floating platform is held on station by vertical tendons or tethers which are anchored by a template foundation, suction caissons, or pile driven anchors (Wang et al. 2010). TLP wind turbines can be assembled and commissioned onshore, avoiding logistical difficulties of offshore assembly. The fully assembled platform is towed to the deployment site, avoiding the need to charter and mobilize expensive derrick crane barges or heavy-lift vessels for offshore construction (Wang et al. 2010). An advantage of the TLP wind turbine is its less dynamic response to waves that results in small heave, roll and pitch motions compared to the other floating foundations (Wang et al. 2010, Chen and Kim 2022). This foundation is subject to an occurrence known as "pull down" which is an increase in draft as the platform is offset from its equilibrium position (Wang et al. 2010). The TLP wind turbine is suitable for deployment in waters with depths greater than 50 m (Chen and Kim 2022). Challenges for TLP-type turbines include instability during assembly and their high vertical load moorings or anchors (Musial 2021).

Semisubmersible type – Semisubmersible-type platforms are comprised of a few large column tubes connected to one another by tubular members. A wind turbine on this type of platform can be placed in three different configurations: a) the turbine may sit on one of the column tubes, b) the turbine could sit on of all the columns, or, c) the wind turbine may be positioned at the geometric center of the column tubes and supported by lateral bracing members (Wang et al. 2010). The column tubes are partially filled with water and provide the ballast for the foundation. The foundation is buoyancy-stabilized, the righting moment is contributed either by the large water-plane area of the columns or small cross-sectional areas at some distances from the central axis. Mooring lines keep the semisubmersible floating wind turbine in position (Wang et al. 2010, Chitteth Ramachandran et al. 2021). Semisubmersible designs have relatively shallow draft that allows for site flexibility and provides good stability to the wind turbine. This foundation can be constructed onshore and wet-towed to the deployment site, which is one of its greatest advantages (Wang et al. 2010, Chen and Kim 2022). The semisubmersible concept is one of the most feasible floating platforms and rapidly being developed with the offshore industry moving into deep waters. Several semisubmersible designs are currently being tested (e.g., Tri-floater by GustoMSC and the OC4 DeepCwind by NREL), and WindFloat by Principle Power is operating at two commercial wind farms in Europe (i.e., WindFloat Atlantic and Kincardine Offshore Windfarm; Chen and Kim 2022). The semisubmersible wind turbine is suitable for deployment in waters with depths greater than 50 m (Chen and Kim 2022). The challenges for semisubmersible-type turbines include that they have higher exposure to waves compare to other design types, and that more of the structure is above the waterline (Musial 2021).

Barge (pontoon) type – Barge-type platforms consist of a large shallow-draft barge structure that carries a single or group of wind turbines and is one of the earliest design concepts.

Stability is achieved by using distributed buoyance and a large waterplane area for the righting moment (Wang et al. 2010, Chen and Kim 2022). Barge foundations are moored to the bottom using traditional catenary anchor chains (Wang et al. 2010). The main advantage of the barge-type foundation is its simple manufacturing (Chen and Kim 2022). This foundation can be constructed onshore and wet-towed to the deployment site. The main disadvantage of this type of foundation is its susceptibility to the roll and pitch motions in waves, and therefore can be mainly used in calm seas, such as in a harbor, sheltered cove, or lagoon (Wang et al. 2010, Chen and Kim 2022). The barge-type wind turbine is suitable for deployment in waters with depths greater than 50 m (Chen and Kim 2022). One of the challenges for barge-type turbines is that they have higher exposure to waves compared to other design types (Butterfield et al. 2007, Chen and Kim 2022).

As FOWT technology is in its early development stage, there are no universally accepted optimal designs or procedures for manufacturing, installation, operation, maintenance, or decommissioning. To date, the practices have largely been adapted from the offshore oil and gas industry but incorporate unique challenges which have required bespoke design solutions (Barter et al. 2020). The advantages and disadvantages for spar, TLP, and semisubmersible platforms for all stages of the turbine's life cycle are presented in Table 1.4.1. Section 6.2.2 discusses these platforms and how they relate the Jones Act Compliance.

Table 1.4.1. Advantages and Disadvantages Concerning Installation, Operation and Maintenance, and Decommissioning of Different Types of FOWTs (Reproduced from Chitteth Ramachandran et al. 2022).

Platform Type	Installation	Operation and Maintenance	Decommissioning
Spar type	- High draught makes towing difficult - Requires heavy-lift vessels - Unstable motion of floater during mating - High installation cost - Tighter weather constraints - Requires deepwater ports and sheltered areas	+ Similar to bottom-fixed wind turbines - Heavy-lift vessels might be required for major repairs - Needs deepwater ports and sheltered areas for repairs	- Partially decommissioned in deepwater - Requires heavy-lift vessels
Semi-submersible type	+ Easy installation +Fully assembled quayside Cheaper mooring and anchoring system +Short installation time +Low installation cost - More sensitive to wave height limits during towing	+ Simple unhook from mooring system +Can be towed back to quayside for major repairs +No heavy-lift vessels required +Helicopter access possible	+ Can be completely towed back to shore for dismantling + Uses easily recoverable drag-embedded anchors +No heavy-lift vessels required
Tension leg platforms	+ Can be completely constructed onshore - Complex mooring and anchoring system - Slow and lengthy installation process - High installation cost - Bespoke barge required - High environmental impact	- Difficult to unhook, more on-site repairs - Mooring system highly susceptible to fatigue damage	- Difficult process due to complex mooring system - Difficult or non-recoverable pile-driven anchors

+: relative advantage, -: relative disadvantage

Types of Moorings

The floating platform is stabilized by at least three mooring lines anchored to the seafloor. Mooring lines experience some drift, leading each turbine to drift within a certain radius of its station (Simos et al. 2018). The materials most frequently used for mooring lines are steel chain, steel wires, and synthetic rope (Monfort 2017). There are currently three primary types of mooring systems: catenary, taut, and semi-taut (Monfort 2017, Maxwell et al. 2022).

Catenary mooring

The mooring lines form a catenary or curve shape. Each mooring line may be divided into two segments. The upper segment of lighter and more flexible line connects to the floating substructure and is suspended in the water column. The lower segment of heavy chain weighs down the line along the seafloor (Monfort 2017). Catenary mooring lines are designed to be four times longer than the depth of the water column to account for wave action and prevent vertical loading on the anchors (Barter et al. 2020). A substantial proportion of chain rests on the seafloor and may liftoff from and ground on the sediment through surface wave action, causing abrasion and trenching where the chain contacts the seafloor (Low et al. 2018, Maxwell et al. 2022). The catenary mooring system has the largest relative physical and ecological footprint of the three systems (James and Costa Ros 2015, Maxwell et al. 2022). Catenary moorings are most commonly used with the spar-buoy, semisubmersible, and barge platforms (Barter et al. 2020).

Taut mooring

The taut-leg mooring system has tightly drawn mooring lines that are typically at a 45-degree angle to the seafloor (Monfort 2017). This system does not allow for much vertical movement; therefore, these systems will experience large amounts of force acting on the anchors due to any wave action that the platform experiences. The optimal line types for taut-leg systems are synthetic or wire ropes that have higher elasticity (Monfort 2017). The taut-leg mooring system probably induces the smallest physical footprint and smallest ecological footprint, however the tradeoff is a more challenging installation process (James and Costa Ros 2015). The taut-leg mooring system is most commonly used with the TLP-type structures (James and Costa Ros 2015, Monfort 2017).

Semi-taut mooring

Semi-taut mooring systems represent a combination between the taut-leg and catenary systems in terms of stability and forcing. Synthetic fibers, chains, or wire moorings are the most common materials incorporated with a turret system. A single point on the platform is connected to a turret with several semi-taut mooring lines connecting to the seafloor (James and Costa Ros 2015). The semi-taut mooring system has a medium footprint, as it is flexible enough to accommodate for wave action without the added disruption of mooring chains resting on the seafloor (James and Costa Ros 2015). Semi-taut mooring systems are used on some semi-submersible platforms (Maxwell et al. 2022).

Types of Anchors

The ideal anchor technology for securing the mooring lines to the seafloor depends on the composition of the sediment at the deployment site. The four main anchor types used for floating offshore wind platforms are drag-embedment, suction caissons, gravity anchor, and anchor piles (steel-driven or drilled and grouted; James and Costa Ros 2015, Golightly 2017). There are several other anchor types and many others in development (e.g., drop anchor/torpedo pile, vertical load anchor, suction embedded plate anchor, and multi-line anchors) motivated by the challenges of anchoring in rocky, irregular seafloors in deeper water (Golightly 2017).

Drag-embedment anchor

Drag-embedment anchors function similarly to boating anchors. They are best suited to cohesive sandy sediments, that are not too stiff to impede penetration with adequate soil layering and depth with no bedrock. Drag-embedment anchors are simple to install and are recoverable during decommissioning (James and Costa Ros 2015, Maxwell et al. 2022).

Suction caissons anchor

Suction caissons anchors are embedded into the seafloor by the negative pressure inside the caisson. They require at least equal depth of non-consolidated clays and/or sands. These anchors and their installation and decommissioning processes are well established from oil and gas platforms. Suction caissons anchors are recoverable during decommissioning (Golightly 2017, Maxwell et al. 2022).

Gravity anchor

Gravity or a deadweight anchor is an anchoring system that uses a heavy weight to secure a turbine to the seafloor. The anchor's ability to hold the turbine in place is proportional to the anchor's weight. These anchors are suitable for medium to hard sediments (sandy to rocky) that are stable enough to support the heavy anchor. The new gravity anchors designs do not require a crane for installation, reducing the installation time and costs. Gravity anchors can be difficult to remove during decommissioning, although they do have the potential to be repurposed (James and Costa Ros 2015, Maxwell et al. 2022).

Anchor piles

Anchor piles are permanently driven or drilled and grouted vertically into the seafloor. They can be use in a wide range of cohesive sediments without rocks or boulders. Anchor piles can be precisely located and can achieve very high vertical load capacity. They cannot be removed during decommissioning (James and Costa Ros 2015, Maxwell et al. 2022).

Cable arrays

A range of cables are used to effectively transmit power from the turbine array to shore. In addition to mooring lines, inter-array cables extend between each of the floating platforms and converge to connect to terminal cables, which then lead to an offshore electrical substation (Maxwell et al. 2022, Rentschler et al. 2020).

These inter-array cables are not fixed, but rather are 'dynamic' cables that allow some movement as the array is impacted by currents and winds, but are built particularly stiff to control excessive motion and have additional protections at joints to control and stabilize the load. The depth at which these cables are loosely suspended depends on the design of the floating platforms and the depth of the water at the array site. Configurations can range from a 'lazy wave' shape where buoyancy elements are fixed to intermediate parts of the cable to keep it loosely suspended in the water column, to a free-hanging cable sitting low from its own weight, to cables which may be deliberately buried or weighted to the seabed between floating structures (Maxwell et al. 2022).

Often, the distance between floating platforms in a turbine array is a trade-off between wake loss (reduction of wind speeds at downwind turbines due to wakes caused by upwind turbines) and cable costs, which increase as distance between turbines increases. The FOWT industry is still young with consistent design advancements as the industry grows, however the current typical spacing varies between 6 times to 8 times the diameter of the rotor with that trade-off in mind (Maxwell et al. 2022). Therefore, the dynamic array cables between turbines can be extensive, and represent a significant physical and ecological footprint.

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2 Economic Impacts to Maritime Industries and Activities

Economic impacts to New Hampshire maritime industries and activities, which may result from offshore wind development in the GOM, are evaluated in this section. An overview of potential maritime activities that may be affected is provided, along with a characterization of likely effects as either positive or negative. Commercial fishing and other commercial maritime activities are addressed along with potential compensatory mitigation activities to offset impacts. Supply chain operations, port utilization opportunities, and workforce opportunities are also discussed. This evaluation also includes the potential impact on recreational marine uses, insurance, shipping and navigation, and concludes with a discussion of how offshore wind development may affect aviation and radar assets.

2.1 Commercial and Recreational Maritime Activities

A wide range of commercial and recreational maritime activities may be affected by offshore wind development in the GOM. Table 2.1.1 summarizes these activities and characterizes potential effects as direct or indirect and either positive or negative.

Activities that would be directly affected by offshore wind development are activities that occur in the immediate vicinity of the wind energy area or are an immediate result of the offshore wind development activity. Commercial fishing would be an example of an activity that may experience a direct, negative effect from offshore wind development. For example, if a wind energy area is located in a popular commercial fishing area, commercial fishing would be directly affected because the wind energy area has the potential to affect commercial fishing operations. Commercial fisherman may choose to no longer fish within the wind energy area because of concerns of snagging their gear, striking the turbine structures, or decreasing their maneuverability.

Indirect effects by offshore wind development are secondary impacts that occur as a result of a direct effect. For example, onshore resource exploration and extraction industries may be indirectly affected if published bathymetric and hydrological surveys and environmental studies make offshore extraction relatively more cost effective than onshore extraction. This is an example of an indirect, positive effect.

Some activities, such as recreational fishing, could be impacted both positively and negatively. The development of a wind energy area would have direct effects on ocean habitat. The wind turbine structures and anchoring for floating structures could act as artificial reefs attracting more or different species of game fish. This aggregation of target game species could result in a positive direct effect on recreational anglers. Most offshore wind projects in the GOM will likely use floating technologies with anchoring cables connecting turbines to the ocean floor. These cables could introduce the potential for gear entanglement for recreational anglers targeting pelagic species. This would be a direct, negative effect.

Table 2.1.1. Maritime Activities That May Potentially be Affected by Offshore Wind Development.

Activity or Use	Directly Affected	Indirectly Affected	Positively Affected	Negatively Affected
Air traffic	●			●
Aquaculture (e.g., mussels, seaweed, salmon)	●			●
Artisanal fishing	●			●
Charter boat fishing	●	●	●	●
Charter boat touring	●			●
Commercial fishing	●			●
Cultural heritage	●			●
Diving		●	●	
Dredge disposal location	●			●
Marine sanctuaries and critical habitat areas	●			●
Maritime navigational safety	●			●
Military operations		●		●
Mineral exploration and extraction[a]	●	●	●	●
Radar, signals, and beacons	●			●
Recreational fishing	●		●	●
Recreational boating	●			●
Shipping	●			●
Tribal use	●			●
Vessel traffic	●			●
Visual resources	●			●

[a]For example, sand and gravel mining

[b]Co-location of seaweed farming and wind farms can provide wave attenuation.

2.2 Commercial Fishing

Based on preliminary evaluations and results from Ecology and Environment, Inc. (2014), commercial fishing is the maritime activity most likely to be affected by offshore wind activity off the coast of New Hampshire. Therefore, this section focuses on commercial fishing and potential mitigation alternatives. To assess potential commercial fishing impacts from offshore wind development off the New Hampshire coast, the report presents the following:

- Sections 2.2.1 through 2.2.5 provide a background and overview of modeling changes to a commercial fishery,
- Sections 2.2.6 through 2.2.9 show the evaluation of potential changes to New Hampshire commercial fishing from offshore wind development,
- Section 2.2.10 summarizes the results of the evaluation, and
- Section 2.2.11 provides an overview of potential approaches to mitigate the effects of offshore wind development on commercial fisheries. The discussion follows the guidance in the BOEM's 2014 Final Report on Best Management Practices and Mitigation Measures: Development of Mitigation Measures to Address Potential Use Conflicts between Commercial Wind Energy Lessees/Grantees and Commercial Fishermen on the Atlantic Outer Continental Shelf (Ecology and Environment, Inc 2014).

2.2.1 Background on Modeling Commercial Fishing Economics

Commercial fisheries are complex: catch rates are seasonal and variable, fish and fuel prices vary, vessels often target a variety of species and can switch gear if needed, boats can sail from and offload at different ports, the number of crewmembers can vary, the weather has implications for catch and safety, and regulations often impact both harvest costs and market prices. This subsection provides a brief introduction to the concepts that are applied to model the commercial fishing impacts from offshore wind development including:

- the production or supply side of the market,
- counterfactual supply modeling (i.e., scenarios that could occur with offshore wind development),
- the consumption or demand side of the market, and
- the equilibrium analysis of supply side impacts

2.2.2 Production and Supply

Economists refer to the producing side of a market as supply. In economic modeling it is represented by mathematical functions that link costs and output. The following discussion and graphical depictions are based on a mathematical model that simulates fishing vessel behavior in the New England groundfish fleet. The model was created to understand behaviors and outcomes under days at sea (DAS) and total allowable catch (TAC) regulations (Bingham et al.

2010).[2] It simulates the behavior of a vessel operator choosing whether and where to fish over a season, given limits on fishing days or total quantity, and costs and catch rates that differ across sites and days. Trip-taking behaviors are identified using a mixed-integer optimization model that solves for the least cost days and sites to fish given a specified minimum total seasonal catch.[3]

The diverse behaviors that underlie this model can be condensed into cost curves that economists use to analyze markets[4]. The information discussed below is for a hypothetical scenario and used for illustrative purposes to help explain model concepts. The curve depicted in Figure 2.2.1 below is the vessel's marginal cost curve. It was created by incrementally increasing the specified catch and then operating the computational model to identify the total and incremental minimum costs associated with increasing harvest quantities.

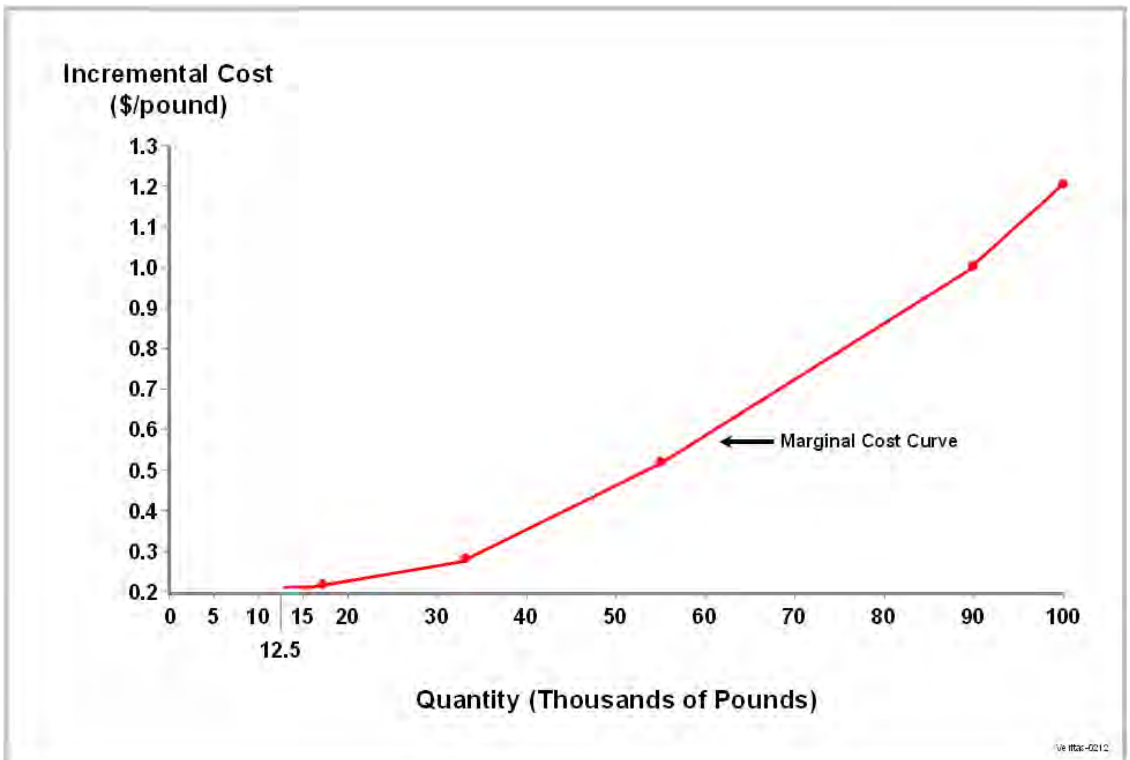

Figure 2.2.1. Vessel marginal cost curve.

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[2] DAS regulations limit effort by placing a cap on the number of days a vessel can fish. TAC regulations are the more traditional vessel-level quotas.

[3] Optimization was conducted in Analytica 4.2 using mixed integer formulation and Frontline optimizer. The mixed integer approach supports more realistic specifications such as "fish/don't fish" than simpler linear optimization.

[4] In economics, the term curve is commonly used to define the visual representation of a mathematical function.

As shown in this hypothetical example, at the lowest quantities (below 12,500 pounds) marginal costs are less than $0.20 per pound. When quantities are this low, the vessel is able to limit its fishing to the least costly and most productive days and sites. As the quantity increases, the vessel fishes more expensive and less productive days and sites. Ultimately at the highest harvest levels, the remaining sites and days have harvest costs of over $1.00 per pound.

This marginal cost curve represents the incremental change in costs that occurs with an incremental change in harvest. The area underneath this curve represents the total cost of catching a given quantity of fish in the season. Like marginal costs, total costs increase with quantity. At 90,000 pounds this area equals $45,000.[5]

The importance of marginal cost curve to economic analyses is demonstrated when they are graphed in the "market" space of prices and quantities, and when profit-maximizing behavior is assumed. This is accomplished by augmenting the previous cost-focused depiction with prevailing market price. In Figure 2.2.2, note that the horizontal axis has not changed from Figure 2.2.1, but the vertical axis now represents both the incremental cost of harvest and the prevailing market price (e.g., $1.0 per pound [illustrative purposes only]).

With this modification, the profit-maximizing vessel's marginal cost curve becomes its "supply" curve. This is because the curve indicates the quantity of fish the profit-maximizing vessel would supply at any given market price. To see why, consider the depicted illustrative market price of $1 per pound (Figure 2.2.3). As the curve indicates, when fish are $1 per pound, the per pound cost of catching more than 90,000 pounds is above the $1 per pound price and therefore unprofitable. Note that a price of $1 and quantity of 90,000 pounds implies total revenues of $90,000. With costs of $45,000, this leaves a difference of $45,000.[6,7]

The prior example describes a single vessel. However, fisheries are typically composed of many fishing vessels. To represent them, we specify that the fishery consists of an additional 999 identical vessels.[8] This leads to a small but important change to the graphical depiction. Specifically, while the horizontal axis previously represented thousands of pounds coming from a single vessel, it now represents millions of pounds coming from all vessels (Figure 2.2.4). This

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[5] This is a model result. It can be visualized by observing that the curve approximately bisects an area of $90,000 ($1/lb x 90,000 lbs).

[6] Depending on study perspective and preference, economists refer to this result as revenue net variable costs (RNVC), producer surplus, or profit.

[7] In a typical arrangement, half of this may go to captain and crew with the remainder going to fixed costs such as berthing and loan service.

[8] Specifying 1,000 identical vessels makes the discussion easy. This is not an unreasonable specification for the New England groundfish fishery based on past numbers of vessels in the GOM. Other markets have more differentiated vessels. For example, scallops are fished in day boats and much larger trip boats. These vessels have different supply curves.

is equivalent to summing individual vessel supply over the 1,000 identical vessels.[9] This changes how the depiction should be interpreted. The supply curve becomes a market supply curve rather than a vessel supply curve. Similarly, costs, revenues, and profit now reflect market results rather than individual vessel results.

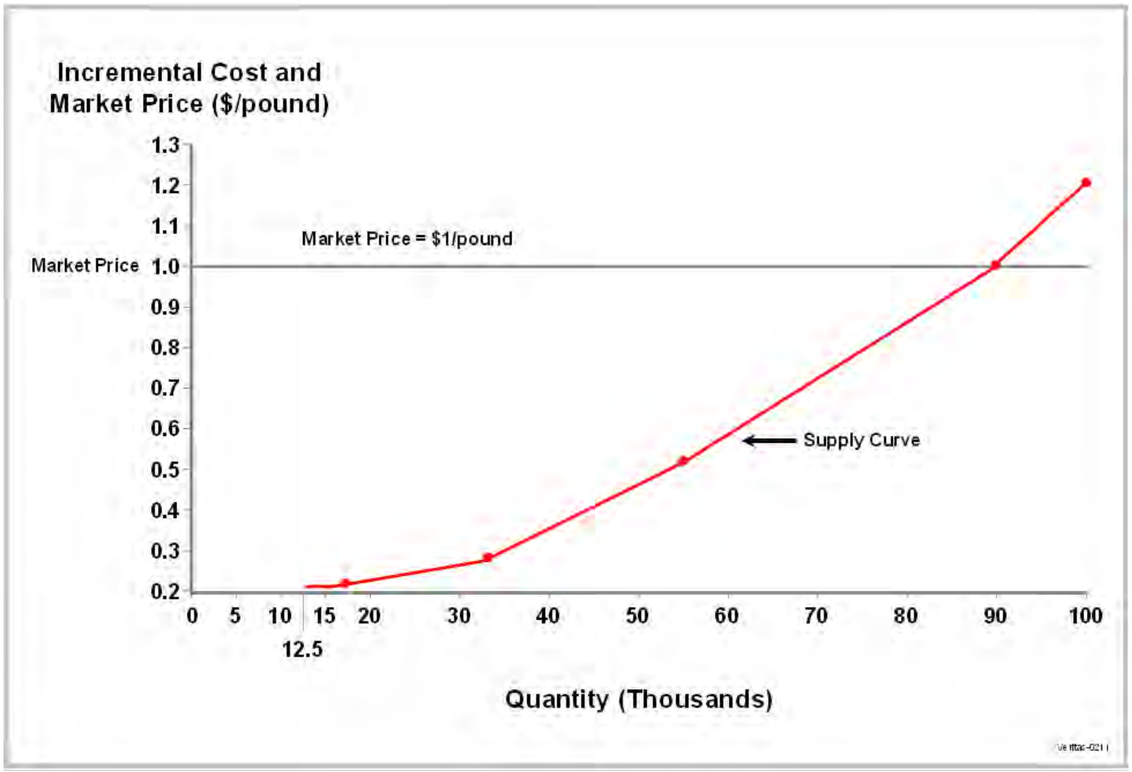

Figure 2.2.2. Vessel supply curve.

[9] Vessels that are differentiated by type or operator skill would have differently shaped curves. Like identical curves, they are summed to create market supply.

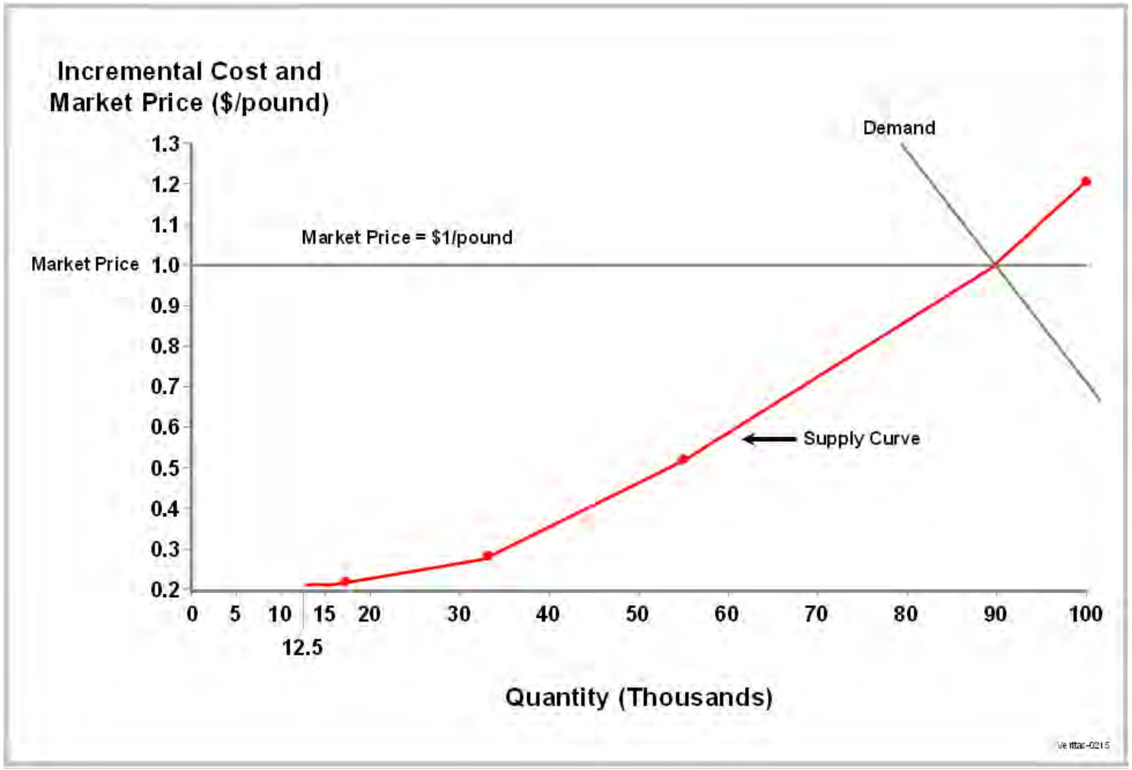

Figure 2.2.3. Vessel supply and market demand curve.

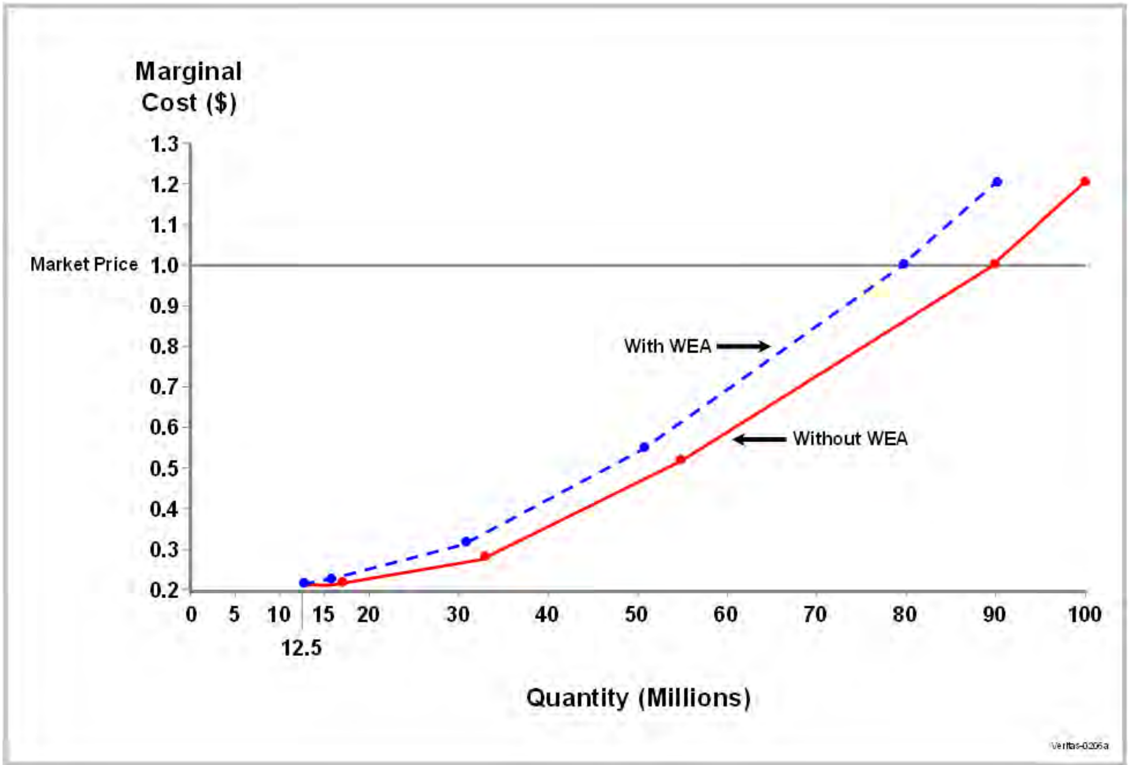

Figure 2.2.4. Baseline and Counterfactual market supply.

2.2.3 Counterfactual Modeling

Economists use counterfactual modeling techniques to evaluate the economic implications of changes to harvest costs. A baseline represents things as they would be without the project, and counterfactuals represent scenarios being evaluated. One potential effect of offshore wind development is that sites might become unavailable to fish under certain conditions (such as high winds). To simulate this, certain day/site combinations within the example model are "closed," and the previously described process for developing the vessel/market supply curves is repeated.[10] This process results in the Counterfactual (With Wind Energy Area [WEA]) supply curve (dotted blue line) which is depicted along with the Baseline supply curve (red line) in Figure 2.2.4.

Counterfactual costs (dotted blue line) are higher than Baseline costs (red line). Under Counterfactual conditions, incremental harvest costs now exceed market price at levels above 80

[10] Closing a site to fishing for all days and times represents a worst-case counterfactual scenario. In its analysis of offshore wind impacts on commercial fishing, BOEM (Kirkpatrick et al. 2017b) specified potential commercial fishing conditions within wind energy areas, and Equinor has evaluated the likelihood of commercial fishing within wind energy areas.

million pounds. As a result of the cost increase, harvest shrinks to 80 million pounds. Costs are now $40 million, and "profit" for the market is reduced by $5 million to $40 million.[11]

2.2.4 Consumption and Demand

Economists refer to the consuming side of a market as demand. Demand is impacted by many factors including price, income, cost of substitutes (other fish and foods), and trends. In the market space of prices and quantities, the slope of the demand curve represents the intuitive inverse relationship between prices and quantities (i.e., as prices decrease the quantity demanded increases). The placement of the demand curve in this space is determined by all the other factors (i.e., income, cost of substitutes, and trends). Figure 2.2.5 adds a demand function (illustrative only) to Figure 2.2.2 and adjusts the individual supply to be market supply.

This demand curve has a downward slope representing the expected inverse relationship between prices and quantities. A deeper understanding of this intuitive relationship can be gained by recognizing that market demand is the sum of demand from many individual buyers. These individuals are part of the market because they hold a willingness-to-pay for fish. This willingness-to-pay is represented in the demand curve. Buyers with a higher willingness-to-pay comprise the leftmost portion of the demand curve where higher prices result in lower quantities demanded. As market price decreases, buyers with lower willingness-to-pay enter the market and the quantity demanded increases.

This backdrop provides perspective for analyzing the value of the market to consumers, and market equilibrium. While the demand curve represents what someone would be willing to pay, the price line indicates what they do pay. This means that the area above the price line and below the demand curve indicates the value of the market for consumers. For example, a consumer willing to pay $1.20 but only having to pay $1.00 is receiving value of $0.20 per pound. The implication is that in actions that mirror producers who provide costs that are less than or equal to price, buyers purchase quantities in which willingness-to-pay is greater than or equal to price. At this point, quantities demanded are equal to quantities supplied and the market is said to be in equilibrium. Equilibrium analysis in the previously described Baseline and Counterfactual structure is central to quantitative economic analysis as illustrated in the following section that depicts a complete analysis.

[11] This market result is mirrored by individual vessels where harvest drops to 80,000 pounds, revenues are $80,000 and both costs and revenue net of variable costs are $40,000.

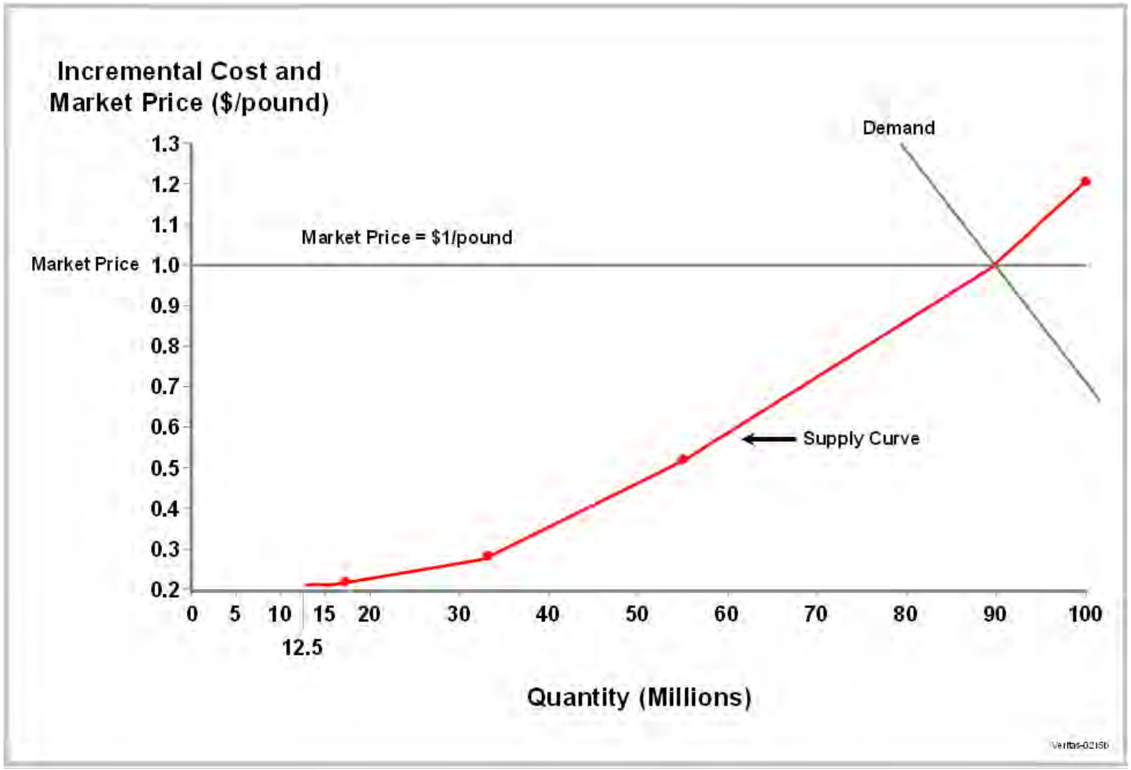

Figure 2.2.5. Market demand.

2.2.5 Equilibrium Analysis

A complete equilibrium analysis of commercial fishing supply impacts consists of evaluating the implications of a shift in harvest costs as depicted in Figure 2.2.4 with the static demand curve depicted in Figure 2.2.5. Equilibrium analysis is depicted in Figure 2.2.6.

As Figure 2.2.6 shows, decreases in catch-rate increase the cost of harvesting. This leads to the supply curve shifting to the left from the red Without Wind Energy Area (WEA) supply curve to the blue With WEA supply curve. The dockside market demand is represented by the Demand curve. In the figure, landings decrease and the price increases. Depending on the demand, elasticity total revenue could go up, go down, or not change.

Implementing this process requires the mathematical functions represented by supply and demand curves for the relevant fisheries being evaluated. The following subsections describe how the baseline and counterfactual evaluations were developed for the analysis. In New Hampshire, revenue from lobstering dominates the commercial fishery. Table 2.2.1 presents the value (revenue) and landings from the species landed at New Hampshire ports from 2012 through 2021. As the table shows, American lobster (*Homarus americanus*) produced $44.2 million in commercial harvest revenue in 2021 whereas the species with the next highest revenue, menhaden, produced $1.7 million. Lobster has consistently accounted for the vast majority of commercial harvest revenue in each of the years presented in Table 2.2.1. Given lobster's predominance in New Hampshire's commercial fishery, the analysis described in the next subsection focuses on the potential effect of offshore wind development on lobster fishing.

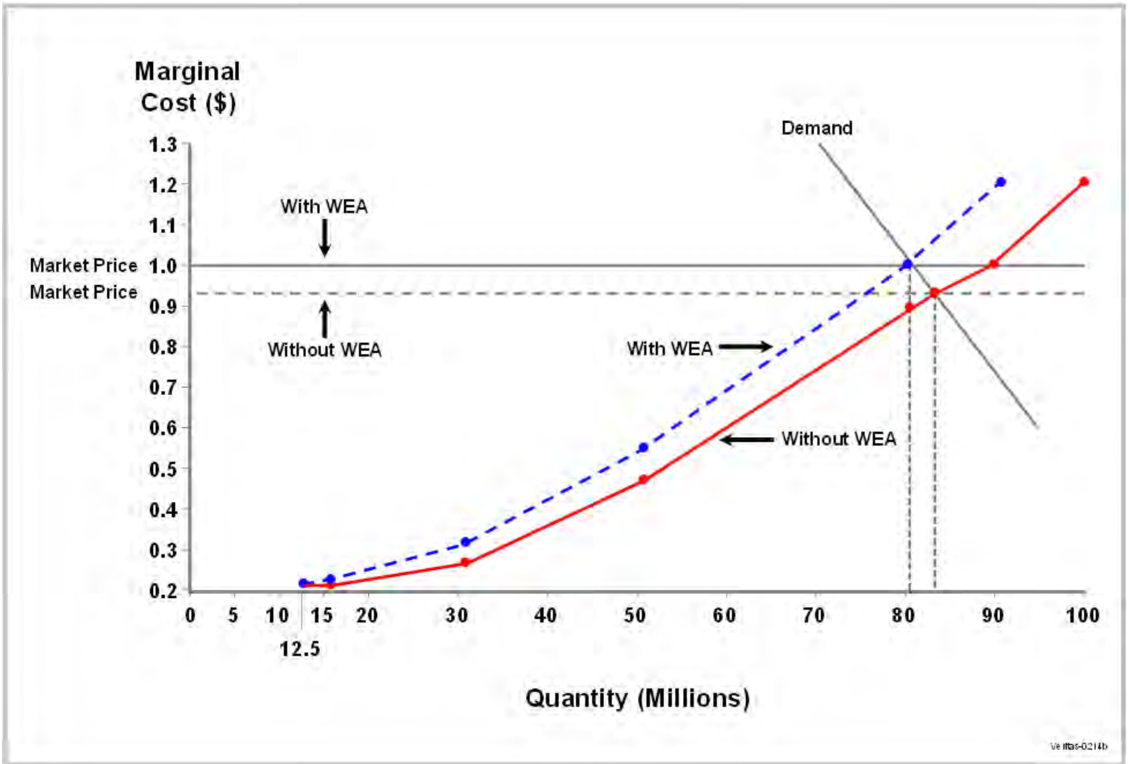

Figure 2.2.6. Commercial fish market supply shift equilibrium analysis.

Table 2.2.1. Commercial Fishery Landings, New Hampshire: 2012–2021.

	2021		2020		2019		2018		2017	
Species	Value	Landings	Value	Landings	Value	Landings	Value	Landings	Value	Landings
Lobster, American	$44,164,031	5,708,942	$26,550,588	5,014,143	$36,020,851	6,093,615	$35,672,477	6,199,365	$32,364,527	5,645,434
Menhadens	$1,697,400	4,807,900	—	—	$791,716	4,540,800	—	—	—	—
Tuna, bluefin	$858,266	162,492	$474,814	124,544	$619,891	120,803	$1,144,694	196,758	$852,848	156,788
Haddock	$504,803	370,828	$292,739	265,467	$132,603	106,517	$107,048	79,785	$22,489	17,790
Withheld for confidentiality[1]	$298,119	892,215	$1,391,480	5,116,541	$278,840	1,016,667	$230,843	871,228	$51,646	43,376
Goosefish	$224,918	283,217	$175,172	343,515	$311,742	576,745	$352,837	539,684	$421,716	549,562
Hake, white	$211,752	141,585	—	—	$150,347	113,236	$148,434	124,388	$16,331	11,992
Pollock	$198,744	110,514	$280,171	225,656	$268,862	175,030	$284,196	185,685	$188,523	108,388
Scallop, sea	$184,416	10,897	$72,886	6,406	$385,083	35,750	$154,936	11,746	$65,654	4,979
Cod, Atlantic	$124,631	45,836	$182,664	67,340	$243,959	98,439	$209,414	88,755	$149,768	70,960
Crab, Jonah	$94,028	123,729	$19,949	31,658	$42,589	70,818	$14,894	22,434	$82,715	114,155
Flounder, witch	$38,012	23,503	$47,843	28,159	$25,225	11,402	$37,287	17,457	$48,186	18,234
Hake, silver	$20,185	27,254	$36,147	72,035	$138,032	193,925	$129,410	163,968	$160,662	214,535
Halibut, Atlantic	$14,266	1,914	$22,754	3,662	$27,390	3,984	$24,916	3,212	$26,786	3,687
Flounder, American plaice	$13,430	13,893	$9,824	9,516	$27,112	15,224	$77,370	40,000	$113,772	51,129
Flounder, winter	$10,721	6,002	$10,441	6,098	$35,856	14,635	$23,662	9,966	$30,824	12,321
Flounder, yellowtail	$8,604	12,129	$9,425	14,389	$35,772	19,415	$59,278	30,971	$76,509	37,011
Redfish, Acadian	$1,565	2,863	$3,516	5,508	$1,500	2,013	$1,836	1,887	$336	369
Cusk	$790	1,628	$1,535	2,039	$3,199	2,686	$2,388	2,488	$1,224	2,378
Mackerel, Atlantic	$221	410	—	—	—	—	$1,028	1,080	—	—
Oyster, eastern	—	—	—	2,880	—	5,422	—	—	—	—
Skate, winter (Rajidae)	—	—	—	—	$3,608	13,284	$5,113	18,001	$2,320	8,797
Herring, Atlantic	—	—	—	—	—	—	$436,184	1,511,450	$827,156	2,829,007
Hake, red	—	—	—	—	—	—	—	—	$8,863	40,347

Table 2.2.1. Continued.

	2021		2020		2019		2018		2017	
Species	Value	Landings	Value	Landings	Value	Landings	Value	Landings	Value	Landings
Shark, dogfish, spiny	—	—	—	—	—	—	—	—	$177,800	858,120
Shrimp, northern	—	—	—	—	—	—	—	—	—	—
Alewife	—	—	—	—	—	—	—	—	—	—
Eel, American	—	—	—	—	—	—	—	—	—	—
Mummichog	—	—	—	—	—	—	—	—	—	—
Butterfish	—	—	—	—	—	—	—	—	—	—

[1] Withheld for confidentiality – This label indicates species that have no dollar value or landings shown are present in the NOAA NMFS commercial landings database however the landings are confidential and have been grouped into "Withheld for confidentiality" with other confidential landings in New Hampshire. Landings data that could be used to identify the data contributors are designated as confidential. In order to protect the business information of those engaged in commercial fishing, it is necessary to aggregate or otherwise hide confidential data that were collected from fewer than the requisite number of vessels, fishermen and/or dealers. Once data have been deemed confidential, they must remain so at all levels (NOAA NMFS 2022a).

Table 2.2.1. Continued.

	2016		2015		2014		2013		2012	
Species	Value	Landings	Value	Landings	Value	Landings	Value	Landings	Value	Landings
Lobster, American	$30,372,614	5,782,098	$24,543,716	4,721,826	$20,750,561	4,374,656	$16,602,039	3,817,707	$17,169,373	4,229,227
Menhadens	—	—	—	—	—	—	—	—	—	—
Tuna, bluefin	$1,340,157	168,080	$685,087	118,916	$365,807	52,116	$143,903	20,626	$858,116	87,372
Haddock	$14,420	9,282	$8,111	5,740	$18,224	10,472	$22,234	10,301	$95,021	44,543
Withheld for confidentiality	$233,110	899,209	$336,159	1,169,673	$1,052,522	3,113,850	$60,176	18,940	$44,891	76,542
Goosefish	$337,777	331,349	$351,282	314,359	—	—	$186,120	162,472	$152,849	126,392
Hake, white	$11,287	6,191	$31,298	20,696	—	—	$167,724	129,789	$223,080	172,822
Pollock	$207,290	97,838	$356,059	270,275	$859,815	628,712	$1,134,670	983,007	$1,223,879	1,048,898
Scallop, sea	$283,742	23,597	$397,611	30,999	$344,840	27,192	$296,071	24,822	$143,120	12,251
Cod, Atlantic	$108,696	55,162	$93,294	44,701	$571,619	263,511	$546,325	229,878	$1,750,400	725,539
Crab, Jonah	$105,075	150,341	—	—	$289,089	404,703	$235,826	340,751	—	—
Flounder, witch	$41,950	11,661	$55,584	20,699	—	—	$29,761	11,136	$69,537	35,092
Hake, silver	$258,262	323,365	$229,975	288,104	—	—	$205,202	263,836	$251,681	963,012
Halibut, Atlantic	$14,342	2,076	$12,274	1,573	—	—	$7,027	924	—	—
Flounder, American plaice	$85,190	38,218	$50,772	34,445	—	—	$20,909	13,402	$50,695	32,793
Flounder, winter	$12,948	5,954	$6,218	3,366	—	—	$12,079	6,095	$20,346	10,377
Flounder, yellowtail	$50,672	30,292	$43,197	38,256	—	—	$42,946	29,973	$76,303	54,603
Redfish, Acadian	$903	1,088	$2,235	3,135	—	—	$8,534	9,113	$6,713	9,038
Cusk	$824	1,422	$1,752	2,575	$1,792	2,153	$4,065	4,775	$1,474	2,031
Mackerel, Atlantic	—	—	$3,609	5,152	$39,554	248,613	$3,048	6,187	—	—
Oyster, eastern	—	—	—	—	—	—	—	—	—	—
Skate, winter (Rajidae)	—	—	—	—	—	—	—	—	$1,173	3,956
Herring, Atlantic	—	—	$585,787	3,998,860	—	—	$231,619	1,579,020	$349,081	2,390,747
Hake, red	—	—	—	—	—	—	—	—	—	—

Table 2.2.1. Continued.

	2016		2015		2014		2013		2012	
Species	Value	Landings	Value	Landings	Value	Landings	Value	Landings	Value	Landings
Shark, dogfish, spiny	—	—	—	—	—	—	$95,881	515,448	$419,658	1,788,503
Shrimp, northern	—	—	—	—	—	—	$134,235	73,980	$329,085	327,579
Alewife	—	—	—	—	—	—	$1,174	4,420	$778	2,681
Eel, American	—	—	—	—	—	—	$793	106	$1,928	167
Mummichog	—	—	—	—	—	—	$116	9	$58	4
Butterfish	—	—	—	—	—	—	—	—	$1,469	4,312

Source: NOAA NMFS 2022a

2.2.6 Supply Functions

Supply functions can be created either by directly considering underlying factors such as engine and vessel size or by econometrically estimating them using data from fishing trips. Given the variation in characteristics across vessels, the most straightforward approach would use econometrically estimated curves. Econometrically estimating supply curves requires a time series of data on the market of an individual species including harvest, effort, price of output, input prices, biomass, and information on the regulatory structure. Econometrically modeling supply falls roughly into one of the three categories below. The most relevant of econometrically modeling for offshore wind is the first category.

- Estimating a random utility model of harvester choice among locations (for example, Haynie and Layton 2004, Kirkpatrick 2017a). This requires trip-level data on expenditures by vessel and expected returns or catch rates by location.
- Using trip or seasonal-level data by vessel to estimate cost or production functions that can be converted to supply functions. These models are estimated at the individual level and typically not aggregated (see Squires and Kirkley 1991 for an example).
- Estimating models of bioeconomic equilibrium. This approach typically begins by modeling effort, including the biological growth function, and then whatever market structure is appropriate. This approach implicitly creates a cost function, but it entails an equilibrium bioeconomic model of the species. These models are more appropriate for the long run when both vessels and biomass adjust and are in equilibrium (for example, Homans and Wilen 1997).

Kirkpatrick et al. (2017a, 2017b) studied the effect of commercial fishing from offshore wind development for BOEM in *Socio-Economic Impact of Outer Continental Shelf Wind Energy Development on Fisheries in the U.S. Atlantic* (hereafter, the BOEM study). The study assessed the potential impacts to commercial and recreational fisheries and their shoreside dependents from wind energy development on the Atlantic OCS. Kirkpatrick et al. (2017a, 2017b) used a location choice model with a random utility model framework to estimate a utility function based on observed choices and covariates defined over a set of discrete choices. In the BOEM model, the covariates (variables) included expected revenue, costs, revenue net of variable costs (RNVC), wind speed, prices of important species, season, and vessel characteristics that influence the utility each choice-maker derives from a trip. The model supply functions are composed of vessels trip cost functions expressed in a spatial framework of ports and fishing sites. Trip cost functions are based on the trip-cost model estimated in the BOEM study and presented in Equation 1. Table 2.2.2 lists the cost estimation parameters (Kirkpatrick et al. 2017b).

Equation 1

ln(Trip Cost) = β0 + β1 Trip Duration + β2 Trip Duration2 + β3 Trip Duration3 + β4 Distance + β5 Mean Fuel Price + β6 Length + β7 Gross Tonnage + β8 Gear + β9 Gear x Tons per Foot + β10 Distance x Gross Tonnage

This function requires inputs on vessels and fuel costs as well as trip durations and distances. Fishery specific typical vessel information is used to represent a typical vessel across size (tonnage, length) and gear type (pot, net, trawl) for fisheries that were evaluated. Supply curves were created by integrating this cost information into potential fishing trips.

Table 2.2.2. Cost Estimation Parameters (Reference Gear Group: Dredge).

Variable	Parameter	Standard Error
Trip Duration	0.05**	0.0005
Trip Duration^2	–0.0002**	0.0000
Trip Duration^3	0.0000003**	0.00
Distance (port to centroid of fishing)	0.004**	0.0001
Mean Fuel Price	0.20**	0.01
Gross Tons per Foot	–0.01	0.05
Gillnet	–0.22**	0.03
Hand	–0.60**	0.15
Longline	0.40**	0.06
Other	1.24**	0.14
Pot	0.42**	0.14
Bottom trawl	0.01	0.03
Midwater trawl	0.49*	0.22
Length	0.01**	0.001
Gross Tonnage	0.01**	0.001
Tons per Foot x Gillnet	–0.06	0.04
Tons per Foot x Hand	0.22	0.30
Tons per Foot x Longline	–0.08	0.11
Tons per Foot x Other	–0.62**	0.07
Tons per Foot x Pot	–0.36*	0.11
Tons per Foot x Trawl Bottom	–0.01	0.02
Tons per Foot x Trawl Mid	–0.20**	0.07
Distance x Gross Tonnage	–0.000025**	0.0000
Constant	4.04*	0.05
Observations	21,269.00	
Log likelihood	–153,840.20	
Akaike information criterion (AIC)	307,728.50	

Note: *p<0.05; **p<0.01

Source: Kirkpatrick et al. 2017b (Table I-xi).

Costs are based on traveling from a port to a particular ocean site. This requires identifying fishing sites. Several approaches were considered. These include various specifications of sites that are in the open ocean as well as sites over structures such as reefs. Ultimately the spatial characterization was driven by the limited availability of catch information. Most importantly, catch per unit effort (CPUE) for different locations is a critical variable that is not readily available.

Given the lack of specific fishery data for lobster, the availability of fishery independent data was evaluated. Fishery independent data consists of estimates of biomass and population estimates that are not based on catch. The best available fishery independent data are the biomass estimates from the Marine Life and Data Analysis Team (MDAT). The data contains spatially explicit (latitude and longitude) biomass information.

2.2.7 Demand Functions

Conducting an equilibrium-based analysis also requires specification of a demand function. Similar to supply, demand functions can be estimated econometrically or transferred from existing studies. Considering estimation, as described above, demand can be impacted by many factors including price, income, cost of substitutes (other fish and foods), and trends. In the context of offshore wind development impacts, the approach of Graddy (2006) is appropriate for modeling dockside demand. This model estimates the relationship between daily price and daily landings. This process involves specifying a model where price on each day is a function of landings on that day and other variables. This is most appropriate when daily landings are not driven by daily price and the species is sold fresh (not frozen).

A search was undertaken to identify public and readily available data suitable for evaluating lobster demand. Although no suitable data were identified, several models have estimated demand elasticities (evaluations of the percentage change in quantity for a percentage change in price) for individual species that are potentially useful for functional transfer. Table 2.2.3 lists the demand elasticities for fish products in the U.S. as reported in the literature. The estimates are negative because of the inverse relationship between quantity demanded and price (i.e., as price increases quantity demanded will decrease and vice versa).

Table 2.2.3. Demand Elasticities for Fish Products, US.

Product	Own-Price Elasticity	Price Type	Source
Sea scallops	–1.53	Ex vessel	Bell (1968)
Yellowtail	–2.29	Ex vessel	Bell (1968)
Large haddock	–2.17	Ex vessel	Bell (1968)
Small haddock	–2.19	Ex vessel	Bell (1968)
Cod	–3.15	Ex vessel	Bell (1968)
Ocean perch	–250.00	Ex vessel	Bell (1968)
Whiting	–17.05	Ex vessel	Bell (1968)
Cod fillets	–0.46	Wholesale	Tsoa et al. (1982)
Flatfish fillets	–1.04	Wholesale	Tsoa et al. (1982)
Redfish fillets	–0.70	Wholesale	Tsoa et al. (1982)
Fish blocks	–2.89	Wholesale	Tsoa et al. (1982)
Crawfish	–2.44	Ex vessel	Bell (1986)
Pacific salmon	–3.62	Ex vessel	Anderson and Wilen (1986)
Pacific halibut	–5.56	Ex vessel	Lin et al. (1988)
Shellfish	–0.89	Retail	Cheng and Capps (1988)
Finfish	–0.67	Retail	Cheng and Capps (1988)
Norwegian salmon	–1.97	Trade	Herrmann and Lin (1988)
Atlantic salmon	–2.00	Trade	DeVoretz and Salvanes (1993)
Norwegian salmon	–1.35	Trade	Herrmann et al. (1993)
Domestic shrimp	–0.45	Trade/ex vessel	Sun (1995)
Farm-raised shrimp	–0.34	Trade/ex vessel	Sun (1995)
Wild-caught shrimp	–0.57	Trade/ex vessel	Sun (1995)
Seafood	–0.14	Retail	Huang (1995)
Canned tuna	–0.47	Retail	Wallström and Wessels (1995)
Alaska snow and tanner	–1.43	Wholesale	Greenberg et al (1995)
Catfish	–1.01	Wholesale	Zidack et al. (1992)
Frozen cod fillets	–1.89	Trade/ex vessel	Mazany et al. (1996)
Frozen cod blocks	–3.16	Trade/ex vessel	Mazany et al. (1996)
Catfish	–0.87	Wholesale	Kinnucan and Thomas (1997)
Catfish	–0.71	Wholesale	Kinnucan and Miao (1999)

2.2.8 Baseline (Without WEA) Lobster Model

A Baseline (Without WEA) lobster model was specified with trip origins coming from the Port of Portsmouth and lobstering sites being those in the vicinity of New Hampshire where MDAT biomass data were collected. Figure 2.2.7 depicts the data of the Baseline model. The Baseline model identifies and calculates the time and cost for boats to travel to each of the lobstering locations illustrated in Figure 2.2.7.

In addition to employing data on costs, the Baseline component of the model also employs data on revenue, which, when combined with cost information, provides estimates of the relative profitability of trips from each port to each lobstering ground depicted by the grid in Figure 2.2.7. Revenues for each trip are the product of dockside price and harvest. Harvest for a given trip is the product of landings per unit effort (LPUE) and time on site. Figure 2.2.7 illustrates the expected landings for the different lobstering locations included in the model. Landings are abundance data measured in LPUE.

Profitability is calculated based on trip information for each possible trip. In simulations, lobster boats choose trips based on profitability resulting in model-based estimates of effort in the various lobstering grounds.

The figure also depicts the outline of the hypothetical wind energy area developed for illustrative and modeling purposes. The hypothetical New Hampshire Wind Farm is located approximately 40 miles east of the southeastern edge of New Castle Island, the mouth of the Piscataqua River, and approximately 44 miles east of the New Hampshire Port Authority. As Figure 2.2.7 shows, four lobstering locations with landings per unit effort (3 medium LPUE and one very low LPUE) are located within or directly adjacent to the illustrative wind energy area.

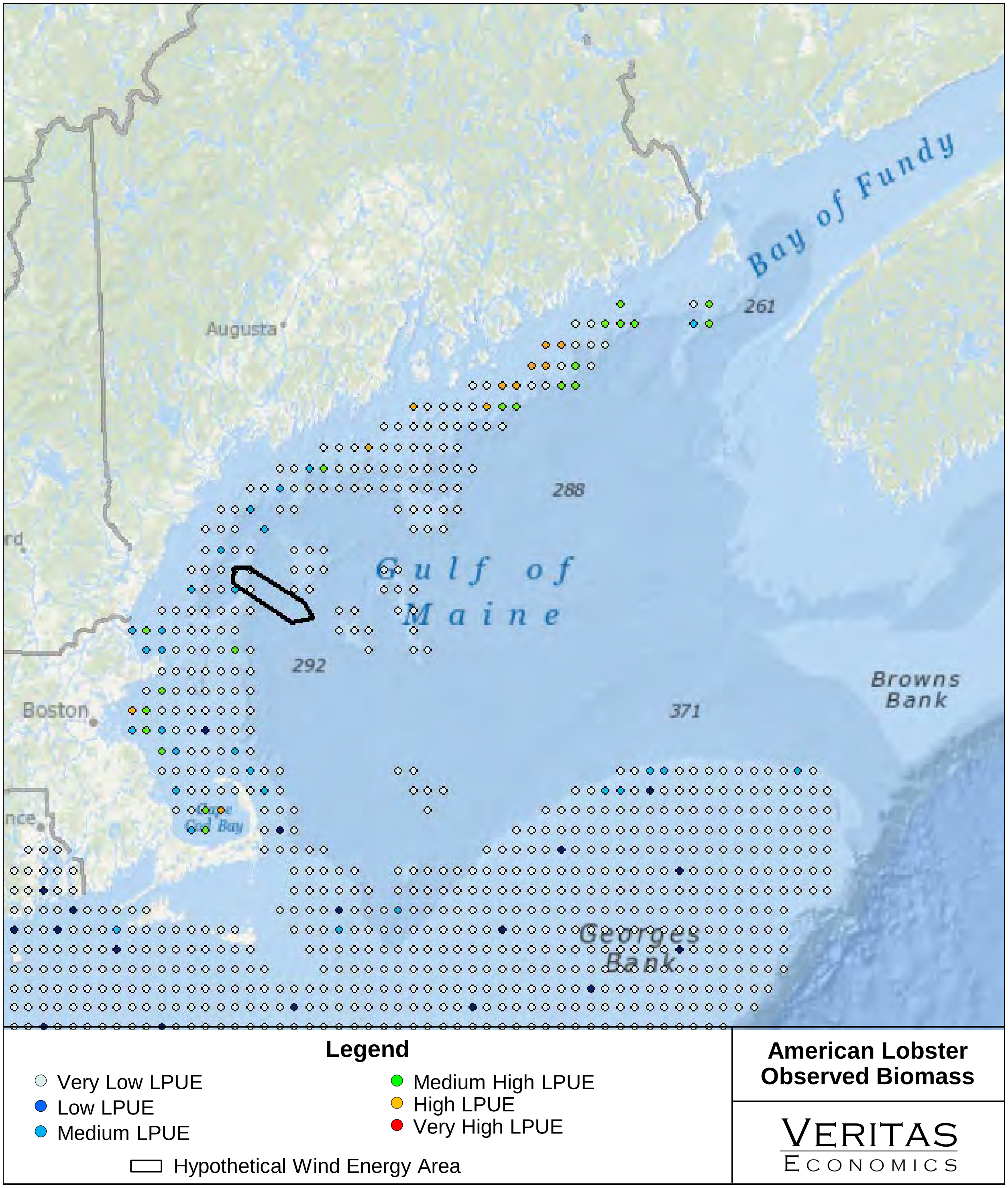

Figure 2.2.7. Depiction of without offshore wind development specification.

2.2.9 Counterfactual Lobster Model Conditions (With the WEA)

There is an array of potential Counterfactual supply conditions. BOEM considered total area closures and partial closures (Kirkpatrick et al. 2017a). Additional possibilities include, but aren't limited to changes in catch rates, increases in gear losses, and impacts to trips with gear losses. Figure 2.2.8 depicts the scenario that would have the largest negative impact on New Hampshire lobstering: lobstermen no longer lobster in the area where offshore wind developoment may occur. Figure 2.2.8 illustrates this maximum impact by removing the lobstering sites within and directly adjacent to the hypotethical wind energy area developed from the model. Under this scenario, the model predicts which of the other lobstering sites commerical lobstermen would choose and what the change in revenue and profit would be from lobstermen no longer lobstering in the wind energy area and choosing other lobster sites. This scenario represents the largest potential impact of offshore wind devleopment on commerical lobstering. Under the lowest impact, commerical lobstermen may continue to lobster in the wind energy area and experience no change in revenue or profit.

In supply-focused scenarios such as these, possible Counterfactual demand conditions typically consist of different own-price demand elasticity specifications (i.e., evaluations of the percentage change in quantity for a percentage change in price).[12] As described in the demand methods section, there are no data available for a straightforward estimate of elasticity for lobster. In addition, the relatively small, estimated changes in lobster harvest are unlikely to have price implications. Therefore, elasticities are specified to be zero, meaning that there is no change in price under the specified scenario.

[12] By comparison, a demand focused assessment might include income elasticities and cross-price elasticities.

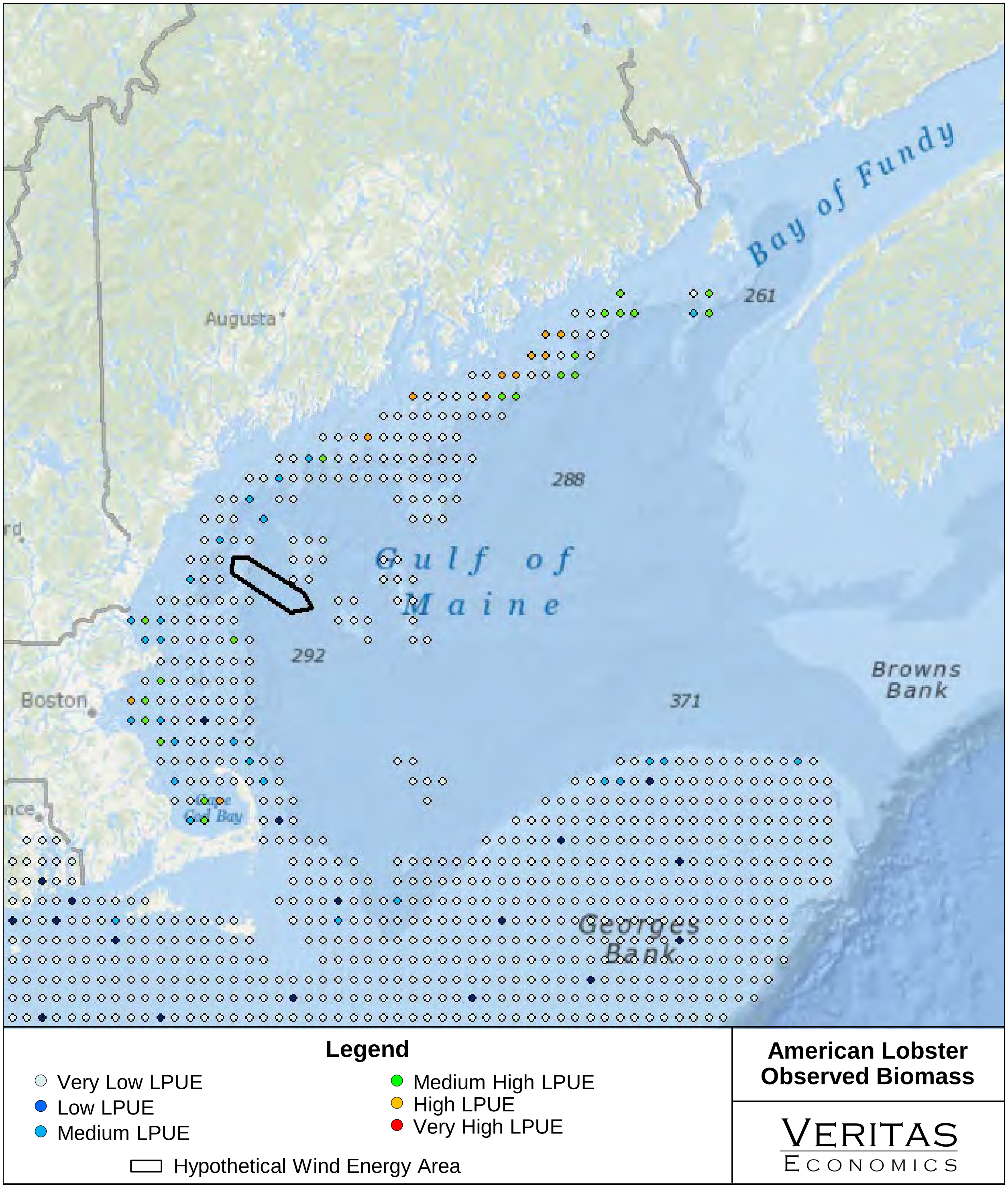

Figure 2.2.8. Depiction of with offshore wind development specification.

2.2.10 Commercial Fishing Results

The results of the Baseline and Counterfactual simulations were evaluated for lobster using the specifications described above in Sections 2.2.8 and 2.2.9 under the following two scenarios:

- No change to the status quo – lobstering continues in the wind energy area under the same conditions as baseline once the wind energy area is constructed, and
- A complete reduction in lobstering occurs in the wind energy area.

As the results in Table 2.2.4 show, under the two scenarios the potential impacts to commercial lobstering from offshore wind development range from no change in revenues or profits for New Hampshire lobstermen to a maximum reduction of nearly $2 million in annual revenues and nearly $3.3 million in annual profits. The greater decrease in profits than revenues for the complete reduction scenario indicates that in addition to revenues being lower at the other sites where the lobstermen switch their lobstering to, the costs of lobstering at those locations are higher than the sites in the wind energy area.

Table 2.2.4. Potential Impacts to the New Hampshire Lobster Fishery from Offshore Wind Development.

Scenario	Annual Revenue Change	Annual Profit Change
No change in the status quo of New Hampshire lobstering	$0	$0
A complete reduction in lobstering in the hypothetical wind energy area	-$1,990,000	-$3,250,000

2.2.11 Potential Mitigation Measures

Offshore wind development is occurring alongside a complex fishery that is evolving to meet changing fish stocks and regulations. Within this context, developers interface with potentially affected commercial fishermen, and are expected to mitigate and compensate those commercial fishermen for impacts from offshore wind development (Ecology and Environment, Inc 2014). Commercial fisheries are complex: catch rates are seasonal and variable, fish and fuel prices vary, vessels often target a variety of species and can switch gear if needed, boats can sail from and offload at different ports, the number of crewmembers can vary, the weather has implications for catch and safety, and regulations often impact both harvest costs and market prices.

Designing an offshore wind project with no potential for impacts to commercial fishing is challenging. In the open ocean, vessels can fish and transit in rough weather and captains towing huge nets can make 180 degree turns at any point. Wind turbines can impact these commercial fishing operations. Commercial fishing activities are most impacted by high turbine density, but reducing density results in increased cost per megawatt. This tension indicates that commercial fishermen are likely to view mitigation attempts as inadequate, while wind developers see fishing industry requests for wider turbine spacing as unreasonable and expensive.

Although wind energy area Construction and Operation Plans (COP) focus on a single site, the tension between developers and fishermen takes place on a larger scale. The commercial fishing community is aware of goals for offshore wind deployment and recognizes that there will be many offshore wind areas coming soon. This rapid deployment of offshore wind is taking place as fishermen are also concerned about dangerous weather events and stock movements.

In practice, developers mitigate impacts to commercial fishing by implementing the best management practices presented in BOEM's 2014 Report *Development of Mitigation Measures to Address Potential Use Conflicts Between Commercial Wind Energy Lessees and Commercial Fishermen* (Ecology and Environment, Inc 2014). In the report, BOEM notes that:

> Under the National Environmental Policy Act (NEPA), the U.S. Department of the Interior (USDOI), Bureau of Ocean Energy Management (BOEM), is required to assess the potential environmental and socioeconomic impacts of offshore wind energy development. A major part of the NEPA analysis requires consideration of the competing uses of offshore areas. In planning efforts related to issuing commercial wind leases off Massachusetts and Rhode Island, commercial fishing has emerged as the most significant competing use issue, and BOEM anticipates that it will be a significant issue in other Atlantic Coast states as well. To address future potential conflicts between fishing and wind projects, BOEM sought input from commercial and recreational fishing industries, as well as fisheries management agencies and scientists, to develop reasonable best management practices (BMPs) and mitigation measures (Ecology and Environment, Inc 2014, p. iii).

Changes in fishing behaviors and harvests depend upon the degree to which impacts have been mitigated. For example, developers minimize snagging on transmission cables by burying them, and wind facilities are well marked with radio, lighting, and safety equipment. Moreover, BOEM regulations require a safety system with procedures for collisions, gear snagging, catastrophic failure of a turbine, or other events that could impact safety.

Despite these efforts, impacts or the perception of them, will remain. Results from Europe, where offshore wind installations are already prevalent, provide insight into potential negative outcomes. Gray et al. (2016) surveyed fishermen to understand changes to fishing practices resulting from the development of five offshore wind energy areas around the United Kingdom. Most surveyed fishermen said that the wind energy areas had either a negative or very negative impact on their income. Surveyed fishermen stated that they either reduced or stopped fishing near wind energy areas and cabling during construction and only a small number returned post construction.

Safety was the primary reason cited for avoiding wind energy areas. Fishermen report believing that fishing within offshore wind energy areas is risky, primarily due to potential gear snagging and the possibility that engine failure within a wind energy area would lead to collisions with turbines. This result indicates that even with substantial up-front mitigation, impacts to commercial fishing may nevertheless occur.

Impacts to commercial fishing that are not mitigated under BOEM's first four best management practices (BMP 1-4) are to be offset under BOEM's fifth best management practice: BMP5 - Financial Compensation. BOEM presents four main provisions in BMP 5 (Ecology and Environment, Inc 2014):

- Gear and Safety,
- Fishery Enhancement,
- Offsetting Lost Income, and
- Enhancing Fishing Ports.

The following sections describe each of these provisions and how they can be evaluated to determine the appropriate level of mitigation for potential impacts to the lobster fishery as well as other fisheries off the New Hampshire coast.

Gear and Safety

Some commercial fishermen are concerned that they will not be able to safely fish in wind energy areas. An important safety concern arises from gear snagging. BOEM's BMP 5 states that the lessee "will consider various forms of direct compensatory mitigation support for gear loss or modification in order to develop or purchase wind facility safe fishing gear" (Ecology and Environment, Inc 2014).

Fishing gear consists of nets, traps, pots, dredges, lines, and hooks. Fishing gear is deployed in a dynamic and opaque environment, and its repair and replacement is an ongoing part of commercial fishing. Snagging on electrical cables or wind turbines could lead to additional gear damage and loss.

Cables are buried under the ocean floor, when possible, to minimize conflicts with gear that fishes the ocean bottom. Approaches for mitigating turbine impacts can include considering turbine density and layout, developing gear that is wind-facility safe, and replacing lost gear. Impacts from wind turbines depend on the type of gear being deployed. Lobstering uses fixed gear that consists of traps that are baited to attract and capture the lobsters. Fixed gear is placed on the seafloor with a rope and buoy connecting it to the surface. Fixed gear is less affected by turbines than mobile gear. However, space that is occupied by fixed gear presents a use conflict with mobile gear that could be exacerbated by wind energy development.

Mobile gear such as long lines, purse seines, trawl nets, and dredges rely on vessel movement. Long lines and purse seines are rarely used in U.S. Atlantic wind development areas. Trawl nets target demersal and midwater species. The largest of these are towed behind beam trawlers which tow nets from derricks that extend from the sides of the vessel. Beam trawlers are prohibited in certain North Sea wind installations and these vessels are unlikely to be used in U.S. sites spaced at one nautical mile.

Sea scallop dredges consist of a steel frame and collection bags made of a steel ring mesh that are dragged on the seafloor. Like trawls, dredges can be deployed from beams or directly behind a vessel. By regulation, larger vessels with limited access permits can employ up to two 15-foot-wide dredges while smaller vessels with general category permits employ a single dredge with a maximum of 10.5′ width.

Clam dredges target surf clams (*Spisula solidissima*) and ocean quahogs (*Arctica islandica*) using pumped seawater to separate clams from sand. The clams are collected in steel mesh dredge chambers that are used to raise them to the surface. Clamming is regulated by quotas rather than gear restrictions. As a result, clamming vessels are often larger than scalloping vessels. The Vineyard Wind Environmental Impacts Study (Kirkpatrick et al. 2021b) notes that clam industry representatives state that their operations require a minimum turbine spacing of two nautical miles.

The BOEM best management practice of developing or purchasing wind facility safe gear recognizes that problems arise when fishing gear is snagged on wind facility components (Ecology and Environment, Inc 2014). However, gear that mitigates this problem without having a negative impact on catch rates has not been developed. Given that gear loss from snagging predates offshore wind, breakthroughs in this area appear unlikely. In the absence of such gear, fishermen may experience increased gear loss, use smaller gear, change fishing patterns within the wind energy area, or avoid the area altogether.

With weather, catch rates, and fishing regulations all varying by time of year, there is an important interaction between the time of year and the effect that offshore wind development has on fishing. For example, because of rougher weather, commercial fishermen that fish a wind energy area consistently in the summer may avoid it in the winter for safety reasons. Employing a seasonal representation of commercial fishing as depicted in Figure 2.2.9 provides the ability to estimate the effect of this situation. The top panel of Figure 2.2.9 shows the modeled catch per unit effort (CPUE) in spring, summer, and fall months for the wind energy area, and the bottom panel shows the modeled CPUE for winter months. To evaluate the effect of commercial fishermen avoiding the wind energy area in the winter, the winter component of the commercial fishing model reduces catch per unit effort to zero for each fishing location in the wind energy area. This is illustrated in Figure 2.2.9 by removing the dots (fishing areas) within the wind energy area.

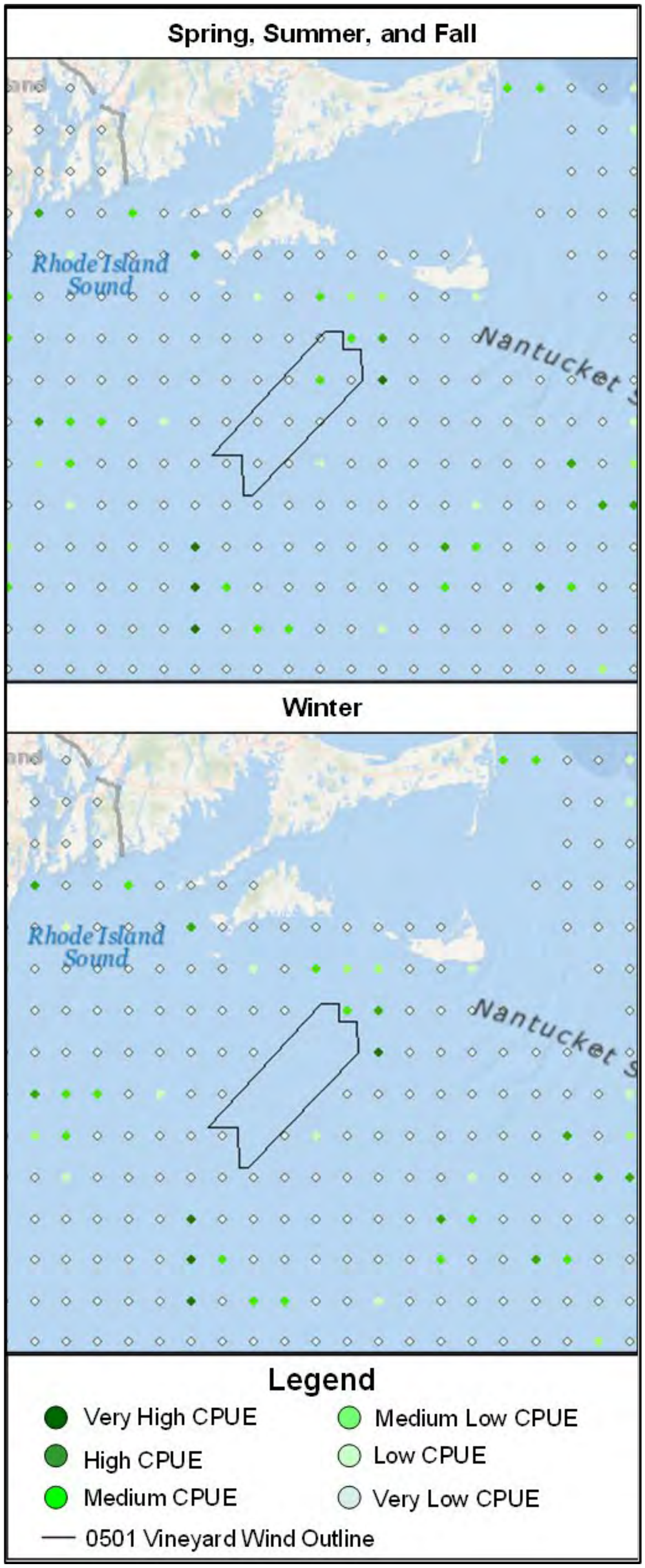

Figure 2.2.9. Safety effects of a wind energy area being avoided in the winter.

Fishery Production Enhancements in Lease or Nearby Areas

It may be that despite mitigation efforts, certain vessels will avoid wind energy areas or experience lowered catch rates within them. A potential mitigation approach involves offsetting this impact by boosting densities of target species. This is consistent with BMP 5 which states that “the lessee will explore measures that could have a beneficial impact on fishing to offset any negative consequences” (Ecology and Environment, Inc 2014). Approaches that have been employed to enhance fish stocks include establishing marine protected areas (MPAs), enhancing or creating habitat, and direct stock enhancement approaches such as stocking and seeding.

MPAs are an area of the ocean that is managed for conservation purposes. MPAs typically restrict human activity including tourism, oil and gas development, and fishing. Although their efficacy for enhancing stocks of highly migratory species is unclear, MPAs have been shown to be effective in supporting many different types of marine life. MPAs often do not allow commercial fishing; however, their outside boundaries can be productive fishing areas. With respect to mitigation of wind farm impacts, MPAs have limited value because they often make an area of ocean unavailable for commercial fishing which is looked upon unfavorably by commercial fishermen.

Direct stock enhancement approaches include hatching and seeding. Marine hatcheries are not common. The Texas Parks & Wildlife Department’s marine hatcheries produce juvenile Red Drum (*Sciaenops ocellatus*), Spotted Seatrout (*Cynoscion nebulosus*) and Southern Flounder (*Paralichthys lethostigma*) for stock enhancement (TPWD 2023). The Taunton Bay Marine Hatchery in Franklin, Maine was designed for rearing multiple species of finfish and contains three broodstock systems to hold warm- or cold-water fish such as California Yellowtail (*Seriola lalandi*), Atlantic Halibut (*Hippoglossus hippoglossus*), and Atlantic Cod (*Gadus morhua*) for aquacultural purposes (CCAR 2023). Marine hatcheries and stock enhancement operations could be developed to support East Coast fisheries.

Seeding programs that focus on less mobile species such as lobsters, scallops, clams, and oysters are much more common, and for many species hatchery production is already established at commercial or near-commercial scales. For example, Figure 2.2.10 depicts modeling of clam enhancement to offset impacts to clamming vessels that avoid the Massachusetts Wind Energy Area. The top panel in Figure 2.2.10 depicts a Baseline in which the vessel goes past areas with low catch rates to a site with medium-high catch per unit effort within the wind energy area. In the With-Project case, illustrated in the bottom panel, seeding has improved clam harvest in the areas the vessel previously bypassed. The vessel makes a shorter trip to harvest more clams than under Baseline conditions, thereby offsetting the wind energy area impact. Seeding programs could be developed for lobsters or other less mobile species in the GOM to enhance production in areas with low catch rates to offset wind energy area impact. Further studies would be needed to determine the viability of hatchery or ocean-based nursery lobster stock enhancement in the GOM to ensure ecological and economic benefits, focus on the requirements necessary to maximize growth and survival under hatchery and nursery conditions, and to reduce costs associated with mass culture in hatcheries to ensure enhancement efforts would be commercially meaningful (Beal 2012, Ellis et al. 2015).

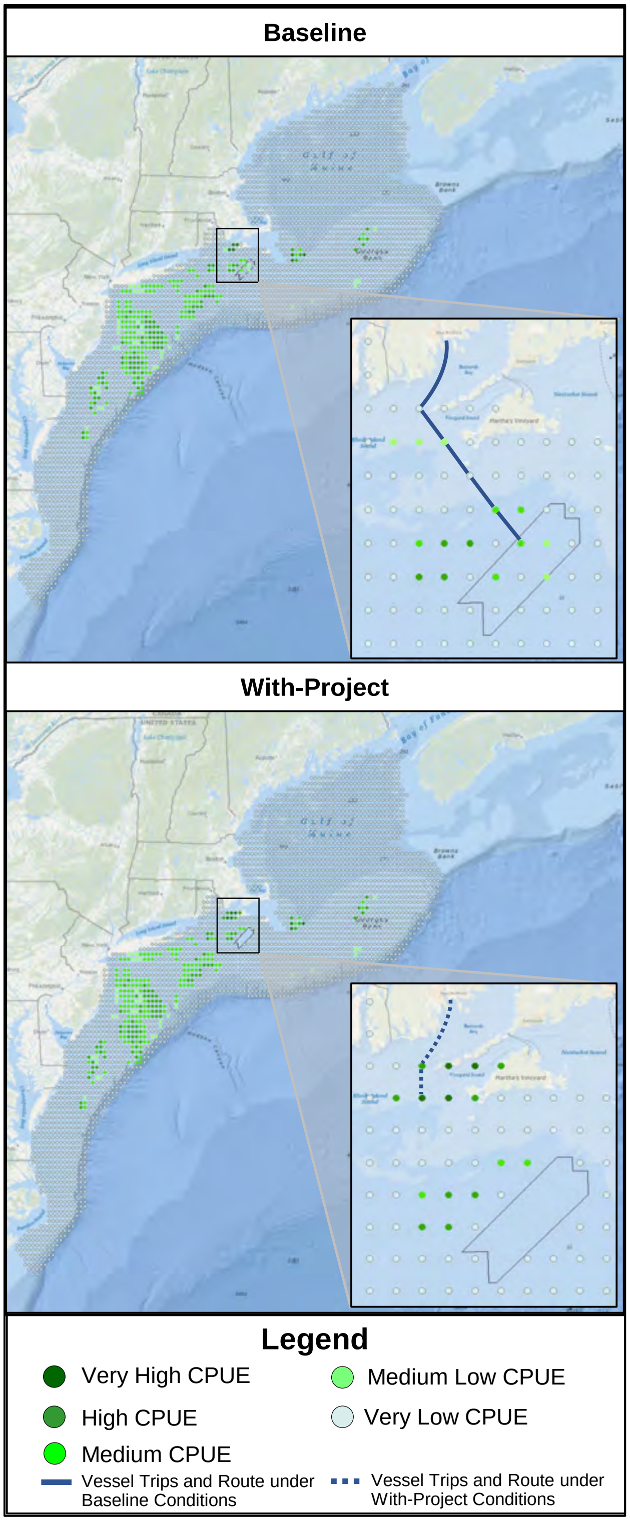

Figure 2.2.10. Evaluating fishery production enhancements: an example from clam seeding in the Massachusetts Wind Energy Area.

Offsetting Lost Income

Even with mitigation in turbine layout and programs to enhance safety, some vessels may choose not to fish in a wind energy area. Moreover, for some fisheries, it may be impractical to offset impacts by stocking or seeding. BMP 5 notes that a "fuel purchase subsidy program could be established if fishermen become displaced" and that fuel subsidies may be appropriate if "offshore wind facility locations result in increased fuel costs from increased steaming time as fishermen avoid traveling through a wind facility" (Ecology and Environment, Inc 2014).

Avoiding fishing or transiting a wind energy area places costs on commercial fishermen that can be identified using appropriate With-Project specifications. To model areas as not being fished, sites within wind energy areas are removed from the model, making them unavailable for fishing. The measured differences in costs and revenues across Baseline and With-Project conditions are used to estimate financial impacts to be offset. A similar exercise can be conducted for vessels that will not transit a wind energy area. For these vessels, in the With-Project representation, routes that travel through the wind energy area are changed so that they go around the wind energy area. Again, Baseline and With-Project results are compared to measure differences in costs between the two routes and provide an estimate of the lost income to be mitigated. Figure 2.2.11 depicts this process using the Massachusetts Wind Energy Area as an example.

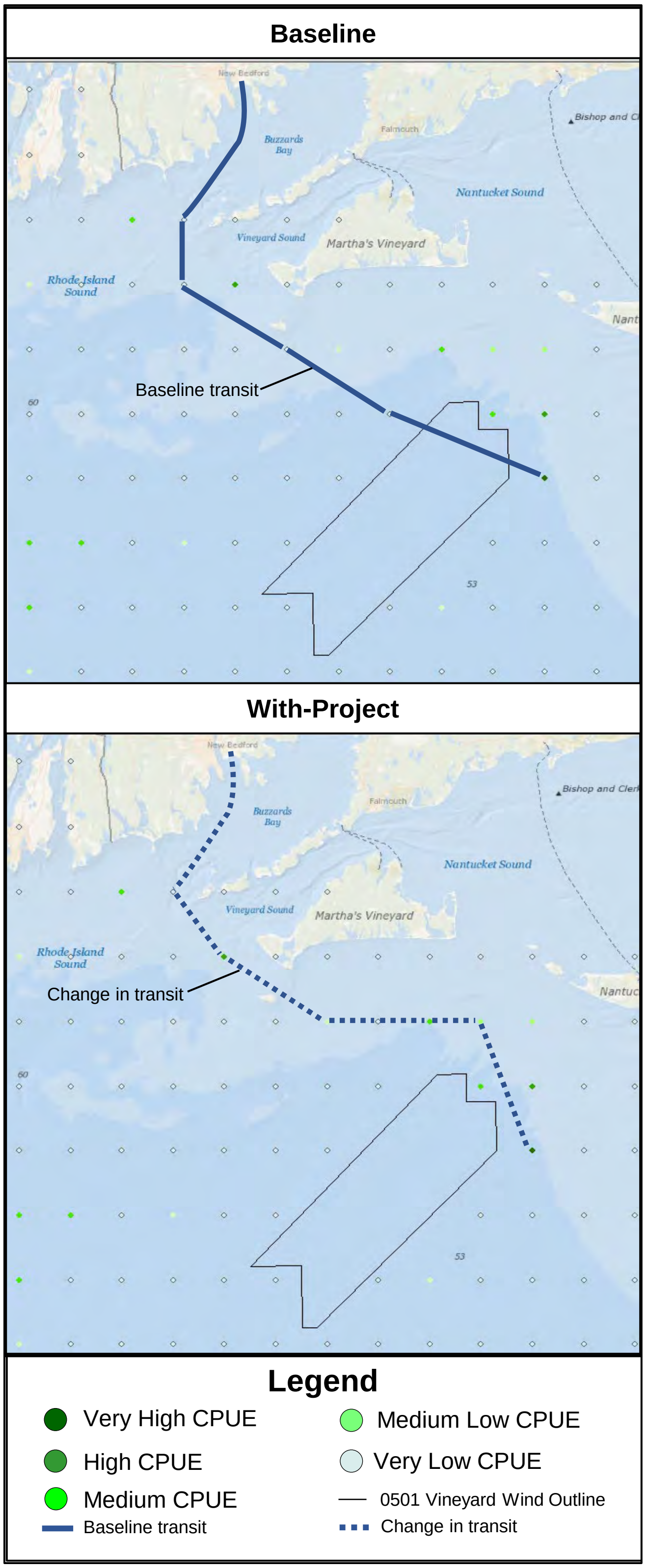

Figure 2.2.11. Evaluating lost income from having to travel around wind energy areas using the Massachusetts Wind Energy Area as an example.

Enhancing Fishing Ports

BMP 5 states that, "the lessee will consider monetary support for enhancing or improving fishing port or shore-side facilities associated with an offshore wind facility" (Ecology and Environment, Inc 2014). Fishing ports are critical to the economies and local culture of many coastal communities. As commercial fishing brings revenue and provides a sense of identity, thriving fisheries support the viability of these communities. In addition to offshore wind, many of these fisheries are under pressure from regulations, stock movements, and other competing uses.

Port enhancement offers opportunities for wind developers to adhere to a best management mitigation practice in a tangible way that is visible to the local community. Port enhancement can come about as developers create the facilities needed to build and operate wind energy areas, as additional efforts that focus exclusively on supporting commercial fishing (e.g., repairing existing facilities, gear or fuel storage, or freezers), and as more broad-based efforts that improve fishing ports more holistically. Well-maintained port facilities are important for the efficient and safe operation of every fishing vessel. As a limited number of fishermen would likely benefit from a particular port improvement project, detailed discussions among the impacted fishing community, local governmental bodies, and the lessee are necessary to determine the improvements that would provide the most benefits to the fishing community and the level of financial support required for improvements.

Economic Impacts of Offshore Wind Development Activities

Offshore wind development is a substantial construction undertaking that requires port facilities for staging and shipping, infrastructure for electricity routing, and facilities for ongoing maintenance. Although components are generally sourced globally, construction and operation activities that result in jobs and expenditures will occur in local areas.

The largest effect is likely to result from development and use of port facilities. These facilities are needed for offloading shipments of components, preparing them for installation, and loading them onto vessels headed to the lease area. Developers face some limitations in selecting ports for this purpose. Access to interstate highways and proximity to the wind energy area are important. Supporting installation activities also requires port facilities with berths to accommodate construction vessels, and decking with sufficient space and support for laydown and fabrication.

Ports with industrial waterfronts and the ability to host construction and installation activities would require the least modification. However, even these ports are likely to require development. Possible activities include grading, resurfacing, dredging, shoreline stabilization, and berth construction. Ports may also need new structures to accommodate the workforce and equipment.

Certain requirements may have limited flexibility. For example, onshore locations for a new substation to support power distribution will typically have a small number of potential locations, and ports suitable for receiving and shipping parts needed for in-water construction activities may require a minimum channel depth. However, there is flexibility within these decisions that allow addressing local concerns. For example, a developer could choose a location based on both its convenience and beneficial outcomes to a particular local economy.

The economic impacts of port development to local economies can be measured using a technique called input-output analysis. Input-output models include interindustry relationships to represent economic linkages. This allows input-output models to characterize the downstream "ripple" effects that occur as expenditures pass through supply chains and wages are spent in a local economy.

Figure 2.2.12 depicts downstream economic effects that occur as demand for labor increases in a local area. As new employees are paid, they spend money in local economies, improving the prospects of local small businesses. These businesses may also synergistically support commercial fishing. For example, as depicted in Figure 2.2.12, restaurants have an increased demand for locally caught fish.

Although the construction and operations activities of offshore wind development will boost a local economy, these activities have location limitations, and they typically do not directly improve commercial fishing. However, it is possible to have synergistic effects. For example, if a port requires additional berths to support development of a wind energy area these berths may exceed what is required for ongoing maintenance. In this case, development activities will result in additional berthing capacity that can directly benefit commercial fishing.

Activities that can improve a port can also occur independently from wind development efforts. In either case, the best opportunities emerge by evaluating specific ports to identify constraints to commercial fishing viability. An understanding of port economics and review of publicly available information can provide insights. Considering port economics, certain aspects of ports are what economists refer to as quasi-public goods. These types of goods are often subject to funding difficulties because they are difficult to charge for and shared by multiple users of different types.

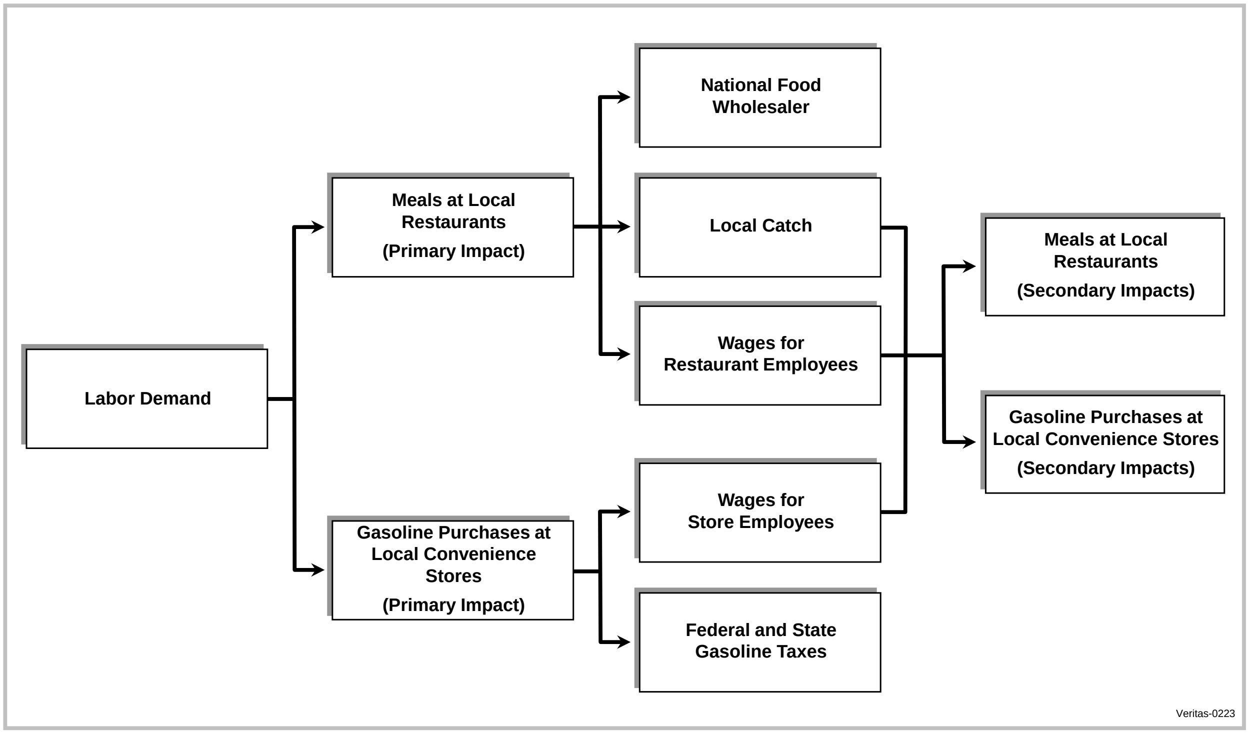

Figure 2.2.12. Local economic effects of increased labor demand.

For example, safe access to open waters is critical to commercial fishing harbors. For many harbors, this requires expensive channel dredging. Since there are significant asymmetries in the channel usage and depth requirements for different vessels, charging vessel owners to fund dredging can be difficult. Harbor dredging was historically funded by a tax on shipping. However, with the size growth of cargo ships, smaller harbors no longer ship and receive cargo, and shippers no longer pay for dredging these harbors. Activities to deepen channels can include dredging, funding dredging, and participating in developing and supporting municipal dredging plans.

Harbors may also lack sufficient berthing to accommodate the commercial fishing industry. Berthing remedies should be based on an evaluation of supply and demand conditions for each harbor with consideration of on-site conditions. Possibilities for improvements include optimizing existing berthing via repair and reorganization, finding more efficient means to use existing mooring and dock space, offsetting commercial berthing fees, providing new dedicated berthing for commercial vessels or securing access rights to existing berths, and reducing conflict with recreational users by creating transient recreational dockage.

Fish offloading capabilities may also be insufficient. This can lead to longer waits and turnaround times. This situation can be improved by installing or repairing hoists and cranes, reconfiguring dock or shoreside space, building more space, repairing space, and providing staff to facilitate loading and offloading. Specific improvements needed for NH harbors will require harbor specific reviews and input from the local fishing communities to ensure improvements will benefit and meet the needs of the community.

In some ports there may be limited parking for commercial fishermen. Improving this situation requires first determining how parking is used during different times of day and over the year. Results may indicate that dedicating parking for commercial fishing, increasing parking spaces, and expanding opportunities for overnight parking will benefit commercial fishermen.

A final potential consideration would improve the fishing situation for very small vessels that use ramps to access the fishery. Many of these ramps are seasonally crowded or in disrepair. Adding new ramps, improving existing ramps, and creating ramps that are dedicated to commercial fishing would improve fishing access for small vessels.

Synergistic Considerations

As touched on previously, there is a potential overlap between offshore wind development activities and port improvements. Cost-effective and socially beneficial outcomes can be identified by thinking through these relationships. For example, a developer that chooses a port that is slightly undersized for development and maintenance activities may need to build new berths and dredge. After completing development, berths could be made available to commercial vessels and ongoing dredging for maintaining wind energy areas could also benefit commercial fishing.

2.3 Supply Chain Operations and Port Utilization Opportunities

The supply chain for offshore wind consists of the systems of parts and people that come together to deploy, operate, and support offshore wind farms. This section describes the offshore wind supply chain with consideration of opportunities for New Hampshire businesses and citizens. The subsections include timeline and outlays, manufacturing, ports and harbors, and labor.

2.3.1 Timeline and Outlays

This section provides information on project development activities including the timeline for developing, operating, and decommissioning an offshore wind farm and relative financial outlays in each phase. Phases include:

- **Project Development**—Project development activities begin up to 10 years before commissioning of the plant and account for up to 5% of total expenditures. In this phase, developers such as Avangrid Renewables, Hexicon USA, and TotalEnergies SBE US engage with environmental survey companies to understand biological, physical, and social impacts of potential wind farms and to obtain federal, state, and local authorizations, approvals, and/or permits.
- **Turbine and Generator Sourcing**—Turbine and generator sourcing begins two to three years prior to construction and accounts for up to 30% of total outlays. In this phase, turbine and tower makers buy components such as internal pieces for the tower, housing for the nacelle, structural fasteners, yaw/pitch drives, power cables, cooling system, and ducting.
- **Balance of Plant Sourcing**—The balance of plant includes all components except the turbine. Balance of plant sourcing occurs two to three years before construction. This phase accounts for up to 20% of expenditures as manufacturers purchase cable accessories, scour protection, corrosion protection, onshore infrastructure, offshore substation facilities, foundations, array cables and export cables.
- **Installation and Commissioning**—This phase begins one to three years before operations commence and accounts for up to 20% of total outlays. In this phase, developers and the companies supporting them use support vessels, port and marine services, and onshore civil and construction, to install foundations, turbines, subsea cables and onshore infrastructure that comprise the wind farm.
- **Operations and Maintenance**—Operations and maintenance occurs over the thirty-year life of the wind farm and could be up to 30% of total outlays. Activities include offshore inspection, maintenance and repair, and associated port and marine services for maintaining turbines. This phase requires components for replacement and repair of gearboxes, bearing bolts, other internals, and foundations. Activities include providing aquatic protections, dealing with corrosive environment and seabed monitoring.
- **Mitigation Efforts**—The optimal location of wind farms may overlap with productive commercial fishing areas. Wind turbines can impact these commercial fishing

operations. A potential mitigation approach involves offsetting this impact by boosting densities of target species. Approaches that have been employed to enhance fish stocks include enhancing or creating habitat, and direct stock enhancement such as stocking and seeding. Port enhancement offers opportunities for wind developers to adhere to a best management mitigation practice in a tangible way that is visible to the local community. Port enhancement can come about as developers create the facilities needed to build and operate wind energy areas, as additional efforts that focus exclusively on supporting commercial fishing, and as more broad-based efforts that improve fishing ports more holistically.

- **Decommissioning**—At the end of their lifetime the turbines are removed and recycled.

2.3.2 Manufacturing

A generalized depiction of the offshore wind lifecycle supply chain is shown in Figure 2.3.1 and described below.

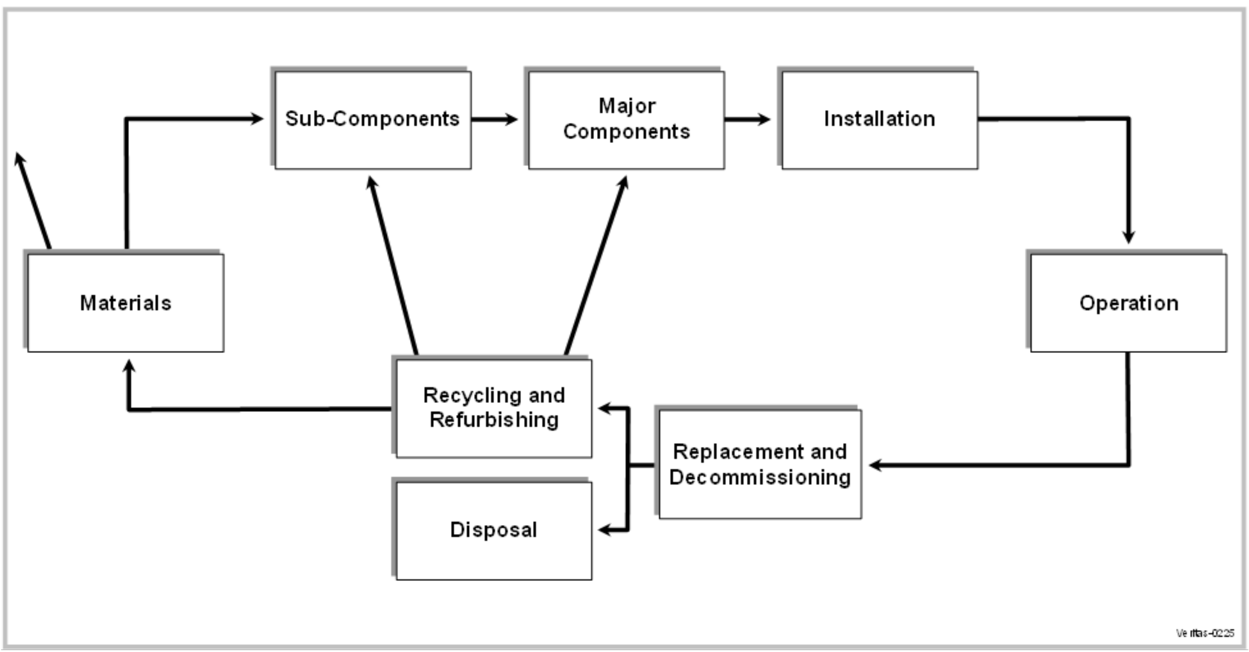

Figure 2.3.1. Offshore wind lifecycle supply chain.

- **Materials** are used to create subcomponents and major components. A variety of raw and processed materials go into creating offshore wind components. Metals used include steel, copper, bronze, iron, platinum, zinc, neodymium, dysprosium. Wood inputs are balsa. Compound materials used include fiberglass, carbon fiber, resin, and foam.
- **Subcomponents** include electrical equipment including generators, cables, transformers and switchgear and additional turbine parts such as gearboxes, bearings, castings, and semiconductors.

- **Main components** are created directly from materials and assembled from subcomponents. Main components include the substructure, foundation, towers, nacelle, hub, and blades. Main components include nacelles, blades, towers, floating structures, substations, dynamic array cables, and dynamic export cables.
- **Installation**—the process whereby the turbines undergo assembly of main components into deployed offshore wind turbines. This phase includes overland and water movement of large pieces and requires land-based and water-based activities.
- **Operation**—Turbine operation will go on for decades. During this period, the system will require maintenance and periodic parts replacement.
- **Replacement and Decommissioning**—Over the lifetime of the facility (25 to 30 years;) certain parts may need to be replaced. At the end of the facility lifetime the facility will be decommissioned (Maienza et al. 2020).
- **Recycling and Refurbishing**—Most wind turbine parts can be recycled. Many shore-based turbines are reaching the end of their lifetime and recovery channels already exist.
- **Disposal**—Although most parts can be recycled, blades in particular are not as easy to recycle. Currently, many retired wind turbine blades end up in landfills. If this trend continues, approximately 235,000 wind blades will have been decommissioned in the U.S. by 2050, adding a significant volume of waste to some landfills (Walzberg et al. 2022). DES estimates that New Hampshire's disposal capacity may fall short of projected disposal need starting in 2034, assuming that the TLR-III Refuse Disposal Facility (Turnkey Landfill) reaches the end of its currently permitted capacity and that no additional disposal capacity is permitted by that time (NHDES 2022). Blades consist of various materials, including metal, thermoset/glass fiber composites, balsa wood, and adhesives, making it extremely difficult to separate the materials and recycle the parts (Mishnaevsky 2021). The metal components are stripped away and recycled as valuable scrap material. The balsa wood is burned and used for heat during the process of extracting the glass fiber from the rest of the blade remnants. The glass fiber remnants can be upcycled for a variety of products including 3D printer filament, automotive parts, sports equipment, boats, cement kiln fuel additives, and binding agents for concrete mixes. Several companies are developing recycling technologies for the composite materials to help increase sustainable blade end-of-life management (Mishnaevsky 2021, WETO 2022). See more information on wind turbine disposal in Sections 4.4.4 and 4.4.5.

Manufacturers are characterized by tier level according to their proximity to final products. For offshore wind, Tier 1 suppliers are the companies that design and assemble wind turbines such as Vestas, Siemens Gamesa, and GE. Tier 1 suppliers both manufacture components and contract for them from Tier 2 suppliers. Tier 2 suppliers manufacture components with input from Tier 3 suppliers. For example, blades for GE's Halide-X offshore wind turbine are made by Tier 2 companies such as LM Wind Power. LM Wind Power has a factory in the Castellón province in Spain where over the course of two days, 100 employees use fiberglass fabric, balsa wood, and foil to fabricate a blade for the Halide-X. Blade inputs are sourced from Tier 3 suppliers. Upon completion of the blade, the Tier 2 manufacturer ships it to the Tier 1 manufacturer.

In recent years, offshore wind turbine designers have created extremely large turbines that have exceeded the size restriction for federal and state highway transportation. As a result, any Tier 1 manufacturing facilities developed to support the growing offshore wind industry in the eastern United States will likely be built with direct port access. Since Tier 2 manufacturing facilities do not assemble the wind turbines, they have smaller size requirements than Tier 1 facilities. They are likely to be clustered around the Tier 1 facilities to minimize transportation issues when shipping the components to Tier 1 facilities.

Tier 1 manufacturing facilities require a large area. For example, the Cuxhaven plant, the largest offshore wind turbine factory in Germany is 55,000 sq meters. It has a 32-meter-high factory building, the production hall is 320 meters long and more than 160 meters wide. The site also has a 3,800 sq meter office and canteen building and employs 800 people (Siemens Gamesa 2022a).

2.3.3 Ports

Ports and harbors can support offshore wind by serving as primary installation facilities (marshalling ports) or in a support role (maintenance ports). The most stringent infrastructure requirements are for marshalling ports which must meet requirements for aerial clearance, depth, storage and staging space, and load bearing capacity. Aerial clearance of 145-200 meters is required for both floating and fixed platforms. Other requirements differ for anchored and floating wind turbines (Shields et al. 2022).

For anchored installations, the most stringent marshalling port requirements arise from hosting a wind turbine installation vessel (WTIV). These vessels carry assembled turbines to project areas and mount them on pre-installed foundations. WTIVs require channel and quayside (loading area) depths of at least 12 meters. If the WTIV remains offshore, feeder barges could allow marshalling ports with depths as shallow as six meters (Shields et al. 2022, 2023).

Floating turbines are expected to be assembled in a single port and towed to the project site. Floating wind substructure technologies require a water depth of at least 12 meters and a channel width of at least 75 meters (Porter and Phillips 2016). The depth requirement can be mitigated using equipment to provide buoyancy. However, floating wind technology is evolving toward ever larger turbines that will require more depth.

Quayside and laydown requirements arise from assembly and loading. For anchored projects, the turbines and support structure are handled separately. Quayside space of 500 meters with a bearing capacity of 15 tons per square meter is required for assembling and loading turbines. Floating turbines are expected to be assembled as a single unit and towed to the project site. This requires quayside berthing of up to 660 meters and a bearing capacity of 15 tons per square meter. The laydown area is used for storage and may also be used for substructure assembly and integration of the turbine and substructure. This could require approximately 70 acres for floating turbines and 25 acres for fixed-bottom projects. acres and a minimum bearing capacity of 10 tons per square meter (Shields et al. 2022).

Current U.S. wind energy manufacturing capabilities are limited because it is relatively new to the United States. Siemens Gamesa Renewable Energy is developing the first offshore wind turbine blade facility in the United States. Siemens Gamesa will develop more than 80 acres at the Portsmouth Marine Terminal in Portsmouth, Virginia upon execution of a firm order for the 2.6-GW Coastal Virginia Offshore Wind Commercial Project with Dominion Energy. The facility will perform finishing of Siemens Gamesa turbine blades and will cost more than $200 million (Siemens Gamesa 2022b).

The Port of Albany and private partners are undertaking what will be the first offshore wind tower manufacturing facility in the United States. The Port of Albany initiated an expansion project in 2018 with the acquisition of an 80-plus acre parcel zoned for industrial purposes (Port of Albany 2019a). The facility will produce towers and transition pieces. Maximum draft at the Port of Albany is 31.9 ft, and it can accommodate ships up to 750 ft long and 110 ft wide with a maximum air draft of 134 ft (Port of Albany 2019b).

According to the latest National Oceanic and Atmospheric Administration (NOAA) navigation chart, the maintained navigation channel of Piscataqua River extends past the Port of Portsmouth upriver approximately 4.5 miles almost reaching the Little Bay Bridge with a minimum depth of 30 ft (NOAA 2022). Based on the vessel accessibility of the Port of Albany and its ability to support a Tier 2 manufacturing facility, the Port of New Hampshire and dredged area of the Piscataqua River could potentially support a Tier 2 manufacturing facility. The Piscataqua River is lined with other manufacturing facilities such as SubCom and Georgia-Pacific Gypsum. Repurposing an existing manufacturing plant to produce wind turbine components with functional, pre-existing shipping capabilities is more likely than building a brand new manufacturing plant on the shores of the Piscataqua River.

2.3.4 Vessels

Many different types of vessels are used to install and maintain an offshore wind farm. Prior to construction of the offshore wind farm, site data is collected using medium sized vessels that are specialized to collect data through various methods such as conducting bathymetric and geotechnical surveys. After the project development and permitting phase is complete, construction begins. Construction of the wind farm using fixed-foundation turbines require seabed preparation which often includes dredging for port access, flattening of sand waves on the seabed and seabed leveling before installing gravity-based foundations, installation of scour protection around monopiles, protection of subsea cables, and installation of a rock mat for the gravity-based foundations. These tasks require trailing suction hopper dredgers and fall pipe vessels. Trailing suction hopper dredgers remove boulders and levels the seafloor to allow for jack-up vessels to jack up. Fall pipe vessels dump rock at future monopile sites during seabed preparation.

Construction is the most active phase. Barges, tugs, and transport vessels are used for transporting the larger components such as the substation foundation, jacket, and wind turbine components. Heavy lift vessels are used for installing the monopiles and jackets, jack-up crane vessels are used for lifting and installing the foundations. As this occurs, support and noise mitigation vessels protect sea life by generating bubble curtains around the construction operation to mitigate noise from the construction process. A wind turbine construction vessel (often a jack-up vessel) is used to both transport and construct the largest components of the wind turbines including the mast, nacelle, and blades. These large construction vessels are also used to transport and build the offshore substation. If the offshore substation is too large for these vessels, a semi-submersible crane vessel must be used. Semi-submersible crane vessels are used when structures exceed 5,000 tons.

Floating offshore wind farms will require the use of fewer vessels because they are fully constructed in-port before being towed to their final location. Anchor handling tugs are used to tow the floating wind turbines and their foundation from the port to the installation site. Once at the site, subsea construction vessels are used to install suction pile anchors as well as any other subsea operations that require lifting.

Cable laying vessels are used to export cable between the wind farm and the shore as well as between wind turbines. These vessels maneuver cable barges to help reduce tension in the cables, jointing/splicing cables, plugging cables into turbines, and bringing cables to shore. These vessels are also used to bury the cable and install cable protections. Guard vessels are also used during this process to carry out operational safety procedures related to cable laying activities (American Clean Power 2021).

Throughout its operational life, the wind farm will require regular maintenance. Construction and maintenance crew must be transported to and from the wind farm. Crew transport vessels and service operation vessels are required to house and transport technicians and light equipment to and from the wind farm. Diving support vessels are used for underwater inspection and maintenance. Heavy maintenance activities such as replacing the larger turbine components (i.e., turbine blades) require the use of a jack-up crane. Accommodation platforms, also known as flotels, house technicians offshore during the commissioning work.

Many vessels that serve offshore wind farms will be required to be compliant with the Jones Act (See Section 7.3). The Jones Act requires that ships carrying cargo from one U.S. port to another are United States constructed, crewed and flagged. As offshore wind farms are defined as U.S. ports, the implication is that vessels going from a port to a wind farm must be constructed in the United States. This has implications for wind farm construction and operation as well as the shipbuilding industry. For example, the most specialized vessel for installing anchored turbines is a WTIV. Currently, there are no Jones Act Compliant WTIVs. However, Dominion Energy has commissioned the construction of one. According to Dominion Energy, the vessel's hull will have a length of 472 ft, a width of 184 ft, and a depth of 38 ft, making it one of the biggest vessels of its kind in the world. The vessel will accommodate up to 119 people. It is designed to handle current turbine technologies as well as next generation 12 MW or larger turbines. The vessel will also be capable of the foundation installation and other heavy lifts. The overall project cost, inclusive of construction and commissioning, is estimated to be approximately $500 million (Dominion Energy 2022).

Given the lack of Jones Act compliant vessels, developers will implement various workarounds. For example, the Vineyard Wind project is importing most of the equipment from Europe and may be able to avoid some Jones Act requirements by effectively having a European port perform certain marshalling port functions. Also, it is possible to use Jones Act compliant barges to bring turbines to the WEA from U.S. ports and then use a WTIV that is not Jones Act compliant to construct the wind farm.

The combined implications of vessel and Jones Act requirements are that there may be additional shipbuilding activities. There is a long history of ship and boat building on the New Hampshire seacoast. In 1800, the Portsmouth Naval Shipyard was established to build large naval warships and submarines. Today, their work mostly involves repairing submarines (New Hampshire State Council on the Arts 2022). Portsmouth Naval Shipyard, located directly across the Piscataqua River from Portsmouth Harbor, could potentially support the demand for Jones Act compliant vessels used during the wind farm construction operation; however, as a 2019 report from the Center for Strategic and Budgetary Assessment notes, “most shipyards that build larger U.S. Navy and Coast Guard ships do not generally construct commercial vessels.” While other shipbuilding companies exist in New Hampshire it is unlikely that they would have the infrastructure to build such large, specialized vessels.

2.3.5 Employment

Development and operation of an offshore wind farm requires a workforce in all stages of the wind farm life cycle. Employment opportunities for offshore wind generally fall into the following categories: construction, manufacturing, operations and maintenance, supply chain management, environmental oversight, and onshore administration.

The development phase of the offshore wind farm employs biologists, policy experts, project managers, and community planners which fall into the categories of environmental oversight and onshore administration. Supply chain management is another important component of the development phase, employing engineers, factory workers, logistics managers, and harbor employees to design, manufacture, transport, and store the various components of the wind farm. Employment in the construction category includes highly skilled technical workers who assemble and install the major components of the wind farm. It also includes vessel operators who are located both in the harbor and on ships. Common jobs in this category include the marine crew, engineers, and construction crews. The final category, operations and maintenance, includes wind farm managers and specialized wind turbine technicians who inspect, maintain, and repair all aspects of the wind farm. As the wind farm is located offshore, operation and maintenance activities will also require maritime ship crews to transport technicians to and from the wind farm (Stefek et al. 2022).

Offshore wind development requires expertise from many different occupational fields. Gould and Cresswell (2017) determined that the offshore wind workforce is composed of as many as 74 different occupational fields. Table 2.3.1 recreated from Gould and Cresswell (2017) lists each occupation, the minimum/common credentials needed to perform the job, the estimates annual wages, and during which part of project development and operation each occupation participates.

Table 2.3.1. Occupations Associated with Offshore Wind Development and Operation (Gould and Cresswell 2017).

Functional Area	Occupation	Minimum/Common Credentials	Estimated Annual NYS Wages	P&D	MFG	C&I	O&M	T,R&C
Accounting, Finance & Procurement	Accountant	Bachelor's Degree	$91,630	•	•	•	•	•
	Bookkeeper	High school diploma or equivalent	$42,740	•	•	•	•	•
	Buyer	Bachelor's Degree	$67,890	•				
	Insurer and Underwriter	Bachelor's Degree	$78,610	•	•	•		
	Power Marketer and Analyst	Bachelor's Degree	$77,280	•	•	•	•	
Admin, Clerical & Back Office	Admin and Clerical Staff	High school diploma or equivalent	$31,220–$52,490	•	•	•	•	•
	Human Resources Professional	Bachelor's Degree	$72,380	•	•	•	•	•
	Information Technology Specialists	Bachelor's Degree	$40,530–$111,170	•	•	•	•	•
	Public Relations Officer	Bachelor's Degree	$158,100	•	•	•	•	•
Construction & Assembly Workers	Assemblers of Electrical and Electro-mechanical Equipment	Apprenticeship or post-secondary certificate/license	$32,850–$37,110		•	•		
	Construction Laborer	Apprenticeship or post-secondary certificate/license	$36,400–$47,370			•	•	
	Laborers and Freight, Stock, and Material Movers, Hand	Apprenticeship or post-secondary certificate/license	$30,040		•	•	•	
Consultants & Researchers	Health and Safety Specialist	Apprenticeship or post-secondary certificate/license	$71,910	•	•	•	•	•
	Operations Research Analyst	Bachelor's Degree	$101,540				•	•
Development Technical Specialists	Regulatory and Permitting Expert	Bachelor's Degree	$110,000	•				
Directors and Executives	Director of Business Development	Master's Degree or higher	$186,940	•		•		
	Director of Finance	Master's Degree or higher	$162,210	•	•	•	•	
	Director of Health, Safety, and Risk	Master's Degree or higher	$55,420–$71,910	•	•	•	•	
	Director of Procurement	Master's Degree or higher	$129,030	•	•	•	•	
	Director of Sales	Master's Degree or higher	$183,610	•	•			

Abbreviations: P&D = Planning & Development; MFG = Manufacturing; C&I = Construction & Installation; T,R&C = Training, Research & Consulting.

Table 2.3.1. Continued.

Functional Area	Occupation	Minimum/Common Credentials	Estimated Annual NYS Wages	P&D	MFG	C&I	O&M	T,R&C
Engineers	Aerospace/Aeronautical Engineer	Bachelor’s Degree	$113,080		•			•
	Civil Engineer	Bachelor’s Degree	$91,110	•		•		•
	Composite Materials Engineer	Bachelor’s Degree	$87,930		•			•
	Control Systems Engineer	Bachelor’s Degree	$55,490		•			
	Design Engineer	Bachelor’s Degree	$81,010	•	•			•
	Electrical Engineer	Bachelor’s Degree	$98,430	•	•	•	•	•
	Environmental Engineer	Bachelor’s Degree	$90,220		•			•
	Geotechnical, GIS, and Geophysical Engineer	Bachelor’s Degree	$51,590–$91,370	•	•			•
	Industrial Engineer	Bachelor’s Degree	$85,460		•			•
	Marine Engineer	Bachelor’s Degree	$91,660	•	•	•		•
	Mechanical Engineer	Bachelor’s Degree	$85,840	•	•	•	•	•
	Sales Engineer	Bachelor’s Degree	$107,010		•			
	Test Engineer	Bachelor’s Degree	$95,550	•	•	•		•
	Wind Energy Engineer	Bachelor’s Degree		•	•	•	•	•
Legal	Attorneys	Law Degree	$155,050	•	•	•	•	•
	Paralegal	Bachelor’s Degree	$57,920	•	•	•	•	•
Management and Supervisors	Commercial Site Manager	Apprenticeship or post-secondary certificate/license	$79,460				•	
	Construction Project Manager	Apprenticeship or post-secondary certificate/license	$114,330			•		
	Engineering Manager/ Chief Engineer	Master’s Degree or higher	$151,740	•	•		•	
	Production Supervisor/ Manager	Bachelor’s Degree	$64,520		•		•	
	Quality Manager	Master’s Degree or higher	$120,390		•	•		
	Site/Plant Manager or Operations Manager	Bachelor’s Degree	$79,460		•	•	•	
	Wind Project Manager	Bachelor’s Degree	$110,100				•	
Maritime, Port, and Terminal Professions	Divers	Apprenticeship or post-secondary certificate/license	$84,940	•		•	•	•
	Stevedore/ Longshoreman	Apprenticeship or post-secondary certificate/license	$30,040–$46,530			•	•	
Scientists	Archaeologist	Bachelor’s Degree	$82,580	•				•
	Ecologist	Bachelor’s Degree	$70,640	•				•
	Environmental Scientists	Bachelor’s Degree	$75,780–$96,010	•				•

Table 2.3.1. Continued.

Functional Area	Occupation	Minimum/Common Credentials	Estimated Annual NYS Wages	P&D	MFG	C&I	O&M	T,R&C
Scientists	Geoscientist/Geologist and Hydrologist	Bachelor's Degree	$78,320–$87,030	•				•
	Marine and Wildlife Biologist	Bachelor's Degree	$65,870–$77,430	•				•
	Meteorologist	Bachelor's Degree	$83,400	•		•		•
Technicians	CAD Specialist/ Technician	Bachelor's Degree	$44,650–$70,630	•	•			
	Environmental Science Technician	Bachelor's Degree	$48,560	•			•	
	Wind Turbine Technician	Apprenticeship or post-secondary certificate/license	$53,000 (national)				•	
Trade Workers	Cement Worker/ Concrete Operative	Apprenticeship or post-secondary certificate/license	$60,810			•	•	
	CNC Operator	Apprenticeship or post-secondary certificate/license	$46,330		•			
	Crane Operator	Apprenticeship or post-secondary certificate/license	$78,870			•	•	•
	Electrician: Inside	Apprenticeship or post-secondary certificate/license	$72,540			•	•	
	Electrician: Outside	Apprenticeship or post-secondary certificate/license	$77,070			•	•	
	Ironworker/Steelworker	Apprenticeship or post-secondary certificate/license	$84,750			•	•	
	Machinists	Apprenticeship or post-secondary certificate/license	$43,560		•			
	Operating Engineer	Apprenticeship or post-secondary certificate/license	$72,610			•		
	Rigger	Apprenticeship or post-secondary certificate/license	$45,870–$58,060			•	•	
	Rodbuster	Apprenticeship or post-secondary certificate/license	$96,210			•	•	
	Welder	Apprenticeship or post-secondary certificate/license	$43,310		•	•	•	

Table 2.3.1. Continued.

Functional Area	Occupation	Minimum/Common Credentials	Estimated Annual NYS Wages	P&D	MFG	C&I	O&M	T,R&C
Trainers, Teachers, and Professors	Professor	Master's Degree or higher	$91,260–$110,280					•
	Technical Trainer/ Instructor	Apprenticeship or post-secondary certificate/license	$65,970					•
	Training and Develop-ment Manager	Master's Degree or higher	$135,620					•
Transport and Logistics	Heavy-Load Truck Drivers	Apprenticeship or post-secondary certificate/license	$47,500		•	•	•	
	Logistician	Bachelor's Degree	$73,930	•	•	•	•	
	Transportation Worker	Apprenticeship or post-secondary certificate/license	$38,760	•	•	•	•	
Vessels and Aircraft Workers	Commercial Aircraft Pilots	Apprenticeship or post-secondary certificate/license	$94,840	•		•	•	•
	Deck Crew (Mates, Ship Boat and Barge)	Apprenticeship or post-secondary certificate/license	$65,450	•		•	•	•
	Ship and Boat Captains	Apprenticeship or post-secondary certificate/license	$73,130	•	•	•	•	•

2.3.6 New Hampshire Implications

The preceding review provides the backdrop for consideration of offshore wind implications for New Hampshire. This section overviews the U.S. East Coast situation for ports, manufacturing, vessels, and labor. This East Coast overview is used to understand the implications for New Hampshire.

East Coast Ports

Ports are required for manufacturing, marshalling and for support. The most comprehensive study of U.S. port suitability for supporting offshore wind was conducted by the NREL. Shields et al (2022) indicates that port infrastructure is a current challenge. Considering marshalling ports in particular, many U.S. ports lack the minimum 12-m channel and quayside depth requirement. With the rate at which offshore wind is being planned and developed and the size of the geography over which turbines will be deployed it is likely that several ports for marshalling or combined manufacture and marshalling will be required to service the region. Getting ports up to speed can cost $250 million or more (Shields et al 2022).

Shields et al (2022) evaluated the east coast ports most likely to be used as offshore wind marshalling ports. The top ports evaluated for marshalling are New Bedford, MA; New London State Pier, CT; South Brooklyn Marine Terminal, NY; New Jersey Wind Port, NJ; Tradepoint Atlantic, MD, and Portsmouth Marine Terminal, VA. The assessment also indicated that only two of these ports, the New Jersey Wind Port and the Portsmouth Marine Terminal, VA are currently suited for WTIV on the East Coast. Neither of these two ports are in the northeast region where a GOM offshore wind farm would be located. There are five feeder ports on the East Coast, three of which are in the northeast region; however, none are in New Hampshire.

Figure 2.3.2 presents the location of East Cost WEAs, ports, original equipment manufacturers (OEMs), and Tier 1 suppliers. The ports presented in this figure represent the sites most likely to be upgraded to a level which can support WTIV and support a portion of the region's offshore wind farm construction.

Portsmouth Harbor

Portsmouth Harbor refers to the last 8.8 miles of the Piscataqua River before it empties into the GOM. The harbor contains a 6.2 mile long, 35 ft deep (10.67m), 400–600 ft wide navigational channel that is maintained by the U.S. Army Corps of Engineers (USACE; USACE 2022, Pease International and NH DOT 2021). Portsmouth Harbor is the sole deep draft harbor in New Hampshire. It handles about 3.5 million tons of shipping a year for New Hampshire, eastern Vermont, and southern Maine. Items include petroleum products, rubber and plastics, iron and steel scrap, salt, limestone, gypsum, and fish products (USACE 2022). Portsmouth Harbor is used by submarines from the Portsmouth Naval Shipyard in Kittery, ME and for fuel deliveries to the Pease International Tradeport in Newington. Portsmouth Harbor is also used extensively by commercial fishermen and the lobster fleet, charter fishing vessels, excursion boats to the Isles of Shoals situated nine miles offshore, and local and transient boats based at or visiting the nearly 20 boating facilities in the area (Pease International 2023). Population centers around Portsmouth Harbor include Portsmouth, New Castle, Newington in New Hampshire and Kittery and Elliot in Maine.

The Port of New Hampshire, also known as the Market Street Marine Terminal, is located on the southern banks of the Piscataqua River in Portsmouth. It is the only significant port in New Hampshire and the only port in the state that is likely to support offshore wind. Market Street Marine Terminal is the only deep water, public access, general cargo facility on the Piscataqua River. The terminal has one 600-ft (182.9 m) long berth with an alongside depth of 35 ft (10.7 m) at mean low water and one 95.1 m long berth with alongside depth of 6.7 m (Pease International 2023). The port has an air draft restriction of 135' (41.15m; Moran Portland Shipping Agencies 2022). At three nautical miles from the open sea, the terminal is located less than one kilometer (km) from the Interstate 95 highway and just over three kilometers from the Pease International Tradeport, a 1.2 thousand hectare business and aviation park. Market Street Marine Terminal has 20,000 sq ft (1,858 sq m) of covered warehouse, 8 acres (3.2 hectares) of paved outside lay-down area, and on-site rail access (Pease International 2023). The marine terminal users co-exist with boating and commercial fishing. The Port of New Hampshire handles bulk cargoes (salt, wood chips, scrap), breakbulk (construction materials and machinery and industrial parts), project cargo (vacuum tanks and power plant components), and container cargo (Pease International 2023).

Foreign Trade Zone #81 includes five sites and one subzone, including 4.5 hectares at the Port of New Hampshire's Market Street Terminal, 30.4 hectares at the Portsmouth Industrial Park, 20.2 hectares at the Dover Industrial Park, 566 hectares at the Manchester Airport, and 769 hectares at the Pease International Tradeport.

The Division of Ports and Harbors (DPH) also manages a wide range of passenger vessel facilities that serve charter boats for fishing, diving, cruising, and sightseeing as well as party fishing boats, whale watching boats, ferries, and cruise ships. The Port also contains berths and slips for commercial fishing vessels.

Offshore wind marshalling ports are deep water ports where the wind turbine components are stored, assembled, loaded onto vessels, and deployed. Section 2.3.3 describes the port parameters required to undertake these activities. Each task carried out at the marshalling port requires port employees with specialized skills to plan, coordinate, and carry out the tasks. Harbor logistics coordinators are required to direct boat traffic in and out of the harbor, plan for wind turbine component storage and in-port construction activities, and schedule loading of materials on large vessels like WTIV. Specialized large machine operators in the port are needed to move the massive wind turbine components into and out of storage areas and load them onto vessels for transport. Boat crews are required to operate each vessel transporting people and materials to and from the wind farm. The port must also have tugboat operators to guide larger vessels through the channel and into port.

To be used as a marshalling port, the Port of New Hampshire would need major upgrades. Marshalling activities would require significant land acquisition to increase the lay down area by approximately 60 acres for adequate component storage. The State of New Hampshire in collaboration with the USACE would also have to undertake a large dredging campaign deepening the 6.2 mile long channel by at least 1.5 m. The air draft restriction would also have to be increased from 41.15 m to 150 m which would involve removing or restructuring the Memorial Bridge. Lastly, to support the marshalling operation, the port would have to hire additional employees to support increased port activity and equipment and/or vessel requirements.

Given the significant changes that would be required at Port of New Hampshire, it is unlikely that this port would be used as a marshalling port. However, the Port of New Hampshire could potentially be used as a maintenance port during the operational life of the wind farm. Maintenance ports play an important role supporting the day-to-day wind farm operation requirements. Except for large scale maintenance activities such as replacing a wind turbine blade, requiring a jack-up vessel, all operation and maintenance activities, supplies, crews, and vessels originate from the maintenance port. Proximity to the wind farm is the most important component of a maintenance port as it is important to minimize travel time to and from the wind farm to minimize travel cost of the crew and wear and tear on the vessels used for the maintenance activities.

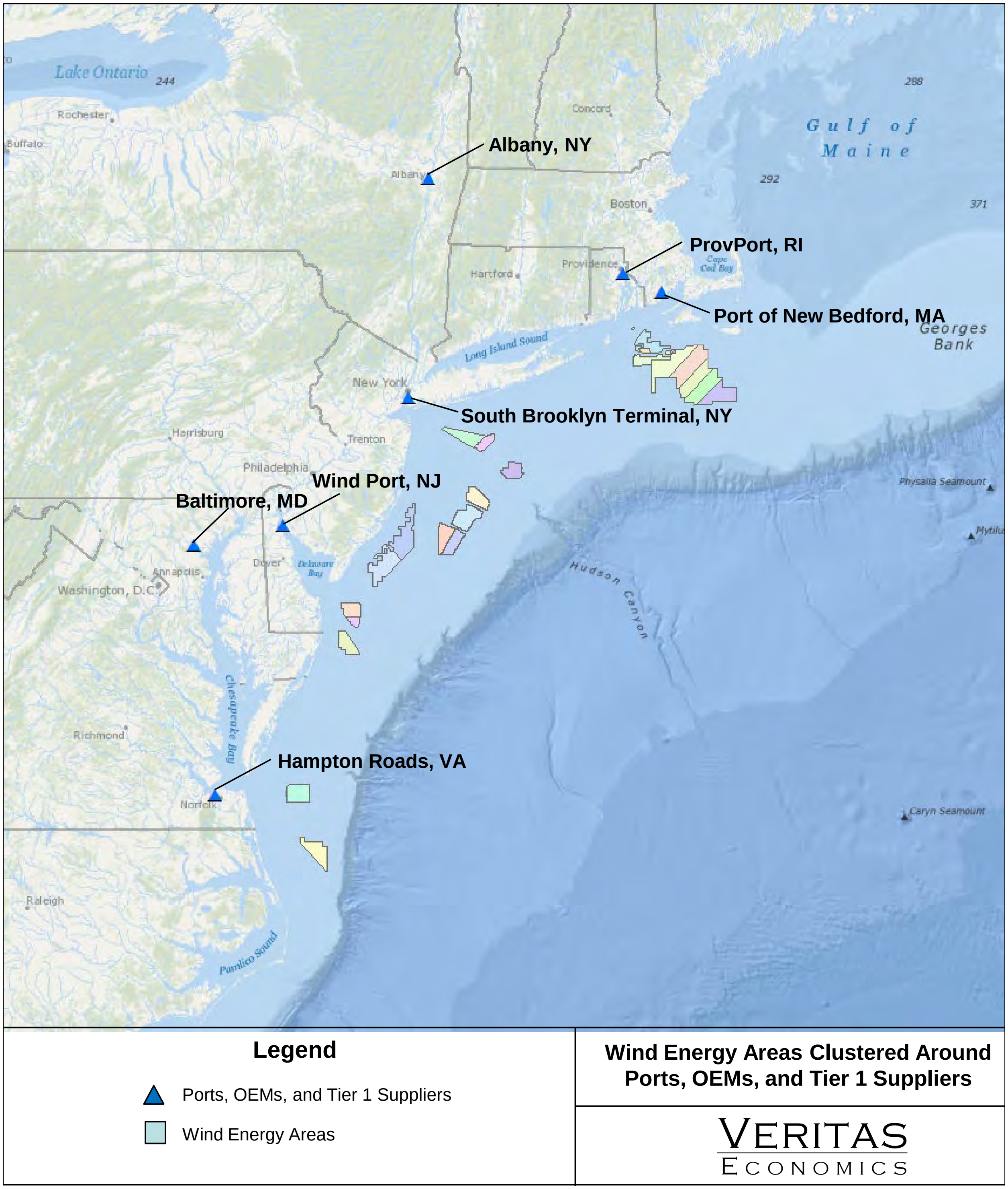

Figure 2.3.2. East Coast Wind Energy Areas, ports, and potential Tier 1 facilities.

Labor

Offshore wind development in the GOM will require a workforce for all stages of a wind farm life cycle. According to the Bureau of Labor Statistics, the New Hampshire unemployment rate as of June 2023 is 1.8%. The Economic and Labor Market Information Bureau lists trade, transportation, and utilities account for over 20% of nonfarm jobs, followed by education and health services at 18%, and professional business services at 14% (NHES 2022). Table 2.3.2 shows the nonfarm employment by sector.

Current employment in the offshore wind energy industry is limited because it is relatively new to the United States. While there is some overlap with other industries for a portion of the skilled labor jobs, there is need for significant workforce development. A diverse set of trade workers, from electricians to commercial divers, constitute a vital part of the workforce during the assembly and deployment of turbines. Career and technical education centers, the Community College System of New Hampshire, the University System of New Hampshire, private educational institutions, and union apprenticeship programs will play a critical role in developing new or enhanced programs to train an offshore wind-ready workforce. Other New England states, including Massachusetts, have developed consortiums to bring relevant educational institutions together to create strategies for offshore wind workforce development. (NHCSOWPD 2022).

Table 2.3.2. New Hampshire Nonfarm Employment by Supersector.

Industry	Number of Jobs
Total Nonfarm	749,650
Total Private	656,290
Goods Producing	111,150
Service-Providing	638,500
Private Service Providing	545,140
Mining and Logging and Construction	35,270
Mining and Logging	1,050
Construction	34,220
Manufacturing	75,880
Durable Goods	56,520
Non-Durable Goods	19,360
Trade, Transportation, and Utilities	153,780
Wholesale Trade	33,560
Retail Trade	100,690
Transportation, Warehousing, and Utilities	19,530
Information	13,060
Financial Activities	38,180
Finance and Insurance	30,440
Real Estate and Rental and Leasing	7,740
Professional and Business Services	104,160

Table 2.3.2 Continued.

Industry	Number of Jobs
Professional, Scientific, and Technical Services	50,580
Management of Companies and Enterprises	10,610
Admin and Sup and Waste Mgmt and Remediation Svcs	42,970
Education and Health Services	133,410
Educational Services	32,590
Health Care and Social Assistance	100,820
Leisure and Hospitality	75,800
Arts, Entertainment, and Recreation	12,670
Accommodation and Food Services	63,130
Other Services	26,750
Government	93,360
Federal Government	9,340
State Government	23,300
Local Government	60,720

Source: NHES 2022.

2.3.7 New Hampshire Economic Evaluation and Workforce Opportunities

To evaluate opportunities and implications of offshore wind for New Hampshire, a hypothetical wind farm was conceptualized for both this economic evaluation and the power system assessment. The hypothetical New Hampshire Wind Farm is specified to be located approximately 40 miles east of the southeastern edge of New Castle Island, the mouth of the Piscataqua River, and approximately 44 miles from the New Hampshire Port Authority (See outline in Figure 2.2.7). This location was chosen because there are no direct conflicts with habitat areas of particular concern, marine sanctuaries, suitable deep-sea soft or stony coral habitat areas, recreational scuba diving areas, or commercial whale watching areas (Northeast Ocean Data 2022). Additionally, when a wind farm is more than approximately 30 miles offshore it becomes cost effective to convert the power to DC before sending it onshore (Middleton and Barnhart 2022).

As specified, the hypothetical wind farm's total design capacity is 1,200 MW and consists of 100 12MW wind turbines. Bathymetric surveys presented by Northeast Ocean Data (2022) indicate the site is approximately 230 m deep. This means that like most sites in the GOM the wind farm will require floating wind turbines. The offshore substation would likely be located approximately 1 mile (1.6 km) west of the wind farm, approximately 43.1 (69.4 km) from the maintenance port.

There are multiple sites in the immediate area of the Piscataqua River that could be used as the plant's Point of Interconnection (POI). These sites include the Schiller Generating Station (Schiller), Newington Generating Station (Newington), Essential Power LLC Newington

(Essential Power), and Seabrook Nuclear Generating Station (Seabrook). The option modeled in this analysis is the recently retired Schiller Generating Station in Portsmouth on the Piscataqua River. Schiller is located approximately 46 miles from the wind farm. Schiller is a recently retired generating facility with the available transmission capacity to handle the electricity produced by the hypothetical offshore wind farm. Since it is located on the Piscataqua River, it eliminates the need for a landfall to interconnection trench.

Based on the review of potential offshore wind related economic activity in New Hampshire, a New Hampshire marshalling port or Tier 1 manufacturing facility appear unlikely. It is more possible that the Port of New Hampshire will be a support port and that supporting manufacturers are in New Hampshire. The New Hampshire economic impacts of this outcome are evaluated using input-output analysis. Input-output models assess economic activity in three categories:

- *On-Site Labor and Professional Services*—Dollars spent on labor from companies engaged in development and on-site construction and operation of power generation and transmission.
- *Local Revenues and Supply Chain*—Expenditures in this category are driven by the increase in demand for goods and services from direct on-site project spending. Businesses and companies included in this category of economic activity include construction material and component suppliers, analysts and attorneys who assess project feasibility and negotiate contract agreements, banks financing the projects, all equipment manufacturers (e.g., blade manufacturers), and manufacturers of replacement and repair parts.
- *Induced Results*—Expenditures in this category are driven by reinvestment and spending of earnings by direct and indirect beneficiaries. Induced results are often associated with increased business at local restaurants, hotels, and retail establishments, but also include childcare providers and any other entity affected by increased economic activity and spending occurring in the first two categories.

Input-output modeling is typically conducted using a software package that contains geography-specific economic linkages between initial and downstream expenditures and employment. Well-known input-output modeling systems include IMPLAN and REMI. A disadvantage of these systems for offshore wind is that they require cost information by industry categories to conduct the analysis. NREL's Jobs and Economic Development Impact (JEDI) model is an input-output modeling system specifically designed to estimate the number of jobs and economic impacts associated with the development and operation of an offshore wind farm in a particular geographic area.

Based on the superior capabilities of JEDI for evaluating the economic impacts of offshore wind development, the New Hampshire module was employed to evaluate the economic impacts of the hypothetical wind farm. The analysis assumes that the area will develop the supporting manufacturing capabilities prior to construction of the wind farm which in this hypothetical scenario is scheduled to begin in 2030. Based on this, the wind farm is specified to have 100% of its maintenance conducted in New Hampshire, and 10% of components manufactured in New Hampshire. All the maintenance labor and onshore electric maintenance is specified to be performed locally as well as the operation, management, and generation administration; operating facilities; environmental, health, and safety monitoring; insurance; and annual leases and fees. The analysis specifies that 50% of the vessels used for maintenance activities will be owned and operated locally. However, none of the vessels or labor will originate from the local New Hampshire community during the construction period of development, and the only construction materials produced locally are portions of the operation and maintenance spare parts. All other materials and labor are specified to originate from outside of New Hampshire.

Using the inputs described above to populate the JEDI model, the projected project cost for the hypothetical New Hampshire Wind Farm is $4.56 billion, with annual O&M costs of $142.94 million. Table 2.3.3 presents the project's resulting economic impacts estimated using JEDI. The table presents the estimated full-time jobs expected to be created in New Hampshire under the expenditure assumptions for the construction and operation and maintenance phases of the hypothetical offshore wind project. It also presents the corresponding earnings from the new jobs, the value added to New Hampshire's economy from the expenditures, and the total economic output in New Hampshire. Value added represents the value of all final goods and services produced from the expenditures and total economic output represents the total direct, indirect, and inducted impacts related to the expenditures.

As the results in Table 2.3.3 show, the hypothetical offshore wind project is estimated to produce 3,640 jobs in New Hampshire with job-related earnings totaling $268.9 million. These employment impacts (jobs and earnings) represent the number of jobs that the industry contributes to the local economy, including employees of the industry and the associated job impacts in related sectors. Table 2.3.3 lists the specific sectors where the jobs are estimated to occur. The induced employment impacts result from the spending of the employees in each identified sector.

A study conducted by Georgetown Economic Services (2020) estimates that the offshore wind industry will create approximately 2.06–3.17 local job-years per MW during the construction phase and 0.18–0.26 permanent jobs per MW during the operations and maintenance phase.[13] As stated in Section 2.3.1, the installation and commissioning phase, or construction phase, is estimated to be relatively short, lasting approximately one year.

The hypothetical offshore wind project is also estimated to contribute $407.8 million in value added to New Hampshire's economic activity which represents approximately 0.41% of the value of New Hampshire's final goods and services ($99.67 billion – New Hampshire's 2021 Gross Domestic Product, Bureau of Economic Analysis 2022).

[13] A job-year is one year of work for one person.

Table 2.3.3. Economic Impacts Resulting from the Hypothetical New Hampshire Wind Farm.

Project Activity	Jobs (FTE)	Earnings[a]	Value Added[b]	Output[c]
Construction				
Installation Activities	0	0	0	0
Component Manufacturing and Supply Chain/Support Service	2,044	$168.0M	$228.6M	$540.1M
Induced	822	$42.7M	$81.7M	$139.2M
Operations and Maintenance				
Technicians and Management	169	$13.7M	$13.7M	$13.7M
Supply Chain/Support Services	319	$27.2M	$55.4M	$100.2M
Induced	286	$17.3M	$28.4M	$48.4M
Total	3,640	$268.9M	$407.8M	$841.6M

Notes: The results are presented in 2019 dollars

[a] Earnings are the wages earned by the employees associated with the project expenditures and economic impacts.

[b] Value Added is the value of final goods and services produced as a result of the expenditures. It is comparable to Gross Domestic Product which was $99.67 billion in New Hampshire and $23.32 trillion in the United States in 2021 (Bureau of Economic Analysis 2022).

[c] Output is the sum of direct, indirect, and induced economic impacts related to the project expenditures. It represents the value of all the final goods and services produced from the project expenditures (direct impacts), the value of the inputs used to produce the final goods and services (indirect impacts), and the expenditures from the wages employees earned to produce the direct and indirect goods and services (induced).

Offshore wind employment opportunities generally fall into the following categories: construction, manufacturing, operations and maintenance, supply chain management, environmental oversight, and onshore administration. The 3,640 jobs estimated to be created under the hypothetical New Hampshire scenario are projected to occur in the Component Manufacturing and Supply Chain/Support Service industries during the construction phase, and Technicians and Management and Supply Chain/Support Services industries during the operations and maintenance phase (Table 2.3.3). The functional job areas these workforce opportunities are projected to fall into are presented in Table 2.3.4.

Table 2.3.4. Functional Job Areas Resulting from the Hypothetical New Hampshire Wind Farm.

Project Activity	Functional Job Areas
Construction Phase	
Component Manufacturing and Supply Chain/Support Service	Engineers Trade Workers Transport and Logistics Administration, Clerical, and Back Office Accounting, Finance, and Procurement
Operations and Maintenance Phase	
Technicians and Management	Technicians Trainers, Teachers, and Professors Management and Supervisors
Supply Chain/Support Services	Transport and Logistics Vessel and Aircraft Workers Maritime, Port, and Terminal Professions Administration, Clerical, and Back Office Accounting, Finance, and Procurement

2.4 Recreational Marine Use

This section evaluates the potential economic effects of offshore wind development on New Hampshire recreational fishing and other recreational marine uses. Based on preliminary evaluations, recreational fishing is the marine use most likely to be affected by New Hampshire offshore wind development (Ecology and Environment, Inc 2014). Therefore, this section focuses on recreational fishing.

An offshore wind farm within boating distance of the New Hampshire coast could impact recreational fishing. Affected trips are expected to be boat trips traveling from a protected harbor or inlet to the open sea. These trips could come from Dover, Exeter, Hampton, New Castle, Newington, Newmarket, Portsmouth, Rye Harbor, Seabrook, Stratham, and other coastal points in New Hampshire (NOAA NMFS 2021).

A potential wind farm in New Hampshire waters would be located well offshore and recreational boat fishing off coastal New Hampshire mostly occurs within approximately 35 miles of the coastline (Fishing Status, LLC 2022; Office of National Marine Sanctuaries 2010). However, offshore wind farms may attract fish through artificial reef effects which may improve catch rates and draw recreational anglers (Farr et al. 2021, Smythe et al. 2021). It is also possible that anglers targeting large species such as tuna and sharks far offshore could experience reduced catch rates from line entanglements. This section characterizes recreational offshore and deep-sea fishing in New Hampshire and evaluates the implications of a potential wind farm off the coast of New Hampshire.

2.4.1 Varying Bottom Types

The nearshore basins of the Western GOM contain bottom sediments that are largely mud except near rock outcrops where shelly gravel occurs (Kelley and Belknap 1991). Striped Bass (*Morone saxatilis*), the main recreationally targeted species in New Hampshire coastal waters, inhabit nearshore ocean and coastal rivers (NHFG 2021, NOAA NMFS 2022b, VIMS 2022).

The continental shelf off the coast of New Hampshire in the Western GOM is complex and contains diverse features including extensive bedrock outcrops, marine-modified glacial deposits, seafloor plains, and marine-formed shoals. The continental shelf is composed of sediment types ranging from mud to gravel. The seafloor sediments and physiography frequently change dramatically over relatively short distances (tens of meters). Anglers have identified several ledges, points, and rocks in New Hampshire waters as fishing locations (Fishing Status, LLC 2022). Several recreationally targeted species including Atlantic Cod, Atlantic Mackerel (*Scomber scombrus*), Haddock (*Melanogrammus aeglefinus*), and Pollock (*Pollachius virens*) thrive in these ocean habitats (Ward et al. 2021a, 2021b, Greene et al. 2010, USACE 2004). More information on environmentally sensitive areas and fish is presented in Sections 5.1 and 5.2.

2.4.2 Artificial Reef and Wreck Sites

Marine life, including species targeted by recreational anglers, congregate at areas with complex bottom structure including reefs and wreck sites. New Hampshire has no formal program for creating artificial reef sites (Rousseau 2016). However, anglers have identified a natural reef (Whaleback Reef), shipwrecks, and other submerged vessel sites in the state's waters as fishing locations (Fishing Status, LLC 2022).

Aquatic species also congregate at offshore fixed-foundation turbines and their associated scour protection. For example, the Block Island Wind Farm, off the coast of Rhode Island, has become a destination for recreational spearfishermen and anglers as fish species congregate there (Rhode Island Sea Grant 2019). Spearfishermen reported that the support structures quickly colonized with mussels and crustaceans that attract pelagic fish, including Striped Bass, Bluefish (*Pomatomus saltatrix*), Bonito (*Sardini* spp.), and Scup (*Stenotomus chrysops*; ten Brink and Dalton 2018). Recreational anglers from Rhode Island participating in a two-year study reported enhanced catch and positive experiences when fishing within the Block Island Wind Farm (NHCSOWPD 2022). The mooring lines and floating substructure of FOWT are expected to act as fish aggregation devices (Farr et al. 2021) and will likely have similar effects as observed at the Block Island Wind Farm attracting a variety of species. A floating offshore wind farm placed in ocean waters near New Hampshire's coastline will likely result in new fishing opportunities and locations for recreational fishermen.

2.4.3 Marine Recreational Information Program (MRIP) Data

The Marine Recreational Information Program (MRIP) collects recreational saltwater fishing catch and effort data. The data are available at aggregate levels and can be used for additional refinements. The figure below depicts the relevant available MRIP data for New Hampshire during 2021, the latest year with complete data. The catch rate combines the catch of Striped Bass, Black Sea Bass (*Centropristis striata*), Bluefish, and other species as described in Bingham et al. (2011). As Figure 2.4.1 indicates, relevant data (i.e., fishing trips by mode and total catch rate by mode) are only available at the state level and for ocean locations (zone) that are within 3 miles of shore (state territorial sea) and beyond 3 miles (Federal Exclusive Economic Zone [EEZ]). Mode, types of fishing, is divided into categories based on an angler's fishing mode: shore, private or rental boat, headboat (party boat), or charter. The private or rental boat, headboat (party boat), and charter boat modes are relevant to offshore wind farm development. Catch rate, the estimated number of fish caught per angler trip, is determined using data collected by the Access Point Angler Intercept Survey.

Table 2.4.1 lists estimates for all fish caught to compare angler catch rates for three categories of boat fishing trips taken within three miles (nearshore) and beyond three miles (open water) of the New Hampshire coastline during the years 2017–2021 (NOAA NMFS 2022c). Table 2.4.1 shows that open water trips nearly always result in higher catch rates during each year, compared with nearshore fishing sites.

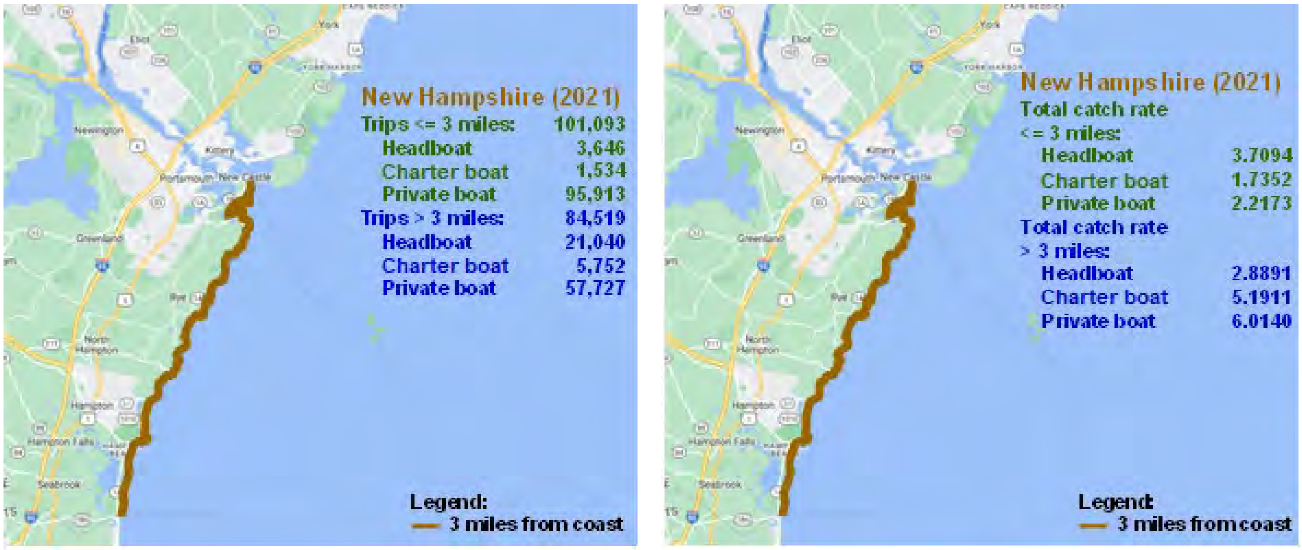

Figure 2.4.1. New Hampshire 2021 recreational fishing trips (left panel) and total catch rates (right panel) by zone and mode.

Table 2.4.1. Comparison of Recreational Angler Catch Rates Over Time.

Year	Headboat	Charter Boat	Private/Rental Boat
Nearshore			
2017	2.4954	2.1997	3.4833
2018	2.1924	1.2652	2.9270
2019	3.3506	2.1000	2.0433
2020	2.6799	2.1863	2.7760
2021	3.7094	1.7352	2.2173
Open Water			
2017	3.5392	5.4912	3.6587
2018	3.7356	5.0695	4.5059
2019	3.4696	7.0292	6.1013
2020	3.1204	6.8833	4.1435
2021	2.8891	5.1911	6.0140

Source: NOAA NMFS 2022c

2.4.4 Recreational Fishing Economics Methods

Recreational fishing economic techniques are used to evaluate the potential effects of offshore wind development. This section provides background material for the methods that are applied.

Recreational Fishing Demand

Economists refer to recreation as a "nonmarket" good. This terminology recognizes that recreation does not have a traditional market-driven production side. As a result, there are no supply curves, and the economics of recreational activities are typically evaluated using only demand functions. Recreational demand functions describe the recreators willingness to pay for trips to a recreation site. The "price" is the total cost of taking a trip to that site and includes transportation costs, the opportunity cost of time, entrance fees, and other trip-related costs.

Figure 2.4.2 depicts an econometrically estimated demand curve (Bingham et al. 2011). Here, the example angler's round-trip travel cost is $25.[14] Each additional trip is valued somewhat less than the previous trip. The fifth (and higher) trip is valued at less than travel cost. As the angler is not willing to pay more than $25 for more than four trips, the angler maximizes his utility by taking four trips. In the figure, the gray area above the per-trip cost and below the demand curve is the difference between what an angler pays for fishing trips to a site and the value that the angler holds for those trips. This is consumer surplus, and it is the dollar measure of the satisfaction received from trips to the site. It is the difference between what the angler does pay to visit a site and how much anglers are willing to pay to visit the site.

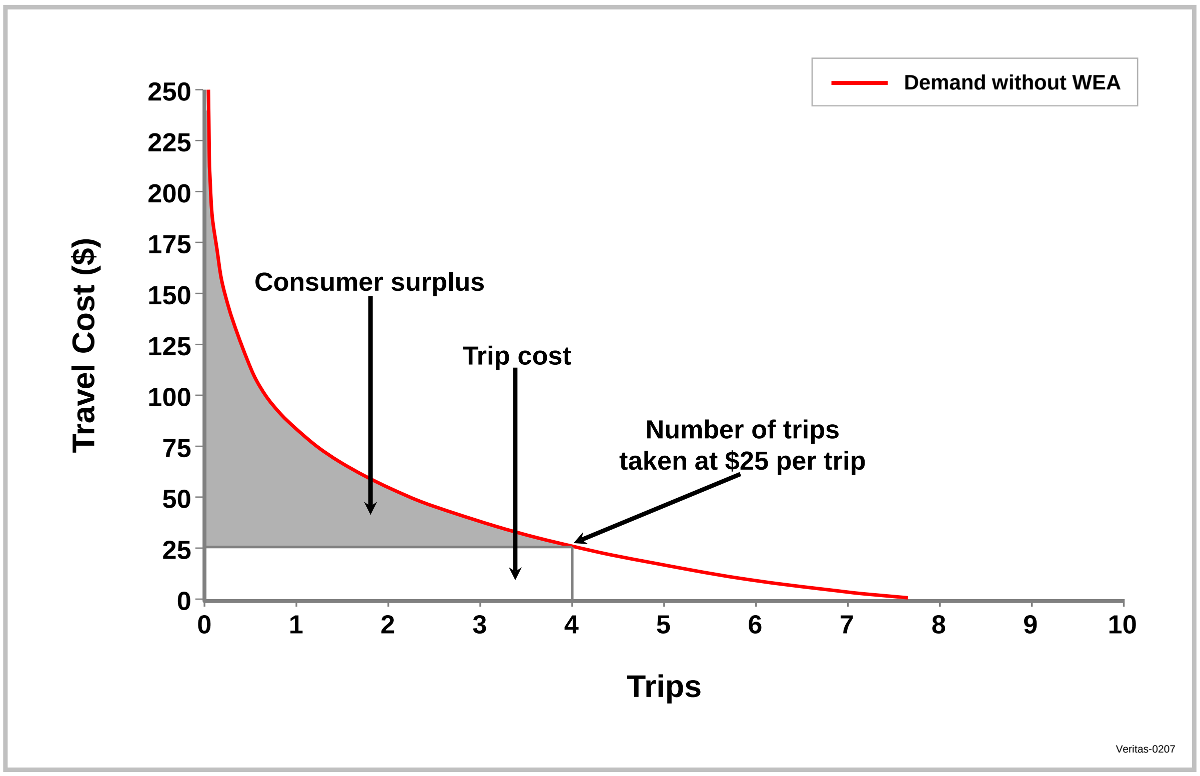

Figure 2.4.2. Example site demand curve and consumer surplus.

[14] Travel cost consists of direct expenditures and the value of time going to and from the site.

Counterfactual Modeling

Measuring the value of changes in catch rates is accomplished by measuring changes in consumer surplus. Figure 2.4.3 depicts the process. In the figure, the red demand curve reflects baseline catch rates. The blue curve depicts the demand curve with improved catch rates. This new demand curve is to the right of the baseline curve because higher catch rates have increased the value of trips to the site. As a result of improved site conditions, the angler takes more trips to the site (five trips rather than four) and these trips have a higher value. The change in value associated with the increased catch rates is the change in consumer surplus and is indicated by the grey area.

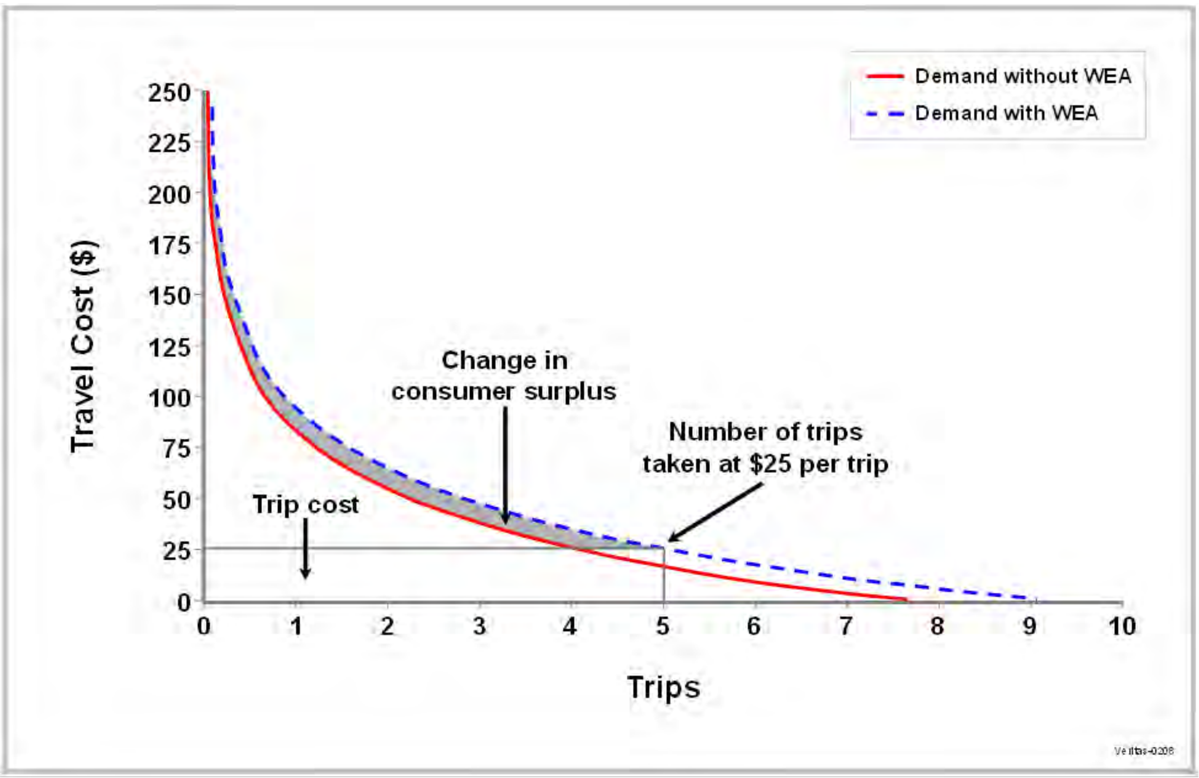

Figure 2.4.3. Increase in consumer surplus from increase in catch rates.

Population Representation

The single-site, single-person representation is applied to a population of anglers and sites by connecting the demand curve to a group of geographically distributed populations and sites. This is depicted for a single site in Figure 2.4.4 below.

In this population depiction, the number of people experiencing each travel cost is introduced on the right axis and used to characterize aggregate behaviors. Specifically, there are four population centers: under Baseline conditions 1,000 people average one trip to the site, 10,000 people average two trips, 5,000 people average three trips, and 8,000 people average four trips for a total of 68,000 trips to this site over this time-period. Under the Counterfactual condition, the positive change in quality results in outward movement of the demand curve as depicted in Figure 2.4.5.

This outward movement on the demand curve results in more trips from each origin and more trips to the site. As seen in Figure 2.4.5, the population center with 8,000 recreationists was previously averaging four trips per visitor and was responsible for 32,000 trips to the site. This group is now averaging five trips to this site per visitor and is responsible for 40,000 trips to the site. This outward shift in demand is also associated with higher welfare (willingness to pay) for all trips. At the individual level, willingness to pay is calculated as described previously (area between curves and above expenditures). To identify societal benefits or costs, it is calculated for all individuals (and sites), then summed.

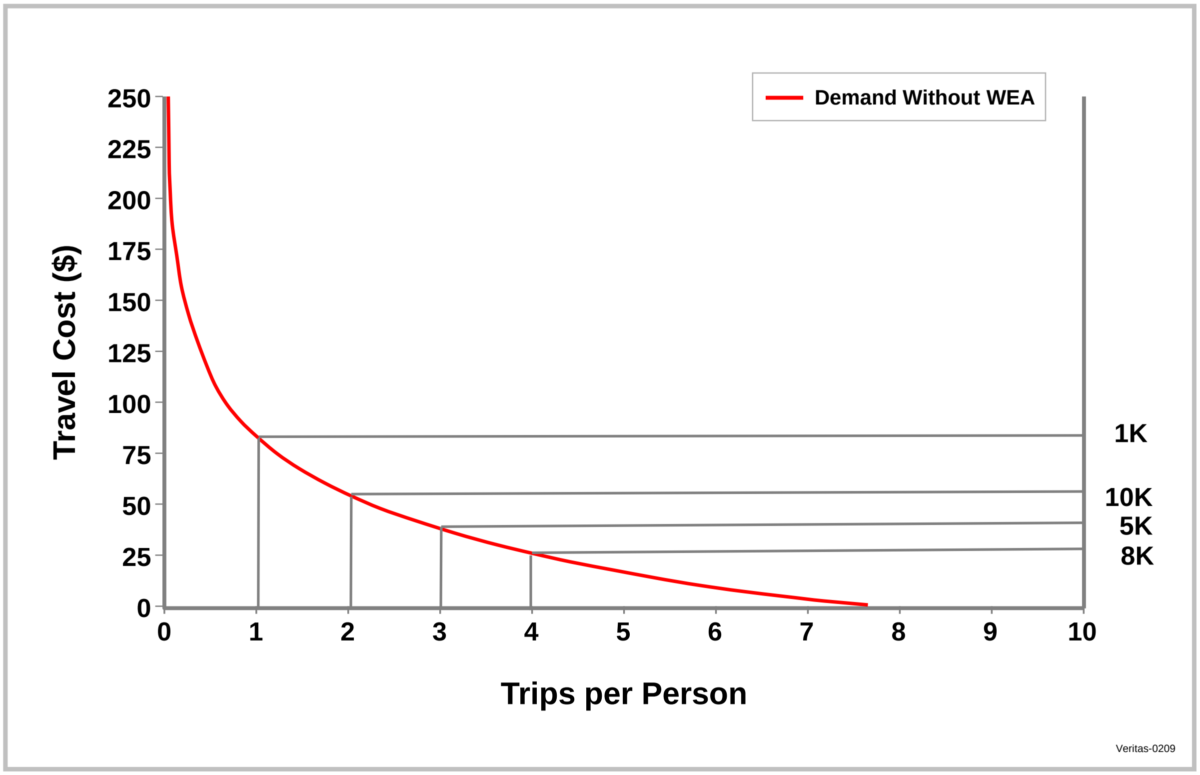

Figure 2.4.4. Baseline site demand—Population.

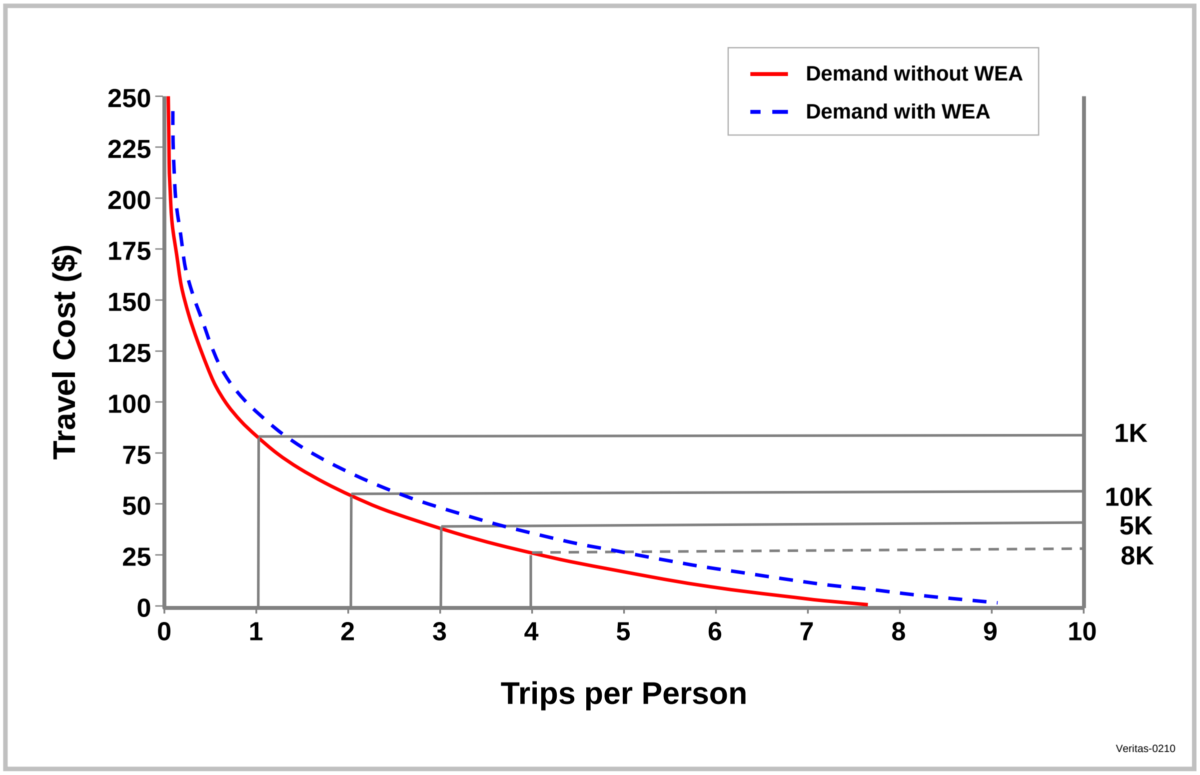

Figure 2.4.5. Site demand with improved catch rates.

Demand Functions

Angling demand functions can be estimated specifically or transferred from a similar context. Estimation of context specific demand curves was not possible for this evaluation, and a search for an appropriate demand function to transfer was undertaken. An important differentiating feature of WEA impacts is that they would occur in ocean sites and not in nearshore areas. There is a large amount of literature on recreational angling demand, and scores of recreational angling demand functions have been estimated. However, the literature on demand for offshore sites is limited. A literature search was conducted and found a single modern example of offshore recreational angling demand, a study of small boat fishing on the island of Oahu, Hawaii (Haab et al. 2008). In this study, angler choices were composed of the joint selection of where to launch their trailered boat and their ocean fishing destination. This allowed the authors to study the spatial aspects of boat fishing including the benefits and costs associated with different parts of the ocean, along with fishing aggregation devices.[15]

[15] Hawaii has had fish aggregation devices that "hold" pelagic fishes in an area to enhance fishing (PacIOOS 2021). The establishment of offshore fish aggregation devices may provide a way to divert fishing pressure from coastal reefs (Anderson and Gates 1996).

This study provides a very helpful characterization of boat fishing, but its usefulness for transferring to New Hampshire and the GOM is limited by important context differences. In Hawaii, water depths drop off very quickly and the fish species present are tropical. This means Oahu anglers have access to a different set of deepwater species and at much closer distances than New Hampshire coast anglers. As a result, the primary interest from this study is the preference coefficient on travel costs of getting to a launch as compared to those of going from a launch site to an open ocean site. The statistical model presented indicates that although travel cost overland and overwater are calculated independently, there is a single travel cost coefficient. Although this is not discussed in detail, the implication is that the authors had reason to believe that preferences related to these costs are identical. This is important because it supports the notion that land-based travel cost coefficients can be transferred to water-based travel costs.

To evaluate the factors influencing anglers' decisions, the analysis uses the angler preference function presented in Bingham et al. (2011). The econometric model in Bingham et al. (2011) was estimated with data that covered fishing sites across New Jersey and explicitly considered various fishing experiences, including ocean, estuarine, and freshwater sites (e.g., inland lakes, rivers, and streams). The survey process was consistent with accepted survey protocols. The study's response rate was consistent with survey research standards, and its models were rigorous, performed well, and revealed results that were consistent with expectations (Bingham et al. 2011). Model coefficients reflect the importance of that site characteristic to angler welfare. Table 2.4.2 contains the relevant coefficients and t-statistics from the Bingham et al. (2011) model. Positive coefficients indicate that as the value of site characteristics increase so does angler welfare, whereas negative coefficients indicate that as the value of site characteristics increase angler welfare decreases. The t-statistics indicate the directionality of the effect, in this case a negative t-statistic shows a reversal of angler welfare, an unwillingness to pay. The greater the magnitude of the t-statistic the larger the evidence that there is an effect of the site characteristic on angler welfare.

Species groupings account for the fact that species-level values for specific taxa are difficult to estimate. For example, although anglers have different preferences, most models are based on an "average" angler. In addition, anglers often misidentify catch (Page et al. 2012) and many "species" coefficients are actually based on species groupings (Lupi et al. 1998).

Table 2.4.2. Coefficients from the Bingham et al. (2011) Model.

Characteristic	Coefficient	t-Statistic
Travel cost	-0.024	-9.93
Other saltwater	0.36	8.86
Saltwater small game	0.16	3.01
Flatfish	0.95	10.70

The statistical model estimated in Bingham et al. (2011) is a nested logit. To delineate potential differences in angler preferences with respect to fishery type, a three-level fishing structure was used. On the first level, anglers choose whether or not they will fish. On the second level, anglers choose which waterbody type to fish from (freshwater, saltwater, or tidal sites). Lastly, after selecting a water body type, anglers decide which site to choose.

For an evaluation of small boat ocean fishing a different structure is appropriate. In considering the effects to be evaluated, the addition of a wind farm would result in new structure to fish recreationally. To evaluate this effect, a nested logit demand function was created in which anglers choose whether to ocean fish in a small boat, and then if they decide to do so, they fish either on the open ocean or at a wind turbine installation (Figure 2.4.6).

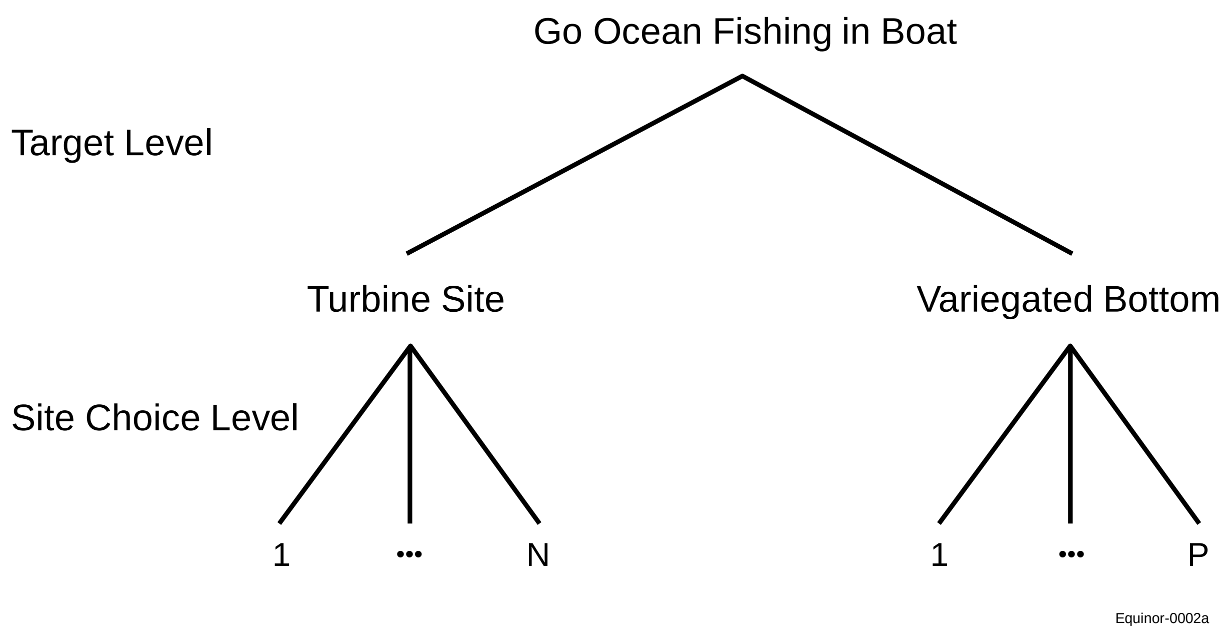

Figure 2.4.6. Nested logit demand function for fishing.

Recreational Fishing Baseline Characterization

Baseline fishing conditions are defined as the current conditions with respect to anglers potentially affected, the number of fishing trips the anglers take, the sites that those anglers visit, and catch rates. As described previously, there is high-quality fishing off the coast of New Hampshire, including a variety of bottoms, artificial and natural reefs, and Jeffreys Ledge, which is one of the best fishing grounds in the western GOM (Amazing Fish-a-Metric Enterprise 2017). Current and detailed Baseline information regarding fishing trips is limited to aggregate MRIP data. To develop an estimate of potentially affected recreational trips, MRIP estimated trips beyond three miles are scaled to represent the expected number of offshore recreational fishing trips originating from the New Hampshire coast. Baseline catch rates at each site are specified as the available open water catch rates for private boats from the National Marine Fisheries Service (NMFS) presented in Table 2.4.1 above (NOAA NMFS 2022c).

The Baseline model was specified to be consistent with this information using the departure locations and fishing sites depicted in Figure 2.4.7. NOAA NMFS (2021) identified marinas, boat ramps, jetties, and other locations where New Hampshire anglers depart for boat-based trips. The model's departure locations are identified from the New Hampshire MRIP interview locations. The modeled fishing sites are from the set of fishing destinations New Hampshire anglers identified as fishing locations that they visit. These locations are published by Fishing Status, LLC (2022) within an online map. To predict the number of trips to each fishing site, travel costs are calculated for the distances between each departure location and each fishing site. Catch rates are then applied to each site, and the site-choice function from Bingham et al. (2011) is used to predict the total number of trips to each site as a function of the travel cost from each departure location and fishing site, and the catch rates available at each fishing site.

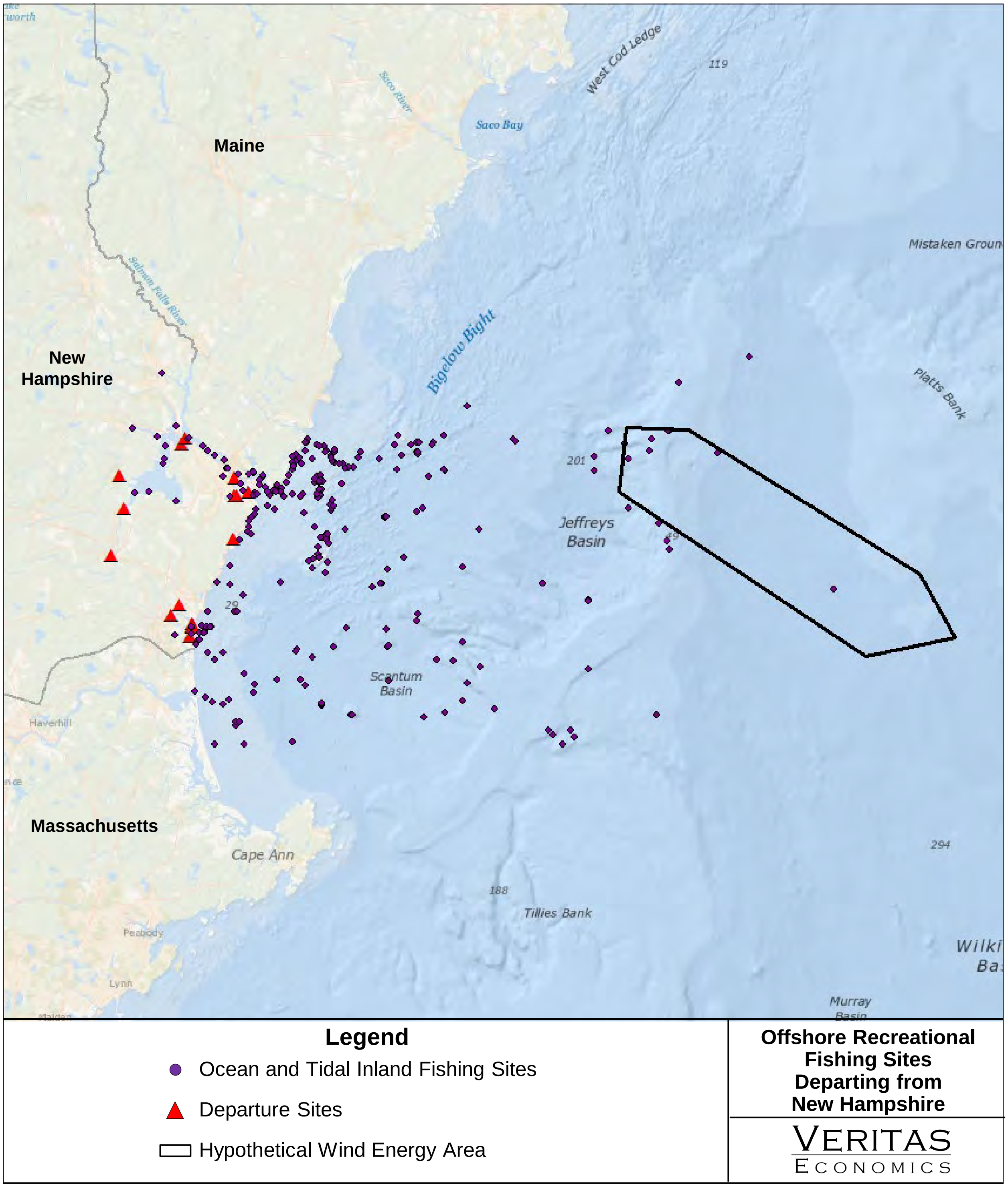

Figure 2.4.7. Recreational boat fishing Baseline conditions.

Recreational Fishing Counterfactual Specification

For the Counterfactual evaluation, several new fishing sites are added to the hypothetical wind energy area. To evaluate the effect of the new sites on recreational fishing behavior, two catch rate scenarios are specified within the model:

- Scenario 1—no increase in catch rates at the new sites within the hypothetical wind energy, and
- Scenario 2—catch rates increase by 50% at the new sites within the hypothetical wind energy area.

Figure 2.4.8 illustrates the addition of the new sites within the hypothetical wind energy area. Under these Counterfactual scenarios, the model predicts how many more trips would occur to the wind energy area with the changed catch rates and what the increase in recreational angler wellbeing would be with the increased catch rates.

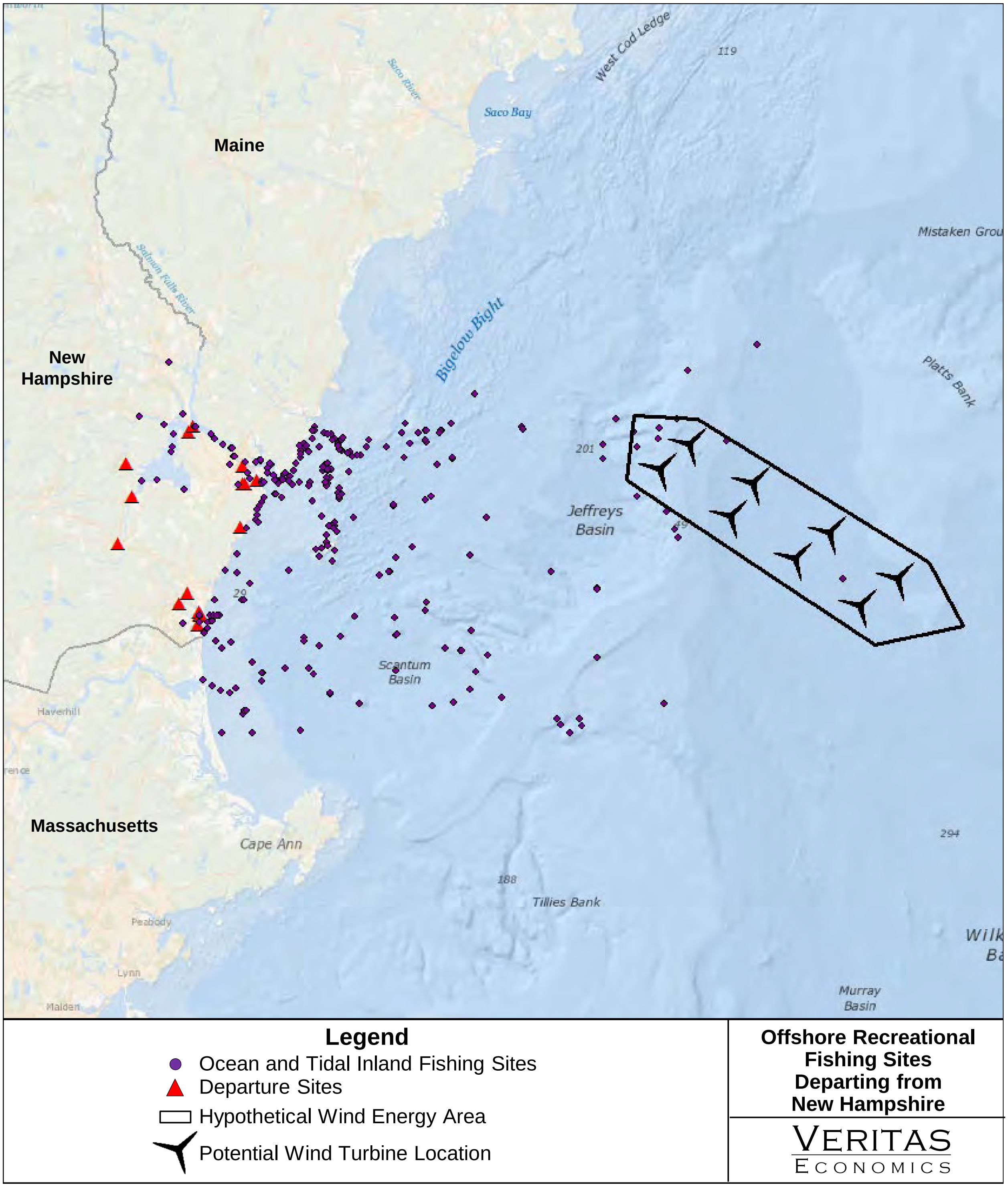

Figure 2.4.8. Recreational boat fishing Counterfactual conditions.

Recreational Fishing Results

Table 2.4.3 presents the Baseline and Counterfactual recreational fishing trips predicted to sites within the hypothetical wind energy area developed for the analysis, and illustrated in Figure 2.4.7 and Figure 2.4.8. The results are presented for each scenario. The annual increases in economic welfare from the creation of the wind energy area range from $0 (Scenario 1) to $2,000 (Scenario 2).

Table 2.4.3. Recreational Fishing Model Results.

Scenario	Annual Baseline Trips	Annual With Wind Energy Area Trips[a]	Annual Welfare Increase
No change in catch rates at the new sites within the hypothetical wind energy area	28	28	$0
50% higher catch rates at the new sites within the hypothetical wind energy area	28	95	$2,000

[a] These are redistributed trips from other sites.

2.5 Insurance

The insurance implications for fishing in offshore wind farms (OWFs) are evaluated in this section. The discussion begins with consideration of insurance in the context of additional risk, followed by a subsection on the outcomes with existing OWFs. As commercial scale offshore wind is limited in the United States the discussion focuses on the condition in Europe. The concluding subsection evaluates important differences across European and United States offshore wind with consideration of the implications for New Hampshire.

2.5.1 Risk Overview

OWFs are subject to Coast Guard safety requirements, however they are a potential hazard to and are themselves subject to being damaged by other ocean users. The primary ways that OWFs could lead to injury and damage are collisions between vessels, collisions between vessels and wind infrastructure, commercial fishing gear entanglement with turbine substructure, and contact between vessel anchors or commercial dragging or dredging gear and electrical cables.

Considering vessel-to-vessel collisions, OWFs may impact navigational lanes and lead to greater congestion. This may occur if ships have less maneuvering space due to turbine placement. This risk applies to vessels of all types traveling in or near OWFs and is exacerbated by inclement weather and rough seas. Vessels at particular risk include those that are unpowered as designed or unpowered due to having mechanical difficulties.

Collisions between vessels and wind infrastructure could occur if vessels are operating near or within wind farms. As with vessel-to-vessel collisions, unpowered vessels and those operating in unfavorable conditions are at highest risk. The potential increased risk could apply to all vessels operating in or near wind farms including commercial fishing and cargo vessels, private and rental recreational boats, yachts, and military vessels. However, commercial fishing vessels are likely to be the most affected as fishing activities are focused in a particular area. As fishing grounds may overlap with wind farms, opportunities for collisions increase. In addition, commercial fishing vessels use gear which could potentially snag on offshore wind infrastructure and increase the risk of collision.

The potential for fishing gear interactions with wind farms depends on the type of gear being deployed. Fixed gear, consists of pots and traps that are baited to attract and capture crabs and lobsters, is placed on the ocean bottom with a rope and buoy connecting it to the surface. This gear type may interact with wind farm substructure due to inclement weather moving the pots or traps from their set positions. Mobile gear such as long lines, purse seines, trawl nets, and dredges rely on vessel movement, and could snag wind farm infrastructure while being actively fished if fishing occurs near or in the wind farm. Trawl nets target demersal and midwater species. The largest of these are towed behind beam trawlers which tow nets from derricks that extend from the sides of the vessel. Sea scallop dredges consist of a steel frame and collection bags made of a mesh of steel rings. These dredges are dragged on the ocean bottom. Like trawls, dredges can be deployed from beams or directly behind a vessel. Clam dredges target surf clams and ocean quahogs using pumped seawater to separate clams from sand. Additionally, lost fishing gear can be transported large distances by tides and currents (Macfadyen et al. 2009) and could become entangled in offshore wind infrastructure even if fishing activities are not occurring near or in the wind farm.

The largest financial risk to offshore wind farm operators arises from damaged electrical cables, which accounted for up to 80% of the total financial losses and insurance claims for the industry globally during the last ten years. Cable failures in the open ocean caused by fishing gears, anchor strikes, and erosion were one of the two main categories of failures (Gulski et al. 2021). The export cable which runs from the wind farm to shore is particularly important. Repair and replacement of this cable requires a specialized vessel and requires bringing the cable aboard and undertaking complex splicing and rejoining which can take months. As disruption of this cable interrupts farm operations, revenue from the entire wind farm is lost during this downtime. Such disruption would occur if a cable became unburied and the unprotected cable was snagged by an anchor or fishing gear. Hydraulic clam dredges, which penetrate seafloor sediments nearly 1 ft below the surface and deeper than other fishing gears, present a challenge to buried cables. If a clam dredge passes through an area several times, this could potentially uncover a cable (Tetra Tech, Inc 2021). Interactions between fishing gear and anchor strikes and buried cables could be reduced by several mitigation measures including cable armoring and burial to target depths of 5 to 6 ft (1.5 to 1.8 m; Tetra Tech, Inc 2021). Floating wind turbines are a developing technology, as a result the potential financial risk of and the amount of potential damage to the dynamic cables is currently not well understood.

No public information about how insurers are thinking about wind farm risks to fishing vessels has been identified. Given that vessel operators and wind farm operators face some of the same risks, wind farm insurance was investigated. Insurance companies and wind developers operate in competitive environments and provide limited information. What is publicly available is regarding insuring wind farm development and operations generally, rather than vessels operating in wind farms, and does not specifically address the insurance implications for other users. For example, Windpower Engineering & Development (2019) contains an interview with an underwriter who insures wind farms and the vessels used to construct and maintain them. Although there is presumably some amount of overlap in risks across developers and other ocean users within wind farms and above cables, this is not discussed.

2.5.2 European Outcomes

Given the limited information available for constructing a forward-looking understanding of the U.S. insurance situation, it is potentially helpful to evaluate European outcomes. European countries began building OWFs more than 20 years ago. When evaluating offshore wind, these countries considered the potential for multi-use conflicts within OWFs and recognized that commercial fishing could be directly affected by access reduction and indirectly affected through impacts to the prices and availability of insurance. Several studies reviewing European insurance outcomes are discussed below.

In one of the earliest studies, Mackinson et al. (2006), reported the investigation findings of the United Kingdom Department for Environment, Food and Rural Affairs (DEFRA) which sought to understand the views of the United Kingdom (UK) fishing industry about wind farm development. Most fishermen were very concerned about their ability to insure their vessels when operating near or within wind farms, suggesting that any accident would result in large increases in insurance premiums or companies declining to provide coverage. Their concerns led fishermen to believe that they "cannot fish within wind farms" and a decision to "avoid fishing in wind farms, even if legal."

Van Hoey et al. (2021) examined wind farm effects on fisheries in the European Union and reported that policy officials, wind farm developers, and fishermen expressed concerns about insurance coverage. These concerns included that fishing in offshore wind farms was risky, that it is very difficult to insure against the risks (e.g., collisions and damage to cables), and anxiety about fishing within wind farm areas for both personal safety and insurance reasons. Depending on the national regulations, fisheries may be banned or may have full or only partial access to OWFs, which may lead to a loss of fishing grounds. Where fisheries are not prohibited within wind farm areas, safety risks and insurance issues appear to make it generally impossible in practice.

Schupp et al. (2021) examined local stakeholder perspectives from two case studies to measure the feasibility of commercial fisheries operating within or near OWFs. The study areas were the German North Sea Exclusive Economic Zone and the east coast of Scotland. Schupp et al. (2021) conducted semi-structured interviews with stakeholders in both Germany and Scotland. The study noted that in both areas the offshore wind industry showed little interest in multi-use solutions unless clear added value was demonstrated and no risks to their operations were involved. Schupp et al. (2021) found that the regulatory frameworks in both cases were missing requirements on multi-use insurance models. This causes steep premiums for indemnity policies for activities potentially dangerous to OWF infrastructure or operations. To overcome this regulatory drawback, the authors recommended that both wind farm developers and fishermen need to be provided comprehensive insurance to protect the other party from potential harm in a multi-use situation. Regulatory intervention and assurance from the regulators and policy makers may be required to make sure the insurance burden on the smaller actor is not disproportionate.

NYSERDA (2022) reported that the Netherlands Enterprise Agency conducted a workshop to understand the potential consequences of future offshore wind development for Dutch fisheries and included insurance companies as stakeholders. In Europe, annual insurance costs during the operational phase of OWFs are considered a significant percentage of the overall operational expenditure. Allowing for safe fishing operations requires creating wider corridors, resulting in larger OWFs or fewer turbines and a probable increase in the cost of insurance policies for both wind developers and fishing industries.

In the United Kingdom (UK), fishing is not excluded from OWFs. However, the European Parliament (2021) stated that "insurance for fishing vessels operating in UK wind farms is very problematic owing to the insufficient indemnity levels offered by fishing vessels' insurance policies." The Fishery Liaison Officer for the National Federation of Fishermen's Organizations, UK, was interviewed about the interactions of UK fishermen with insurance companies and stated that fishermen as well as charter boat operators have expressed fear that the insurance companies will either forbid them from entering an OWF or increase their premiums for doing so. To date, no insurance company has placed any restrictions or increased any premiums on commercial fishermen because of a wind farm in the UK. The liaison officer noted that if it is legal for fishermen to enter an OWF that an insurance company cannot tell a fishermen that they cannot enter the wind farm (Williamson 2022).[16]

Stelzenmüller et al. (2020) cited two examples of fisheries and OWFs working together for coexistence. The UK developed best practice guidelines on coexistence of passive fishing techniques in OWFs. Additionally, insurance companies did not increase prices or restrict certain areas for fishing inside OWFs. However due to uncertainties around safety, gear retrieval, insurance, and liability, the fishing sector is reluctant to fish in the OWFs and therefore is not yet a common practice. Stelzenmüller noted that in Denmark, cooperative organizations for insurance have resolved potential uncertainties regarding insurance. Membership in such insurance co-operative societies is mandatory for all parties involved.

Dupont et al. (2020) conducted a background study and found that static gear fisheries, such as crab and lobster pot fisheries in Scotland and the UK, have been conducted successfully in OWFs. Mobile gear fisheries within European OWFs seem unlikely. The Netherlands Enterprise Agency studied the possibility of mobile gear fisheries in future offshore wind farms and concluded that such fisheries would affect all stakeholders and increase the cost of energy produced by affected OWFs. The authors noted the probable increase in the cost of insurance policies for both industries. The prospect of commercial fisheries coexistence with OWFs could potentially improve with technological developments, implementation of turbines with larger generating capacities, and an increase in the spacing requirement between turbines.

The type of fishing conducted in the OWFs is also important. Dupont et al. (2020) noted that for safety reasons associated with accidental damage and collisions to date, most ships are not allowed to enter the vicinity of a European OWF. These authors also stated that because trawling is the dominant fishing method in Europe, fishing activities whether active or passive are in most cases forbidden within the vicinity of an OWF and their associated subsea cables in Europe.

2.5.3 Implications for New Hampshire and Gulf of Maine

Although this review of European approaches and outcomes does not necessarily foretell United States outcomes, it is instructive. To draw conclusions from Europe, it is helpful to

[16] Several laws in the U.S. cover maritime workers: the Jones Act, Death on the High Seas Act, General Maritime Law, Longshore and Harbor Workers' Compensation Act, Outer Continental Shelf Lands Act, and State Workers' Compensation Law (WorkBoat 2020).

understand differences between the European and U.S. situations. As described in the review, for some European countries, fishing in OWFs is not allowed, meaning that the question of insurance is not addressed. This is currently the case for Belgium and the Netherlands. Denmark and Germany may allow commercial fishing in operational wind farms, but this varies depending on the wind farm. Sweden allows fishing in wind farms but prohibits drift and trawl nets. The UK allows fishing in wind farms, but according to the European Parliament the indemnity offered by insurance companies is insufficient. Insurance shortcomings have also been recognized in Denmark, where cooperative organizations with mandatory membership by all parties is required.

It is instructive to put the aforementioned information in the context of the principles of insurance and GOM fishing activities to draw conclusions about implications for a wind farm in the GOM. The fundamental properties of insurance are underwriting and indemnity. These are multifaceted concepts. For this discussion, underwriting concerns the valuation of expected claims and indemnity concerns the assignment of liability for those claims. To underwrite a policy for fishing in an OWF, an actuary evaluates the probability of a claim and its expected value. Insurance companies operate in competitive marketplaces in which they strive to be profitable; however, in analyzing insurance, it is useful to consider the concept of an "actuarily fair" policy which has a net expected value of zero. As an example, if there is a 1% chance of a $100,000 dollar loss each year, the actuarily fair cost of the policy is $1,000 per year.

Considering indemnity, for the purposes of this evaluation, it is presumed that developers bear responsibility for electric lines and that the primary risk faced by insurers of fishing vessels is from collisions between vessels and turbines. With this assumption, the underwriting implications of insuring fishing vessels are limited to the likelihood of collisions with turbines and the expected damages should a collision occur. An implication is that turbine density should have an important role in underwriting.

Farm by farm information on European turbine spacing is not readily available, however metrics of energy density indicate farms tend to be about 5 MW per square kilometer. As many of the installed turbines have capacities of around 5 MW this indicates that in Europe, there is typically a turbine per square kilometer, meaning that turbines tend to be separated by about 1 km. By comparison, U.S. installations appear likely to have wider spacing, with 1 nm being the spacing for Vineyard Wind and other installations. Given that a nautical mile is 1.852 km, U.S. turbine spacing is nearly double that of European wind farms and each turbine's share of the entire wind farm is 3.43 times larger in the U.S. The implication is the safety situation in the U.S. may be an improvement over Europe, and there are potential insurance implications that should be considered in making comparisons with European outcomes.

From an actuarial perspective, the probability of a vessel collision with a turbine should be lower in the U.S. than in Europe generally given turbine spacing and the specific gear. A potentially offsetting effect arises from the type of turbines that will be deployed. The GOM is deeper than the area where European wind turbines are deployed. GOM turbines are expected to be floating turbines tethered by large cables. There are four floating turbine installations in

Europe (Hywind Scotland, WindFloat Atlantic, Kincardine Offshore Wind Farm, and Hywind Tampen) but limited information is available. The cables that hold these turbines in place spread out from the turbines, making a larger footprint per turbine than a monopile fixed-foundation.

As described in the commercial fishing section (Section 5.2.2), New Hampshire commercial fishing is dominated by lobster, which in 2021 was responsible for $44.2 million in revenue—approximately 91% of the revenue from New Hampshire's total catch. Lobster is caught using fixed gear, traps placed on the ocean bottom. The Scottish Government noted that there are examples of successful coexistence of lobster and crab pot fisheries within offshore wind farms. The Westernmost Rough OWF, which extends from 7.7 km off the coast to 13.3 km offshore (4.78 to 8.26 miles) is cited as providing a good example of effective coexistence and co-operation between static gear fishermen and wind developers (Marine Scotland Science 2022, Roach et al. 2018).

The implications of offshore wind in the GOM for insuring fishing vessels are currently unknown. Commercial vessels are expected to be most affected, but the degree of the affect is difficult to determine ahead of time. Although the European experience indicates that fishing in OWFs is limited and subject to insurance difficulties, this may not be the case for the GOM. The major mitigating factors include differences in turbine spacing and type of fishing. U.S. turbines are expected to be spaced much wider than they are in Europe. Furthermore, in Europe the primary fishing activity is trawling, a mobile gear, whereas in the GOM fishing is dominated by the lobster fishery, which uses lobster pots. The use of fixed gear and smaller, more maneuverable vessels among wider spaced turbines should tend to drive down the risk and cost of collisions. This means that underwriting a blanket insurance policy for lobstering in the GOM may not consider the possibility of collisions.

2.5.4 Recreational Fishing Insurance

In the U.S., only two states require insurance for recreational boats: Arkansas and Utah (Forbes Advisor 2022, ValuePenguin 2022). Additionally, Hawaii requires insurance for boats parked in facilities of the Department of Land and Natural Resources Division of Boating and Ocean Recreation (ValuePenguin 2022). Table 2.5.1 lists boat insurance requirements for Arkansas, Hawaii, and Utah.

Table 2.5.1. Insurance Requirements for Recreational Boats.

State	Insurance Requirements
Arkansas	Liability insurance with at least $50,000 in coverage is required for all boats powered by engines of more than 50 horsepower.
Hawaii	Boats parked in Department of Land and Natural Resources Division of Boating and Ocean Recreation (DOBOR) facilities. Liability insurance with at least $500,000 in coverage is required for all boats parked in DOBOR facilities, including harbors and offshore moorings. The insurance policy must name the State of Hawaii, DOBOR as the “additional insured” or “additional interest.” The policy should cover salvage costs for grounded or sunken vessels, damage to docks, pollution containment and wreck removals.
Utah	Bodily injury/death and property damage insurance are required for all boats powered by engines of 50 horsepower or more. Insured must have at least $25,000/$50,000 for bodily injury/death coverage and $15,000 for property damage or a $65,000 combined minimum per accident. Proof of insurance must be carried onboard the boat whenever it is in operation.

Source: ValuePenguin (2022).

Boat insurance and marine insurance are similar, however, boat insurance covers recreational boaters and marine insurance covers commercial vessels (including commercial fishing vessels, charter boats, tugs and barges, and cruises; FindLaw 2017). Marine insurance policies can also provide additional coverage not found in boat insurance including for nets and gear, cargo protection, pollution liability, and crew coverage. Boat insurance is similar to home or auto insurance and provides coverage for the following:

- Boat liability insurance can cover liability when someone is injured while on the insured’s boat.
- The bodily injury clause covers injuries that the insured causes to others while using their boat (including medical bills and legal expenses).
- The property damage clause covers damage that the insured boat causes to someone else’s property, such as a boat or dock.
- The collision damage clause, similar to property damage, covers the repair or replacement of the insured’s boat if it gets damaged.
- The comprehensive clause covers the insured boat if vandalized, stolen, or damaged in some way other than in a collision.
- The personal property clause covers personal property on board, like fishing gear.
- The uninsured boater clause covers damages and injuries caused by uninsured or underinsured boaters.
- The towing and assistance clause covers the insured with a tow to the docks or other assistance (FindLaw 2017).

A review of insurance company websites (US and international) found no stipulations about boating or fishing activities in or near wind farms.

2.6 Shipping and Navigation

The International Regulations for Preventing Collisions at Sea (COLREGS) apply to navigating offshore waters in the U.S. and abroad. Among its regulations, COLREGS define minimum distance between a shipping route and a wind farm, as well as maintaining safe distance during turning maneuvers near wind farm structures (33 CFR § 167B, USCG 2022, USCG Navigation Center 2022). In U.S. waters, the United States Coast Guard (USCG) has responsibility for maintaining "a safe, secure, efficient and resilient Marine Transportation System" including navigation and traffic separation within offshore WEAs under U.S. regulations and COLREGS. USCG responsibilities include reviewing navigation safety risk assessments for wind energy projects (USCG 2021).

Offshore wind development has the potential to affect shipping and navigation in the GOM. Figure 2.6.1 summarizes the current volume of shipping in the GOM in the vicinity of the Port of Portsmouth using the Automatic Identification System (AIS) data available from Marine Cadastre (2022). The yellow and red shading represents higher levels of vessel traffic (101 to over 1,500 vessels) and the blue shading represents lower levels of vessel traffic (1 to 50 vessels). As Figure 2.6.1 shows, there is a high concentration of vessel traffic directly into and out of Portsmouth Harbor, then the traffic steadily dissipates. The figure also depicts the outline of the hypothetical wind energy area developed to evaluate the opportunities and implications of offshore wind for New Hampshire. As the figure shows, the entirety of the hypothetical wind energy area is located in the lowest level of vessel traffic (1 to 50 vessels).

Figure 2.6.1 also shows various cable and pipeline areas located outside of Portsmouth Harbor (Northeast Ocean Data 2022). The hypothetical wind energy area is located outside the boundaries of these cables and piping. The hypothetical wind energy area does fall within the bounds of an Operating Area (OPAREA) which is periodically used for surface and subsurface military training (Northeast Ocean Data 2022). This OPAREA encompasses a large swath of the GOM stretching from the eastern shores of Maine to off the east coast of Nantucket Island.

The hypothetical wind energy area also falls within the bounds of a Military Range Complex which is a geographic area that is used for training and testing of military tactics, platforms, munitions, explosives, and electronic warfare systems (Northeast Ocean Data 2022). Portsmouth Harbor is also home to the Portsmouth Naval Shipyard located on Seavey Island, ME. The harbor hosts submarine traffic coming to and from the shipyard. Figure 2.6.1 labels the submarine transit lane that funnels into Portsmouth Harbor. The hypothetical wind energy area sits roughly 4 miles from the transit lane at its closest point. The interaction with potential submarine traffic is something that will have to be considered during the siting for an actual location of any offshore wind energy areas in the GOM.

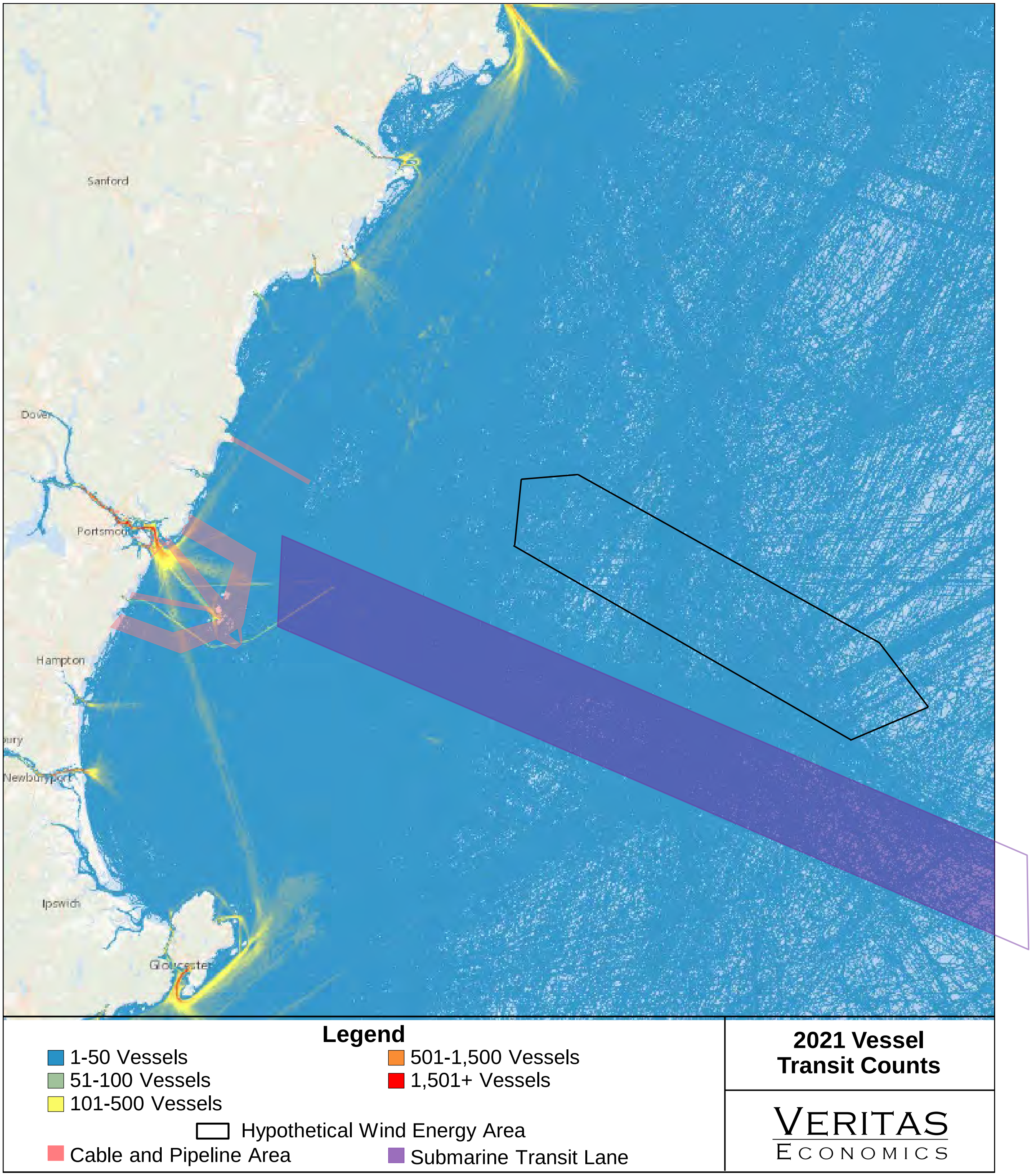

Figure 2.6.1. 2021 Vessel transit counts and navigational constraints in the vicinity of the Port of New Hampshire.

2.7 Aviation and Radar Assets

This section describes the effect that offshore wind development is likely to have on aviation and radar assets. Wind turbines located offshore can interfere with land-based, marine, and aviation radar, and communications (Howard and Brown 2004, Marico Marine 2007, Pizzolla et al. 2010, Ling et al. 2013, Angula et al. 2014). Rawson and Rogers (2015) noted that vessels traveling within 0.45 nm of wind turbines will experience significant impacts upon radar as well as navigational risks.

The National Academy of Sciences (2022) noted that wind turbine generators with blade lengths exceeding 100 meters pose potential conflicts with radar operations supporting air traffic control, maritime commerce, homeland security, national defense, weather forecasting, and other activities relying on this technology for navigation, situational awareness, and surveillance. A particular concern is the impact on marine vessel radar (MVR), which is a widely used, critical instrument for navigation, collision avoidance, and other specialized purposes including small target detection and tracking, especially in low visibility conditions. MVRs are not optimized to operate in the complex environments of a fully populated, offshore wind farm. There is no simple MVR modification that will result in a robust wind turbine generator operating mode (National Academy of Sciences 2022).

Anatec Limited (2021) reported the results of trials at the North Hoyle Offshore Wind Farm (North Hoyle), North Wales, UK. The trials assessed the potential impacts of the wind farm on navigation, communication, and position fixing equipment and identified the following results:

- Very high frequency (VHF) communications: small marine vessels using VHF transceivers for voice communications experienced no noticeable effect within the wind farm. VHF communications used with search and rescue missions were also unaffected. Since the trials at North Hoyle, no significant effects with VHF communication have been observed or reported in relation to UK wind farm projects.
- VHF direction finding equipment in trial boats did not function correctly within 50 m (164 ft) of wind turbine generators (WTGs). However, there is limited use of VHF direction finding equipment. Search and rescue missions using VHF for a radio homer system had no adverse effects.
- The trials at North Hoyle revealed no significant impact on transmitting and receiving antennas of an automatic identification system (AIS).
- The Navigational Telex (NAVTEX) system is used for maritime safety in the U.S. and international waters. Although NAVTEX tests were not undertaken at North Hoyle, no significant effect on NAVTEX has been noted at operational sites.
- Global positioning system (GPS) trials also were undertaken at North Hoyle, and no problems with basic GPS reception or positional accuracy were reported.
- Marine radar tests at North Hoyle identified potential impact on marine and shore-based radar systems because of large vertical extents of WTGs. The extents can produce interfering side lobes and reflected echoes (also called false targets or ghosts). Additional tests at the Kentish Flats Offshore Wind Farm and modeling for a proposed wind farm

in the UK also found that WTGs affect marine radar. However, mariners have become increasingly aware of radar effects and can mitigate them by careful adjustment of radar controls. There is a resulting risk of losing targets with a small radar cross section including buoys or small craft.

- A study associated with the Cape Wind Project in the U.S. found that spacing between WTGs influences the frequency of side lobe effects.
- Larger WTGs (in height or width) have more effects on radar by returning greater target sizes or stronger false targets.
- Vessels transiting within 1.5 nm of a wind farm experience radar interference as shown within the Galloper and Greater Gabbard wind farms in the UK (Anatec Limited 2021).

Colburn et al. (2020) used the WindTRx simulation model to conduct line of sight (LOS) and interference analysis for eight wind farms in planning stages or future scenarios (Skipjack, South Fork, Grand Strand, Mayflower, Vineyard Wind, Bay State Wind, Ocean Wind, and Empire Wind) and four major radar types, as well as a test case cumulative scenario for Rhode Island and Massachusetts. As part of their analysis, the following radar types were evaluated:

- Airport Surveillance Radars (ASR)—The ASR-8 and ASR-9 series of radars are the primary air traffic control system for the airspace surrounding airports.
- Air Route Surveillance Radars (ARSR)—The ARSR-4 is a long range, L-band radar used by the Federal Aviation Administration (FAA) and Department of Defense (DOD) to monitor airspace on and around the U.S. border.
- NEXt-generation RADars (NEXRAD)—The NEXRAD S-band pulse-Doppler weather surveillance radar supports the weather assessment, forecast, and warning missions of the National Weather Service (NWS), the FAA, and the DOD.
- SeaSonde Radars—These high frequency (HF) radar systems measure coastal ocean currents. SeaSonde radars work individually or in a network with nearby systems. They are unique to the coastal environment (Colburn et al. 2020).

Colburn et al. (2020) found that the proposed and hypothetical wind farms are within LOS of 36 radar systems and will generate interference to these radars under normal atmospheric conditions. SeaSonde radars were the type of radars most affected, due to their large number along the Atlantic coast. The study also found that atmospheric ducting may cause a wind turbine to be observed by radar when it otherwise would not be, potentially causing interference with the radar signal. Atmospheric ducting is a phenomenon that alters how electromagnetic waves propagate through the atmosphere by refraction causing them to extend well beyond their normal range. The conditions that lead to ducting occur along the U.S. Atlantic coast approximately 10 - 30% of the time, on average. Radars that are not in LOS of offshore windfarms under normal atmospheric conditions can become impacted during ducting events.

MARICO Marine (2007) reported on the data collection of observed effects on ship's radar when navigating near the Kentish Flats Offshore Wind Farm (Kentish Flats), UK. The project collected the following data and information: sets of radar recordings taken from a range of vessels, including fishing and recreational vessels; recorded information from experts, such as pilots, masters, and navigating officers; used a survey vessel to provide a controlled small target around and within Kentish Flats in conjunction with some of the observed voyages; data from the Port of London Authority's vessel traffic services; and comments from mariners and project observers. MARICO Marine concluded that:

- Mariners passing Kentish Flats were aware of the effects on radar, but they felt little concern in the conditions of these trials.
- The phenomena detected on marine radar displays near a wind farm can be produced by other strong echoes nearby, although not necessarily to the same extent. Trained mariners are expected to recognize and understand the causes of these effects.
- Reflections and distortions caused by ship structures and fittings created many of the observed effects. Strong radar returns from Kentish Flats highlighted vulnerabilities in ships' radar scanner installations.
- Observed effects were transitory in relation to the speed of the vessels passing the wind farm.
- Ship structures and fittings combined with the reflecting qualities of the turbines frequently generated spurious echoes.
- The inherent limitations of marine radar systems combined with the reflecting qualities of the turbines produced the other effects.
- In the study's investigation trials, navigators were able to effectively track other vessels within and behind Kentish Flats.
- Ships operating near Kentish Flats were able to detect selected small craft operating in and near the wind farm by radar. The radar return signals appeared to be relatively unaffected by passing through the array, although normal or automatic gain levels could obscure very small targets.
- Echoes of small craft within a wind farm can merge with strong echoes generated by the turbines when the craft passes close to them, making the small craft invisible to automatic plotting facilities or radar observers. This effect is temporary and lasts until the craft moves away from the turbine.
- When small craft and other vessels were both operating within Kentish Flats, the small craft were less detectable by the radars of the other vessels. This may be attributable to enhanced effects from the close approach to the turbine towers and the reflective effects caused by them. Carefully adjusting of the radar gain level could improve detection, however the operator must be skilled.
- The quality of the returned echo of a buoy used as a reference target by project observers was not adversely affected regardless of vessel position.
- Pilots were aware of possible interference, but most did not analyze it closely.
- Commercial cargo vessels particularly are fitted with radar scanners that may not be optimally sited in relation to obstructions onboard the vessel and other considerations.

- AIS-equipped vessels did not lose signal either outside or within Kentish Flats.

The U.S. Department of Energy WINDExchange noted that coordination with the U.S. DOD, FAA, Department of Homeland Security, and NOAA during the siting process for a wind farm can prevent radar interference issues before a wind farm is built (WINDExchange 2022a). For example, during the siting process, developers must apply through the FAA's Obstruction Evaluation/Airport Airspace Analysis process that identifies the potential of radar interference from a proposed wind farm (WINDExchange 2022b). The siting process can also identify mitigation techniques, such as adjusting the location of the turbines to minimize effects on radar. As shown in Figure 2.4.8 and Figure 2.6.1 of this report, the majority of commercial and recreational fishing vessels are not expected to travel within the potential area of a wind farm located in GOM waters off the New Hampshire coast. Mitigating radar effects on fishing vessels traversing in or near a wind farm can include deploying radar-related software upgrades or hardware (WINDExchange 2022a).

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3 Energy Sector and Energy-Related Economic Impacts

The effects of offshore wind development on the energy sector are evaluated in this section of the report. It begins by describing the power system modeling that Veritas conducted. Consistent with New Hampshire requests, the model specification reflects the cumulative projected activities of ME, MA, RI, CT, NY, and NJ, clean energy requirements of ME and MA, and licensing status of the Seabrook Station Nuclear Power Plant (NH G&C 2022).

The cumulative activities of other states include many gigawatts of offshore wind generated electricity coming from waters southeast of RI and MA. Renewable electricity from the GOM has a different wind speed profile and tends to be both competitive with (i.e., in development and generation costs) and complementary to wind electricity from the waters southeast of RI and MA. Modeling results indicate planned offshore wind and carbon dioxide (CO_2) reduction goals result in substantial electricity shortfalls. As requested by New Hampshire, these shortfalls are evaluated in the context of storage and emission-free energy sources. The final section evaluates implications for New Hampshire procurement including subsidies and interconnection capabilities (NH G&C 2022).

3.1 Power System Modeling Background

Electricity generated from offshore wind is delivered to onshore power systems. In the case of power generated from an offshore wind farm near New Hampshire, any resulting grid-tied electricity would come ashore, and interconnect in either Maine, New Hampshire, or Massachusetts. As Figure 3.1.1 depicts, the electrical grid in these states along with Connecticut and Rhode Island are part of a regional transmission organization known as the Independent System Operator New England, Inc. (ISO-NE). ISO-NE is an independent, not-for-profit company authorized by the Federal Energy Regulatory Commission (FERC) to perform grid operation, market administration, and power system planning for the region.

The introduction of offshore wind will have substantial implications for the operation of ISO-NE. Veritas evaluated the potential power system effects of offshore wind development for New Hampshire using its Electricity Policy Simulation Model (EPSM; Veritas Economics 2011). EPSM is a sophisticated electricity modeling system that has been applied in several national analyses and scores of peer-reviewed, plant-specific studies.

EPSM is populated with data from the U.S. Energy Information Administration (EIA) and the Emissions & Generation Resource Integrated Database (eGRID). The EIA data provide all of the generating units in ISO-NE. eGRID provides annual data on power plant generation and emissions and is available on the EPA's website (eGRID 2022). The eGRID data are organized by year, state, and plant. EPSM uses the following two specific eGRID data sources:

- The most recent unit year data, which gives readings for individual units of a plant, and
- The most recent generator year data, which gives readings for generators in each plant.

The Unit dataset provides unit descriptors, the unit's operational status, the primary fuel type, annual readings of heat input in MMBtus, annual nitrogen oxide (NOx) emissions in tons, annual sulfur dioxide (SO_2) emissions in tons, and CO_2 emissions in tons. The Generator dataset provides the same descriptor variables, as well as the generator nameplate capacity in megawatts, generator capacity factor, and generator annual net generation in megawatt hours (MWhs). Finally, state-level data are combined for New Hampshire, Maine, Vermont, Massachusetts, Connecticut, and Rhode Island to represent the generation of all the operating units in ISO-NE.

EPSM solves at the hourly level by dispatching thermal units to most cost effectively meet the load anticipated for each hour of a year. Operating EPSM to evaluate policy and strategy decisions requires specifying scenarios that represent possible generation systems. In this case, a Baseline scenario that represents expected ISO-NE operations through 2035 based on known carbon and renewable targets and plans, nuclear retirements, and expected load growth. It also includes a Counterfactual scenario in which an offshore wind farm is constructed off the coast of New Hampshire in the GOM and becomes operational in 2033. Comparisons of system reliability and economic outcomes across the two scenarios are used to evaluate the power system implications of New Hampshire offshore wind development. It is important to note that transmission constraints are not included in the EPSM.

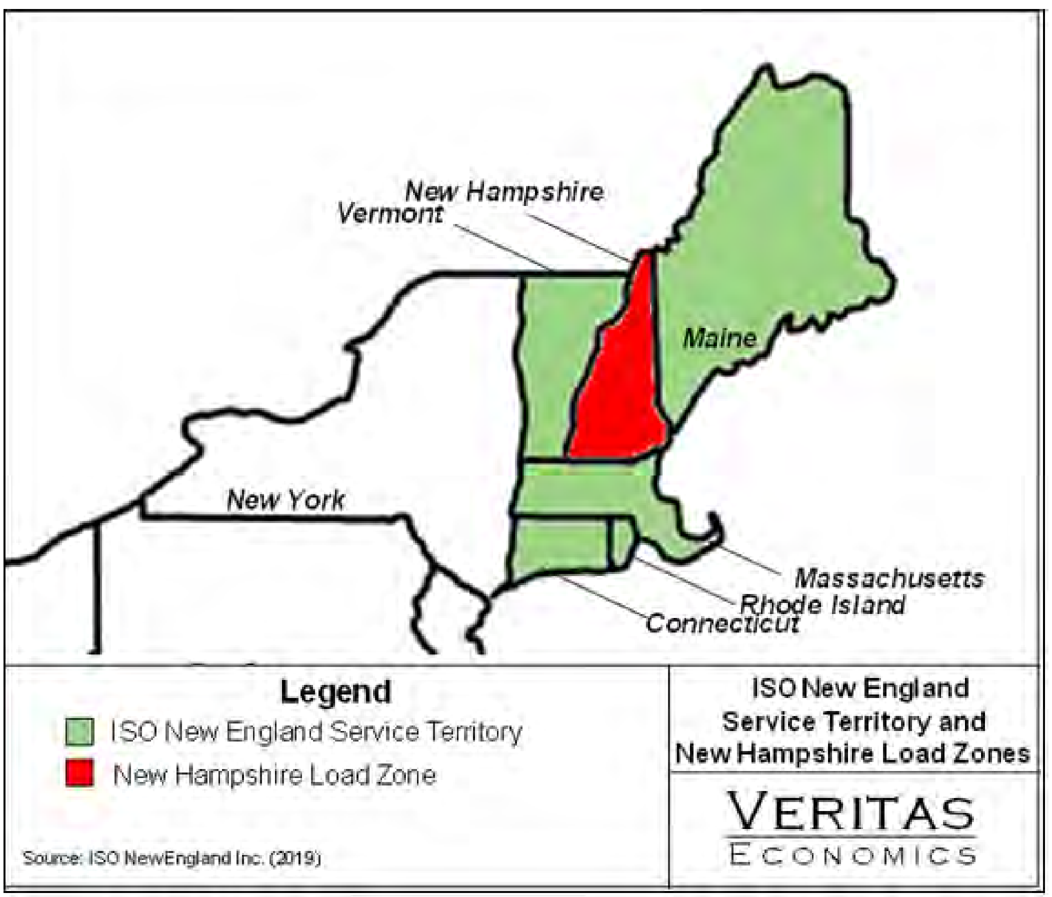

Figure 3.1.1. **ISO New England service territory.**

3.2 Baseline Power System Model

The Baseline power system model consists of a representation of demand and supply conditions over time. For this evaluation, the period selected for evaluation is 2023 through 2035. This period is suitable for representing the completion of all planned wind farms off the southeastern coast of Massachusetts and Rhode Island, evaluating progress toward state level emission reduction goals, and modeling the implications of a nuclear license termination in the Baseline model. Additionally, the Baseline model and Counterfactual model temporal dimensions must match, this timeframe is sufficient for representing the development of offshore wind in the GOM enabling comparisons between the two scenarios. This subsection describes the Baseline demand specification and the Baseline generation supply across generation categories of nuclear, renewable, and fossil powered plants.

3.2.1 Baseline Demand

Baseline demand is specified as hourly load net of home solar and expected efficiency improvements for ISO-NE. Figure 3.2.1 presents the 2023 hourly load specified in the analysis.

EPSM incorporates the best information on future expected energy demand for the ISO-NE states. Based on ISO-NE's 2022 10-year Capacity, Energy, Loads, and Transmission (CELT) forecast (ISO-NE 2022a), electricity use is projected to increase 1.8% per year over the next 10 years from 140,536 gigawatt-hours (GWh) in 2022 to 164,965 GWh in 2031. Figure 3.2.2 presents the predictions from ISO-NE's CELT forecast.

The CELT forecast also produces the following projections for summer and winter peak demands, the measure of the highest amount of electricity used in a single hour, under typical and extreme weather conditions (ISO-NE 2022a):

- Summer peak demand under typical summer peak weather conditions is projected to increase 0.7% a year over the next 10 years from 27,743 MW in 2022 to 29,519 MW in summer 2031 (Figure 3.2.3).
- Summer peak demand under above-average summer peak weather conditions, such as might occur under an extended heat wave, increases peak demand to 29,472 MW in 2022 and 31,336 MW in 2031.
- Winter peak demand under typical winter peak weather conditions is projected to increase by an average of 1.8% a year over the next 10 years from 22,031 MW in the winter of 2022–2023 to 25,880 MW in the winter of 2031–2032.
- Winter peak demand under more extreme winter peak weather increases peak demand to 22,717 MW in the winter of 2022–2023 and 26,725 MW in the winter 2031-2032.

Hourly load consistent with the most recent historical hourly patterns and the CELT forecast of gross and peak load for the period 2023 to 2033 were developed. Figure 3.2.4 depicts modeled hourly load for 2033.

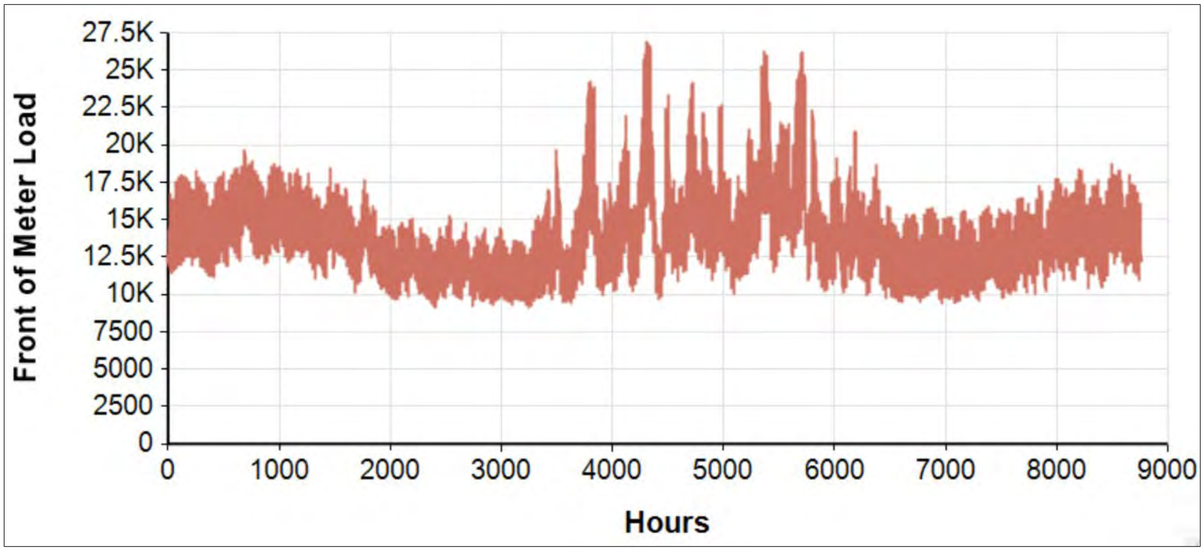

Figure 3.2.1. ISO-NE modeled hourly load for 2023.

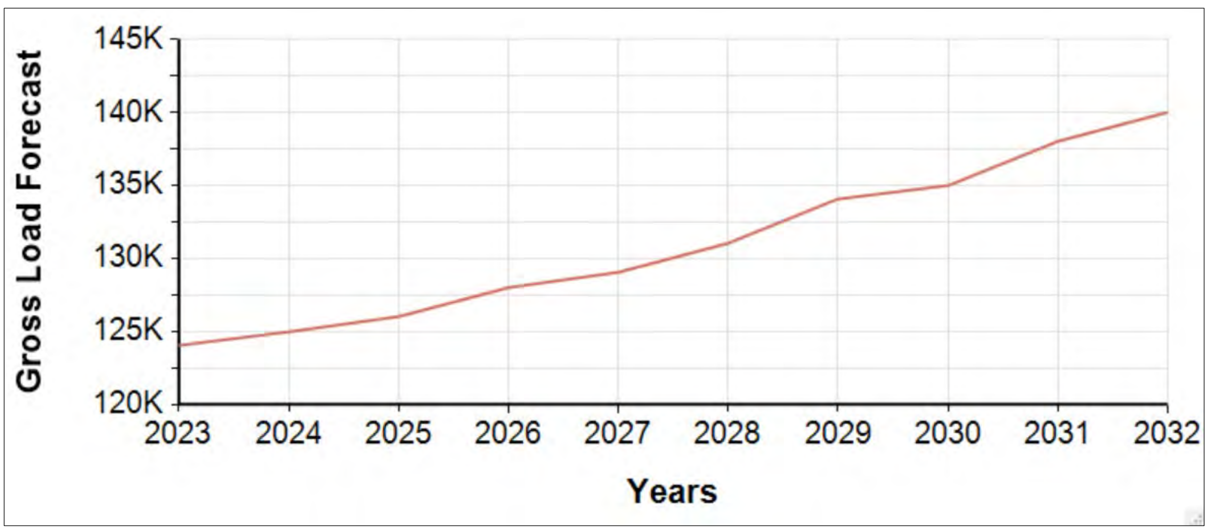

Figure 3.2.2. Annual gross load forecast from ISO-NE's 2022 CELT Forecast.

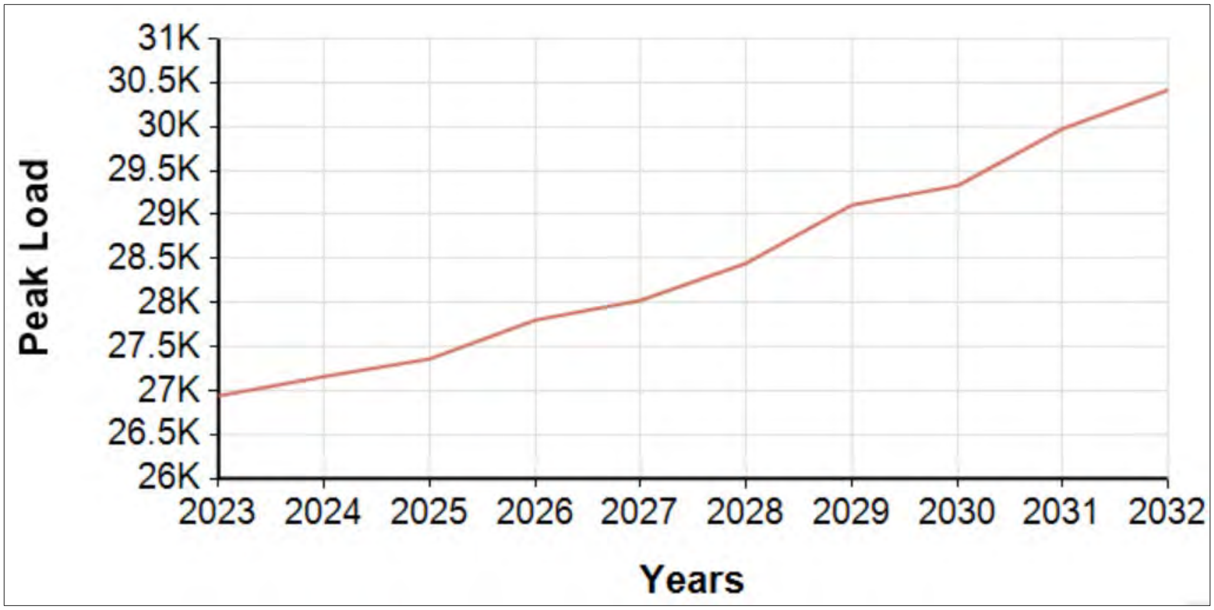

Figure 3.2.3. Projected summer peak load ISO-NE's 2022 CELT Forecast.

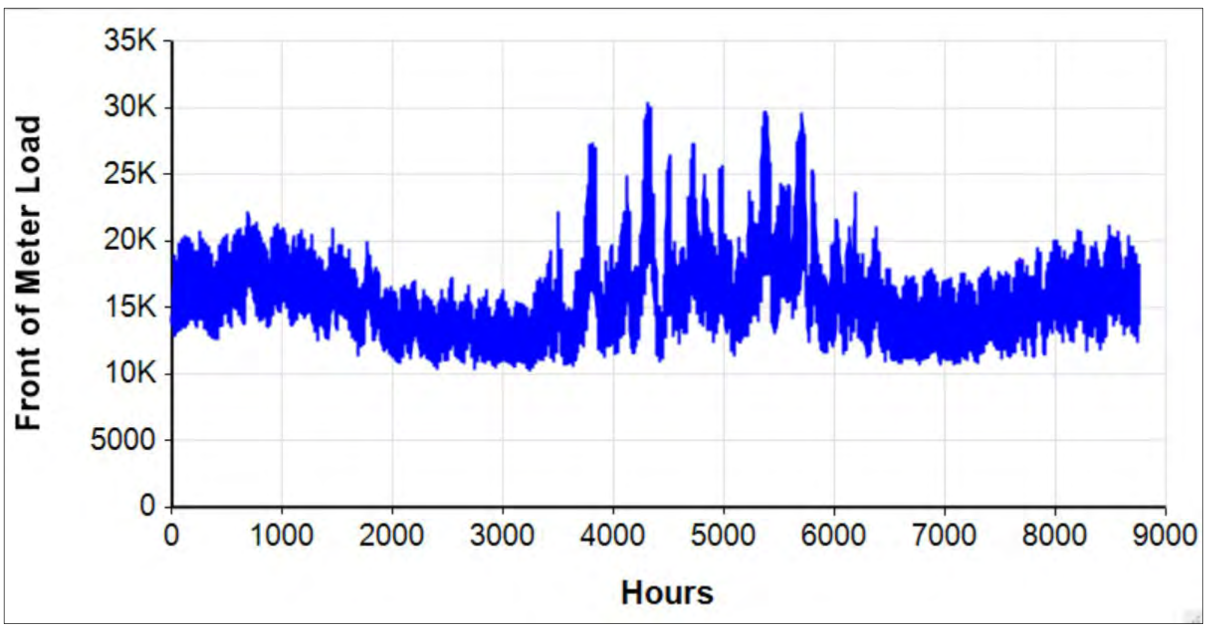

Figure 3.2.4. Baseline demand 2033.

3.2.2 Baseline Supply – Clean Energy Targets

Maine, Rhode Island, Connecticut, Vermont, and Massachusetts all have emission reduction targets that will impact the makeup and operation of ISO-NE. Table 3.2.1 presents the clean energy requirements for Maine, Massachusetts, Connecticut, Rhode Island, and Vermont.

These targets are accounted for through the modeled closure of fossil plants and introduction of renewables. Fossil plant closures render them unavailable for operation and therefore unable to emit CO_2. Renewable plants (e.g., solar and onshore wind) outcompete fossil generation in the least cost dispatch framework and result in a reduction in fossil generation that increases as more renewable generation is introduced. The approach for handling fossil fuel plant closures and introducing new renewables is covered in the following subsection.

Table 3.2.1. Clean Energy Requirements for Maine and Massachusetts.

State	Clean Energy Requirement
Massachusetts	Net zero by 2050
	80% renewable electricity production by 2050
Maine	100% reduction in greenhouse gases by 2050
	Carbon neutral by 2045
Connecticut	100% of electricity produced by renewable sources by 2040
Rhode Island	100% of electricity produced by renewable sources by 2030
Vermont	90% of electricity produced by renewable sources by 2050

Source: 2021 Economic Study: Future Grid Reliability Study Phase 1 (ISO-NE 2022a)

3.2.3 Baseline Supply – Fossil Fuel Plants

New England fossil fueled plants are expected to see closures for economic and carbon pollution regulatory reasons. To account for this, the Baseline model is specified such that retirements occur for the year in which they are requested. Retirements go through 2026 and are in Table 3.2.2 below.

For 2027 through 2035 there is no list of retirements. To keep Maine, Massachusetts, Connecticut, Rhode Island, and Vermont on a path to meet the clean energy requirements in Table 3.2.1, additional fossil-fueled units in the model were retired. Within the model, generation costs are calculated as the product of projected fuel cost and heat rate. Smaller, more costly units were retired earlier than large, less expensive units. Retirements were specified to maintain an even, downward trajectory of CO_2 emissions.

Table 3.2.2. Retirements through 2026.

Resource Name	Relevant FCA Summer QC (MW)	Effective Retirement Date
Pawtucket Power	53.805	6/1/2023
GRS-Fall River	3.028	6/1/2023
Covanta Haverhill Landfill Gas Engine	1.040	6/1/2023
CDECCA	51.685	6/1/2024
Cleary 8	24.825	6/1/2024
West Springfield 3	94.276	6/1/2024
Cherry 10	1.900	6/1/2024
Cherry 11	1.900	6/1/2024
Coventry Clean Energy	3.688	6/1/2024
Coventry Clean Energy #4	2.795	6/1/2024
Doreen	16.600	6/1/2025
Rutland 5 GT	7.919	6/1/2025
Woodland Road	15.962	6/1/2025
West Springfield 10	17.143	6/1/2025
West Springfield GT-1	38.873	6/1/2025
West Springfield GT-2	39.000	6/1/2025
Vergennes 5 and 6 Diesels	3.934	6/1/2026

3.2.4 Baseline Supply – Renewables

Currently existing renewable generation resources are specified in EPSM. These resources are specified to continue to exist and to produce electricity over the evaluation period. New renewables are specified to be solar, onshore wind, and offshore wind. New solar generation capacity is based on ISO-NE CELT forecasts of photovoltaic resources and the historical ISO-NE hourly solar generation profile (ISO-NE 2022a). Based on ISO-NE projections, solar capacity is specified to increase by 7,397 MW by 2035. New onshore wind generation capacity is based on ISO-NE CELT forecasts of onshore wind resources and the historical ISO-NE hourly wind generation profile (ISO-NE 2022a). Based on ISO-NE projections, onshore wind capacity is specified to increase by 1,805 MW by 2035. New offshore wind generation is based on existing project plans. Currently, there are six projects in various stages of planning and development including Revolution Wind, New England Wind, SouthCoast Wind[17], Beacon Wind, Vineyard Wind, and Bay State Wind. The locations of these planned wind farms are depicted in Figure 3.2.5.

[17] On August 29, 2023, the developers of SouthCoast Wind announced an agreement to pay $60 million to Massachusetts' three leading utilities to terminate the existing power purchase agreements. SouthCoast Wind plans to rebid the project in the Massachusetts' next offshore wind procurement (Mohl 2023).

Although wind developers make planning level projections for wind farm specifications, the exact nature of a particular wind farm tends to evolve, and some information is typically held as proprietary. This means that certain information such as site-specific wind speeds and the number and type of turbines used in any given project are not known. Moreover, wind is an inherently variable resource and even projections with precise design and historical wind speed information will only approximate realized electricity output from a particular wind farm.

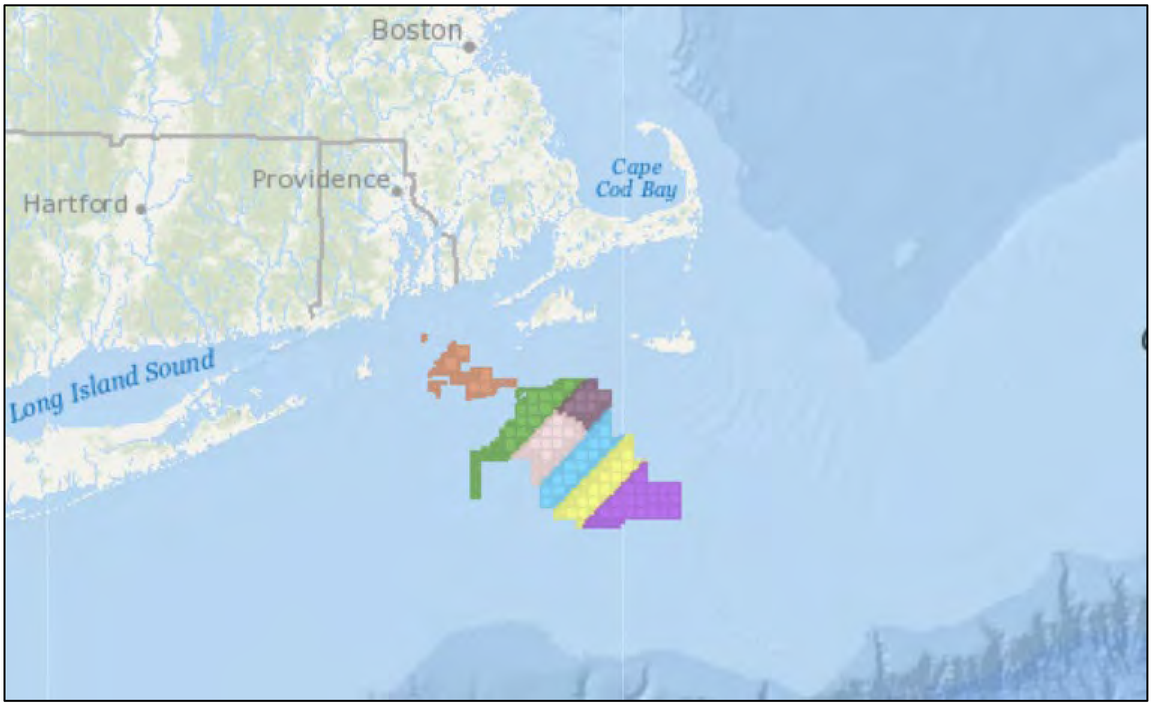

Figure 3.2.5. Planned ISO-NE offshore wind.

New generation from offshore wind used in modeling the New England power system within EPSM is estimated based on calculations from the best currently available public information. Input information includes the number of towers, their blade length and efficiency, air density and estimated hourly wind speeds. This information is used to calculate the swept area of each turbine. Combined with capacity limitations and hourly wind speed, this is used to estimate output from each turbine. Example hourly wind speeds are shown in Figure 3.2.6.

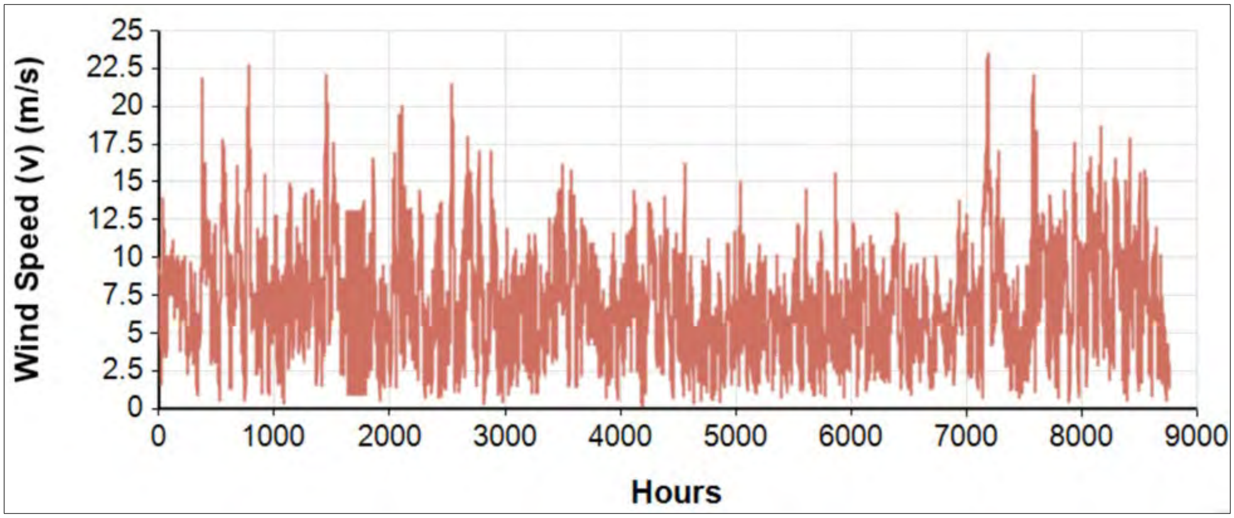

Figure 3.2.6. Example hourly wind speed.

Hourly wind speeds are specified based on hourly wind profiles and annual average wind speeds from NOAA.[18] As annual average winds speeds are more widely available than hourly wind profiles, these two NOAA sources are combined. Hourly windspeeds for each wind farm are based on the five-year average of the nearest site with hourly wind speeds scaled by the relative five-year average of that data and the nearest site with annual average information.

Air density is specified at 1.225 kg/m^3 and efficiency is specified at 50%. With specified turbine features and meteorological conditions wind speeds are converted to electricity output for each turbine. For example, with air density specified at 1.225 kg/m^3, efficiency of 50%, a 109-m blade, and a 12 MW capacity, the wind profile of Figure 3.2.6 returns the electricity output of Figure 3.2.7.

The number of towers and their size is based on judgement and public information using the midpoint of expected number of turbines and the maximum turbine size in public information. For example, if public information such as a Construction and Operation Plan indicates between 60 and 80 turbines with capacity of either 10 or 12 MW the wind farm is specified to have 70 turbines of 12 MW each.

Table 3.2.3 depicts the information specified for each wind farm in EPSM.

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[18] Hourly data are from National Oceanic and Atmospheric Administration National Data Buoy Center. 2022a. Recent data. [accessed 2022 December multiple dates]. https://www.ndbc.noaa.gov/. Annual average data are from National Oceanic and Atmospheric Administration National Data Buoy Center. 2022b. Historical NDBC data. accessed 2022 December multiple dates]. https://www.ndbc.noaa.gov/historical_data.shtml.

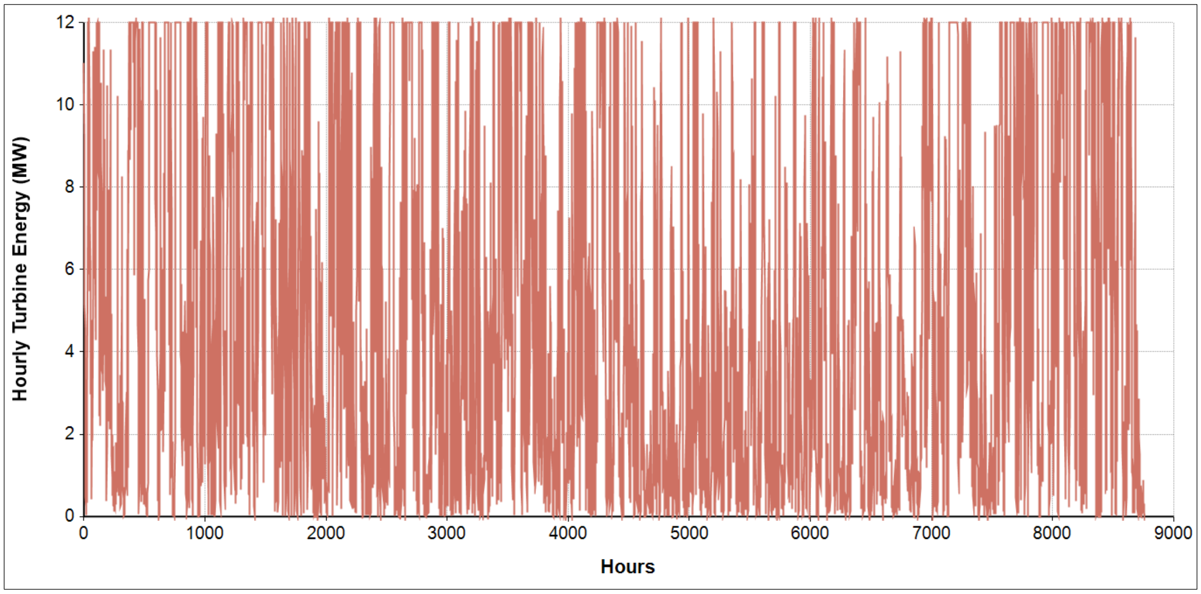

Figure 3.2.7. Single turbine estimated generation.

Table 3.2.3. Planned ISO-NE Offshore Wind Information Used in EPSM.

Wind Farm	Turbines	Capacity (MW)	Year Online
Bay State Wind	110	1,000	NA[a]
Beacon Wind	NA[a,b]	1,230	2028
Commonwealth Wind	64–88	1,232	2028
Park City Wind	41–62	804	2027
Revolution Wind	100	704	2025
SouthCoast Wind	149	804	2025
Vineyard Wind	106[c]	800	2023

[a] NA indicates that this information is currently unavailable from public sources.

[b] At the time of modeling this data was unavailable, currently information indicates up to 155 wind turbines.

[c] Since the completion of modeling, new project information indicates only 62 wind turbines will be used to generate 800 MW of electricity.

With information specified as described in Table 3.2.2, and per turbine output calculated, the total output from the offshore wind farms is calculated, summed, and added to the appropriate year and hour of generation for ISO-NE. Electricity from offshore wind is added in the load specification cumulatively across generators and time. Figure 3.2.8 depicts the total additional wind generation in 2029 from the new resources of

Table 3.2.3 using this process.

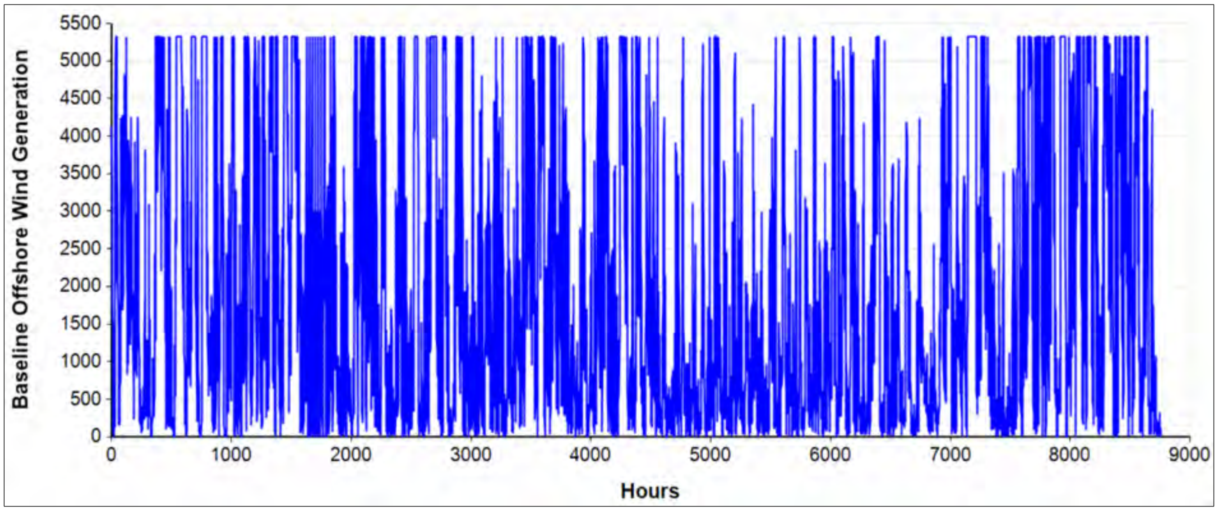

Figure 3.2.8. Specified generation from all planned New England wind farms 2029.

3.2.5 Baseline Supply – Nuclear

ISO-NE has two nuclear plants. Nuclear power plants that operate in the United States are licensed by the Nuclear Regulatory Commission (NRC). For a plant to obtain this license, they must complete one of two licensing processes. The original licensing process permits the plant to operate for 40 years. After operating for 40 years, the license can be renewed in 20-year increments. During the renewal process, the plant is subject to NRC inspection, environmental impact reviews, and verification of aging effects calculations and/or analyses to ensure the plant can continue to operate safely during the renewal period.

The first NRC operating license in the United States expired in 2009; more than 40% have expired. As of January 2022, the NRC has renewed the operating licenses of 94 commercial nuclear reactors. Thirty-five reactors are operating within their initial 40 years of operation, while one reactor with a renewed license shut down before reaching 40 years of operation. Fifty-eight reactors have entered their extended period of operation, with eight of these reactors having since ceased operations (NRC 2022). The decision to seek license renewal is strictly voluntary and nuclear power plant owners (i.e., licensees) must decide whether they are likely to satisfy NRC requirements and whether license renewal is a cost-effective venture (NRC 2020).

NextEra Energy Seabrook Station (Seabrook Station) and Millstone Nuclear Station (Millstone) are the two nuclear stations operating in ISO-NE. Seabrook is located on 900 acres on the New Hampshire coast approximately 13 miles south of Portsmouth. Seabrook Station began operation in August of 1990. In March of 2019, the NRC accepted Seabrook's first license renewal application. Seabrook Station's operating license is now extended to March 15, 2050. Millstone is located in Waterford, Connecticut approximately 3 miles Southwest of New London. Millstone's began operation of Unit 1 in 1970. In 1975 and 1986 the plant added two additional units to the facility. In 1996, Unit 1 was permanently shut down by the NRC for safety violations. Units 2 and 3 were allowed to continue operation. In 2005, the NRC accepted Millstone's first license renewal application which extended operations of Unit 2 until 2035 and operations of Unit 3 until 2045.

NextEra Energy Seabrook Station

Seabrook Station is a 1,242 MW nuclear station operating in ISO-NE. It is located on 900 acres on the New Hampshire coast approximately 13 miles south of Portsmouth. Seabrook Station began operation in August of 1990. In March of 2019, the NRC accepted Seabrook Station's first license renewal application, and its operating license is now extended to March 15, 2050.

The plant is comparatively inexpensive to run but it is not flexible. Given its low cost and low flexibility, it is most economic to run as much as possible. Seabrook Station is included in the EPSM Baseline scenario running at its historic baseload capacity through the entire time period of the analysis. Given the generation shortfalls associated with the renewable energy goals of the ISO-NE states, current planning should anticipate a second license renewal application for Seabrook Station.

3.2.6 Projected Activities of ME, MA, RI, CT, NY, and NJ

As part of evaluating the energy sector and energy-related economic impacts of offshore wind development in New Hampshire, the power system modeling included the projected activities of Maine, Massachusetts, Rhode Island, Connecticut, New York, and New Jersey as part of the EPSM Baseline specification. The Baseline specification includes the plans for future electricity generation in each state by fuel source.

3.2.7 Impact of Clean Energy Requirements in ME and MA

In addition to Maine and Massachusetts, Rhode Island, Connecticut, and Vermont all have emission reduction targets that will impact the makeup and operation of the ISO-NE. The EPSM Baseline specification includes the clean energy requirements for each these states to evaluate the implication those requirements have for offshore wind development in New Hampshire under the model's Counterfactual specification.

3.2.8 Consideration of Potential Cumulative Effects

To evaluate the energy sector and energy-related economic impacts of offshore wind development in New Hampshire, the power system modeling requires the specification of Baseline and Counterfactual scenarios. Comparisons of system reliability and economic outcomes across the two scenarios provide the power system implications of New Hampshire offshore wind development. To evaluate the implications of cumulative effects, the Baseline specification includes the requested and economic shutdowns of model generators; projected generation by fuel source; and clean energy requirements in Maine, Massachusetts, Rhode Island, Connecticut, Vermont, New York, and New Jersey. The evaluation of cumulative effects also includes many gigawatts of offshore wind generated electricity coming from waters southeast of Rhode Island and Massachusetts. The electricity from offshore wind is added in the load specification cumulatively across generators and time.

3.2.9 Baseline Outcomes

With all the Baseline conditions specified as described, EPSM is operated to meet load at minimum cost under existing Baseline conditions. Operating the model under these Baseline conditions produces by state CO_2 emissions depicted in Figure 3.2.9. As the figure indicates, some New England states experience substantial reductions in CO_2 emissions over time. State level emissions are estimated as the total emissions from all of the electricity generators operating in an individual state. As New Hampshire does not currently have a CO_2 reduction target, its existing plants operate more in the future increasing CO_2 output. In the states with CO_2 reductions, the reductions occur because of closures of fossil fueled plants with planned closures, the introduction of offshore wind, and the previously described analyst specified closures employed for consistency with state CO_2 emissions reduction targets (Section 3.2.3 Baseline Supply—Fossil Fuel Plants above).

An important feature of this result is that achieving CO_2 reductions requires including a significant amount of dispatchable, emission-free electricity. The emission-free, dispatchable generation required by year is depicted in Figure 3.2.10. As this figure indicates, the reduction in fossil generation is offset by the emission free dispatchable resources allowing reductions in CO_2. However, with the closure of Millstone 2 in 2035 there is a substantial increase in the required amount of emission-free dispatchable generation. Hourly output for the emission-free, dispatchable generation is shown in Figure 3.2.11.

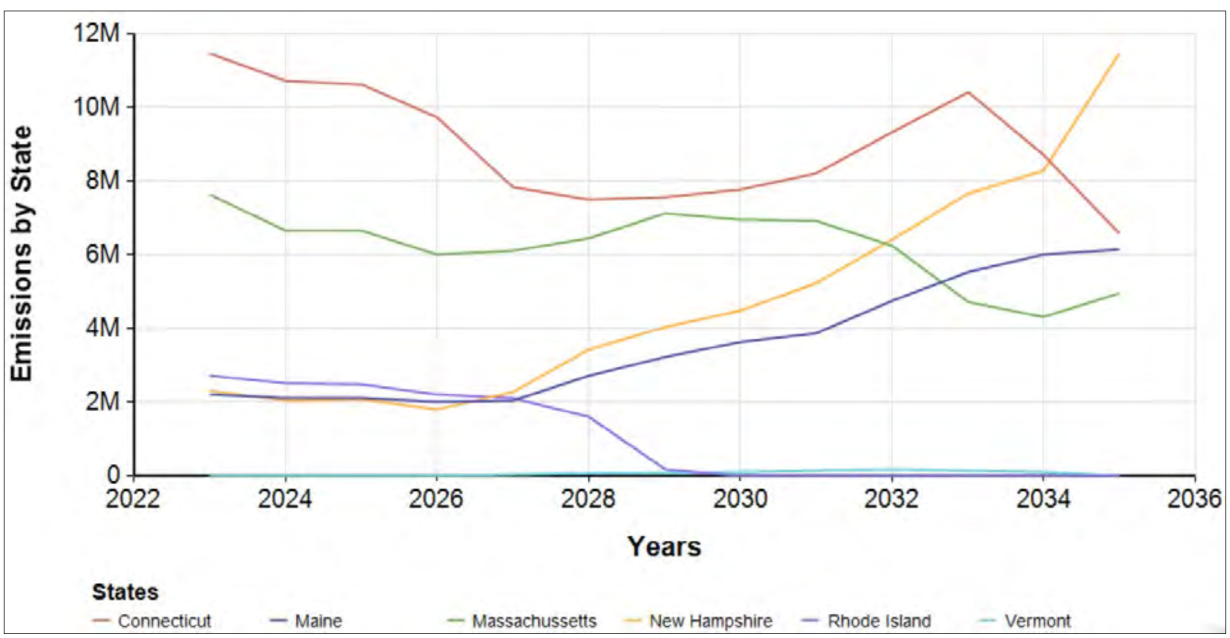

Figure 3.2.9. Baseline CO_2 emissions by state.

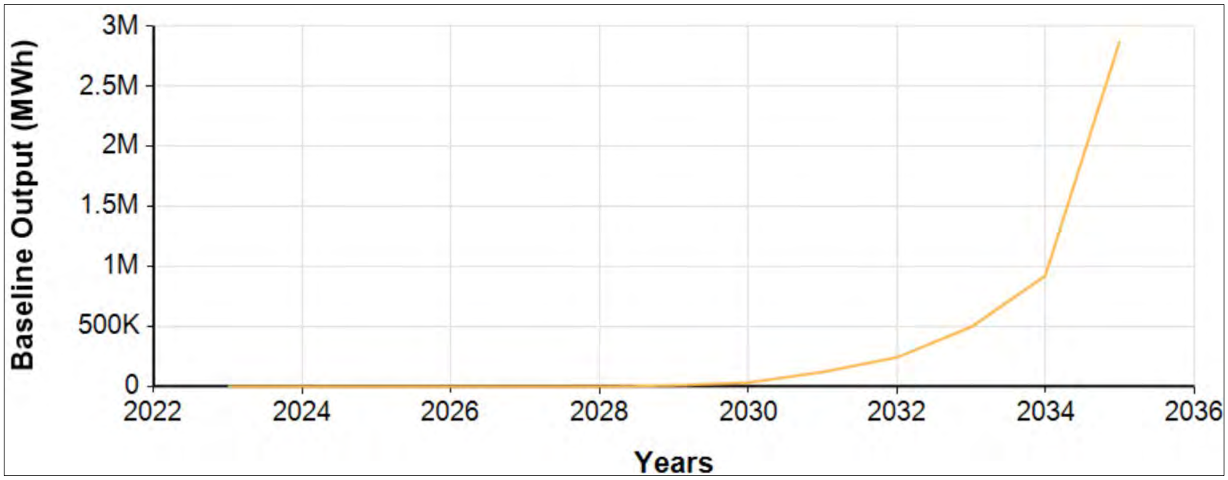

Figure 3.2.10. Emission-free dispatchable generation required by year.

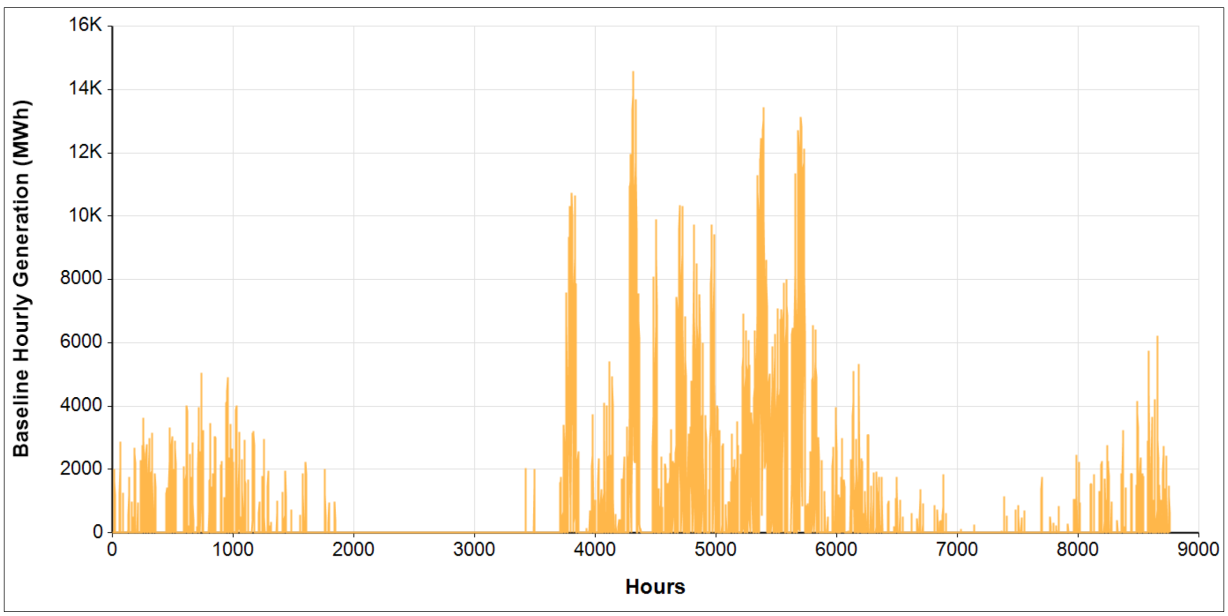

Figure 3.2.11. Hourly output for emission-free dispatchable resource 2035.

3.3 Specify and Evaluate Counterfactual "With-Project" Conditions

To evaluate the power system effects of New Hampshire offshore wind development, EPSM is re-run with additional offshore wind generation. This evaluation represents the With-Project Conditions. Evaluating differences between Baseline and Counterfactual With-Project Conditions provides the basis of determining the implications of adding offshore wind in the GOM to the New England power grid.

3.3.1 Specify – Gulf of Maine Wind Farm

As specific lease areas in the GOM have not yet been identified for New Hampshire, the EPSM's Offshore Wind Generation Module incorporates generation profiles from illustrative offshore wind development to evaluate the effect of adding offshore wind generated electricity to the ISO-NE power system market.

The specified wind farm is a 100-turbine farm with turbines having 107 m blades, 50% efficiency, and a capacity of 15 MW. Generation is calculated as described for the wind farms included in the Baseline scenario and is shown in Figure 3.3.1.

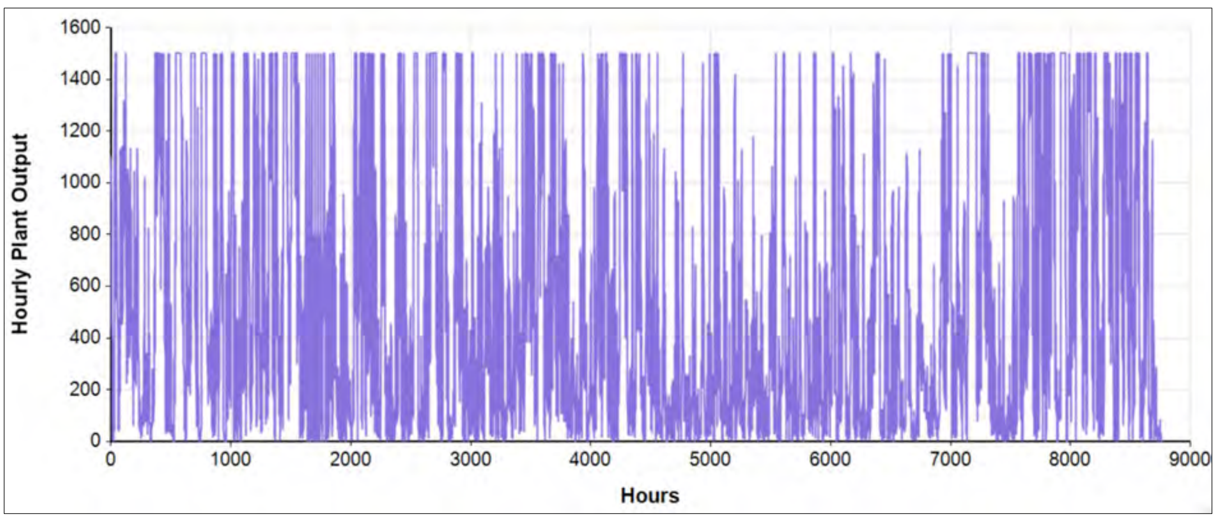

Figure 3.3.1. Hourly generation of hypothetical New Hampshire offshore wind farm.

3.3.2 Evaluate – "With-Project" Counterfactual Conditions

Under Baseline conditions, EPSM required a significant amount of dispatchable, emission-free, electricity to be consistent with state emission objectives and to achieve ISO-NE reliability standards. The amount required increased dramatically in 2035 with the closure of Millstone Unit 2. Under the Counterfactual scenario, this issue is ameliorated but not eliminated. Figure 3.3.2 presents the difference in emission-free dispatchable generation between the Baseline and Counterfactual scenarios. As the figure shows, the amount of required dispatchable, emission-free generation under the Baseline scenario is approximately 60,000 more MWhs in 2034 than under the Counterfactual scenario. This difference increases to approximately 200,000 MWhs in 2035. As Figure 3.3.2 indicates, the addition of new offshore wind in the GOM in 2033 leads to a substantial reduction in the amount of emission-free dispatchable generation that is required to meet load in comparison to the Baseline conditions. The difference in hourly requirements for emission-free dispatchable resources in 2035 between the Baseline and Counterfactual scenarios is illustrated in Figure 3.3.3.

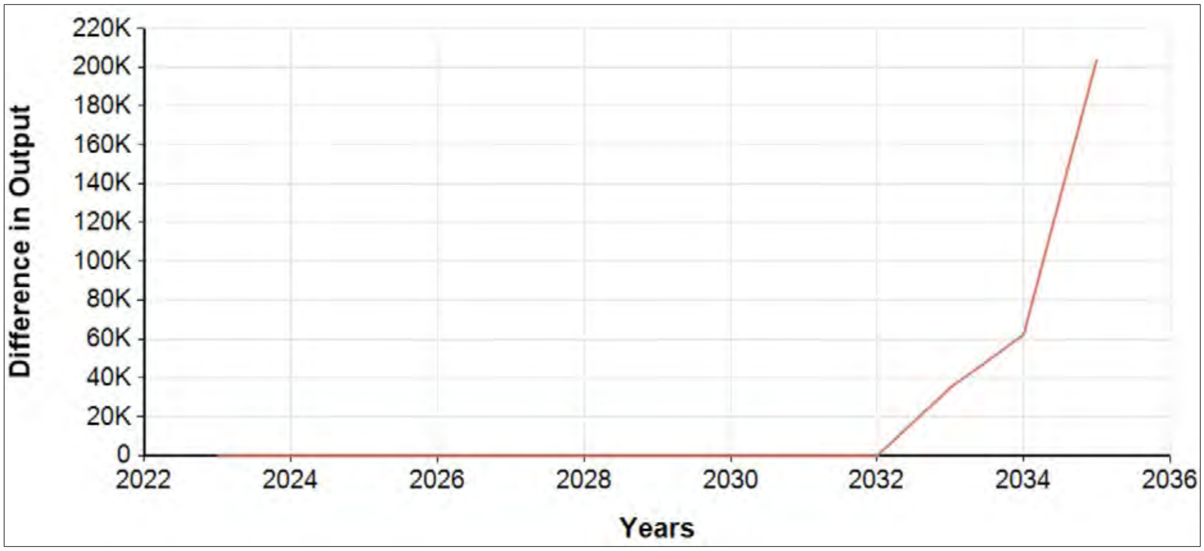

Figure 3.3.2. Difference in emission-free, dispatchable generation in megawatt hours between the Baseline and Counterfactual scenarios.

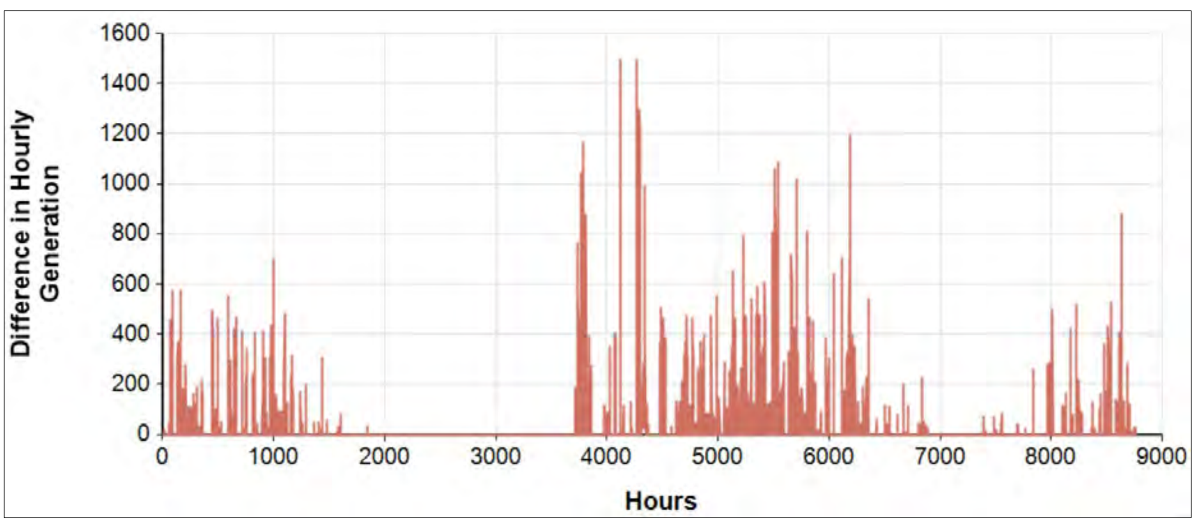

Figure 3.3.3. Difference in hourly megawatt hour requirements under Baseline and Counterfactual scenarios for emission-free dispatchable generation in 2035.

3.4 Implications of Power System Modeling Results

Based on this evaluation, there is a substantial potential for a shortfall in generation resources. Although this evaluation does not include transmission adequacy, the New England States Committee on Electricity (NESCOE) examined transmission systems under conditions which included the addition of 8,000 MW of offshore wind (ISO-NE 2020). This study indicates that at these levels there is a minimal potential for transmission congestion leading to generation curtailment. This means that resource adequacy—having sufficient generation available to meet electrical load—is the primary concern for a New England grid that is primarily served by non-dispatchable renewable energy.

Load fluctuates by time of day, day of week, and season. In traditional electrical systems power plants are dispatched in order of cost and with consideration of flexibility to meet this load. This means that plants with lower costs and less flexibility run as much as possible. For example, Seabrook, a 1,242 MW nuclear plant in New Hampshire produces electricity using steam that is created by a nuclear reaction. The plant is comparatively inexpensive to run but it is not flexible. Given its low cost and low flexibility, it is most economic to run this sort of plant as much as possible and that is the case with Seabrook, which historically operates about 85% of the time (average from 2003-2018, NextEra Energy Seabrook LLC 2019).

On the other end of the cost and flexibility spectrum are combustion turbines. Combustion turbines use exhaust from burning biogas, natural gas, or fuel oil to spin a turbine. These units are a much more expensive way to produce electricity. However, when not operating, they are inexpensive to maintain, and they are able to go from not operating to putting electricity on the grid in minutes. Consequently, these types of units run infrequently. Although these units operate infrequently, they are critical to grid stability because they are dispatched to meet peak loads, and without them the grid would fail during these time periods.

In between these two extremes are different dispatchable plant types that tend to operate more (or less) based on these criteria of cost and flexibility. The system operator develops an approach for operating these plants so as to always meet load, but to do so at the lowest cost possible given load, generators, and any external constraints. Since load cannot be predicted perfectly, and because generators are not always available, planning includes a "reserve margin" which is an amount of available generating capacity above predicted maximum load. The most recently available Regional System Plan for ISO-NE shows capacity margin requirements of 18.9% for 2023-2024 and 19.3% for 2024-2025 (ISO-NE 2021a).

Introducing large amounts of renewable energy into an electrical system changes the economic and electrical properties of the system in important ways. Considering economics, renewables such as wind energy require no fuel input and therefore have very low generation costs. However, they cannot be dispatched to meet load. This makes their economics very different from traditional power sources which have generation costs but can produce an amount of electricity that is precisely known ahead of time. This results in a dramatic impact on system requirements, an impact which tends to grow as renewable energy becomes a larger part of the grid energy. For example, a recent study indicates that running the New England grid under the most aggressive clean energy scenarios, which included an entirely offshore wind energy scenario, may require a 300% reserve margin (ISO-NE 2022).

Such a large level of overbuilding is not cost effective. Methods to minimize this impact would be required. Certainly, given the large amount of wind that is anticipated, ISO-NE and wind farm owners will apply sophisticated methods to forecast and integrate the resulting energy. Currently the bulk of planned offshore wind generation is located in the ocean southeast of Massachusetts. Although precise wind speeds vary from turbine to turbine, closer together turbines will tend to have correlated output. An implication is that additional wind energy that is sourced from a region with different wind regimes may be complementary to other existing or planned wind energy. As ISO-NE has a significant amount of transmission interfacing with New York, it is important to consider the likely electricity profile of this wind and how it might balance load in ISO-NE and vice versa. To evaluate this, we statistically compared the offshore wind energy profiles from southeastern Rhode Island and Massachusetts with the wind energy profiles where New York projects are located. The comparison uses the last five years of wind speed data. Given the cube in the wind to output function wind speed was converted to generation as described previously.

Our preliminary evaluation indicates that hourly wind speeds are correlated across southern New England and the New York/New Jersey Bight. The implication of this result is that wind generation in both regions will likely be similar and even with the most sophisticated algorithms and wind farm siting that considers correlations in wind speeds, a de-carbonized New England grid may still require a significant amount of emission-free dispatchable generation (renewable energy sources) than what is currently planned and included in the Baseline EPSM specification to meet system demand.

3.5 Energy Storage - Emission-Free Dispatchable Generation

The analysis considered energy storage in the context of emission-free dispatchable generation. Emission-free dispatchable generation describes a generation resource that allows meeting both the power system objectives of ISO-NE and the emissions objectives of the states that comprise ISO-NE. There are several technologies that can be described as emission free and dispatchable, and in practice it is likely that a mixed approach would be applied. This subsection considers sources of emission-free dispatchable generation for ISO-NE generally and with consideration of potential roles for New Hampshire. Approaches considered include energy storage using Canadian hydropower resources, hydrogen powered thermal plants, and fuel cells and batteries. Although biofuels such as wood or biogas burning plants are often considered carbon neutral, these sources are not considered because they are not emission free. Also, although small scale nuclear reactors and dispatchable nuclear reactors are being built and operated internationally, this option is not included because of expected substantial public resistance.

3.5.1 Canadian Hydro Storage Capabilities

The most practical approach for storing energy to generate electricity is in hydroelectric systems. This approach has been in use for nearly a century and accounts for the great majority of energy storage in the United States. The New England states do not have significant available hydroelectric storage capacity. However, ISO-NE has an interface with Hydro-Québec. Hydro-Québec already delivers large amounts of electricity to ISO-NE. It is possible that the Hydro-Québec system could be operated differently, with periodic excess from ISO-NE renewables being sent to serve load in that system while hydroelectric generation is curtailed. The curtailment of hydroelectric generation results in stored energy that can be converted to electricity and sold to ISO-NE at times of high demand.

As this approach relies on the proven techniques of hydroelectric operations and electricity, it is expected to be a technically feasible, reliable, and cost effective approach. However, the current transmission system only supports flows from Hydro-Québec to ISO-NE. Supporting bi-directional flows is infeasible in current transmissions, and proposals for new transmission lines have run into opposition. The "Northern Pass Project" was proposed to bring hydropower from Quebec to the New England power grid in Massachusetts through New Hampshire but was denied a critical NH state permit. The developer appealed the decision to deny the permit, the decision was upheld by the NH Supreme Court (NHPR 2019). Developers are now constructing the Central Maine Power (CMP) corridor through Maine that will connect hydropower in Quebec to the New England grid at the Lewiston, ME substation. The project was suspension in November 2021 after Maine voters backed a referendum to stop the corridor. The developers sued the State of Maine arguing the referendum imposed a retroactive law that violated the developers' vested rights on a lawfully permitted project. The CMP corridor project resumed in April 2023 after a civil jury found in favor of the developers (Hirschkorn 2023). A new bi-directional transmission line, Twin States Clean Energy Link, has been proposed to bring Canadian hydropower through Vermont and New Hampshire to the New England grid at a new substation in Londonderry, NH (Barndollar 2023). The success of any of these approaches and degree to which they occur will affect generation and storage decisions in New Hampshire and ISO-NE.

As the remainder of this subsection describes, other technologies for storing electricity are nascent and very expensive. Given the comparative advantages of hydroelectric storage, it is likely that at some point there will be bi-directional flow, effectively supporting energy storage for ISO-NE in Quebec. As operational changes occur with the addition of renewable energy production and distributed energy resources, this is by far the most cost-effective approach. However, its advantage is primarily economic. In terms of resource adequacy, Hydro-Québec and ISO-NE have similar peak demands. This means that when electricity is most needed in New England, Hydro-Québec may be unable to provide it. Hydro-Québec's system is already under resource adequacy pressures (Giguère and Dufort 2023), as illustrated by the call for voluntary customer curtailments in January 2022. Additionally, Hydro-Québec anticipates an increase of 25 terawatthours in energy needs and 4,000 MW in capacity requirements by 2032 due to transportation electrification, initiatives to decarbonize the Canadian economy, and emergence of new sectors (Hydro-Québec 2023). Given the safety-critical nature of winter peaks, significant amounts of other dispatchable and emission-free resources will be required.

3.5.2 Batteries

Battery storage is the next most mature approach for creating dispatchable emission-free electricity. It can provide a variety of services to the electrical grid including frequency regulation, energy arbitrage, load shifting, transmission deferral, and peaking capacity (Balducci et al. 2018, Frazier et al. 2020). Costs are historically very expensive, but recently there have been rapid improvements in this area with costs for utility scale batteries dropping from $2,152 per kilowatt hour (kWh) in 2015 to $625/kWh in 2018 (U.S. EIA 2020). NREL sees mid-range costs for lithium-ion batteries falling an additional 45% between 2018 and 2030 (Clean Energy Council 2021). Recent deployments have been almost entirely lithium-ion technologies (Energy Storage Association 2020). Lithium-ion batteries are being installed at utility scale; California alone has multiple lithium-ion battery energy storage facilities exceeding 100 MW (Yale 2020).

Lithium-ion batteries with short-durations (< 2 hours) can provide grid services that maintain grid stability, while batteries with long-durations (4+ hours) can be used for load shifting that helps meet peak demands (U.S. EIA 2022). FERC Order 841 required all wholesale market operators to modify their market structures to allow energy storage resources to be eligible to participate in all electricity markets including capacity markets. Each market operator established a minimum duration requirement (hours of capacity) for energy storage resources to participate in the capacity markets (Frazier et al. 2020). Minimum duration requirements of U.S. market operators range between 2 hours and 10 hours. ISO-NE has a minimum duration requirement of 2 hours. These duration requirements are important since they reflect the limits of energy storage resources needed to meet resource adequacy requirements. There is substantial economic potential for battery storage with durations of ten hours or less to provide peaking capacity in the U.S. (Frazier et al. 2020).

Battery energy storage has a relatively short lifespan when compared to other peaking technology. Battery lifetime is variable depending on their thermal environment and how they are charged and discharged ranging from approximately 8 to 20 years (Smith et al. 2017, Schmidt et al. 2019, Cole and Karmakar 2023). NREL generally evaluates battery storage facilities using just a 15-year expected lifetime, the near median of the published values (Cole and Frazier 2019, Cole and Karmakar 2023). To operate effectively, battery storage systems must be kept within a certain temperature range making them ideal in mild climates (Olis et al. 2020). When operating in more extreme climates, the facility must heat and cool the facility in the summer and winter months to keep the batteries within their optimal temperature range. Heating and cooling the facility draws energy from the batteries, thus reducing their efficiency and ability to meet peak demand. Extreme weather events occurring mainly in the summer and winter months when the batteries are needed to meet peak demand are also the times when the batteries are operating least efficiently due to the parasitic load of heating/cooling the facility.

After the useful life of the facility, the used lithium-ion batteries will be classified as a hazardous waste and the owner will be considered a hazardous waste generator liable for proper disposal under the Environmental Protection Agency (EPA) Resource Conservation and Recovery Act (RCRA) rules. Due to the battery disposal requirements, plant decommissioning is a very expensive process with estimated costs for dismantling, shipping, and recycling batteries at approximately $50/kWh (Energy Storage Association 2020).

3.5.3 Hydrogen

The last emission-free dispatchable generation option under consideration is hydrogen. Combining electrolysis with offshore wind may enhance wind farm profitability because while wind is not a dispatchable resource, hydrogen can be used to store energy and fuel cells can convert hydrogen back to electricity during peak price periods. Due to this flexibility, hydrogen may enhance the profitability and financial resilience of offshore wind and provide storage alternatives. However, offshore wind developers already face complex decisions about leasing, siting, configuration, and connections. Adding hydrogen production to this mix exacerbates this complexity. Evaluating the potential for employing hydrogen as a storage alternative will require input and analysis on wind speed, wind farm configuration, development costs, energy prices, distance from interconnection, and tax credits.

Currently, the majority of hydrogen is produced from natural gas in a process called steam methane reforming. This process creates hydrogen from natural gas along with carbon monoxide (CO) and a small amount of CO_2 as by-products. When the CO and CO_2 waste is captured and stored, the hydrogen is called “blue” hydrogen. However, more often the CO and CO_2 are released into the atmosphere, in this case the generated hydrogen is called “grey” hydrogen. Hydrogen produced from coal is called “brown” hydrogen. Hydrogen can also be created using electricity in a process called electrolysis. When the electricity used to create hydrogen is emission free, the result is “green” hydrogen. Combining electrolysis with offshore wind may enhance wind farm profitability. For example, excess wind energy can be converted to hydrogen to create emission-free dispatchable electricity. Hydrogen can create electricity using either fuel cells or through combustion (Oni et al. 2022, National Grid 2023).

Hydrogen fuel cells are like batteries in that they involve an anode, cathode, and a chemical reaction to create electricity. However, unlike batteries which are charged with electricity and then discharged to produce electricity, fuel cells take in hydrogen and can produce electricity as long as hydrogen is available. Hydrogen fuel cells have a huge potential for future electricity production; however, the technology is relatively new and still unproven on a large scale. Fuel cells for stationary power applications (e.g., supplemental power, emergency backup power systems, and stand-alone power plants for towns and cities) are available and range in size from 5 kW to 2.8 MW (NREL 2023). NEESC (2018) states that existing New Hampshire businesses and institutions have the potential to install 74 MW of stationary fuel cell (2.5 kW to 1.4 MW) electric generation at 455 potential locations, which would have an annual output of approximately 631,000 MWhs.

Electricity can also be generated by burning hydrogen in combustion turbines. Existing combustion turbines typically burn natural gas. Methane, a molecule composed of a carbon atom and four hydrogen atoms, is the energy carrying and largest component of natural gas. Hydrogen, composed of two hydrogen atoms, is highly reactive as a fuel. Hydrogen can be mixed with natural gas and burned in existing turbines. However, hydrogen has both a higher flame speed and a higher flame heat than natural gas. As a result, as the amount of hydrogen in the mixture increases, the turbine burner must be modified to avoid damage. If hydrogen is added to the existing natural gas system, burners for existing turbines could be updated for the new mixture, allowing a gradual transition to a dispatchable resource that is emission free, while preserving existing dispatchable generation assets.

Both hydrogen fuel cells and hydrogen combustion require that sufficient green hydrogen is created and delivered. As described, offshore wind farms offer the opportunity to create green hydrogen. This hydrogen would be a gas that would need to be delivered to fuel cells and turbines. Transporting gaseous hydrogen via existing pipelines is a low-cost option for delivering large volumes of hydrogen. This is common in areas with an established oil production industry. Constructing a new pipeline would require high initial capital costs and constitute a major barrier to expanding hydrogen pipeline delivery infrastructure (EERE 2022). Additionally, if hydrogen is delivered as a gas as created, gaseous hydrogen would have limited utility for energy storage.

Based on the lack of existing infrastructure and the need for stored energy, hydrogen in New Hampshire is likely to be compressed to a liquid and carried in super-insulated, cryogenic tanks. Liquefaction requires lowering the hydrogen temperature to −253°C (−423°F). It is an expensive process, with losses occurring due to "boil-off" and consumption of up to 30% of the hydrogen energy content. After liquefaction, the liquid hydrogen is dispensed to ships and trucks and transported to distribution sites where it is vaporized to a high-pressure gaseous product for dispensing.

The high cost of hydrogen production, lack of carrying infrastructure and losses during liquefication argue against the viability of hydrogen energy storage and electricity production. However, the flexibility of combustion turbines in accepting hydrogen, development of fuel cells, and clear need for new sources of energy in a decarbonized grid indicate hydrogen as a potential option. Moreover, there is significant government interest in this fuel and related technologies with recent legislation supporting the development of hydrogen hubs and promising a $3/kg production tax credit for green hydrogen production (U.S. DOE 2023, Zacarias and McGeady 2023).

3.6 New Hampshire Interconnection, Procurement, and Subsidization

New Hampshire is situated in between states with ambitious CO_2 reduction targets. Much of the intended reduction in CO_2 emissions is expected to come from offshore wind. As seen in the power system modeling, large scale wind farms planned off the coast of Rhode Island and Massachusetts contribute to, but do not accomplish these goals. The quality of the offshore wind resource for electricity production in the GOM is outstanding, and Maine is proceeding with plans to develop offshore wind. Since New Hampshire is part of ISO-NE as are Maine and Massachusetts, its electricity supply will be affected by changes these other states are encouraging. New Hampshire also has the potential to become involved directly in offshore wind. This section evaluates this possibility with consideration of interconnection possibilities, New Hampshire's direct procurement of offshore wind electricity, and subsidization requirements.

3.6.1 New Hampshire Interconnection

New Hampshire's electrical grid is connected to ISO-NE. This means that electricity from offshore wind coming ashore in any New England state will potentially flow into New Hampshire. It is also possible that offshore wind transmission could come ashore and connect to the grid in New Hampshire. The NHDOE, NHDES, and DBEA considered preferred points of interconnection (POI) for offshore wind generation (NHDOE et al. 2022). This consideration included assessing the tradeoffs associated with power capacity and the length of required transmission cable.

Among the most attractive POIs are recently retired generating facilities because they have available transmission capacity. Retired or retiring generating units in southern New Hampshire are typically located on coastal waterways and "provide ready access" for the subsea transmission cables that would deliver the offshore wind generation from the GOM. The POIs receiving the most consideration are:

- Schiller Generation Station (Schiller) in Portsmouth on the Piscataqua River; Schiller closed during 2022.
- Newington Generation Station in Newington on the Piscataqua River, located one-quarter mile northwest of Schiller.
- Essential Power LLC Newington, also near the Piscataqua River and located less than a mile from Newington Station.
- NextEra Energy Seabrook (Seabrook Station), although Seabrook Station may have relatively little surplus transfer capability (NHDOE et al. 2022).

Seabrook Substation is a 345 kV pool transmission facility operated as part of the ISO-NE transmission network. It is interconnected to Seabrook Station with three major 345 kV transmission lines to substations at Scobie Pond near Londonderry, NH; Tewksbury, MA; and Newington, NH (Figure 3.6.1). The interconnection facilities associated with the substation operate to provide reliability to ISO-NE's transmission network even when the Seabrook Station generating unit is not operating (NHPUC 2022; NRC undated).

Seabrook Station provides power directly to New Hampshire, in 2021 it produced 56% of New Hampshire's total in-state electricity net generation (EIA 2022). Additionally, transmission lines interconnected with Seabrook Substation enable power delivery to the Northeast Massachusetts and Boston (NEMA) Load Zone. The connection to this ISO-NE Load Zone indicates the power market that would be most affected by efficiency changes or outages at Seabrook Station.

The ISO-NE transmission network also includes Schiller, Newington Generation Station, and Essential Power LLC Newington (Di Luca 2002; ISO-NE 2021b):

- Schiller has 115 kV transmission lines connecting to Ocean Road Substation in Greenland, New Hampshire, and Portsmouth Substation off Route 1 Bypass, Portsmouth, New Hampshire.
- Newington Generation Station has 345 kV transmission lines connecting to Deerfield Substation, Deerfield, New Hampshire.
- Essential Power LLC Newington has 345 kV transmission lines connecting to Timber Swamp Substation, Hampton, New Hampshire, and Seabrook Substation, Seabrook, New Hampshire (Di Luca 2002; ISO-NE 2021b).

Supporting interconnection could be an important consideration in any efforts that New Hampshire considers in fostering the development of offshore wind in the GOM. Several potential interconnection points have been identified during this review, indicating that New Hampshire is well positioned to receive and distribute power from offshore wind development.

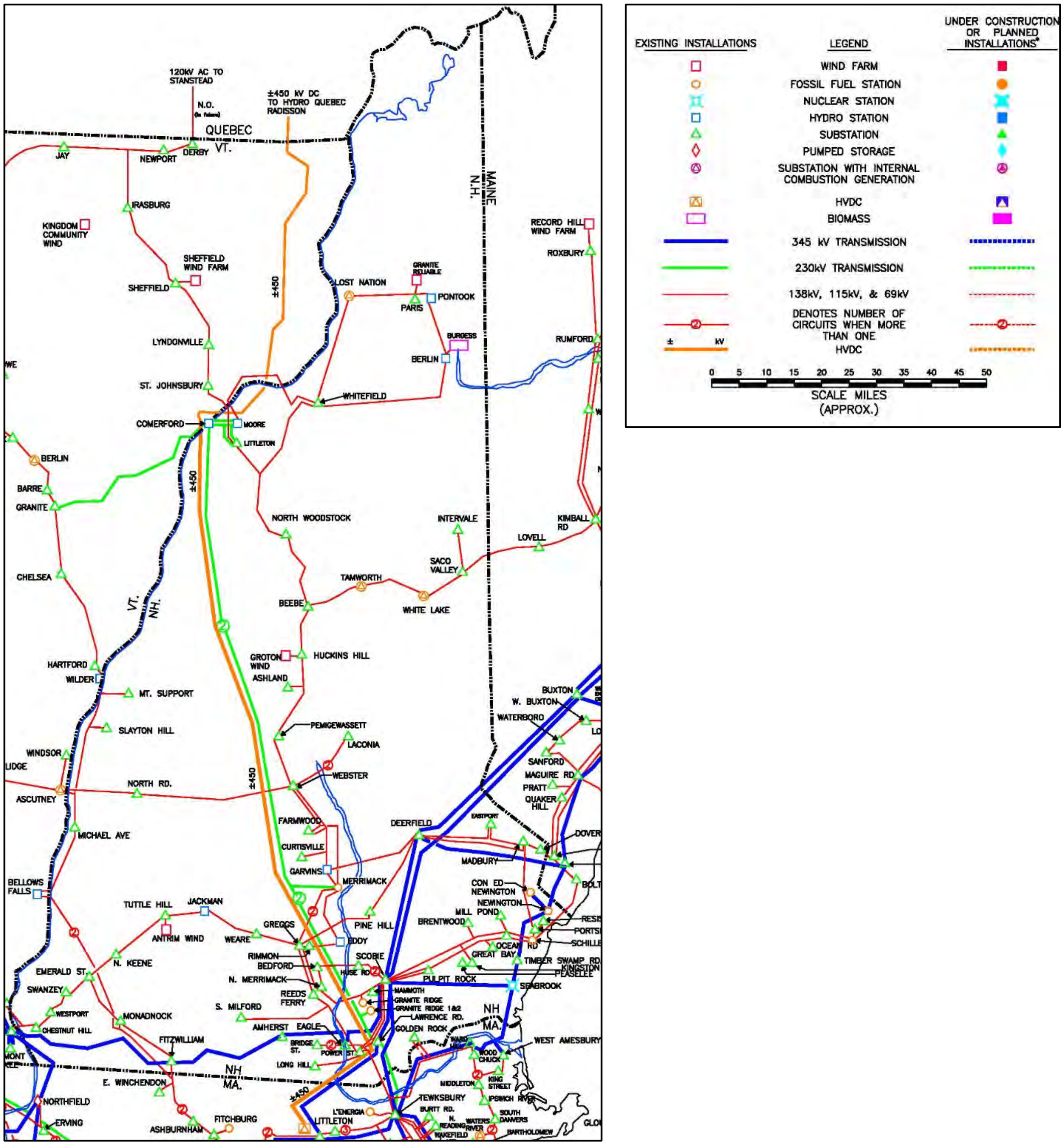

Figure 3.6.1. New Hampshire transmission lines.

3.6.2 New Hampshire Procurement

Offshore wind electricity is both intermittent and relatively more expensive than other sources. Its development is only ensured through a guaranteed market for electricity. Massachusetts is moving ahead aggressively with plans to contract 5,600 MW of offshore wind power by 2027. Maine passed legislation in July 2023 to contract 3,000 MW of offshore wind power by 2040. To date, New Hampshire has not announce plans to contract offshore wind power, but has passed legislation to understand the benefits and impacts of offshore wind development.

Developing offshore wind in the GOM will require the use of floating turbines. FOWT are less proven than fixed-bottom turbines, which is an impediment to development. However, all indications are that the State of Maine intends to overcome technical difficulties and move forward with large scale offshore wind installations. The state has announced plans for a research array to study floating turbines, conducted several supporting technical studies, and formed a group to advise in the regulatory process. On January 19, 2023, BOEM announced its "Determination of No Competitive Interest" for the research lease proposed by the State of Maine. This determination means that the BOEM will move forward to process the state's research application.

Power procurement is accomplished through power purchase agreements. Massachusetts electric distribution companies and Vineyard Wind LLC entered into a Power Purchase Agreement in July 2018 for 800 MW to facilitate the development of offshore wind. Additional power purchase agreements were made between Massachusetts utilities and SouthCoast Wind in 2019 for 804 MW, and with Commonwealth Wind in 2022 for 1,232 MW. The SouthCoast Wind and Commonwealth Wind agreements were terminated by the developers in the third quarter of 2023 due to inflation, rising interest rates, supply chain disruptions, and the Russian invasion of Ukraine which made the projects economically unviable according to developers (Mohl 2023).

Four electric distribution companies operate in New Hampshire, each serving a mutually exclusive franchise territory. They are Eversource Energy (Eversource), Liberty Utilities (Liberty), Unitil Energy Systems, Inc. (UES), and the New Hampshire Electric Cooperative, Inc. (NHEC). Eversource is by far the largest electric utility in New Hampshire, serving more than 70% of the state's residents. Eversource is a distributor of electricity from generators that it does not own. To obtain electricity, Eversource conduct twice yearly auctions. These auctions are competitive bid. Eversource determines the required amount of electricity ahead of time. They then contract for that power and pass costs on to ratepayers.

The New England grid is heavily reliant on natural gas. This has been the case since the early 2000's when inexpensive natural gas led to a movement away from coal and fuel oil. This reliance on natural gas leads to two problems for New England electricity provision. The first is that since this transition, an international market for natural gas has developed. This means that inexpensive natural gas produced in the United States can now be cooled and compressed and sold on the world market as liquified natural gas (LNG). Since the New England grid is no longer isolated from international energy markets, developments such as the Russian invasion of Ukraine can cause natural gas prices to increase and become more variable. This is being reflected in local electricity prices. The second issue relates to supply. New England has no natural gas reserves and is at the end of the gas pipeline system. This leads to physical constraints that are exacerbated by competition from heating uses. To offset this, New England has been bringing in up to 40 million cubic feet a year of LNG (U.S. DOE 2018, 2020). This LNG is unloaded in Everett, MA, where the majority of it is burned in the Mystic Generating Station, the remaining portion goes into regional pipelines.

As utilities such as Eversource conduct auctions, suppliers consider natural gas price expectations. This is leading to high and highly variable pricing, with some New Hampshire customers experiencing a doubling of rates within a single year. Moreover, while extra LNG and oil is typically sufficient to meet load, New England utilities are expressing concern that markets are breaking down and that it may not be possible to secure sufficient electricity through the contracting process.

The question of whether it is useful or desirable for New Hampshire to procure electricity from offshore wind takes place in this context. In Massachusetts, enabling legislation supported the development of power purchase agreements for offshore wind. It is unlikely in the short-term that offshore wind will develop in the GOM without similar activities.

3.6.3 Subsidies

Developing a marketplace in New Hampshire for offshore wind electricity in the near term is likely to require government intervention in some form. As described in the supply chain section, many forms of subsidies, particularly assistance with port and manufacturing facilities, are available and are being undertaken by nearby states.

In Massachusetts, electricity distribution companies and Vineyard Wind joined into a power purchase agreement which outlined that the first-year price for delivery of offshore wind generation and renewable energy certificates is $74/megawatt-hour (MWh) (in 2022 dollars) for facility 1 (400 megawatts [MW]) and $65/MWh (in 2023 dollars) for facility 2 (400 MW). The price rises each subsequent year for the remaining 20 years of the PPA. By comparison with current generation costs, this is expensive. For example, New Hampshire’s Newington combined cycle and Granite Ridge combined cycle are efficient, advanced natural gas plants that produce reliable, dispatchable electricity at less than half of this cost ($36.62/MWh in 2022 dollars).

The current high cost of offshore wind electricity indicates that bringing offshore wind electricity to New Hampshire will require electricity expenditures that are much higher than current generation costs. However, this may not be a permanent situation. Efforts of New England states to decarbonize will lead to increased system costs, making offshore wind more economically viable.

In the GOM in particular, the requirement for floating offshore wind brings both uncertainty and opportunities. The technology is nascent. However, the wind resource in the GOM is extraordinary. Moreover, wind has the unusual feature of increasing returns to scale. As turbines grow larger, they produce increasing amounts of electricity both through an increase in swept area and by capturing the higher wind speeds that occur at higher elevations. Whereas turbine size is constrained by transportation logistics on land, there is no such limitation for offshore wind. Although federal and state policies including preferable tax treatment, subsidies, and government mandates will drive upcoming offshore wind development, technology improvements and industrialization will ultimately lead to offshore wind being competitive on economic merits alone.

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4 Existing Infrastructure and New Infrastructure Needs

Existing New Hampshire electrical infrastructure and new infrastructure that may be needed to bring offshore wind energy from the GOM to New Hampshire connection points are discussed in this section. An overview of the existing transmission cables is provided first, followed by a characterization of potential new transmission grid interconnection points and cable routes. Information on the considerations for routing of offshore wind transmission cables along with existing cables, pipelines, and other infrastructure found in the GOM RFI Area is then presented. Lastly, the decommissioning process for offshore wind turbines is reviewed to provide insight into the full life cycle of offshore wind farms and associated expectations and impacts.

4.1 Transmission Infrastructure and Potential Injection Points

The Seacoast area of southern New Hampshire is served generally by two New Hampshire electric utilities, Eversource Energy (Eversource) and Unitil. Eversource is a major electric and natural gas utility in New England, operating 4,270 miles of electric transmission lines, 72,000 miles of electric distribution lines and 6,500 miles of natural gas pipeline in the states of Connecticut, Massachusetts, and New Hampshire. Based in Hartford, Connecticut and Boston, Massachusetts with major offices in Concord, NH and Westborough, MA, Eversource is the largest electric utility in New Hampshire and Connecticut, and second largest in Massachusetts. Eversource previously owned (as PSNH) most of the larger power plants (Seabrook, Schiller, Newington and Merrimack Stations) and several hydroelectric facilities in the state, and currently serves over 500,000 homes and businesses in 211 communities across the state. This amounts to approximately 70% of the electricity retail customers in New Hampshire (NHPUC 2023). Currently, Eversource has no gas infrastructure in New Hampshire (Eversource 2023).

Eversource has been directly involved in the growth of offshore wind across the northeast. In 2016, the utility invested in a 50/50 partnership with Ørsted, a major federal offshore wind developer, to lease large offshore wind areas off the MA/RI coast, and to develop three major offshore wind projects. These projects included: South Fork Wind, a 12-turbine, 132 MW windfarm which will deliver energy to Long Island; Sunrise Wind, a large 924 MW windfarm which will deliver energy to the New York grid near New York City; and Revolution Wind, a 700 MW windfarm that will deliver 400 MW of energy to Rhode Island and 300 MW to Connecticut. Eversource also has been involved with other wind projects that must tie into Eversource's grid in Connecticut and Massachusetts, including new or upgraded transmission and distribution lines and substations (Ørsted 2022). In 2023, Eversource ended its partnership with Ørsted, divesting it shares in these projects (Ørsted 2023). Eversource has been an active participant in offshore wind discussions in New Hampshire, Massachusetts, Rhode Island, Connecticut, and New York as well (Ørsted 2022).

Unitil, based in Hampton, NH, provides electric and/or natural gas service to customers in specific areas of New Hampshire, Massachusetts, and Maine. Its electric service area in New Hampshire encompasses all or parts of 18 communities, including the city of Concord and 12 surrounding towns and the towns of Hampton, Exeter, Atkinson, and Plaistow in the southeastern and Seacoast area. Unitil provides both electric and natural gas to Fitchburg, MA and a few of its surrounding towns and natural gas to several communities in southern Maine, including the city of Portland.

Unitil's electric lines are for distribution; the company does not own or operate electric transmission lines. However, Unitil owns the Granite State pipeline, which is an 86-mile interstate natural gas pipeline located primarily in Maine and New Hampshire, connecting to natural gas pipelines to the south and Canada to the north.

Although Waltham-based National Grid, the largest electric utility in Massachusetts, does not serve communities in New Hampshire, it should be noted that National Grid operates over 9,000 miles of electric and/or natural gas transmission in five states, including New Hampshire, Vermont, New York, Massachusetts and Rhode Island.

The Seacoast area has four large power generation facilities:

- NextEra, Seabrook Station (1,250 MW) nuclear reactor in Seabrook, located on the Atlantic Ocean, Seabrook;
- Granite Shore Power, Schiller Station (155 MW) fossil/biomass unit, located on the Piscataqua River, Portsmouth;
- Granite Shore Power, Newington Station (414 MW) fossil-fuel unit, on the Piscataqua River, Newington; and
- Essential Power, Newington Energy Station (606 MW) fossil-fuel unit, located on the Piscataqua River, Newington.

All four power plants were once owned by PSNH (Eversource). The power plants were sold to implement 2015 Public Service Company of New Hampshire Restructuring and Rate Stabilization Agreement (Eversource 2018). It should be noted that the Granite Shore Power and Essential Power Plants are located in close proximity to each other in Newington/Portsmouth near the Port of New Hampshire, across the river from Kittery Maine and Seabrook Station is near the NH/MA border closer to load centers.

The future load on the power grid is expected to increase because of the shift to electrification of heating and transportation. With many state governments committed to reduce carbon dioxide emissions by as much as 80 percent, offshore wind power is a clean alternative to the replacement of some fossil fuel generators, but dispatchable resources would still be required to maintain stability in the Grid of the future.

4.1.1 Existing Transmission Infrastructure on the New Hampshire Seacoast

One of the challenges associated with delivering offshore wind power is moving the large amount of power to load centers. The Seacoast area has a three-line 345-kV grid centered around the Seabrook nuclear power plant that is ideal for the interconnection of offshore wind power. Two 345-kV transmission lines head west from Seabrook Station, one line owned by National Grid, goes to the south into Massachusetts feeding several 345-kV substations in the

Merrimack Valley area of Massachusetts. A second 345-kV line owned by Eversource travels northwest through Kingston Substation, in Kingston, NH then to Scobie Substation in Derry. A third 345-kV line runs from Seabrook Station along the Interstate 95 corridor north into Portsmouth to the Three Rivers Substation in Newington. The third transmission line and Three Rivers Substation are owned by Eversource. The third 345-kV line then runs across the Piscataqua River into Maine to the South Gorham 345-kV Substation.

The Seacoast area also has a series of 115-kV lines supplied from Eversource's Timber Swamp Road Substation, a 345 kV to 115 kV and 115 kV switching station like Eversource Ocean Road Substation that traverse the seacoast from north to south to serve Pease Air National Guard Base, Portsmouth Naval Shipyard, and the local load in the Seacoast area. The 115-kV system also feeds smaller 69-kV substations that serve the local load in the Seacoast area. These smaller 115-kV and 69-kV substations may not be large enough to act as a point of interconnection for proposed offshore wind loads as large as 1,200 MW, which is similar to the proposed load generations of 700 to 1,230 MW and 816 to 1,260 MW being developed in southern New England and the New York Bight wind lease areas respectively. However, for smaller projects the existing capacity may be sufficient, pending the outcome of more detailed project-specific transmission studies that would be necessary.

A few energy transmission lines have been proposed to ISO-NE over the past several years, that never progressed to construction. Examples include SeaLink, a 68-mile, 520 MW subsea cable transmission line proposed by NextEra to ISO-NE in 2013 to run from the Seabrook area to greater Boston, and the Northeast Energy Link Project, proposed to ISO-NE in 2007 by Emera and Bangor Hydro to deliver power from the Canadian Maritimes and northern Maine to load centers in Massachusetts and Connecticut. As envisioned, it proposed delivery of 660 MW on a 320-kV direct current line down the I-95 corridor and converter stations in Orrington, ME near Bangor, ME and Tewksbury Station, which is a 345-kV substation on the same network as Seabrook and the other New Hampshire 345-kV substations. The final example is the controversial Northern Pass, a 192-mile, high-voltage transmission line from Canada to bring 1,090 MW of hydroelectric power to load centers in greater Boston through New Hampshire proposed by Eversource and Hydro-Québec in 2010.

4.1.2 Offshore Wind Power Delivery

The delivery of offshore wind power from a hypothetical lease area located anywhere within the GOM RFI Area, in federal waters could be delivered in two separate ways. High-Voltage Alternating-Current (HVAC) submarine cables or High-Voltage Direct Current (HVDC) submarine cables. These delivery methods each have pros and cons.

HVAC Power Delivery

HVAC may be the preferred method for shorter distance offshore substation platforms to onshore Points of Interconnection (POIs). HVAC is typically used for shorter transmission cable lengths. The ISO-NE system operates on alternating current so connecting to the system may be cheaper and require a smaller footprint at the POI primarily by avoiding the need for an onshore DC to AC converter substation. HVAC systems have more impedance and more line loss and would require additional equipment to improve power factor and voltage transformation may be required before connecting to the ISO-NE system. The alternating-current (AC) system operates with three conductors per circuit and up to three circuits or nine power cables can be required to deliver AC power loads from the offshore wind farm to the POI. Onshore manhole spacing would be approximately 500 ft, as each circuit would enter its own manhole and enter every third manhole along the route. The duct banks would also have ground conductors as well as a communication conductor.

HVDC Power Delivery

HVDC power delivery methods may also be selected as the best way to transmit power from the offshore wind farm to the POI. This is a more efficient way to transmit power over distances greater than 60 km (37 miles). The HVDC method is likely preferred for long distance power delivery, however this method requires specially tuned HVDC converter stations on both ends of the line. Offshore platform based HVDC converter stations have been developed and are in use in certain parts of the world, and for some proposed projects off southern New England. The technology is rather new and only limited suppliers are available. The conversion from HVAC to HVDC generates heat, therefore offshore converter stations require the use of once-through non-contact cooling water, with associated permitting implications.

Onshore HVDC terminals would also be required to convert voltage from DC to AC to connect into ISO-NE's power grid. Such HVDC stations require years of planning with long lead times for construction, resulting in high costs. However, once built, a converter station can operate for 40 years with relatively low maintenance costs. HVDC circuits consists of only two conductors, a positive conductor and a negative conductor and this type of cable can carry larger loads limiting the number of conductors and size of export cables from each offshore substation to the POI. Only one HVDC circuit is typically required, reducing the number of conductors from nine or more to two. The number of manholes required along the onshore routes is also reduced three-fold. The HVDC manhole spacing would be on average approximately 1,500 ft. Additional studies are required to determine the best power delivery for each application.

4.1.3 Potential Transmission Grid Interconnecting Points

The Seacoast Area has several possible transmission grid interconnection points available. The search for interconnection points involves looking for high voltage substations, power generation stations or de-commissioned power stations, or even green space near major existing 345-kV lines for new substations. Power stations are ideal locations for interconnection points, as they already have a transmission system infrastructure in place to move power away from the shoreline. Power stations often have space available to build an HVAC switching station or a HVDC terminal station. Remote high voltage substations with multiple high voltage transmission lines or new substations on unencumbered parcels of land adjacent to high voltage transmission lines are desirable POIs. The selected location would ideally be close to the shoreline to allow for a short underground transmission route with unencumbered access from a landfall location.

Two possible interconnection options exist for potential POIs: HVAC high voltage alternating current and HVDC high voltage direct current systems. The New Hampshire Seacoast provides several options for each type of interconnection. Sites along the Piscataqua River offer ideal interconnection options but bringing submarine cables up the river may not be possible due to river congestion, anchorage concerns, and constraints associated with the Portsmouth Naval Shipyard. Additional studies would be required to explore river access.

Seabrook Nuclear Power Station

Seabrook Nuclear Power Station in Seabrook, NH is owned by NextEra Energy. The plant is located on a 900-acre site in Seabrook, NH (Figure 4.1.1). The 1,244-MW unit produces enough electricity to supply approximately 900,000 households or about 44% of New Hampshire's electric load requirements.

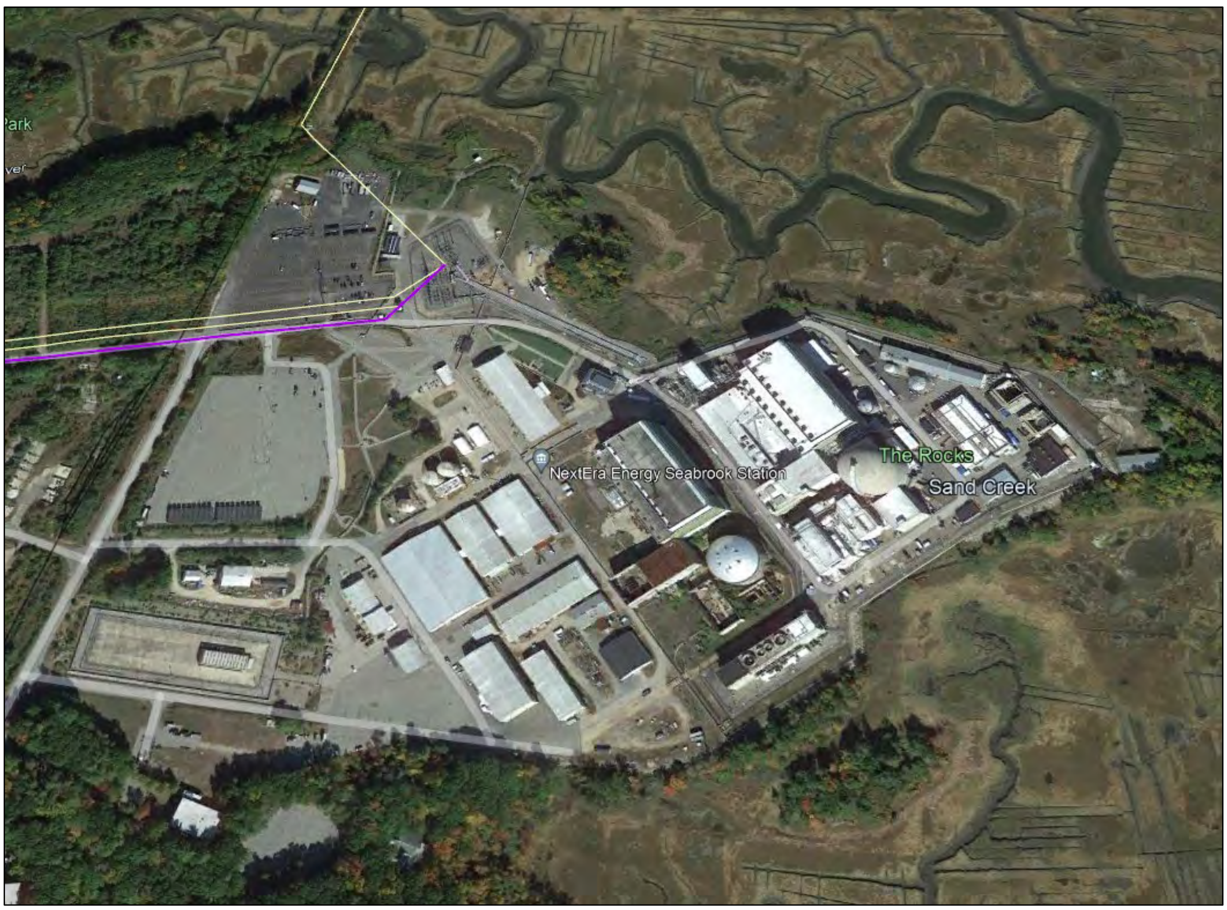

Figure 4.1.1. Seabrook Nuclear Power Station.

The plant was opened for operations in 1990 and was licensed to operate through 2030. In March of 2019 the NRC granted permission to extend the operating life of the plant for another 20 years, until 2050. This plant is the largest standalone unit on the ISO-NE system. The original design for the plant was to have two 1,244-MW reactors. Only one was built due to public pressure in the permitting and construction phase of the project. The cost and deadline overruns in the construction of Seabrook Station caused Public Service of New Hampshire to declare bankruptcy in 1988, which led to its sale to Northeast Utilities (Eversource; Berry 2018). This location can be considered a viable point of interconnection for a HVAC interconnection point. Space appears to be available onsite to expand the substation to include the equipment required for the interconnection of offshore wind power. New power transformers metering and switching equipment along with reactive power equipment would be required for an HVAC POI. The transmission line capacity may be available as the lines were built for two reactor units. Access appears to be available to run multiple AC underground circuits to the site.

Granite Shore Power Schiller Station

The Granite Shore Power, Schiller Station is located on the Piscataqua River just west of the U.S. Interstate 95 bridge in Portsmouth, NH (Figure 4.1.2). The plant, located on 81 acres, is adjacent to the Granite Shore Power, Newington Station. The plant load operates two oil- or coal-fired combustion turbines with a biomass boiler and can reach outputs of 155 MW in the winter. This plant can operate as a peaking unit to support grid power fluctuations created by loss of a base case supply.

Figure 4.1.2. Granite Shore Power, Schiller Station.

This 70-year-old plant has a 345-kV interconnection that could be used as a point of interconnection for offshore wind power generated in the GOM. The 345-kV lines out the Schiller Station connect to Three Rivers Substation at the Newington Station and connect to 345-kV substations in Maine. The plant's 81 acres provides enough space to build a HVDC terminal to convert wind power from DC to AC to meet the requirements of the ISO-NE 345-kV system. Schiller Station could also serve as an HVAC point of interconnection with space available to install AC equipment required to connect with the ISO-NE power grid.

Granite Shore Power Newington Station

The Granite Shore Power, Newington Station is located in Newington, NH on the west bank of the Piscataqua River and was built in 1974. The station is located on a 69-acre parcel of land about 1,200 feet west of the Granite Shore Power, Schiller Station (Figure 4.1.3). This facility is an oil-fired unit that can run on natural gas, with a total output of 414 MW. The plant has a black start capability and is used to provide quick start support to the ISO-NE grid.

Figure 4.1.3. Granite Shore Power, Newington Station.

The Granite Shore Power, Newington Station has a 345-kV station with three 345-kV lines. The first line is a Public Service Company of New Hampshire line going to the Timber Swamp Substation, the second is a Public Service Company of New Hampshire line going to the Three Rivers Substation, and the third is a Central Maine Power line going to South Gorham Substation in Maine. Ultimately, the Granite Shore Power, Newington Station is a candidate for both HVAC and HVDC offshore wind power. There appears to be enough room on the site to build a HVDC terminal or a HVAC switching station to connect offshore AC or DC power from a proposed wind farm in the GOM. Granite Shore Power, Newington Station is accessible with an onshore cable route from the Wells Road or the Odiorne Point proposed landfall locations.

Essential Power, Newington Energy Station

Newington Energy Station, owned by Essential Power, is located in Newington, NH on the west bank of the Piscataqua River. The station, built in 2002, is located approximately 4,000 feet west of the Granite Shore Power, Newington Station (Figure 4.1.4). This facility is a combined-cycle natural gas-fired unit, with a total output of 606 MW, and is located on the same 345 kV line as the Granite Shore Power, Newington Station.

Figure 4.1.4. Essential Power, Newington Energy Station.

Timber Swamp Road Substation

Timber Swamp Road Substation, owned by Public Service Company of New Hampshire, is a 345-kV to 115-kV substation. The 345-kV lines tie with Newington Station and Seabrook Station. The Timber Swamp Road Substation is located in Hampton, NH on Timber Swamp Road and is approximate 4.1 miles from the shoreline in Hampton, NH and 3.5 miles from Seabrook Station (Figure 4.1.5). This substation is located in an area where there appears to be room for expansion and may accommodate a HVDC terminal or a HVAC switching station and may be an appropriate location for either a HVAC or HVDC POI.

Figure 4.1.5. Timber Swamp Road Substation.

The Timber Swamp Road Substation is located in a wooded area of Hampton, NH just west of U.S. Interstate 95. The station is located adjacent to the 345-kV right-of-way and a smaller distribution station and right-of-way running to west. This type of station provides an ideal location to connect offshore wind power.

Several 115-kV stations are available as potential interconnection sites, however the typical load generated from an offshore wind farm similar in size to those being developed off the southern New England and New York/New Jersey coasts would deliver more load than the 115-kV system can handle or would require multiple POIs to deliver the wind power load.

4.1.4 Potential Onshore Cable Routes from Landfall to the Point of Grid Interconnection

Potential Landfall Locations

For this discussion, landfalls are locations or properties along the coastline where offshore submarine cables could come onshore and the armored submarine cable would transition to an onshore or terrestrial cable. The landfall locations are selected using several factors: available workspace, landfall location and shoreline accessibility, roadway and highway crossings, and safe distances to buildings and structures. No detailed analysis of site constraints or risks was considered for the selection of project sites at this preliminary stage of the analysis.

Landfall sites are locations where horizontal directional drill exit pits would be located. This horizontal directional drilling (HDD) would run from the landfall offshore to a location where the cable would transition from the ocean bottom, run under the seafloor and continue underground under the beach or rocky coastline to rise up on the shoreline in the landfall property. The onshore cable routes would begin at these landfall locations. (Landfalls are discussed in more detail in Section 4.2 of this document).

Potential Onshore Cable Routes

Onshore underground cable routes were selected as part of this desktop study because large overhead transmission lines have a very lengthy permitting processes and available space constraints make it difficult to permit an overhead facility. The cable routes in this study were developed by visually assessing aerial imagery using ESRI Layers and Google Earth as a preliminary assessment of landfall locations, shoreline accessibility roadway width, type of roads and congestion, wetland, stream, river and culvert crossings. Railroad crossings and highway crossings along with types of roads were considered i.e., local, county, state or federal roads, as part of the preliminary route selection process.

A total of four potential landfall locations were selected along the New Hampshire coastline. Two route options have been identified as part of this desktop review to connect the landfall with the POI. Some of the routes use the same roads to get to different POIs, as described in the subsections below and summarized in Table 4.1.1. All routes in this discussion are hypothetical, there are no offshore wind projects being developed in the GOM at this time.

Odiorne Point to Schiller and Newington Stations

Due to the proximity of the three power generating facilities located along the Piscataqua River, this route is described collectively with a terminal point for all three facilities; 1) Granite Shore Power, Schiller Station; 2) Granite Shore Power, Newington Station; and 3) Essential Power, Newington Energy Station.

This route to Schiller and Newington Stations begins at a landfall at the Odiorne Point parking area just off Ocean Boulevard Route 1A (Figure 4.1.6). Cables would be installed underground in a manhole and duct bank heading west on Route 1A, where an HDD crossing of a tidal stream is required. The cables would continue west on Route 1A across Sagamore Road and continue down Elwyn Road to the intersection of Route 1, then go north on Route 1 to the Portsmouth traffic circle. An HDD may be required to go under the Portsmouth Traffic Circle and U.S. Interstate 95. The cables would go under the traffic circle and U.S. Interstate 95 and continue along State Route 4 northwest in the shoulder of the limited access highway, then go northeast on Gosling Road to the Woodbury Avenue intersection, where it would then go to either the Schiller Station or Newington Stations. This underground cable route is 8.2 miles.

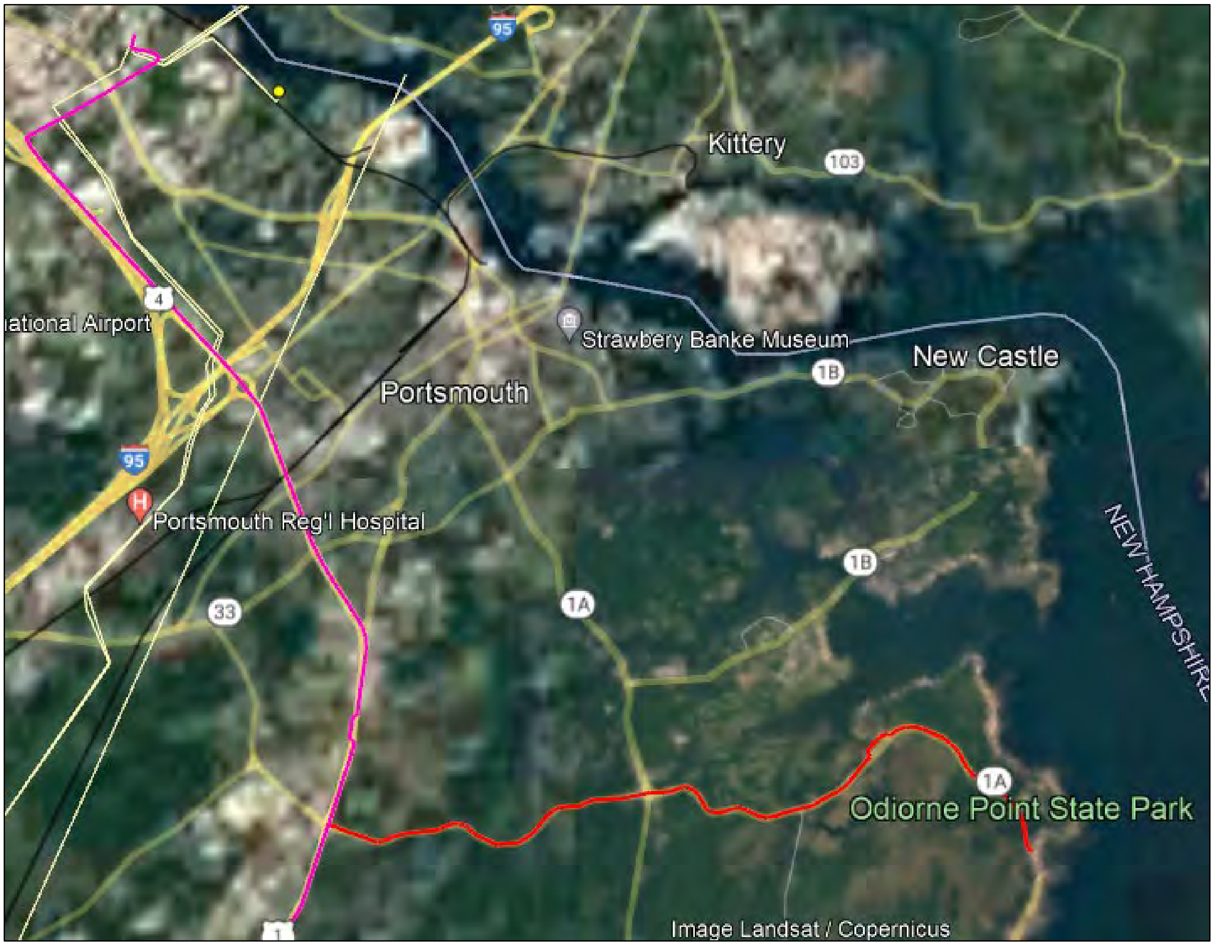

Figure 4.1.6. Hypothetical cable route from Odiorne Point to Newington Station (red and pink lines).

Wallis Road at Pirates Cove Beach to Schiller and Newington Stations

Due to the proximity of the three power generating facilities located along the Piscataqua River, this route is described collectively with a terminal point for all three facilities; 1) Granite Shore Power, Schiller Station; 2) Granite Shore Power, Newington Station; and 3) Essential Power, Newington Energy Station.

This route to Schiller and Newington Stations, begins at a landfall at the end of Wallis Road where an HDD crossing is required under the tidal area and continues along Wallis Road across Brackett Road to the intersection of Sagamore Road, and continues southwest on Wallis Road to the intersection of Lang Road where the cables go northwest on Lang Road (Figure 4.1.7). Another HDD crossing would be required under Berry's Brook. The cable route continues along Lang Road to the intersection of Route 1 and then northeast on Route 1 to the Portsmouth Traffic Circle. An HDD may be required to go under the Portsmouth Traffic Circle and U.S. Interstate 95. The cables would go under the traffic circle and U.S. Interstate 95 along the shoulder of State Route 4 and turn northeast on Gosling Road to the Woodbury Avenue intersection, where it would then go to either the Schiller Station or Newington Stations. This underground cable route is 10.1 miles.

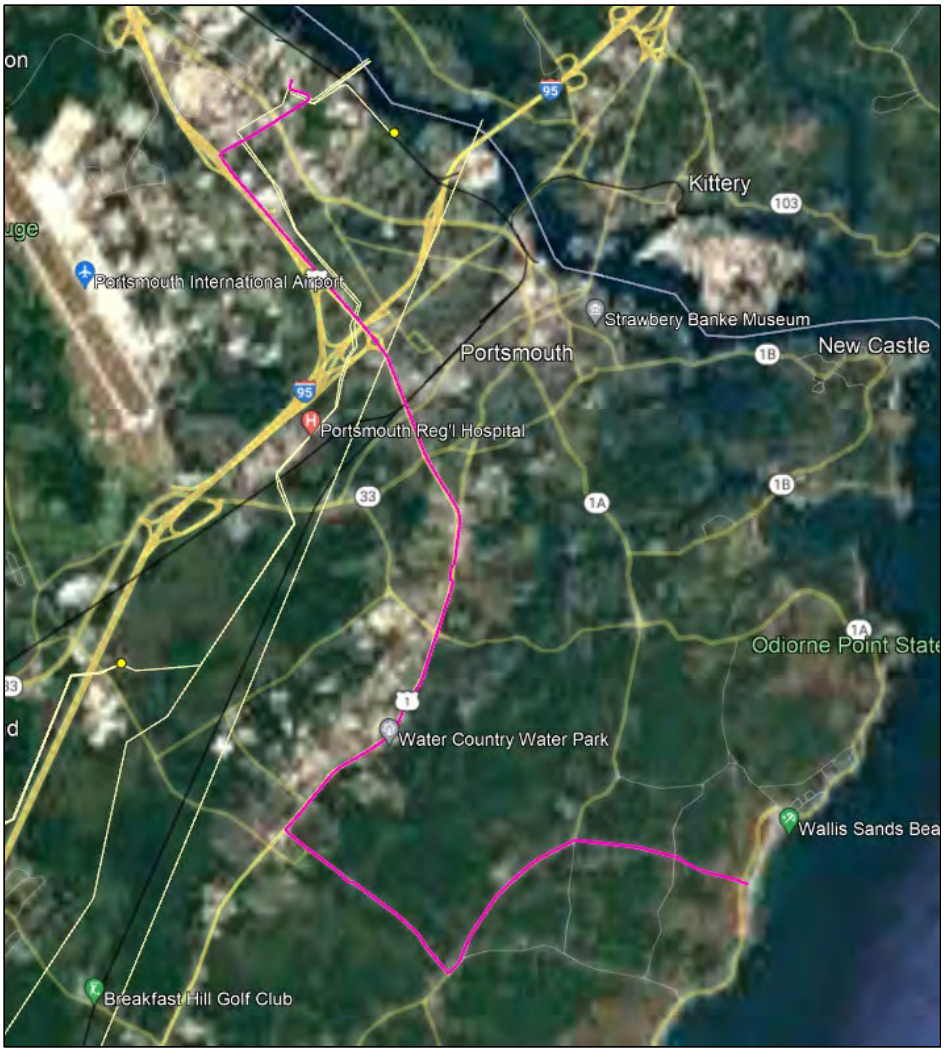

Figure 4.1.7. Hypothetical cable route from Wallis Road at Pirates Cove Beach to Newington Station (pink line).

North Beach to Timber Swamp Road Substation

This route to Timber Swamp Road Substation begins at a landfall selected in a parking area on the north end of North Beach. Underground cables would run west across Route 1A and follow Route 27 west to an HDD crossing of a small tidal stream near Mill Point Lane (Figure 4.1.8). The cables would continue along New Hampshire Route 27 west to the intersection of Route 1. The cables would cross under Route 1 or go south through a parking lot and circle back on to Route 27. The second option avoids construction in the major intersection. The cables would continue west and north along Route 27 until the Route 101 interchange. An HDD crossing of Route 101 would be required. The cables would continue along Route 27 until just after Liberty Street where a second HDD crossing would be required to go under U.S. Interstate 95. The cables would continue west along Route 27 to the intersection of Timber Swamp Road. The cable would go south on Timber Swamp Road then turn west on the access road into the Timber Swamp Road Substation. This underground cable route is 4.8 miles.

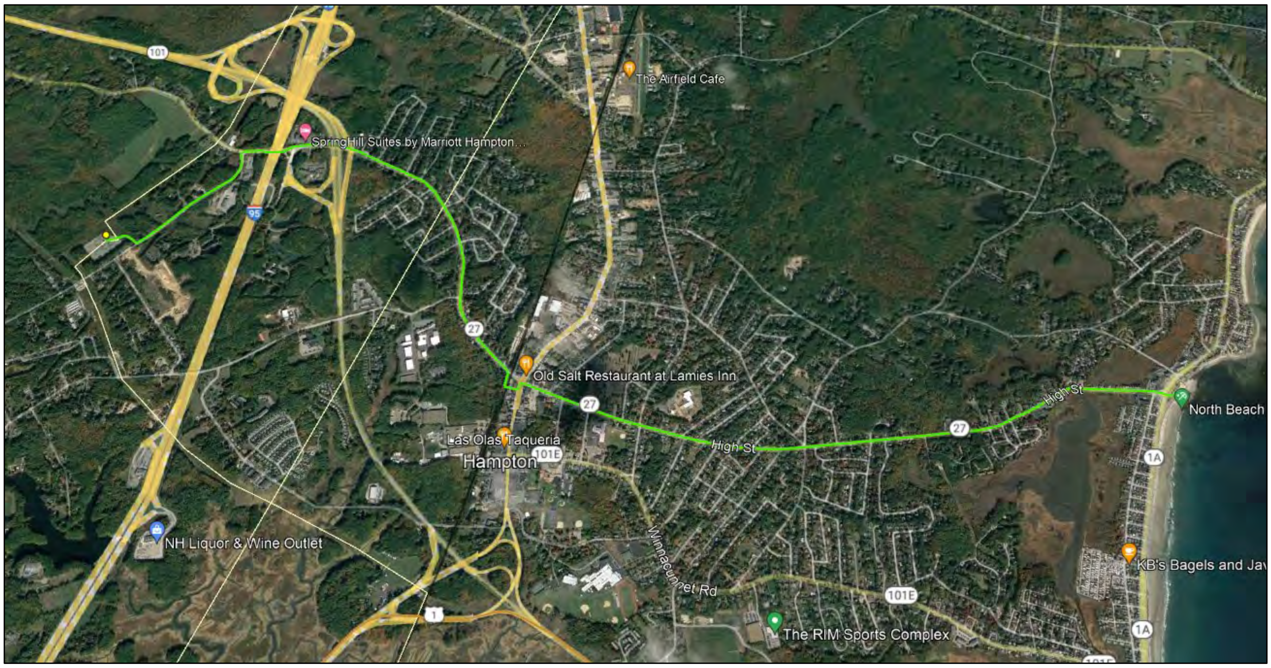

Figure 4.1.8. Hypothetical cable route from North Beach to Timber Swamp Road Substation (green line).

Parking Area on Great Boars Head Avenue, Hampton, NH to Timber Swamp Road Substation – Option 1

This route to Timber Swamp Road Substation begins at a landfall selected in a parking area on the north end of North Beach at Great Boars Head Avenue. The underground cable route goes west on Great Boars Head Avenue and then turns north on Route 1A running in the median between the two lanes (Figure 4.1.9). Any construction in this area would have to be done off season. The cable route follows Route 1A for 0.6 miles and then heads northwest along Route 101E. An HDD crossing of a tidal stream is required. The route continues west along Route 101E to the intersection of Route 1 and heads north on Route 1 to the intersection of Route 27. The underground cables would run through a parking lot to avoid the busy congested intersection of Route 1 and Route 27, then continue west on Route 27. An HDD would be required to go under Route 101. The cable would continue west on Route 27, where a second HDD would be required to cross U.S. Interstate 95 before going south on Timber Swamp Road. The cable would go south on Timber Swamp Road then turn west on the access road into the Timber Swamp Road Substation. This underground cable route is 5.7 miles.

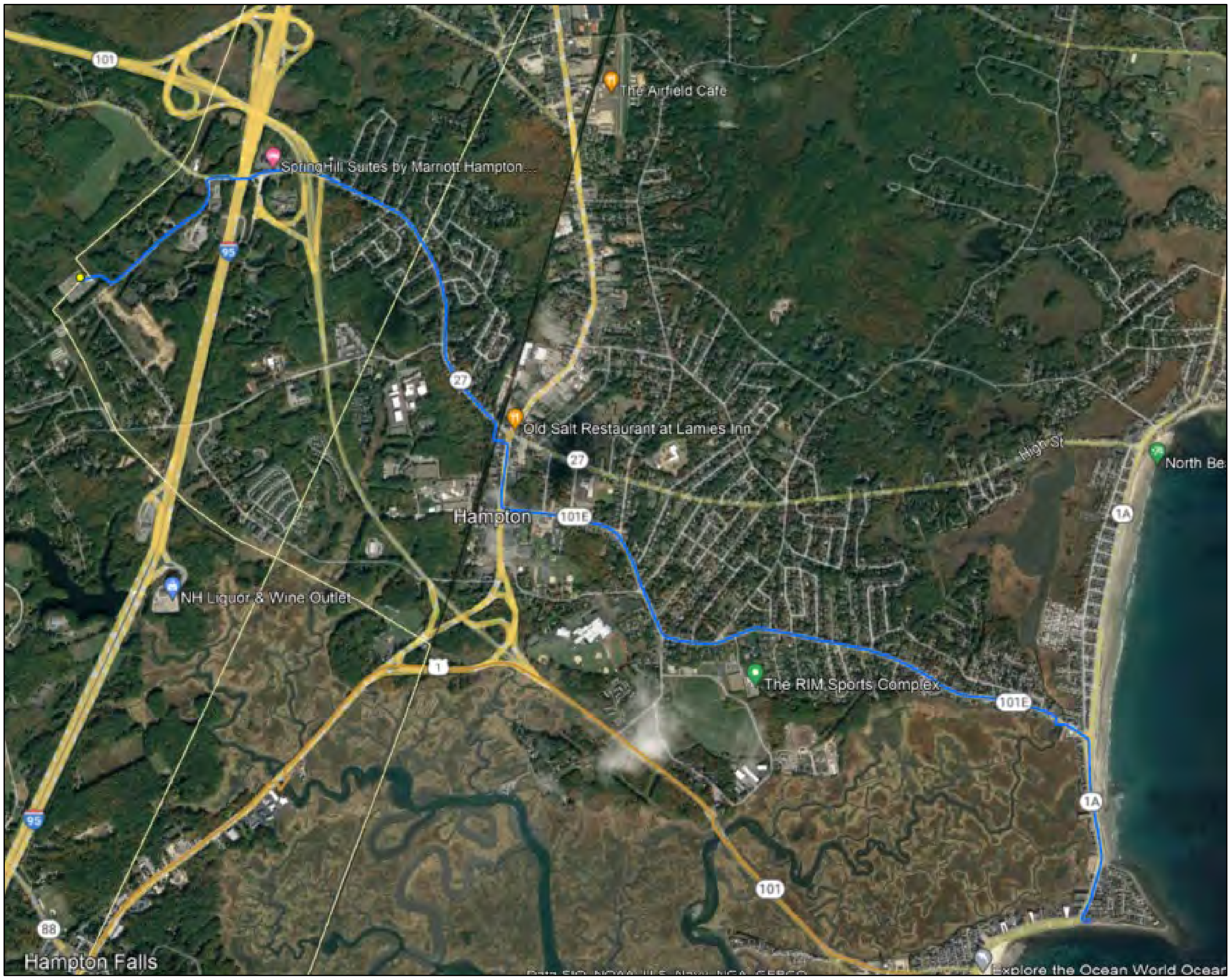

Figure 4.1.9. Hypothetical cable route from parking area on Great Boars Head Avenue, Hampton, NH to Timber Swamp Road Substation Option 1 (blue line).

Parking Area on Great Boars Head Avenue, Hampton, NH to Timber Swamp Road Substation – Option 2

This route to Timber Swamp Road Substation begins at the same landfall selected in Option 1 (a parking area on the north end of North Beach at Great Boars Head Avenue). The underground cable route goes west on Great Boars Head Avenue then South on Route 1A through the median and the parking area of Hampton Beach (Figure 4.1.10). This work would have to be done in the offseason. The cables would travel southwest on Route 1A to the intersection of Route 101 and head west on Route 101. An HDD crossing of a tidal stream on Route 101 is required. The cables would follow Route 101 to the interchange of Route 1 and head north on Route 1. The cable route would continue on Route 1 to the intersection of Route 27, where the cables would go through a parking area to avoid the busy intersection of Route 1 and Route 27. The cables would then head west on Route 27 where an HDD would be required to go under Route 101. The cables would continue west on Route 27 where a second HDD would be required to cross U.S. Interstate 95 before going south on Timber Swamp Road. The cable would go south on Timber Swamp Road then turn west on the access road into the Timber Swamp Road Substation. This underground cable route is 5.6 miles.

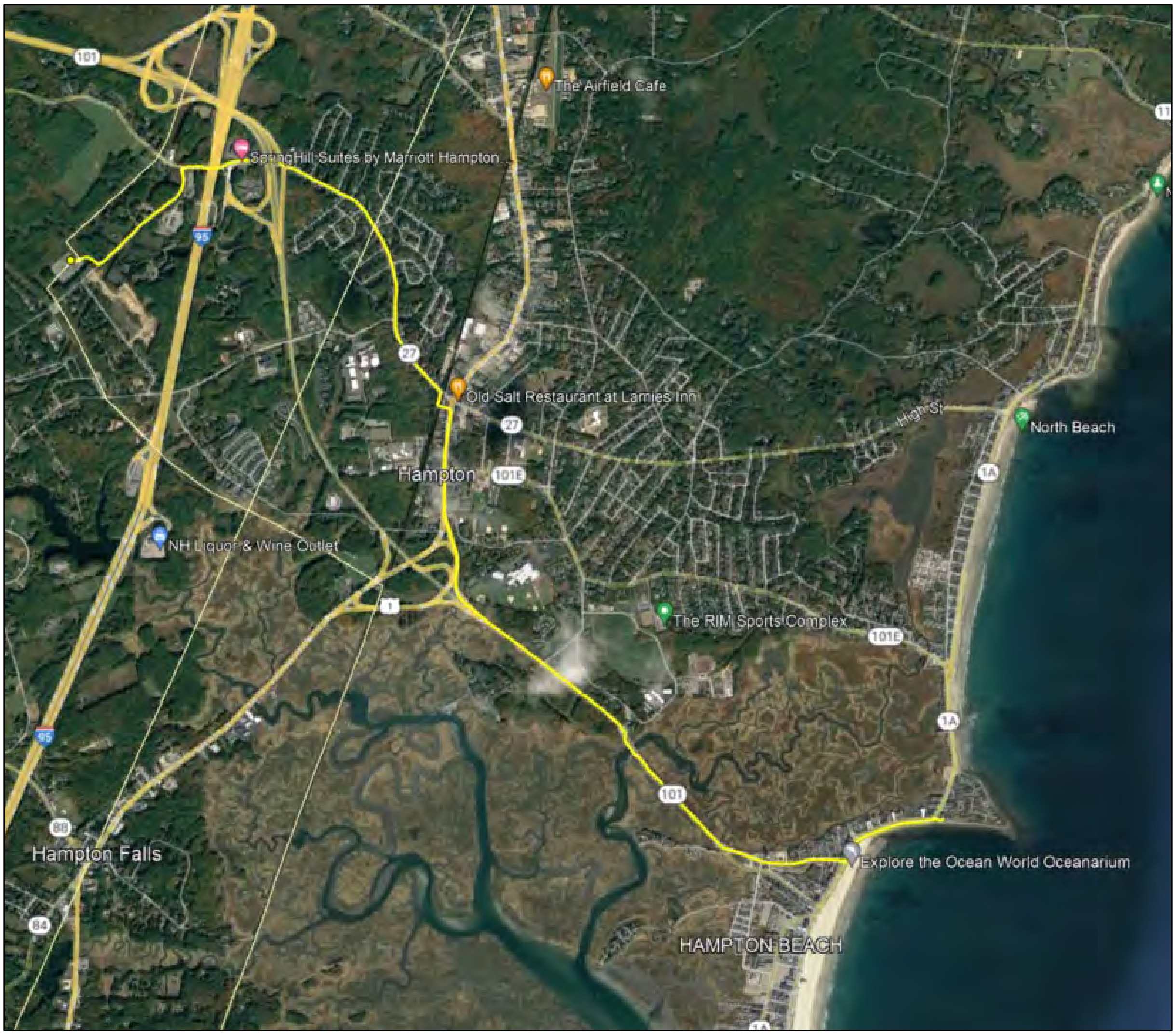

Figure 4.1.10. Hypothetical cable route from Great Boars Head Avenue, Hampton, NH to Timber Swamp Road Substation Option 2 (bright yellow line).

Parking Area on Great Boars Head Avenue, Hampton, NH to Seabrook Station

This route to Seabrook Station begins at a landfall selected in a parking area on the north end of North Beach at Great Boars Head Avenue. The underground cable route goes west on Great Boars Head Avenue then south on Route 1A through the median and the parking area of Hampton Beach (Figure 4.1.11). This work would have to be done in the offseason. The cables would travel southwest on Route 1A to the intersection of Route 101 and head west on Route 101. An HDD crossing of a tidal stream on Route 101 is required. The cables would follow Route 101 to the interchange of Route 1 and head south on Route 1. An HDD crossing of the

Route 1 interchange is required. The cable route continues south on Route 1, where another HDD crossing is required to cross a tidal stream. The cables would continue to the south on Route 1 where another HDD is required under the Hampton Falls River. The cable route would continue south on Route 1 and then turn to the east on the Seabrook Access Road and go into the station. This underground cable route is 6.4 miles.

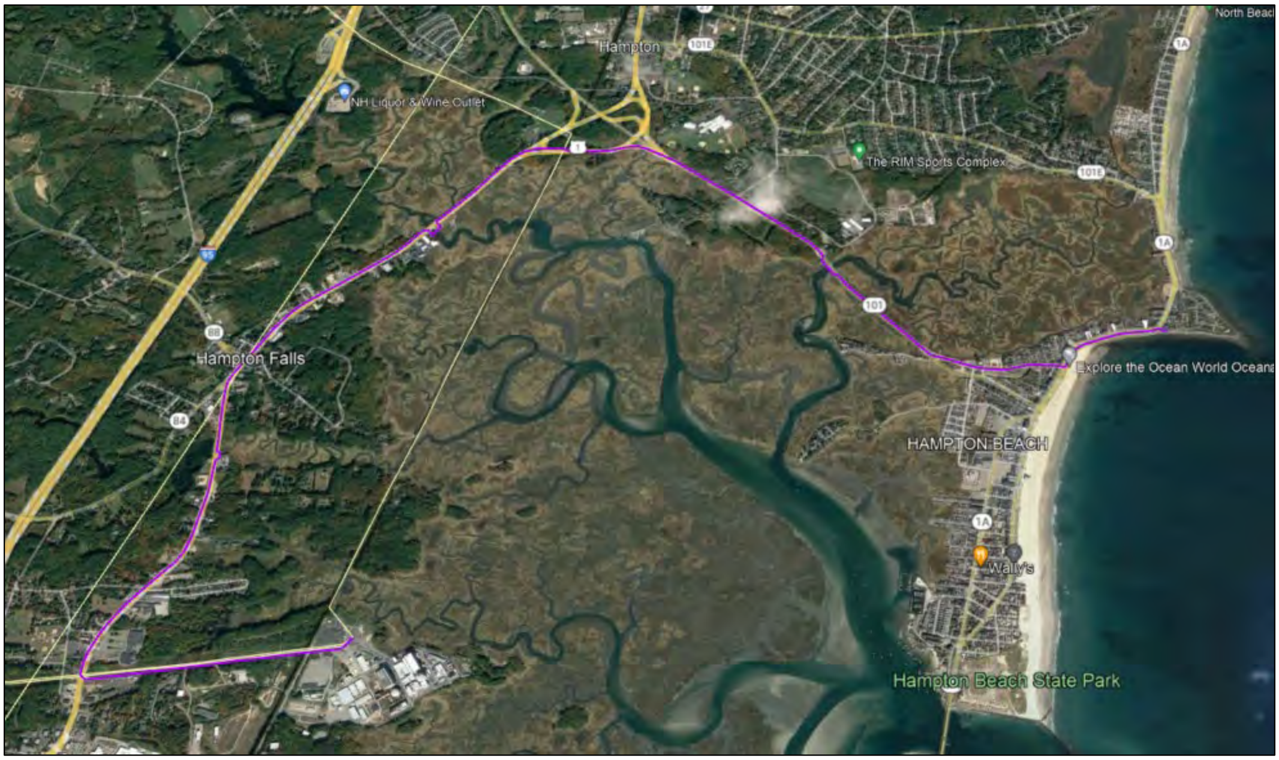

Figure 4.1.11. Hypothetical cable route from Great Boars Head Avenue, Hampton, NH to Seabrook Station (purple line).

Table 4.1.1. New Hampshire Onshore Cable Routing Study

Route #	Route Name	Landfall	POI	Route Length	# of HDD Crossings	Risks
1	Odiorne Point to Schiller and Newington Stations[1]	Odiorne Point, Rye	Granite Shore Power, Schiller Station Granite Shore Power, Newington Station Essential Power, Newington Energy Station	8.2 mi	2	HDD crossing on Route 1A tidal stream Long HDD crossing of Portsmouth Traffic Circle and U.S. Interstate 95 Permits/rights-of-way needed for limited-access highways (U.S. Interstate 95, Route 4)
2	Wallis Road at Pirates Cove Beach to Newington Station	Wallis Road, Rye	Granite Shore Power, Schiller Station Granite Shore Power, Newington Station Essential Power, Newington Energy Station	10.1 mi	3	HDD crossing on Wallis Road tidal stream HDD crossing under Berry's Brook on Lang Road Long HDD crossing of Portsmouth Traffic Circle and U.S. Interstate 95 Permits/rights of way needed for limited-access highways (U.S. Interstate 95, Route 4)
3	North Beach to Timber Swamp Road Substation	Parking Area for North Beach, Hampton	Timber Swamp Road Substation	4.8 mi	3	Construction likely limited to off-season along the beach HDD crossing on Route 27 tidal stream Rights of way needed for private property access on Route 27 and Route 1 HDD under U.S. Interstate 95 and Route 101
4	Parking Area on Great Boars Head Avenue to Timber Swamp Road Substation – Option 1	Great Boars Head Ave, Hampton	Timber Swamp Road Substation	5.7 mi	3	Construction likely limited to off-season along the beach HDD crossing on Route 101E tidal stream Rights of way needed for private property access on Route 27 and Route 1 HDD under U.S. Interstate 95 and Route 101

Route #	Route Name	Landfall	POI	Route Length	# of HDD Crossings	Risks
5	Parking Area on Great Boars Head Avenue to Timber Swamp Road Substation – Option 2			5.6 mi	3	Construction likely limited to off-season along the beach HDD crossing on Route 101 tidal stream Rights of way needed for private property access on Route 27 and Route 1 HDD under U.S. Interstate 95 and Route 101
6	Parking Area on Great Boars Head Avenue to Seabrook Station		Seabrook Station	6.4 mi	4	Construction likely limited to off-season along the beach HDD crossing of tidal streams at; Route 101 and Route 1 HDD under Route 1

[1] Due to the proximity of the three power generating facilities located along the Piscataqua River, this route is described collectively for all three facilities; 1) Granite Shore Power, Schiller Station; 2) Granite Shore Power, Newington Station; and 3) Essential Power, Newington Energy Station.

4.2 Cable Routing, Landfall Selection, Including Necessary Permitting

A preliminary analysis was completed as a screening tool to assist in identifying feasible alternatives and critical flaws associated with potential offshore corridors and landfall locations. The major constraints were evaluated to a potential transmission corridor within the GOM RFI Area (Figure 1.2.1) and potential shore landings along the New Hampshire coast. This evaluation also included identification of relevant stakeholders and associated permitting requirements to facilitate offshore wind development activities with respect to submarine power cables and shore-end landfalls.

4.2.1 Marine Routing Considerations

The primary routing concerns in this region of the Outer Continental Shelf (OCS) vary depending on the area-specific location in question. Further offshore, primary routing drivers include avoidance of potential and/or existing offshore energy leases, minimization of areas of increased risk from external conflict due to commercial vessel traffic and anchoring, reduction of risks due to bottom-contact fishing, and optimizing crossings of existing and planned subsea assets.

On the approaches to landfalls, additional concerns occur in the form of sand resource areas and active sand borrow areas use to replenish beaches, seafloor hazards and obstructions (e.g., unexploded ordnance [UXO], shipwrecks), spans of shallow water and complex geology that limit cable installation methods, and deconfliction from other assets making landfall nearby.

Publicly available data sources are used to inform potential routing and siting criteria associated with offshore export cable routes. These datasets included features that can be classified as both opportunities and constraints relative to their potential impacts to siting a future offshore export cable corridor in the region.

The following datasets were evaluated for this initial assessment:

- BOEM data (e.g., RFI Area, sand borrow areas/sand resources)
- NOAA National Centers for Environmental Information (NCEI) data (e.g., gridded bathymetry)
- NOAA Nautical Charts
- NOAA National Marine Fisheries Service (NMFS) data (e.g., species management areas, habitat areas)
- U.S. Navy data (e.g., operating areas, submarine transit lanes, and special use airspace)
- U.S. Coast Guard data (e.g., protected areas)
- Marine Cadastre (e.g., commercial vessel traffic, charted cables, cable areas)
- U.S. Fish and Wildlife Service (USFWS) National Wetlands Inventory
- U.S. Geological Survey (USGS) data (e.g., seafloor sediment, topographic maps)

- Northeast Ocean Data Portal (e.g., danger zones, traffic separation schemes, anchorage areas, and shipwrecks, eelgrass)
- New Hampshire Geodata Portal (e.g., parcel data)
- Aerial Imagery

Using this information, study areas can be established that encompass the area of interest and limits of potential offshore export cable route corridors for evaluation against relevant data sources. As a result, indicative offshore cable corridor routes can be developed to be further evaluated.

4.2.2 Landfall Considerations

As mentioned in Section 4.1 (Potential Landfall Locations), considerations when selecting potential landfall sites included general proximity to the area of interest and targeted POIs, in addition to the spatial requirements needed to perform a successful shore landing, and associated infrastructure. Larger cleared areas with a potential for direct access—such as parking lots—were targeted to the extent practicable. Suitability of approach from both the marine side and the associated onshore land route were considered important factors in landing site selection. The four potential landfall locations discussed in Section 4.1.4 above (Odiorne Point, Wallis Road, North Beach, and Great Boars Head Ave) are provided in Figure 4.2.1.

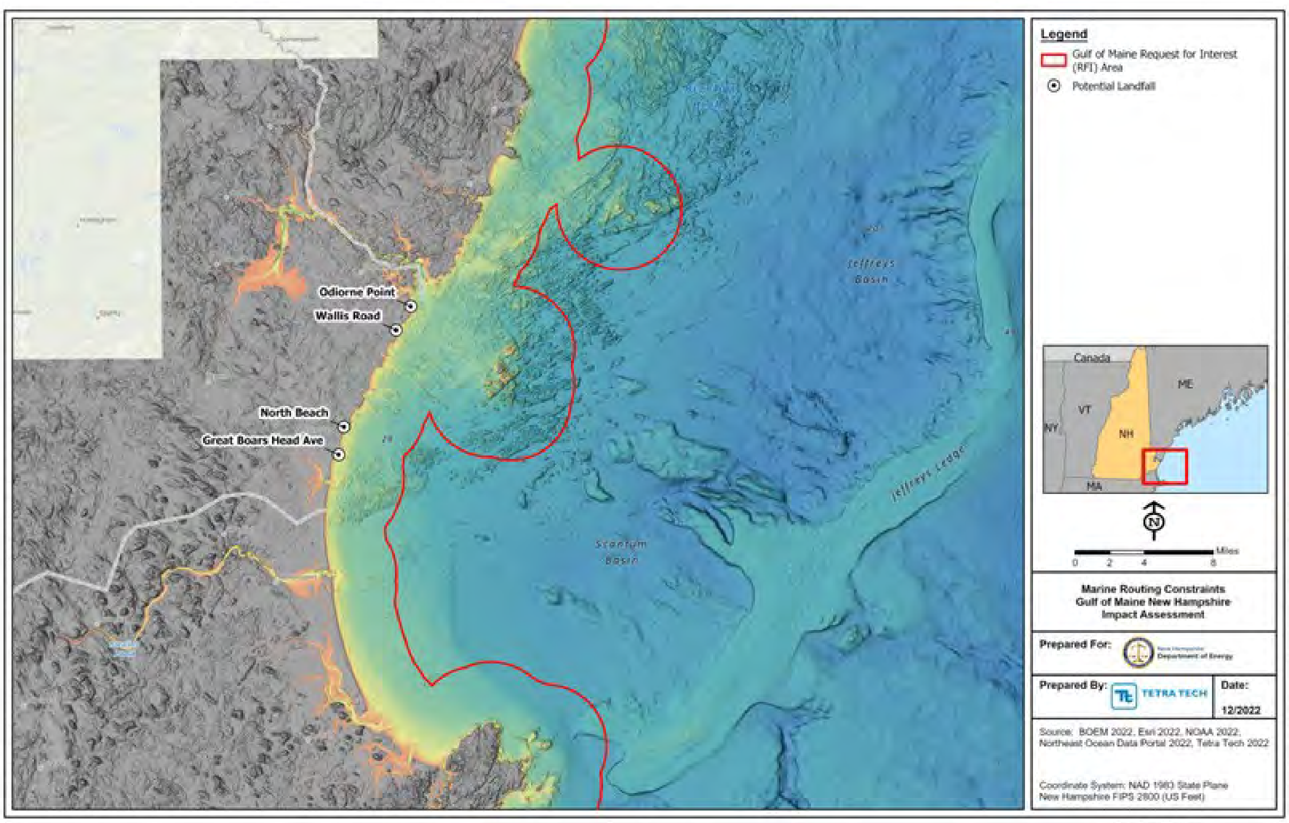

Figure 4.2.1. Potential landfall locations along the New Hampshire coast.

Offshore export cable installation activities at the landfall typically consist of pre-installation of a single cable duct/pipe installed by either jet burial, open cut trenching, or a particular trenchless installation method from the onshore transition joint bay to extend beyond the intertidal area.

Trenchless installation technology offers a variety of methods for the installation of different pipe sizes and types, depending on location, soil type and depth of penetration. Some of the trenchless pipeline installation methods are HDD, horizontal auger boring (HAB), pipe jacking, pipe ramming and impact moling. These methods have proved to be time-and cost-effective when compared to trenching methods.

Ploughing or mechanical cutting (also termed 'open cut' trenching) involves excavating a trench to either install new or repair existing pipes, conduit, and cables. While economical, this method may result in negative social (e.g., site safety and pedestrian safety, stakeholder concerns) and environmental costs (e.g., noise, vibration, dust, and air pollution) during construction.

HDD is a trenchless method of installing underground utilities within a conduit along a pre-designed bore path using a surface-launched drilling rig. HDD is a common alternative to open-cut cable installation to reduce surface disturbance in environmentally sensitive areas (i.e., protected cultural and natural resource areas), to avoid other existing infrastructure (i.e., roadways, railroads, and utilities), to traverse high energy shorelines (i.e., areas of significant tidal changes, wave action, sediment erosion, or outflow) and when deep burial depths are required (i.e., under federal navigation channels). HDD is commonly mandated by regulators and is considered an industry best practice for many situations.

While all landings require further evaluation and detailed design work, initial indications suggest HDD would be advantageous for all landings to mitigate impacts to shorelines. Understanding of historic and cultural resources, and other protected or sensitive areas should be developed for further route micrositing or avoidance as stakeholders and regulators are engaged. Additionally, a thorough geotechnical investigation of the project site is critical to decide the best method and equipment suitable for the project.

4.2.3 Permitting Considerations/Regulatory Setting

Numerous federal, state, and municipal permits and approvals are required for the siting, construction, operation, and decommissioning of an offshore wind project and associated infrastructure including transmission cables. Section 6 Permitting and Regulatory Issues discussed these permits which are summarized in Table 6.0. 1**Error! Reference source not found.** The New Hampshire permits required for a transmission cable landfall are discussed below.

State of New Hampshire Approvals

Landfall in New Hampshire would trigger permit requirements under state and local jurisdictions. The New Hampshire Public Utilities Commission (NHPUC) regulates public utilities as defined in Revised Statutes Annotated (RSA) 362:2 and their affiliates as defined in RSA 366:1, II. Typically, these are investor-owned electric, telephone, natural gas, water, sewer, and steam utilities. The NHPUC is the arbiter between the interests of these utilities and their customers, in accordance with RSA 365.8. A License for Construction across Public Waters and Roadways from the NHPUC is required for construction of utilities across public waters.

The New Hampshire Site Evaluation Committee (NHSEC) is responsible for issuing certificates to energy facilities such as natural gas pipelines and certain electric generating and transmission facilities. The Committee is also authorized to impose terms and conditions upon such certificates and to monitor the construction and operation of the certificated facilities (NHPUC 2022), in accordance with renewable energy goals of RSA 362-F.

Environmental resources in New Hampshire are protected under the New Hampshire Department of Environmental Services (NHDES). Permitting activities to be considered under the Department include:

- Wetlands Dredge and Fill Permit
- Shoreland Protection Act Permit
- Alteration of Terrain Permit
- Section 401 Water Quality Certification

The New Hampshire Coastal Program (NHCP) protects clean water, restores coastal habitats, is one of 34 federally approved coastal programs authorized under the Coastal Zone Management Act (CZMA), and is administered by NHDES. As federal activities can greatly impact a state's coastal resources, the CZMA established a formal review process commonly known as federal consistency. Section 307 of the CZMA, known as the federal consistency provision, provides a mechanism for states to manage coastal uses and resources and to facilitate cooperation and coordination with federal agencies. The NHCP is responsible for issuing all federal consistency decisions in New Hampshire.

4.3 Cables, Pipelines, and Other Infrastructure

Crossings of cables, pipelines, or other seabed infrastructure are common occurrences for linear marine infrastructure planned in developed areas. Crossings require coordination with the owner of the existing asset to ensure the locations and crossing methods can be agreed upon, so operations and maintenance (O&M) on both systems is not encumbered.

4.3.1 Telecommunications and Power Cables

Subsea cables cross the continental shelf and connect coastal areas. In-service and out-of-service or retired telecommunications cables occur throughout the world's oceans. Modern fiber optic cables carry voice and data, while many of the oldest telegraph cables, some installed more than 150 years ago, still lie on or below the seabed. Power transmission cables may also cross nearer to the shoreline as part of a nation's power infrastructure.

The NOAA's Office of Coast Survey is responsible for updating and maintaining the NOAA Nautical Charts of the United States, which were reviewed to identify charted subsea cables. On occasion, the USACE or BOEM may have information regarding seabed assets that are not plotted on nautical charts; therefore, consultation with the USACE and BOEM regarding seabed assets during the normal course of permitting is advisable. Table 4.3.1 and Figure 4.3.1 summarize the four charted and two planned submarine cables within the GOM RFI area.

Table 4.3.1. Identified Seabed Infrastructure.

System	Status	Landing
Hibernia Seg E (EXA Atlantic, formerly GTT/Hibernia)	Operational (2001)	Lynn, MA
French Atlantic (1869)	Abandoned	Green Harbor, MA
Unknown	Abandoned (likely)	Weeset/Orleans, MA
Unknown	Abandoned (likely)	Nauset Beach, MA
Atlantic Link: Option 1 - 775 Southern Route (EXA Atlantic)	Planned	Pilgrim Nuclear Station, Plymouth, MA
Atlantic Link: Option 2 - Nearshore Route (EXA Atlantic)	Planned	Pilgrim Nuclear Station, Plymouth, MA

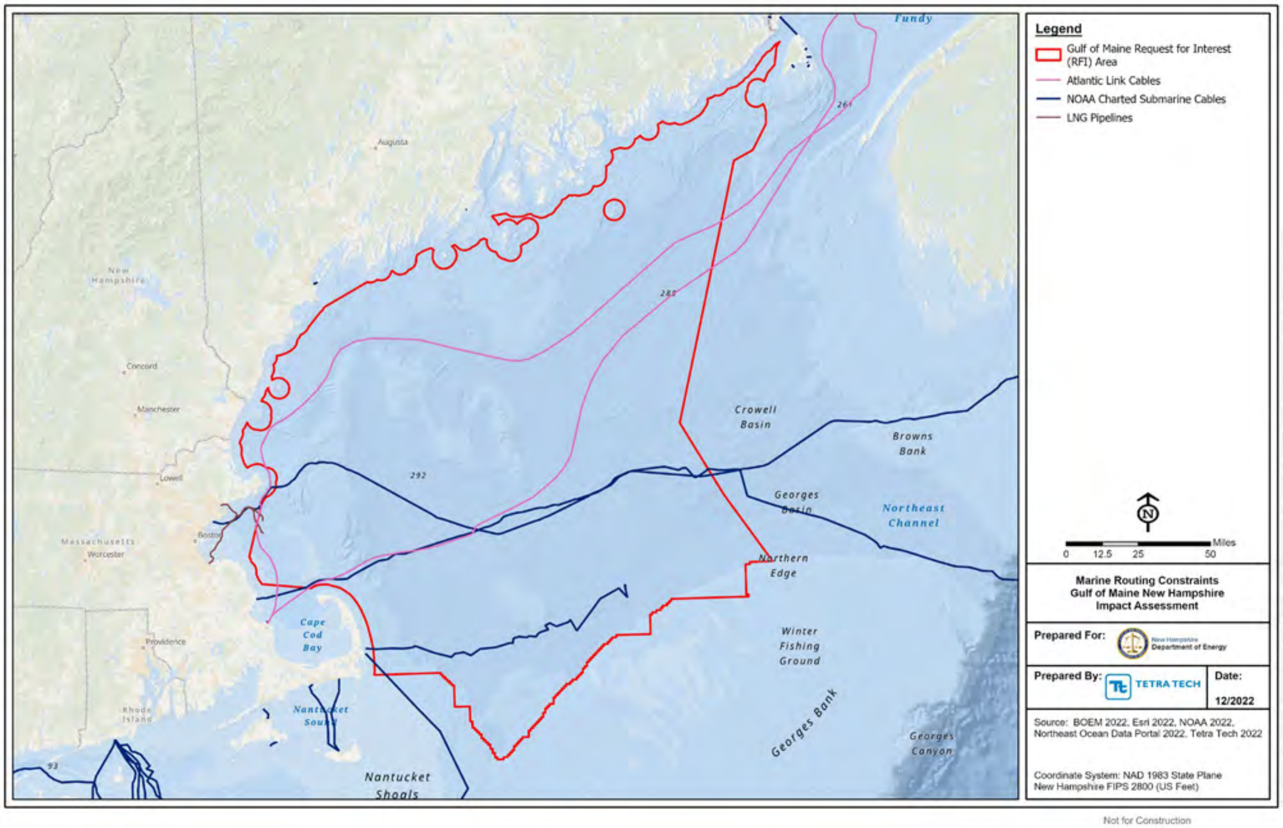

Figure 4.3.1. Submarine cables and pipelines.

Engineering, installation methodologies, and notification requirements for crossing telecommunications cables have been established by the International Cable Protection Committee and formalized in a series of best-practices guidelines. Additional information on cable location, ownership, and owner contact information may be available from federal and local agencies (e.g., U.S. Navy, USACE, and the respective State Ports Authorities), from commercial databases, and from cable maintenance authorities and cable operators. It must be noted that uncharted cables related to DOD activities or facilities may occur within the area. Additional review of existing and proposed telecommunications and power cables should be considered during export cable routing.

Submarine Cable Areas may contain one or more submarine cables. The geographic scope of that area is governed by local conditions but shall include the immediate area which overlies a cable. Charted Cable Areas are identified along the Maine and New Hampshire coasts coinciding with the RFI Area are included in Figure 4.3.2 and described as follows: Off the coast of Maine and New Hampshire, four main cable areas are designated to the Isle of Shoals: Wood Island/Fort Foster (Maine), Sisters Point/Crescent Beach (Maine), Jenness Beach (New Hampshire) and Pirates Cove Beach (New Hampshire).

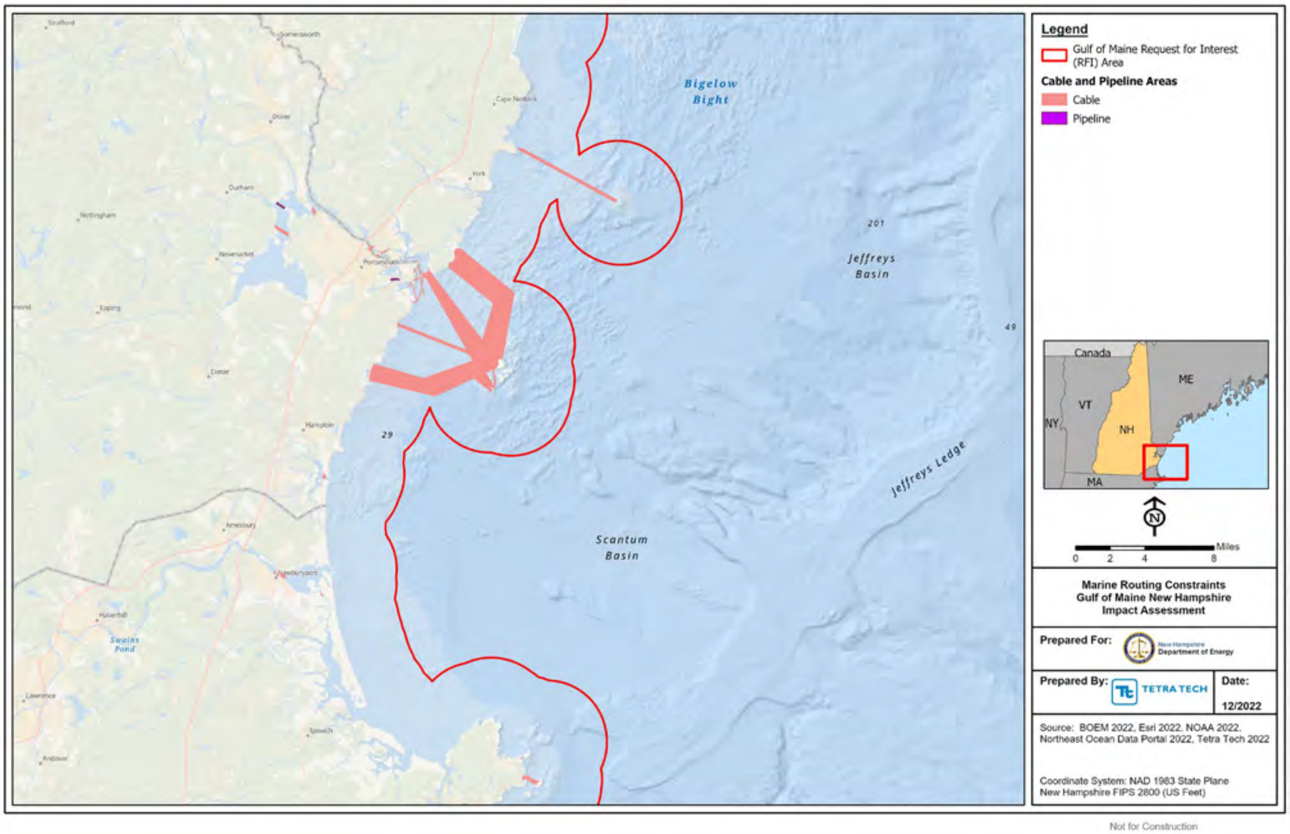

Figure 4.3.2. Submarine Cable Areas.

Numerous smaller Cable Areas are noted at the mouth of Little Harbor and the Piscataqua River, as well as further upstream coinciding with the Blue Star Memorial and Sarah Mildred Long Bridges, and along the southern shore between Kittery Foreside and Seavey Island (Portsmouth Naval Shipyard), Maine. The number, type, or status of any potential crossings within these designated areas is currently unavailable. Other Cable Areas occur along the coast, providing utilities from the mainland to various coastal islands.

Three larger Cable Areas off the coast of Portland, Maine include: Cape Elizabeth to Bailey Island; Casco Bay; and in between Peaks Island, Great Diamond Island, and Long Island. Several cable and pipeline areas traverse the islands offshore of the Portsmouth, Falmouth and Yarmouth coasts, shoreward of the Cape Elizabeth to Bailey Island Cable Area. Cable areas are identified off Popham Beach toward Cape Small in the vicinity of a naval aircraft practice mining range area off South Bristol and Pemaquid Point toward a naval sonobuoy test area. Other cable areas are noted off the northeast coast of Maine along and off the coast of South George, traversing West and East Penobscot Bay, Jericho Bay, and Acadia National Park.

Off the coast of Massachusetts, several cable and pipeline areas traverse the Boston Harbor Islands and across Broad Sound. The number, type, or status of any potential crossings within these designated areas is not known. Other cable areas occur along the coast providing utilities from the mainland to various coastal islands include Manchester (Lobster Cove) to Bakers Island, Gloucester Harbor, Lands End (Loblolly Cove) to Thacher Island, Gap Cove (Rockport) to Straitsmouth Island, and Newburyport (Merrimack River) to Rings Island.

4.3.2 Pipelines

Pipelines, generally transporting water or petroleum liquid or gas products, may also cross coastal areas along with outfall pipes that may be utilized to drain storm water or treated effluent from onshore locations. A Pipeline Area is any area that contains one or more types of pipelines. Within protected waters such as harbors, rivers, bays, estuaries, or other inland waterways, the location of pipelines is indicated as "Pipeline Area" on NOAA nautical charts and maps.

More detailed nautical charts may show outfall pipes as these features typically only extend a few hundred feet from the shoreline. As potential cable landings are evaluated in greater detail, outfall pipes should also be investigated. This is particularly true for the offshore cooling water intake/discharge pipes (tunnels) associated with the Seabrook Station Power Plant, which includes an offshore intake situated above the seafloor approximately one mile offshore. Importantly, abandoned outfalls may or may not be found on charts, and a discussion with local landing municipalities and consultation of old maps may be useful, especially as non-iron-containing (e.g., concrete) buried pipes may be challenging or impossible to detect with standard geophysical techniques.

Two charted pipelines occur within the RFI Area approximately 11 miles (18 km) west of Marblehead Neck, Massachusetts, with landing locations at Salem and Quincy. These areas are associated with the Northeast Gateway and Neptune Deepwater Liquefied Natural Gas (LNG) Ports, connecting into the HubLine Pipeline. No other charted pipelines are evident along the coastline in the vicinity of the RFI Area.

Additional review of existing and proposed pipelines should be considered during export cable routing. As previously mentioned, other regulatory agencies may have additional information regarding potential pipelines.

4.3.3 Obstructions

Numerous obstructions are charted throughout the RFI Area. These obstructions can include artificial reefs and fish havens containing a variety of materials from debris to rocks, or even sunken vessels. Notably, there are charted shipwrecks off the New Hampshire coast that should be avoided. Publicly available shipwreck and obstruction data from NOAA Coast Survey's Automated Wreck and Obstruction Information System was used to identify charted shipwrecks in the RFI Area (Figure 4.3.3).

Obstructions, artificial reefs, fish havens, and submerged piles should all be avoided during export cable routing as a hazard to installation. The increased fishing efforts near these features may also pose an additional risk to submarine cables from potential vessel anchor impacts. Additional items of debris may be encountered during marine survey and should be evaluated as potential hazards and avoided through micrositing or otherwise mitigated through further investigation and removal, if necessary.

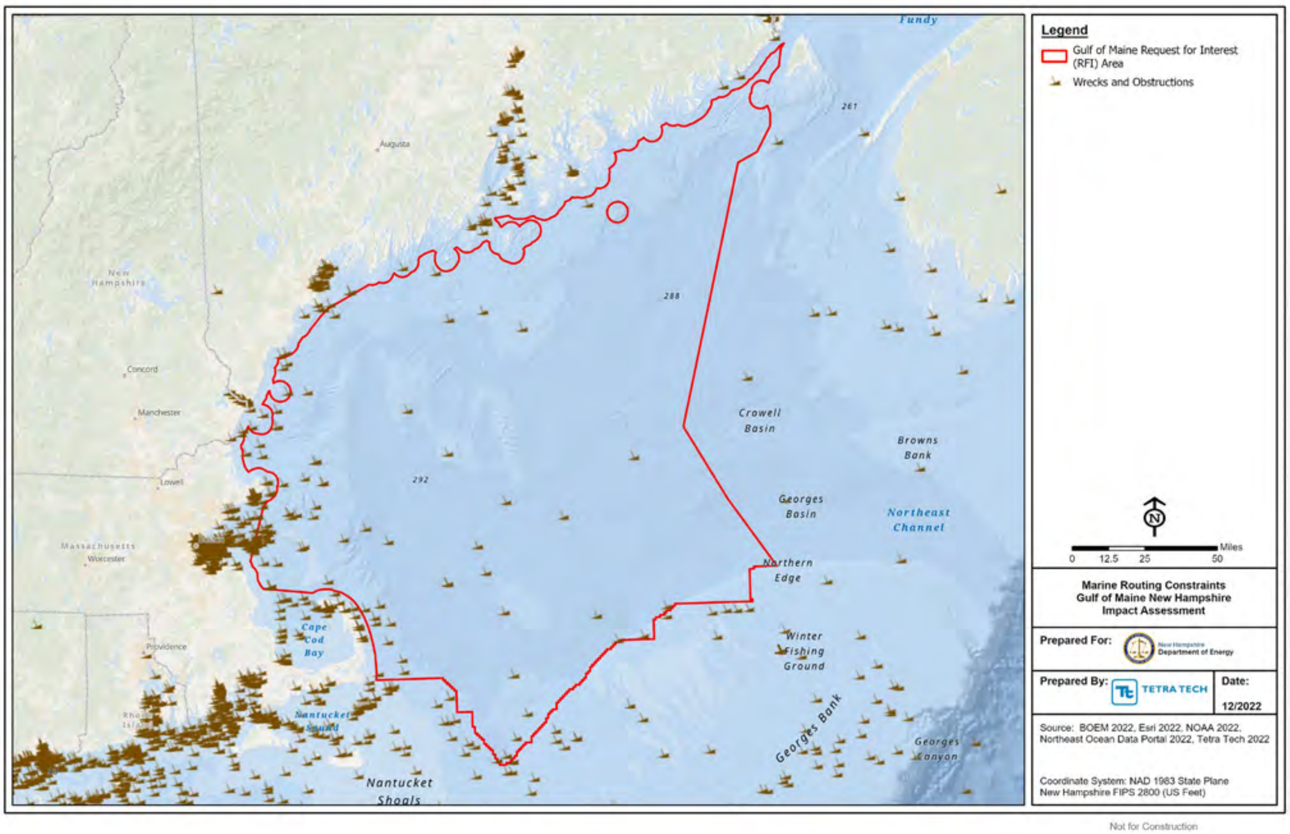

Figure 4.3.3. Shipwrecks and obstructions.

4.3.4 Unexploded Ordnance

Munitions are present in U.S. waters as a result of live-fire training and testing (both ongoing and past), combat operations (acts of war through World War II), sea disposal (conducted through 1970), accidents (periodic), and disposal (e.g., jettisoning) during emergencies (Carton et al. 2017). Unexploded ordnance (UXO), which was either deployed in the marine environment during military activities but failed to initiate or has been dumped at sea, can present a prospective threat. The principal issue is that some activities, such as trawling, dredging of the installation, operation and maintenance, or decommissioning of marine infrastructure, may encounter UXO.

A large area (approximately 9 km diameter, 255 square km) surrounding the Isles of Shoals off the New Hampshire is charted as a Caution Area since it is known that jet-assisted take-off (JATO) racks and associated debris exist in the area.

Larger areas of potential UXO exist off the coast of New Hampshire within the RFI Area as shown in Figure 4.3.4 include:

- Unexploded Depth Charges 60 km offshore, 620 sq km
- Explosives dumping ground 125 km offshore, 1,255 sq km

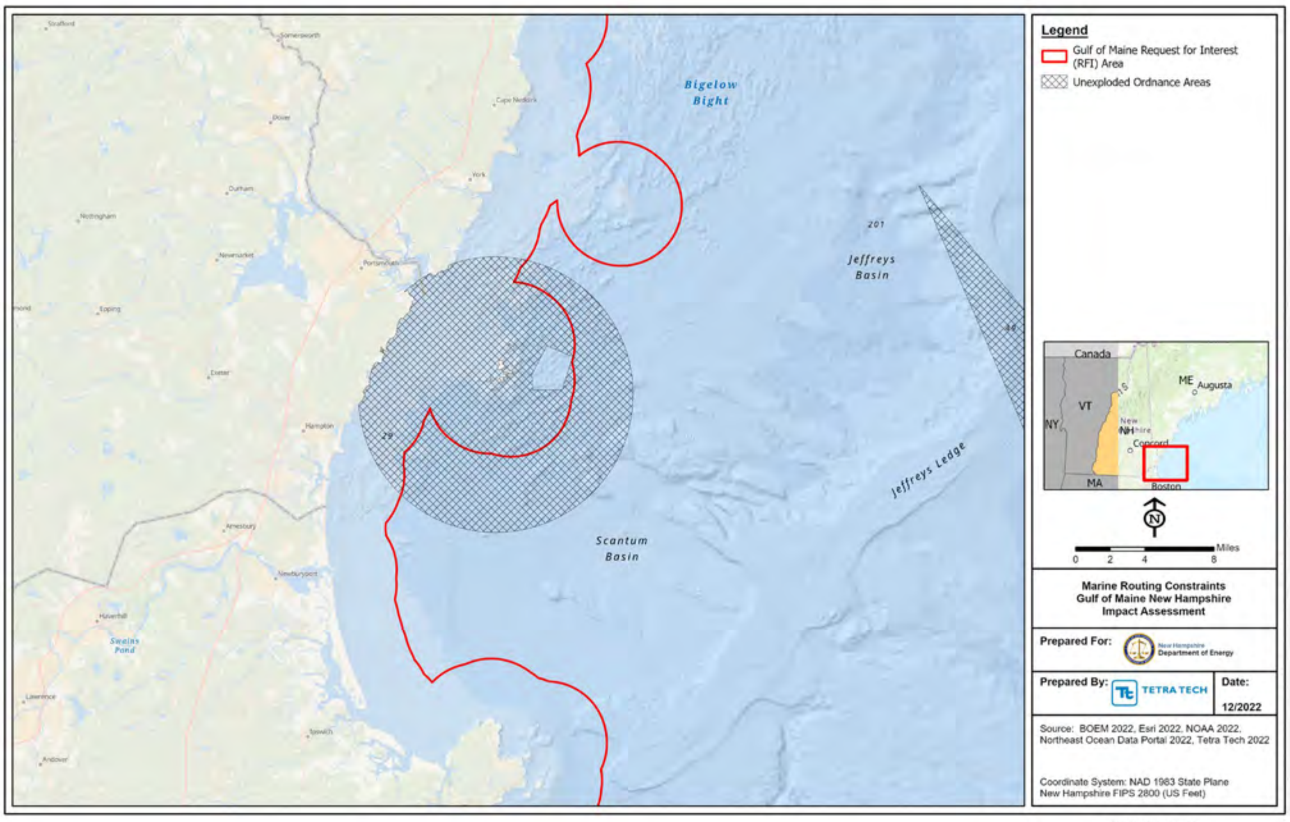

Figure 4.3.4. Nearshore unexploded ordnance off the coast of New Hampshire.

To a lesser extent, areas of potential UXO exist further off the coast of Maine and Massachusetts within the RFI Area as shown in Figure 4.3.5 include:

- Unexploded Depth Charges 10 km offshore Maine, 127 sq km
- Unexploded Depth Bombs 10 km offshore Maine, 490 sq km
- Explosives dumping ground 20 km offshore Massachusetts, 63 sq km

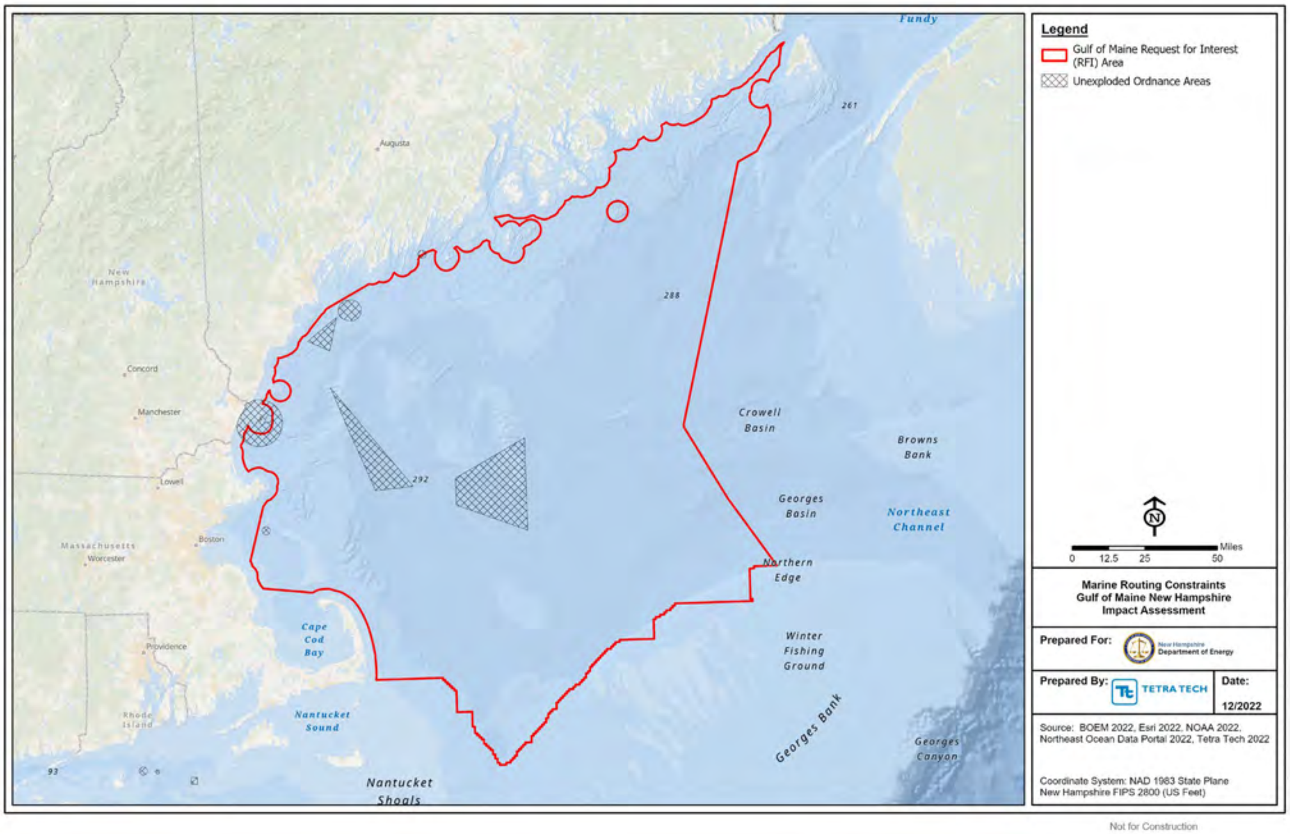

Figure 4.3.5. Offshore unexploded ordnance in the Gulf of Maine RFI Area.

4.3.5 Formerly Used Defense Sites

Formerly Used Defense Sites (FUDS) are properties that were owned by, leased to, or otherwise possessed by the United States and under the jurisdiction of the United States Secretary of Defense and owned by, leased by, or otherwise possessed by the United States and were transferred from DOD control prior to October 1986. These properties can range in their current land uses from privately owned farms to National Parks. They also include residential areas, schools, and industrial areas (USACE 2022a).

FUDS also refers to the U.S. military program created in 1986 for assessment and environmental restoration, if any, led by the USACE. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 and the Superfund Amendments and Reauthorization Act (SARA) of 1986 gave DOD the authority for certain cleanup activities at former DOD sites in the United States and its territories.

The Duck Island Dive Bombing Target FUDS is located in the waters around Duck Island, Maine (USACE 2022b). It encompasses a 230-yard radius circle with an area of about 35 acres in water depths of 440 to 475 ft (134 to 145 m). The site was used as a bombing target range for military munitions and therefore may present the possibility of an explosive hazard.

Areas of the seabed that would be disturbed during installation of submarine cables should be investigated thoroughly prior to installation activities to the extent necessary for both human safety and environmental protection.

4.3.6 Ocean Disposal Sites

The U.S. Environmental Protection Agency (EPA) is responsible for designating and managing ocean disposal sites under the Marine Protection, Research and Sanctuaries Act. Many of these sites are located offshore major harbors and ports nationwide. Designated ocean disposal sites are selected to minimize the risk of potentially adverse impacts of the disposed material on human health and the marine environment (EPA 2022a).

EPA Regional Offices in coordination with the USACE conduct oceanographic surveys (e.g., water quality, sediment, and bathymetry) to monitor the impacts of regulated dumping at the disposal sites since the majority of ocean sites are designated for the disposal of dredged material. These sites are monitored to ensure that disposal will not unreasonably degrade or endanger human health or the environment, to verify that unanticipated adverse effects are not occurring from past or continued use of the site, to verify that material is disposed at the correct location, and to ensure that the terms of the ocean disposal permit are met. Individual projects using the ocean disposal sites are also monitored for compliance with EPA site use conditions. Monitoring may include detailed records of vessel GPS tracks to the ocean disposal site, vessel draft while transporting the material to the disposal site, and documentation of any leaked of spilled materials (EPA 2022a).

Two disposal sites (one discontinued, one active) are located approximately 2 km east of the Isle of Shoals. These disposal sites are shown in Figure 4.3.6. In October 2020, the EPA designated an Ocean Dredged Material Disposal Site (ODMDS) at Isles of Shoals North to serve Maine, New Hampshire, and the northern Massachusetts coastal region. The Isles of Shoals North Disposal Site (IOSN; active site) is located approximately 10.8 nautical miles east of Portsmouth, New Hampshire (EPA 2022b). IOSN will provide a long-term dredged material disposal option for material dredged from regional harbors and navigation channels that will ensure the viability of dredging projects needed to maintain navigation and international commerce over the next 20 years (85 FR 60370).

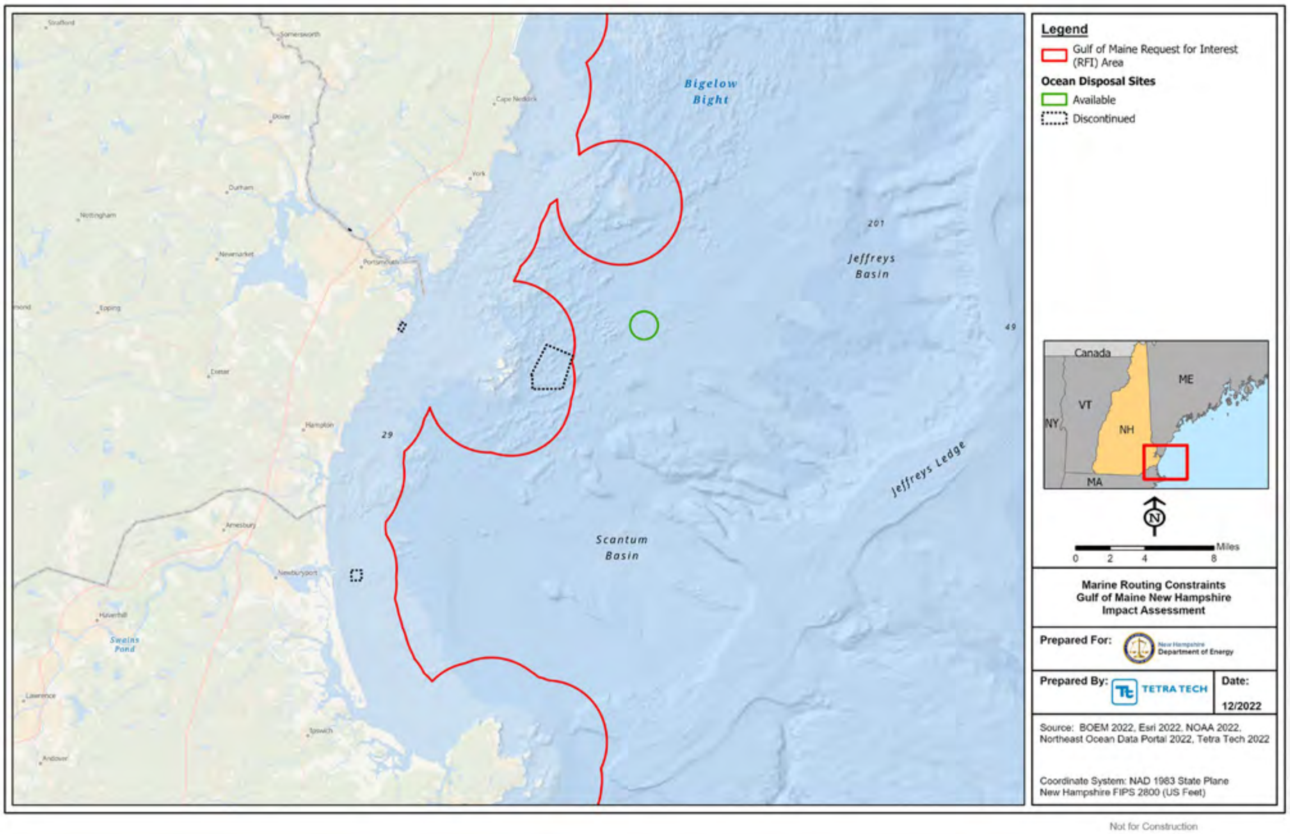

Figure 4.3.6. Ocean disposal sites off the coast of New Hampshire.

4.4 Decommissioning of Turbines at End of Useful Life

As New Hampshire evaluates the potential for offshore wind in the GOM, consideration of the future decommissioning process for wind turbines can provide insight into the full life cycle of offshore wind farms and associated expectations, impacts, and options at the end of design lifetime. The rapid advancement of the emerging offshore wind industry in the U.S. combined with the technological innovation of offshore wind turbines leaves uncertainty regarding turbine decommissioning at the end of a useful life. Globally, relatively few offshore wind farms have gone through decommissioning activities to provide examples of decommissioning solutions and methodologies.

As of January 2023, there are only seven operational wind turbines in U.S. waters, consisting of the five turbine 30-MW Block Island Wind Farm and the two-turbine 12-MW Coastal Virginia Offshore Wind pilot project. The rated power of these operational wind turbines is 6 MW with blade lengths of 241 ft (73.5 m) and hub heights of 328 ft (100 m; GE 2022). The U.S. currently has a 30.7-GW pipeline of offshore wind projects, with 20,951 MW of operational capacity expected by 2030 (S&P 2022). Within this short period, the size of offshore wind turbines available for installation is expected to increase substantially. Given the depths of the GOM, floating wind turbines are expected to be utilized.

Floating offshore wind installations present unique opportunities and challenges due to their ability to be sited much farther offshore than fixed-bottom foundation projects and to capture the strongest wind resources available within U.S. waters. The engineering of floating offshore wind turbine foundations allows for much larger turbines to be installed. Experts on floating wind energy anticipate that blade lengths of these turbines could reach up to 400 ft (122 m) with tower heights over 1,000 ft (305 m; Yale 2022). Along with the increased ability to generate more wind energy at this large scale, port infrastructure requirements for the installation and decommissioning of these turbines must be considered. Given the immediate pipeline of fixed-bottom foundation offshore wind projects, the port infrastructure being planned is focused on the staging, manufacturing, and installation requirements of associated components of these fixed-foundation projects. At its simplest, decommissioning is the reverse of installation that involves offshore dismantling of the major elements and onshore disassembly of sub-components therefore port areas and associated infrastructure must be prepared, and available, for various decommissioning scenarios (Malpas et al. 2022).

The process for decommissioning of offshore wind project areas in the GOM will ultimately be guided by the continued occurrence of decommissioning of currently operational offshore wind farms both globally and those under development in existing OCS lease areas across U.S. coastal waters. The following sections provide early insights into potential end-of-life scenarios for wind turbines and associated facility components.

4.4.1 Design Lifetime and Permitting Requirements

The design lifetime of offshore wind projects typically ranges from 20 to 25 years, although offshore wind turbines could last at least 35 years once operational. Lifetime extension, when feasible, presents the opportunity to generate additional electricity and therefore deliver a lower levelized cost of energy (LCOE) in addition to the deference of the cost of decommissioning. The option for lifetime extension of these projects must consider not only technical specifications and capabilities for project components but also commercial factors and terms of lease and license agreements.

BOEM is the lead regulatory authority for leasing and licensing associated with offshore wind farms. As per the final regulations of the OCS Renewable Energy Program by Section 388 of the Energy Policy Act of 2005 BOEM is authorized to issue leases, easements, and rights of way associated with renewable energy development along the OCS (BOEM 2019). BOEM is additionally responsible for establishing a framework for a fair return for use of OCS lands (BOEM 2020a). BOEM requires leaseholders to prepare conceptual decommissioning plans when their project is first proposed and requires more detailed plans for evaluation at the time decommissioning is requested. Under the construction and operation phase of BOEM's renewable energy authorization process, the lessee is required to submit a COP inclusive of a conceptual decommissioning plan for the entire proposed renewable energy facility (Fernandez et al. 2021).

BOEM's Guidelines for Information Requirements for a Renewable Energy Construction and Operations Plan require that conceptual decommissioning plans include an overview of deconstruction and site clearance in addition to the potential environmental impacts and corresponding mitigation measures for all planned facilities, including onshore and support facilities (BOEM 2020b). Once BOEM approves the COP, the commercial lease will become effective. Prior to the end of the lease term, the developer must submit a plan to decommission facilities. Unless BOEM has authorized the facilities and installations to remain in place or be converted to an artificial reef, the lessee is given two years to fully decommission their operations on the OCS at the end of the lease period following the termination of operations as per BOEM's definition of decommissioning:

"the removal of all facilities, installations, and other devices permanently or temporarily attached to the seabed on the OCS to a depth of 15 feet below the mudline and must be complete within two years following the termination of a lease or grant (30 Code of Federal Regulations [CFR] §§ 585.433 and 585.910)".

BOEM's decommissioning process is made up of three distinct stages to ensure the lease area will be cleared through both regulatory requirements and the incentive of reimbursement of past financial assurances. The three distinct stages are shown in Figure 4.4.1.

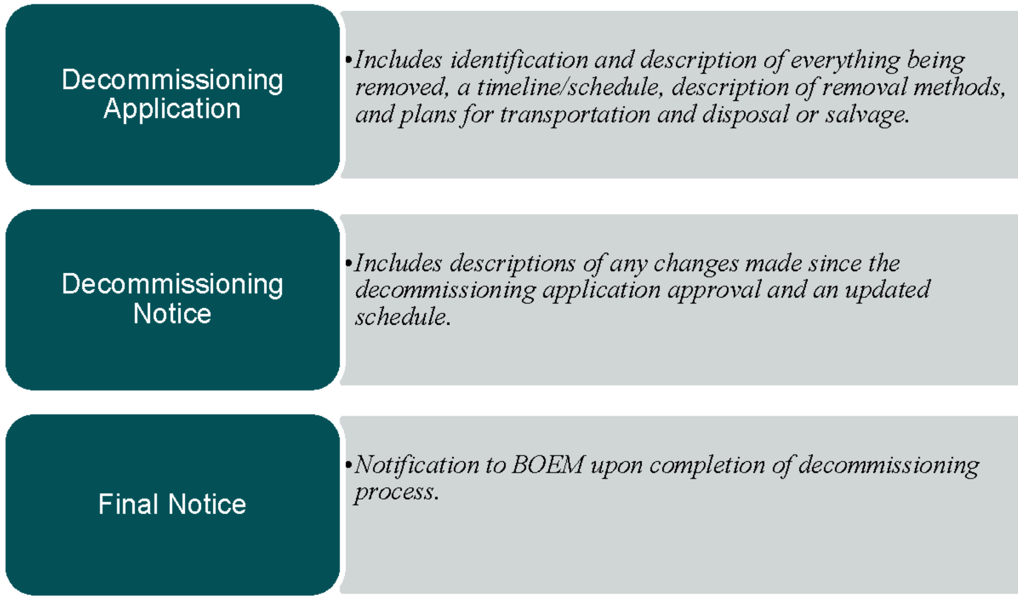

Figure 4.4.1. Stages of BOEM's decommissioning process following termination of a lease.

A decommissioning application must first be submitted to BOEM as early as two years before lease expiration for approval (30 CFR § 585.905). Requirements of this unique decommissioning application include the identification and description of the facilities, cables, and/or pipelines designated for removal; a proposed decommissioning schedule; a description of removal methods and procedures; and plans for the transportation and disposal or salvage of decommissioned materials (30 CFR § 585.906). Upon BOEM approval, a separate decommissioning notice must be submitted by the lessee at least 60 days prior to the start of any activities related to decommissioning (30 CFR § 585.908). Upon lease termination, the lessee is given 2 years to conduct activities to remove all facilities, projects, cables, pipelines, and obstructions and clear the seafloor of all obstructions created by activities on the lease, including a project easement or grant, to a depth of 15 feet below the mudline (30 CFR §§ 585.433 and 585.910). A final notice must then be submitted to BOEM verifying site clearance within 60 days after the removal process (30 CFR § 585.912; Fernandez et al. 2021).

4.4.2 Potential Decommissioning Scenarios

With the first floating offshore wind farm commissioned recently in 2017 (Hywind, Scotland), there are no commercial scale floating offshore wind installations that have reached the decommissioning stage. Therefore, the availability of information is limited to decommissioning strategies researched for potential use or that have been performed for other types of offshore energy installations. Offshore wind project components include both major components and balance of plant components, which typically consist of submarine export cables, foundations, offshore substations, and wind turbines. Each of these components encompasses a wide range of design and material options, each of which influences the decision-making process during decommissioning.

The range of possible decommissioning scenarios for offshore wind projects is expected to grow in the coming years as best management practices are developed during the decommissioning of currently operational offshore wind installations and recommendations are developed to guide the process. These scenarios could include a combination of partial and full removal of components, depending on various commercial, social, financial, and environmental factors.

4.4.3 Benefits of Leaving Offshore Wind Infrastructure In Situ

Requirements to remove offshore infrastructure are largely based on an effort to minimize negative impacts on the marine environment. The potential disturbance that the removal of this infrastructure may cause must be taken into consideration and whether there are advantages to leaving some offshore wind project components in situ rather than opting for their removal.

For offshore export cables, the removal of cables after service life can alleviate the risk of cable crowding. With increasing burial depths, however, cable removal poses greater challenges. Additionally, removing buried cables can cause disruption to sensitive habitat (BSEE 2014). Although submarine cables are typically engineered with a minimum design life of 25 years, they may remain operational for longer. Upon end of service, it is possible for cables to stay in situ and remain inactive on the seafloor. Cables may alternatively be repositioned for redeployment. Guidelines and practices are expected to evolve as interactions between the offshore wind energy and subsea cable sectors continue to expand.

For offshore wind foundations, tools and methods for decommissioning can draw upon the onshore wind and the offshore oil and gas industries. Since floating foundations are still under development, the decommissioning scenarios for this component are largely unknown. However, based on decommissioning operations for oil and gas substructures in addition to studies investigating the advantages and disadvantages to leaving foundations in place, some insight can be gained into potential scenarios. Benefits to leaving offshore foundation components in situ include enhancement of biodiversity, creation of artificial reef habitat, and protection from bottom disturbing activities (e.g., trawling and dredging; Fowler et al. 2018).

4.4.4 Disposal Processing of Wind Turbines and Associated Components

Wind energy has experienced significant growth in the past few decades which is expected to continue. Wind turbines typically have a 20 to 25 year lifespan. The oldest wind farms are reaching the end of their design and service lifetimes (end-of-life) and thousands of wind turbines around the world will need to be decommissioned in the coming years (Jensen 2019, Cooperman et al. 2021). Life cycle assessments show that the materials used for manufacturing wind turbines accounts for 70 to 80% of the environmental impact, therefore ensuring optimal recycling and disposal at the end-of-life is of economic and environmental interest (Jensen 2019). Limited practical decommissioning and recycling experience of wind turbines exists, especially for offshore wind farms (Jensen 2019). The main aspects associated with wind turbine end-of-life, such as standard procedures, regulatory requirements and legislation, and environmental impacts (e.g., waste, pollution and emissions), remain uncertain (Mello et al 2022). Taking lessons learned from onshore wind turbines in the U.S. and Europe, there are three main routes of disposal for end-of-life blades and other wind turbine components (Jenson and Skelton 2018, Mello et al. 2022, Walzberg et al. 2022). The disposal routes identified include landfill, incineration, and recycling. Recycling will be discussed in Section 4.4.5 below.

Many of the components and materials in wind turbines can be recycled, however the composite materials that are the main element in wind turbine blades are more challenging. As mentioned above in Section 2.3.2 Manufacturing, Disposal, many retired wind turbine blades currently end up in landfills. Landfilling is the least preferred disposal method as many states and municipalities have restricted accepted material criteria depending on material type and level of hazardous waste, adding additional economic costs, and permitting implications. Additionally, many local municipal landfills are currently not equipped to handle the large waste of wind turbines. Presently there are thousands of end-of-life blades disposed of in U.S. landfills in Iowa, South Dakota, and Wyoming that involve long transport routes for disposal (Berg 2021). Wind turbine blades are categorized as non-hazardous solid waste (Beauson et al. 2022). The blades are believed to be non-toxic and therefore pose no health threat to the soil or groundwater (Harms 2021). Currently, there are no landfill bans in any state for composite waste and wind turbine blades (Harms 2021, Beauson et al. 2022).

Assuming a 20-year wind turbine lifetime, the current U.S. wind turbines fleet contains more than 190,000 blades that will reach end-of-life by 2040. The projected annual rate of retirement will be between 3,000 and 9,000 blades for the next 5 years, increasing to between 10,000 and 20,000 until 2040 (Cooperman et al. 2021). The cumulative U.S. blade waste is estimated to be 1.5 million metric tons (mt) by 2040 and 2.2 million mt by 2050. The 2050 value represents approximately 1% of remaining landfill capacity (6.2 billion m^3) by volume or 0.2% by mass. These estimates assume that annual waste acceptance rates remain constant at 2018 levels, landfills can be filled to their design capacity before closure, and no new landfills will be constructed. Several New England states, including New Hampshire, are projected to fill their existing landfills before or by 2050, even before end-of-life blade material is considered (Cooperman et al. 2021). The limited landfill capacity in the Northeast may incentivize regional development of alternatives to end-of-life blade landfill disposal. Although, Cooperman et al. (2021) found that landfill space constraints and disposal costs, which are relatively low in comparison to the overall life-cycle cost of energy, appear unlikely to motivate a change in waste handling strategies under current U.S. policy conditions. The move to a more circular economy for wind turbine blades may require large shifts in recycling technologies, waste management policies, or blade design and materials.

New Hampshire is projected to have 3,782 mt (0.08 million m^3) of end-of-life blades by 2050 (Cooperman et al. 2021). New Hampshire's disposal capacity short fall is projected to start in 2034 and range between approximately 950,000 tons in 2035 to 990,000 tons by 2041. These estimates are based on the assumptions that all of New Hampshire's commercial landfills will close after reaching their currently permitted capacity and that no solid waste disposal reduction goals will be achieved (NHDES 2022). The New Hampshire disposal capacity short fall does not appear to consider disposal of offshore wind turbine blades or components.

Currently, out-of-state waste comprises about 50% of the total waste disposed of in New Hampshire landfills. The Commerce Clause of the U.S. Constitution has generally been interpreted to preempt a state from explicitly prohibiting or adopting policies that would restrict a commercial solid waste facility from accepting and disposing of out-of-state waste (NHDES 2022). The New Hampshire General Court has introduced several bills related to solid-waste issues in the last several legislative sessions and established a New Hampshire Solid Waste Working Group by HB 413 in 2021. The working group is tasked with assisting NHDES with planning and policy initiatives related to solid waste management and has been focused on the development of an updated Solid Waste Management Plan (NHDES 2022).

Incineration is the second most common route for wind turbine blades and other components if legislation prohibits landfill disposal (Jensen 2019). Blade incineration permits energy recovery from the combustion of resin and wood and reduces the volume of waste (Cooperman et al. 2021). The byproducts and end products produced by wind turbine incineration, such as ash and non-burnable materials, must be landfilled or recycled into products such as construction materials (Jenson and Skelton 2018, Mello et al. 2022).

4.4.5 Recyclability of Wind Turbines and Other Project Components

Decommissioning is expected to include full or partial removal of offshore wind project components, including the removal of wind turbines at the end of their useful life. This provides the possibility to recycle some of the material components in lieu of disposal. Five materials account for more than 98% of the total mass of a wind turbine as shown in Table 4.4.1.

Table 4.4.1. Total Material Mass of Wind Turbines (NREL 2015).

Material Component	Use	Average % Total of Turbine Mass
Steel	Towers and nacelles	71%–79%
Fiberglass/resin/plastic	Blades	1%–16%
Iron/cast iron	Hub	5%–17%
Copper	Cabling, lighting, and protection system	1%
Aluminum	Miscellaneous	0%–2%

Eighty-five to ninety percent of a wind turbine components (i.e., foundation, tower, generator, and gear box) are recyclable for steel and concrete (Jenson and Skelton 2018, Harms 2021, Mello et al. 2022). Offshore wind foundations, which typically consist of steel and concrete materials, are economically recycled via traditional recycling routes. Offshore wind turbine towers and nacelles are primarily made of steel (Table 4.4.1). The glass fiber reinforced plastic (GFRP) and carbon fiber reinforced plastic (CFRP), the major construction materials of wind turbine blades, pose the most challenge to recycling as the technologies and processes for recycling these composites are presently being developed, despite turbines blades making up the majority of the waste (Jenson and Skelton 2018, Topham et al. 2019). Recycling techniques for these plastics are generally described in three categories, based on the type of processes involved: mechanical (shredders, crushers, or mills), thermal (pyrolysis, microwave pyrolysis), or chemical based

(Paulsen and Enevoldsen 2021, Beauson et al. 2022). Only a few of these recycling techniques are currently available at a commercial scale for end-of-life wind turbine blades (Beauson et al. 2022). Based on processing capacity, cost, environment and technology readiness level, recycling through co-processing in the cement industry is currently the only economical option that has the capabilities to handle large amounts of waste materials (Paulsen and Enevoldsen 2021). Unique to the U.S. market, a contract was signed with Veolia and General Electric Renewable Energy (GE) in 2020 to recycle onshore wind turbines after a breakthrough in the cement kiln co-processing technology for wind turbine blades. This process involves turning the blades into an eco-friendly cement that recovers 90% of the blade's weight: 65% as a raw material, replacing sand, clay and other materials, and 28% as an alternative fuel, replacing coal to provide the energy needed for the chemical reaction in the kiln (Veolia North America 2022). Additionally, a wind turbine recycling plant has been established with the U.S. Department of Energy outside of Knoxville, Tennessee for recycling into new blades and electric vehicles (USDOE 2022). However, there currently is a lack of a secondary market for these materials in the U.S. and global market (Jenson and Skelton 2018). The offshore wind industry continues to develop recycling strategies to avoid landfilling or incineration of end-of-life turbine blades.

4.5 References

30 CFR § 585.905. Code of Federal Regulations, Title 30 - Mineral Resources Chapter V - Bureau of Ocean Energy Management, Department of the Interior Subchapter B - Offshore Part 585 - Renewable Energy on the Outer Continental Shelf, Subpart I—Decommissioning, Decommissioning Applications § 585.905 When must I submit my decommissioning application?

30 CFR § 585.906. Code of Federal Regulations, Title 30 - Mineral Resources Chapter V - Bureau of Ocean Energy Management, Department of the Interior Subchapter B - Offshore Part 585 - Renewable Energy on the Outer Continental Shelf, Subpart I— Decommissioning, Decommissioning Applications § 585.906 What must my decommissioning application include?

30 CFR § 585.908. Code of Federal Regulations, Title 30 - Mineral Resources Chapter V - Bureau of Ocean Energy Management, Department of the Interior Subchapter B - Offshore Part 585 - Renewable Energy on the Outer Continental Shelf, Subpart I— Decommissioning, Decommissioning Applications § 585.908 What must I include in my decommissioning notice?

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5 Environmental and Biological Impacts

The GOM is semi-enclosed, roughly rectangular, international marginal sea of about 36,000 square miles, with Nova Scotia, Canada as its northeastern boundary and the northeast U.S. coast (Massachusetts, New Hampshire, and Maine) as its western boundary. It is a deep indentation in the continental shelf with irregular bottom topography, consisting of three major basins and many smaller ones separated by numerous ridges and ledges. Georges and Browns Banks separate the GOM from the Atlantic Ocean (NOAA NMFS 2017). Surface circulation is generally counterclockwise, with the majority of water exiting at the northern end of Georges Bank, while much of the rest of the periphery has restricted exchange with the open ocean (Xue et al. 2000). The seafloor is highly diverse, with undersea valleys reaching depths of over 1,500 ft and undersea mountains rising from the seafloor to 800 ft, in some cases nearly reaching the surface or exceeding it to create islands (Bigelow 1924, Uchupi 1965).

The GOM contains an ocean environment, habitats, and marine resources that are unique and vary substantially from other areas on the East Coast of the United States (NOAA NMFS 2022a). A combination of colder, nutrient-rich waters from the Labrador Current, an influx of fresh water from 60 rivers in the adjoining watersheds, and the diverse undersea topography, creates an environment of extreme tidal mixing and therefore high primary productivity (Townsend et al. 2006). These waters support nearly 4,000 marine species, including at least 186 cnidarians (corals, sea anemones, hydroids and jellyfish), 762 crustaceans, 504 mollusks, 578 fish, 182 seabirds, and 27 marine mammals, among many others (Incze et al. 2010). These include species of commercial and recreational importance, notably those species supporting fisheries such as Atlantic Cod, Haddock, Atlantic sea scallop (*Placopecten magellanicus*), and American lobster.

Human population densities along the approximately 7,500 miles of GOM coastline vary considerably but have been recorded at upwards of 500 people per square mile along urban centers, with many bordering U.S. states containing 50-80% of their total population along the coast (Schauffler 2013). The RFI Area and adjacent areas are extremely important to the economic and social well-being of communities in the Northeast U.S. and provide many benefits to the nation, including domestic food security (NEFMC 2022). The GOM makes up approximately 10% of the area of the Atlantic waters of the U.S. but produces over half of its value in commercial fisheries (Goode 2021). In addition to fishing, other active and proposed resource uses include marine transportation, aquaculture, oil and gas development, sand and gravel mining, and wind and tidal energy generation. Human pressures, particularly fishing, have influenced the biota of the GOM for thousands of years (Ellis et al. 2011). Over the last 15 years it has been widely documented that the GOM has experienced one of the fastest recorded warming periods of any large marine ecosystem due to climate change, causing changes in circulation patterns, altering ecosystems and food webs, and causing a decline in cold-water species (Pershing et al. 2021).

This section discusses the potential impacts offshore wind development in the GOM may have on the environment, habitats, and species found in RFI Area. The discussion begins with environmentally sensitive areas, followed by important biological and natural resources, and then other topics related to environmental concerns that may affect the environment and citizens of New Hampshire during the construction and operation of an offshore wind farm.

A Biological and Physical Resources

5.1 Environmentally Sensitive Areas

This environmental sensitivity analysis focuses on identifying areas within the GOM RFI Area that are environmentally sensitive. Generally, these areas are characterized as containing plant or animal life, their habitats, or natural features, that are either rare or especially valuable due to their special nature or role in an ecosystem and which would be easily disturbed or degraded by human activities and development. According to permitting regulations required for offshore wind developers to comply with NEPA and other relevant laws, environmentally sensitive areas are defined as follows:

"Essential fish habitat, refuges, preserves, special management areas identified in coastal management programs, sanctuaries, rookeries, hard bottom habitat, chemosynthetic communities, calving grounds, barrier islands, beaches, dunes, and wetlands" (30 CFR § 585.627).

With this definition in mind, and considering the unique aspects of the GOM and the large area that the RFI covers within it, environmentally sensitive habitats contained within the RFI Area which must be considered for further surveying and delineation, protection, or exclusion from potential lease sites include:

1. Deep-sea coral research and protection areas
2. Habitat Management Areas (HMAs) and fisheries Closed Areas
3. Critical habitat for endangered, threatened, or declining species
4. Essential fish habitat (EFH) and habitat areas of particular concern (HAPC)
5. Complex bathymetric features supporting high biodiversity
6. Nursery habitat, calving grounds, and near-shore spawning, haul-out, nesting, and roosting sites (fish, mammals, birds and bats, respectively)
7. Kelp forests

This section will briefly address each of the proposed environmentally sensitive areas, with the following sections providing more detailed analyses on potential ecological impacts on specific biota and natural resources.

5.1.1 Deep-sea Coral Research and Protection Areas

Deep-sea corals in the GOM are found in temperate cold waters between 50-120 m depths, and are among the most three-dimensionally complex habitats in the deep ocean, with biodiversity comparable to that found on tropical coral reefs (Auster and Lindholm 2005, Roberts et al. 2006). They are considered ecosystem engineers, providing zooplanktivorous fish with flows delivering prey, hard surfaces which support invertebrate communities, crevices and structure for shelter from predators and for reproductive activities, and refuge from tidal flows (Auster and Lindholm 2005, Fountain et al. 2019). The corals in the GOM are primarily found on the crests or slopes of topographic rises, with species assemblages often associated with them through the duration of their life histories (Auster and Lindholm 2005, Fountain et al. 2018). Within the GOM and Northeast Channel, over 90 epifaunal species along with various megafauna (including Atlantic Cod, Acadian Redfish (*Sebastes fasciatus*), Silver Hake (*Merluccius bilinearis*), Cusk (*Brosme brosme*), and pandalid shrimp) have been observed to associate with the coral colonies (Auster et al. 2014, Fountain et al. 2018, Metaxas and Davis 2005).

The presence of deep-sea corals in the GOM has been known since the late nineteenth century, however, many areas in the GOM with the potential for corals to proliferate are not yet mapped or not mapped accurately. As a result, the patterns of small-scale distribution, community composition and functional role are unknown (Auster et al. 2013). There are only two areas which have been designated by the New England Fishery Management Council as protection zones (Outer Schoodic Ridge and Mount Desert Rock) and one designated research area (Jordan Basin; Figure 5.1.1; NOAA NMFS 2022a). The Outer Schoodic Ridge location has been identified as a key coral reproductive population in the GOM (Fountain et al. 2019). These areas are defined by high densities of deep-sea corals, but research on these corals in the GOM is relatively recent, and they are continuously being discovered. There are several other areas within the GOM where deep-sea corals and sponges have been observed, some in notably dense concentrations (e.g., in central Jordan Basin and Georges Basin/Lindenkohn Knoll; NOAA NMFS 2022a).

These coral structures grow and form on the timescale of decades to millennia, making them highly susceptible to a multitude of disturbances including bottom fishing activities, oil and gas development, increases in ocean stratification, temperature and acidification due to climate change, and the offshore wind development (Fountain et al. 2019). When selecting prospective leasing areas for offshore wind it will be necessary to conduct fine-scale surveys of the seafloor immediately within development areas as well as along transit and export cable routes to identify the presence of corals and provide a suitable buffer around such areas to avoid long-term disturbance or destruction of these highly fragile habitats.

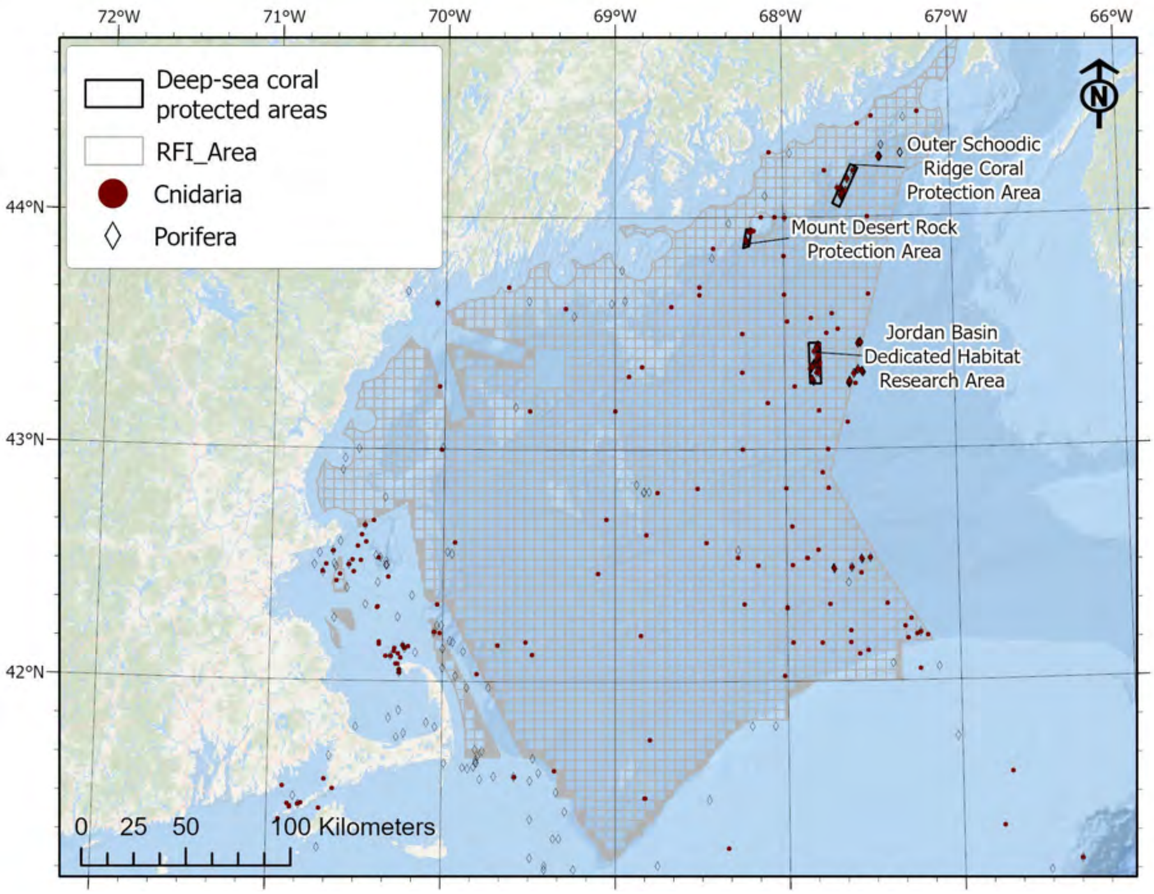

Figure 5.1.1. Map of coral protection and research areas along with coral and sponge point data located in or around the Gulf of Maine RFI Area (NOAA NMFS 2022a). Produced by the National Marine Fisheries Service using the NOAA National Database for Deep-Sea Corals and Sponges (https://deepseacoraldata.noaa.gov).

5.1.2 Habitat Management Areas and Fisheries Closed Areas

The GOM RFI Area contains six Habitat Management Areas (HMAs), two groundfish closure areas, the Stellwagen Dedicated Habitat Research Area (DHRA), and portions of the fisheries Closed Area I North and Closed Area II (Figure 5.1.2). The HMAs include the Western Gulf of Maine Habitat Management Area, Cashes Ledge Habitat Management Area, Fippennies Ledge Habitat Management Areas, Ammen Rock Habitat Management Area, Eastern Maine Habitat Management Area, and Jeffreys Bank Habitat Management Area (Table 5.1.1). HMAs within the GOM have been established to protect sensitive hard-bottom habitats from the adverse effects of fishing, with regulations restricting bottom-tending mobile gear. Similarly, the groundfish closure areas (Table 5.1.2) are intended to protect important species (e.g., Atlantic Cod) as they are spawning, as well as the nursery habitat within which they spawn. Restrictions in closure areas prohibit any fishing vessels or fishermen from entering these areas, and no gear capable of catching multiple species may be used or aboard any vessel within the closure areas (Figure

5.1.2; CLF 2022). These areas often overlap with critical habitat designations for protected species as well as EFH for several species.

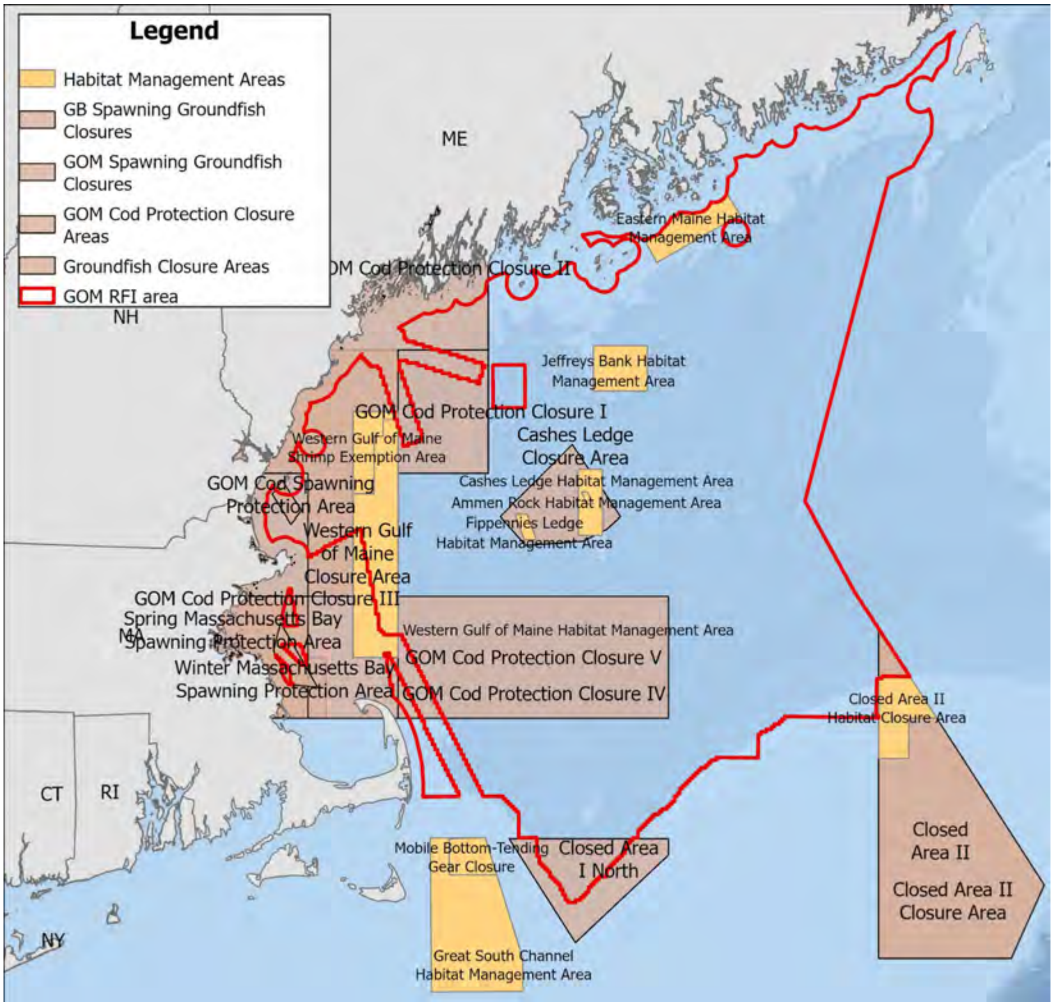

Figure 5.1.2. Habitat management and groundfish spawning and closure areas contained within or bordering the Gulf of Maine RFI Area (NOAA NMFS 2022a). Generated by NMFS using the Northeast Ocean Data Portal (www.northeastoceandata.org).

Table 5.1.1. Coordinates for the Gulf of Maine Habitat Management Areas.

Point		Latitude	Longitude
Western Gulf of Maine Habitat Management Area			
	WGMH1	43˚ 15' N	70˚ 15' W
	WGMH2	42˚ 15' N	70˚ 15' W
	WGMH3	42˚ 15' N	70˚ 00' W
	WGMH4	43˚ 15' N	70˚ 15' W
Cashes Ledge Habitat Management Area			
	CLH1	43° 01.0’ N	69° 00.0’ W
	CLH2	43° 01.0’ N	68° 52.0’ W
	CLH3	42° 45.0’ N	68° 52.0’ W
	CLH4	42° 45.0’ N	69° 00.0’ W
Fippennies Ledge Habitat Management Area			
	ARH1	42° 55.5’ N	68° 57.0’ W
	ARH2	42° 52.5’ N	68° 55.0’ W
	ARH3	42° 52.5’ N	68° 57.0’ W
	ARH4	42° 55.5’ N	68° 59.0’ W
Ammen Rock Habitat Management Area			
	ARH1	42° 55.5’ N	68° 57.0’ W
	ARH2	42° 52.5’ N	68° 55.0’ W
	ARH3	42° 52.5’ N	68° 57.0’ W
	ARH4	42° 55.5’ N	68° 59.0’ W
Eastern Maine Habitat Management Area			
	EMH1*	44°07.65’ N	68°10.64’ W
	EMH2	44° 02.50’ N	68° 06.10’ W
	EMH3	43° 51.00’ N	68° 33.90’ W
	EMH4*	43° 56.62’ N	68° 38.12’ W
	* Points 1 and 4 fall along the outer limit of Maine state waters.		
Jeffreys Bank Habitat Management Area			
	JBH1	43° 31’ N	68° 37’ W
	JBH2	43° 20’ N	68° 37’ W
	JBH3	43° 20’ N	68° 55’ W
	JBH4	43° 31’ N	68° 55’ W

Table 5.1.2. Coordinates for the Gulf of Maine Groundfish Closure Areas and the Stellwagen Dedicated Habitat Research Area.

Point	Latitude	Longitude
Western Gulf of Maine Groundfish Closure Area		
WGMH1	43˚ 15' N	70˚ 15' W
WGMH2	42˚ 15' N	70˚ 15' W
WGMH3	42˚ 15' N	70˚ 00' W
WGMH4	43˚ 15' N	70˚ 15' W
Cashes Ledge Groundfish Closure Area		
CL1	43˚ 07' N	69˚ 02' W
CL2	42˚ 49.5' N	68˚ 46' W
CL3	42˚ 46.5' N	68˚ 50.5' W
CL4	42˚ 43.5' N	68˚ 58.5' W
CL5	42˚ 42.5' N	69˚ 17.5' W
CL6	42˚ 49.5' N	69˚ 26' W
Stellwagen Dedicated Habitat Research Area		
SDHRA1	42° 15.0’ N	70° 00.0’ W
SDHRA2	42° 15.0’ N	70° 15.0’ W
SDHRA3	42° 45.2’ N	70° 15.0’ W
SDHRA4	42° 46.0’ N	70° 13.0’ W
SDHRA5	42° 46.0’ N	70° 00.0’ W

These closures do not directly restrict offshore wind development activities, or installation or maintenance vessels from transiting or operating within these areas. However, the habitats managed and protected with the closures are equally as vulnerable to offshore wind operations as they are to fishing activities, particularly foundation construction and operations, vessel anchoring, cable laying, and other associated development activities that could disturb or destroy fragile benthic marine resources or habitat, which would adversely affect valuable fisheries.

5.1.3 Critical Habitat for Endangered, Threatened, or Declining Species

The Endangered Species Act (ESA) has established protections for fish, wildlife, and plants that are listed as threatened or endangered, including the designation and protection of critical habitats. Table 5.1.3 provides a list of ESA-listed species whose range overlaps with at least some portion of the RFI Area, and whether those species have critical habitat areas either in the GOM or specifically within the RFI Area. Those species with critical habitat areas within the RFI Area are described in further detail in the corresponding report sections 5.2 through 5.4.

Table 5.1.3. ESA-listed species with ranges that overlap with the Gulf of Maine RFI Area (NOAA NMFS 2022a). DPS = distinct population segment.

	Common Name	Scientific Name	ESA Listing	Critical Habitat in GOM	Critical Habitat within RFI Area
Fish	Atlantic Salmon	*Salmo Salar*	GOM DPS - Endangered	yes	no
	Atlantic Sturgeon	*Acipenser oxyrinchus oxyrinchus*	GOM DPS - Threatened	yes	no
	Shortnose Sturgeon	*Acipenser brevirostrum*	Endangered	no	no
Marine Mammals	North Atlantic Right Whale	*Eubalaena glacialis*	Endangered	yes	yes
	Blue Whale	*Balaenoptera musculus*	Endangered	no	no
	Fin Whale	*Balaenoptera physalus*	Endangered	no	no
	Sei Whale	*Balaenoptera borealis*	Endangered	no	no
	Sperm Whale	*Physeter macrocephalus*	Endangered	no	no
SeaTurtles	Loggerhead Sea Turtle	*Caretta caretta*	NW Atlantic DPS - Threatened	no	no
	Green Sea Turtle	*Chelonia mydas*	North Atlantic DPS - Threatened	no	no
	Kemp's Ridley Sea Turtle	*Lepidochelys kempii*	Endangered	no	no
	Leatherback Sea Turtle	*Dermochelys coriacea*	Endangered	no	no
Birds	Roseate Tern	*Sterna dougallii*	NE Nesting Population - Endangered	no	no
	Piping Plover	*Charadrius melodus*	Atlantic Coast Population - Threatened	no	no
	Rufa Red Knot	*Calidris canutus rufa*	Threatened	no	no
Bats	Northern Long-Eared Bat	*Myotis lucifugus*	Endangered		

5.1.4 Essential Fish Habitat and Habitat Areas of Particular Concern (HAPC)

Essential Fish Habitat (EFH) is defined under the Magnuson-Stevens Fishery Conservation and Management Act as *"those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity"* (50 CFR § 600.10). The entirety of the RFI Area overlaps with EFH for species inhabiting GOM waters, therefore it may be most useful to take into account Habitat Areas of Particular Concern (HAPC) when considering potential lease areas. HAPC are subsets of EFH that exhibit one or more of the following traits: rare, stressed by development, provide important ecological functions for federally managed species, or are especially vulnerable to anthropogenic degradation (NOAA NMFS 2022a). There are two HAPCs within the RFI Area, and several others bordering it, which are protected due to the diversity of ecologically important habitat types for several managed fish species (Figure 5.1.3).

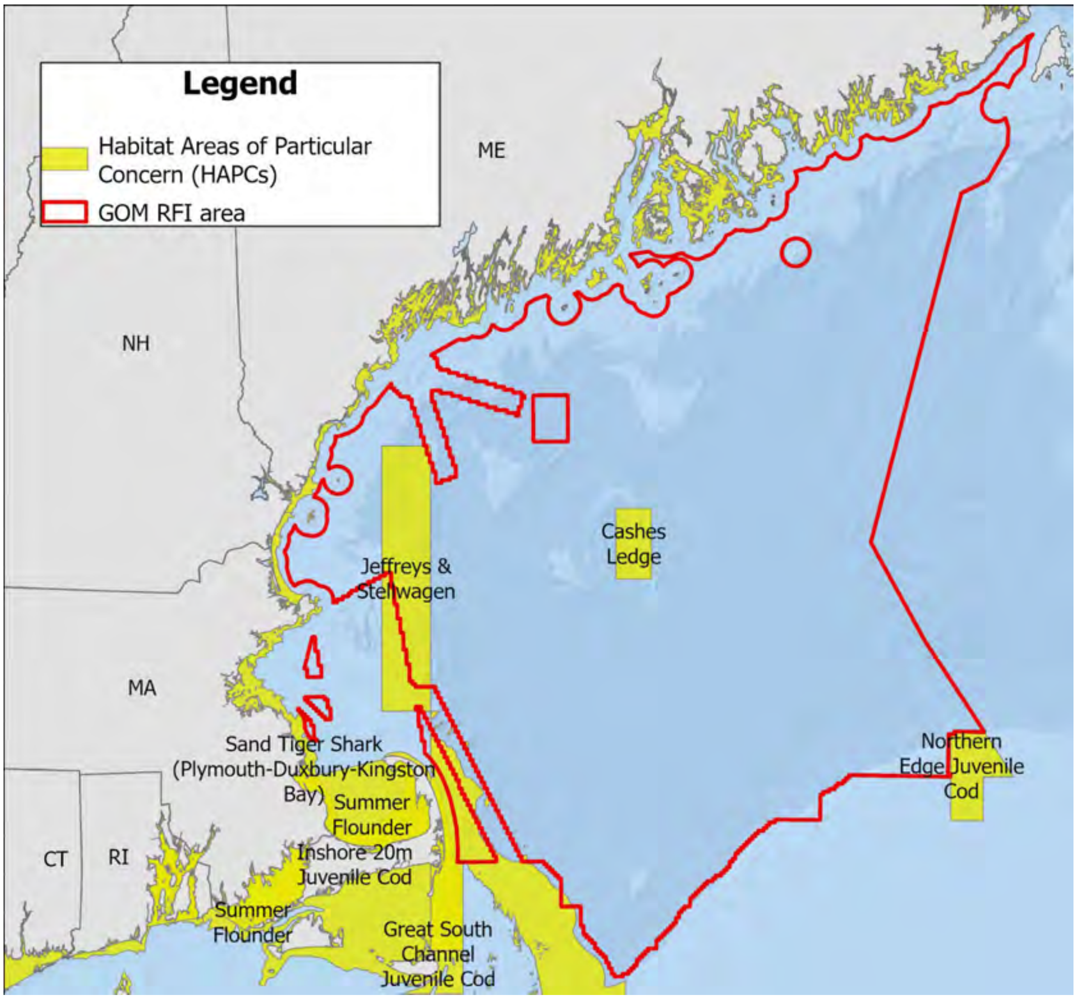

Figure 5.1.3. Map of Habitat Areas of Particular Concern within and bordering the Gulf of Maine RFI Area (NOAA NMFS 2022a). Generated by NMFS using the Northeast Ocean Data Portal (www.northeastoceandata.org).

5.1.5 Complex Bathymetric Features Supporting High Biodiversity

The RFI Area is highly diverse, with basins up to 250m depth separated by ridges, banks, and swells. High points include irregular hard-bottom ridges and hard-bottom 'bumps' (i.e., in western Jordan Basin). Hard-bottom areas support a myriad of species, including epifauna such as deep-sea corals, sponges, anemones, tunicates, bryozoans, and hydroids (NOAA NMFS 2022a). Much of the seafloor contains deposits of fine sediments which supports unique invertebrate communities including amphipods, burrowing anemones, polychaete worms, infaunal mollusks, and a variety of others (NOAA NMFS 2022a). There is a lack of both broad and fine scale habitat data and associated ecological communities for all but select research areas of the GOM, so any lease area must be thoroughly explored to identify and map the benthos contained there.

There are several known bathymetric features in the GOM which support important valuable fisheries, protected species, and ecologically important habitats. These features include, but are not limited to: Cashes Ledge, Jeffreys Ledge, Stellwagen Bank, Jordan Basin, and Platts Bank (Figure 5.1.4). Many of these features have high biological productivity driven by circulation patterns and areas of upwelling resulting in increased plankton and forage fish species abundance, attracting higher trophic level species in large aggregations (Pikitch et al. 2014). Disturbance of these areas could have severe additive effects should development or ongoing offshore wind activities disrupt these natural processes, particularly for protected species such as the North Atlantic Right Whale (*Eubalaena glacialis*), which depends on these physical processes for successful foraging.

Cashes Ledge is a 57 km (35 mile) long, 8 to 10 km (5 to 6 miles) wide underwater granitic mountain range located 80 miles off the coast of Cape Ann in the central GOM (Uchupi 1966). The ledge, comprised of irregularly crested ridges and banks with a series of basins, rises 100 m (328 ft) above the typical level of the GOM floor. The tallest underwater peak, Ammen Rock, is located about 90 miles off the Massachusetts coast in the center of the range and contains the deepest, densest, and healthiest kelp forest in the Western North Atlantic. Water depths at the ledge range from 40 to 60 m (131 to 197 ft) except at Ammen Rock, where the ledge shoals to 9 m (29 ft). Cashes Ledge contains a variety of habitats across depths including rocky ridge, boulder fields, sand and gravel, and mud basin. The community boundaries occur at the following depths: kelp forest at 28 to 40 m (92to 131 ft), suspension feeding invertebrates at 40 to 65 m (131 to 213 ft), and cobble-soft sediment and burrowing anemones at 65 to 90 m (213 to 295 ft; Witman and Sebens 1988, Kraus et al 2016). The cliff faces contain a variety of yellow, red, and blue sponges. The complex topography yields high diversity, high prey resources, and high connectivity among adjacent habitats (Kraus et al 2016). Cashes Ledge has historically been known as a productive fishing ground. The average biomass of all fish on Cashes Ledge is 305 times greater than at coastal sites (Witman and Lamb 2018). The area provides habitat for a range of species including Atlantic sea scallop, Atlantic Cod, Pollock, Atlantic white-sided dolphin (*Lagenorhynchus acutus*), humpback whale (*Megaptera novaeangliae*), and North Atlantic right whale (Stokesbury et al. 2010, Witman and Lamb 2018, Pittman et al. 2006). Cashes Ledge was closed year-round to commercial fishing in 2002 and was considered for a marine national monument in 2016 (Kraus et al 2016).

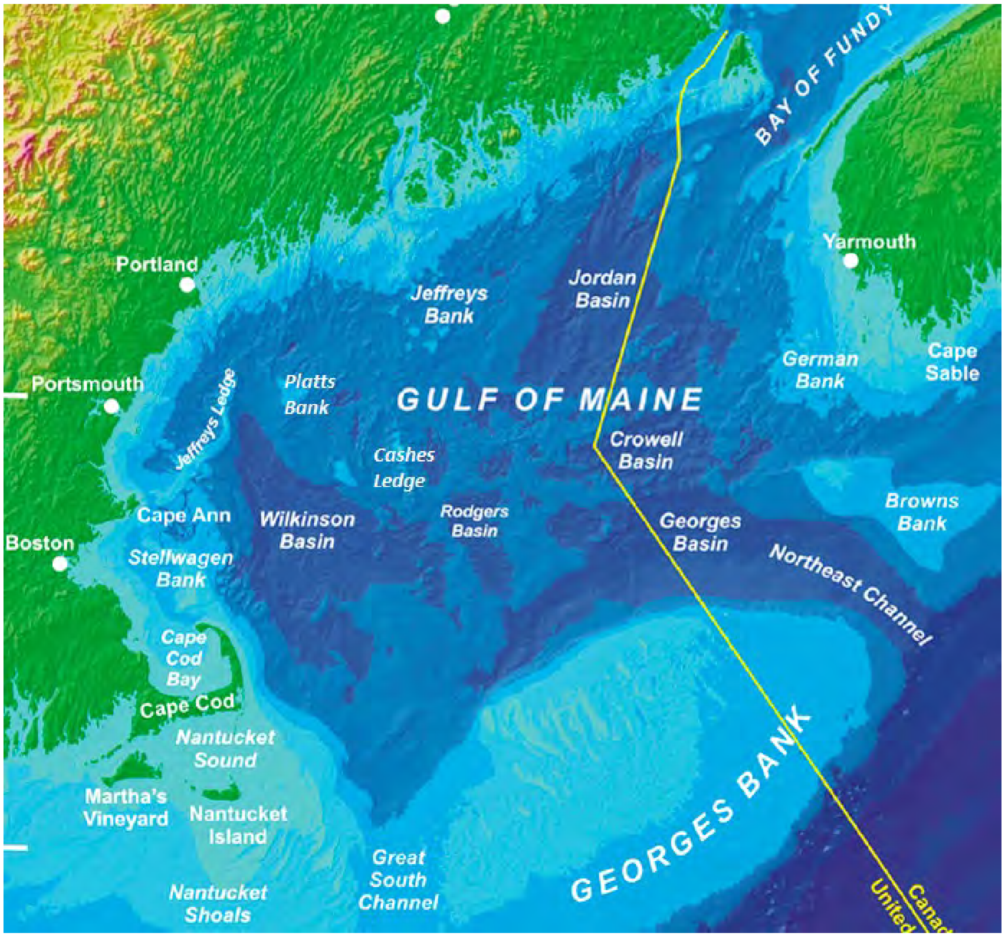

Figure 5.1.4. Map of the Gulf of Maine and major bathymetric features (UMaine Seagrant 2022).

Jeffreys Ledge is a major feature in the western GOM located approximately 50 km (31 miles) off the coast of New Hampshire. It is considered one of the best fishing grounds in the GOM. Jeffreys Ledge rises 150 m (492 ft) from the adjacent Scantum and Wilkinson Basins to depths less than 50 m (164 ft) on the ridge surface. It extends over 100 km (62 miles) along its north-northeast to south-southwest axes, and 5 to 10 km (3 to 6 miles) in width (Uchupi 1965, Oldale et al. 1973, Ward and Johnson 2019). The bottom is predominately gravel and pebbles with sand, muddy sand and sandy mud (Ward and Johnson 2019). Depths range from 49 to 64 m (162 to 210 ft) dropping to 73 to 91 m (240 to 300 ft) on the edges. Sponges are a significant constituent of the benthic invertebrate community on Jeffreys Ledge. The encrusting sponges often cover 30-60% of the available rock substrate at Pigeon Hill, an isolated rocky knoll (McCarthy 2004). Jeffreys Ledge is a primary spawning location for Atlantic Herring (Chase 2002). Additionally, Winter Flounder (*Pseudopleuronectes americanus*) have been documented spawning at Jeffreys Ledge (Fairchild 2017). Silver Hake, Butterfish (*Peprilus triacanthus*), northern shortfin squid (*Illex illecebrosus*), longfin inshore squid (*Loligo pealeii*), and Atlantic sea scallop have been documented as abundant on the ledge (Chase 2002, Stokesbury et al. 2010).

Jeffreys Ledge may serve as important habitat to North Atlantic right whale and other cetacean species that have been consistently documented in the area (Pittman et al. 2006, Weinrich et al. 2006, Duley et al. 2017).

Stellwagen Bank is an underwater plateau at the mouth of Massachusetts Bay, comprised of glacial sand and gravel deposits, stretching 31 km (19 miles) north to south and 10 km (6 miles) across at its widest point. The bank is 19 to 37 m (62 to 121 ft) below the surface, while surrounding waters to the west are as deep as 100 m (328 ft) deep and to the northeast as deep as 200 m (600 ft; Uchupi 1965, USGS 1998, Clark et al 2006). Stellwagen Bank and surrounding areas provide one of the richest, most productive marine environments in the United States, sustaining a large diversity of marine mammals and fishery resources which constitute an important ecological and economic resource for the region (Clark et al 2006). A total of 154 species of fish and 32 species of seabirds have been documented in Stellwagen Bank and the adjacent areas (Auster et al. 2006, Pittman and Huettmann 2006). It is a high use area for a number of cetaceans including humpback whale, fin whale (*Balaenoptera physalus*), minke whale (*Balaenoptera acutorostrata*), and North Atlantic right whale (Pittman et al. 2006). Stellwagen Bank is the heart of the Stellwagen Bank National Marine Sanctuary, an 842-square-mile federally protected marine sanctuary. The sanctuary lies in Massachusetts Bay, 40 km (25 miles) east of Boston, 8.0 km (5 miles) east of Gloucester, and 8.0 km (5 miles) north of Provincetown, Massachusetts. Due to its accessibility, the Bank is used extensively for whale watching, commercial and recreational fishing, and recreational boating (Clark et al 2006). Stellwagen Bank National Marine Sanctuary was excluded from the GOM RFI Area as the area was deemed incompatible with offshore wind energy development (87 FR 51129).

Jordan Basin is the one of the three major basins within the GOM. The Jordan Basin has an area of 8, 070 km^2 and a maximum depth at 311 m (1,020 ft; Uchupi 1968, Du et al. 2021). Deep-sea octocoral gardens occur in the western Jordan Basin providing habitat for Acadian Redfish, Atlantic Cod, Cusk, Pollock, and Silver Hake (Auster et al. 2013). Jordan Basin is a seasonally important foraging area for North Atlantic right whales and one of the main sources for the dense copepod concentrations which the whales prey on (Pace and Merrick 2008).

Platt's Bank is a 19 km (12 mile) long and 12 km (8 mile) wide bank approximately 85 km (53 miles) from Thacher Island. The small, rocky western shoal is approximately 53 m (174 ft) deep. The bank is a glacial deposit composed primarily of sand and gravel with depths ranging from 54 to 64 m (180 to 210 ft). Platt's Bank has 2 crests with minimum depths of about 55 m (180 ft) each, separated by a trough 80 to 90 m (262 to 295 ft) deep (Rich 1929, Stevick et al. 2008). At the edge of the shoal area the bottom gradually slopes to 91 or 110 m (300 or 360 ft), beyond that it suddenly drops to 146 or 164 m (480 or 540 ft) over a muddy bottom. Platt's Bank has historically been and continues to be a productive fishing ground for Atlantic Cod and Haddock in the GOM (Rich 1929, Stevick et al. 2008). Atlantic sea scallops have also been documented as abundant on the bank (Stokesbury et al. 2010). Platt's Bank is a consistent and significant foraging site for a range of species including pelagic fish (Atlantic Herring [*Clupea harengus*] Atlantic Bluefin Tuna [*Thunnus thynnu*s], seabirds (gulls [*Larus* spp.], Wilson's storm petrel [*Oceanites oceanicus*]) and several cetaceans (humpback whale, fin whale, North Atlantic right whale, and Atlantic white-sided dolphin) due in part to the large presence of *Calanus* spp. copepods and euphausiids (krill; Pittman et al. 2006, Stevick et al. 2008).

5.1.6 Near-shore and Coastal Nursery Habitat (Fish, Mammals, Birds, Bats)

While near-shore and coastal areas are not included in the RFI Area for offshore wind, these areas must be considered when selecting potential offshore leasing areas, as any floating array design will require shoreside infrastructure for development, installation, maintenance, and transmission. All these activities have the potential to disrupt important seasonal spawning, roosting, or nesting behaviors of fish, mammals, seabirds, or coastal birds and bats which rely on these sensitive habitats during breeding seasons when they are most vulnerable. The near-shore waters in the GOM include areas of eelgrass, shellfish habitats, and rocky habitats essential for the growth and survival of critical life stages of fish and are identified as EFH and HAPC (e.g., Atlantic Cod, Summer Flounder [*Paralichthys dentatus*]) along the entire coast, including estuarine and inland waters (Figure 5.1.3). Similarly, beaches, small offshore islands, or wetlands which serve as vital habitat for nesting seabirds, bat roosts, and seal haul outs may be adversely affected and must be considered in any ecological models used for zoning onshore infrastructure.

5.1.7 Kelp Forests

Kelp (Laminarian algae) forests are an important part of GOM ecosystems, exhibiting complex three-dimensional character which provide vital nursery and spawning habitats, productive foraging habitat for diverse invertebrate and fish assemblages, and dampen wave action (McGonigle et al. 2011, Witman and Lamb 2018). Kelps have three distinct morphological forms (i.e., ‘canopy’, ‘stipate’ or ‘prostrate’) distinguished by the canopy height of their fronds. These differing morphologies can coexist along with an understory of macrophyte turf and encrusting coralline algae, increasing the structural diversity of the system (Dayton 1985, Steneck et al. 2002). Their distribution is controlled by environmental factors including light, substrata, sedimentation, nutrient availability, water motion, salinity, and temperature (Dayton 1985). Kelp abundance in the GOM is controlled by several local factors including sea urchin grazing, storms, pollution, impacts of invasive species, and indirect effects of top predators, and global factors linked to the El Niño Southern Oscillation and climate change-related ocean warming (Witman and Lamb 2018). Detailed distribution and abundance of kelp and kelp forests in the GOM are generally unknown (Tyrrell 2005). GOM coastal kelp forests are typically zoned by depth with *Alaria esculenta* most abundant at shallow depths less than 5 m (16 ft) and *Saccharina* species (*S. latissima*, *S. digitata*) dominating mid-depths at 5-15 m (16 to 49 ft). Shotgun kelp (*Agarum clathratum*) thrives deeper in the rocky subtidal than *Saccharina* kelp. Coastal kelp communities have been documented at Cape Neddick, Crow Island, Duck Island, Lunging Island, Mingo Rock, Murray Rock, Spout Shoal, Star Island, and White Island. Since the 1970's, kelp have declined at several shallow coastal sites in the southwest coastal region of the GOM (Witman and Lamb 2018).

Due to the logistic constraints of working offshore, less attention has been paid to the ecology of offshore kelp forests. Witman and Lamb (2018) used the 100-m depth contour to define the boundary between coastal and offshore regions in the GOM as it is seaward of the inner shelf margin. The most important offshore kelp forest in the GOM is located on Cashes Ledge. Deep kelp forests (>30 m [98 ft]) were initially described at Ammen Rock, supporting the deepest laminarian kelp assemblages in the Western North Atlantic with densities of *Saccharina latissima* and *Agarum clathratum* kelps reaching 7.0 and 1.0 individual plants per 1.0 m^2 respectively at 30 m depth. Cashes Ledge offshore sites support the greatest density (47.8 plants m^2) and standing crop biomass (5.5 kg m^2 fresh weight) of the foundation species *S. latissima* kelp at this depth in the Western North Atlantic. Offshore densities of *S. latissima* were over 150 times greater than at coastal sites, with similar but lower magnitude trends for congeneric *S. digitata*. However, *A. clathratum* biomass was significantly higher at coastal sites (Witman and Lamb 2018). A significant 36.2% decrease in *S. latissimi* occurred on Cashes Ledge between 1987 and 2015, concurrent with a rapid warming of the GOM and invasion by the kelp-encrusting bryozoan *Membranipora membranacea* (Witman and Lamb 2018).

5.2 Fish and Fisheries

The focus of this section is to assess the potential impacts on fish and the New Hampshire commercial and recreational fisheries present in the GOM RFI Area from the deployment of FOWT. Fish can be defined two ways, the first is the usual definition of a limbless aquatic vertebrate animal with gills (finfish). Finfish in this section will be used when discussing animals under the first definition and will include bony fish (e.g., Striped Bass or Atlantic Halibut) and cartilaginous fish (e.g., sharks and rays). The second definition is under the Magnuson-Stevens Fishery Conservation and Management Act which defines fish as "*finfish, mollusks, crustaceans, and all other forms of marine animal and plant life other than marine mammals and birds*" (50 CFR § 600.10). This section will review potential impacts for both definitions of fish, except for plant life (e.g., seagrasses and kelp).

5.2.1 Fish

The GOM RFI Area supports a wide variety of finfish species and assemblages that are associated with various habitats and depths (Grosslein and Azarovitz 1982, Gabriel 1992, Mahon et al. 1998, Collette and Klein-MacPhee 2002, Methratta and Link 2006, Sosebee and Cadrin 2006, Nye et al. 2009, Auster and Conroy 2019). There are documented to be 578 finfish species from at least 118 families that occur in the GOM, including threatened and endangered species, species of special concern, and species that are commercially and/or recreationally important (Table 5.2.1 and Table 5.2.2; Collette and Klein-MacPhee 2002, Incze et al. 2010). A partial list of finfish species occurring in the GOM is provided in Appendix C. Collette and Klein-MacPhee (2002) provides information on general descriptions, biology, and occurrence in the GOM for 252 species including the species found in Tables 5.2.1 and 5.2.2, with the exception of Red Snapper (*Lutjanus campechanus*).

The GOM RFI Area supports a wide variety of invertebrate species (e.g., 186 cnidarians, 489 annelids, 762 crustaceans, 504 mollusks, and 110 echinoderms; Incze et al. 2010) including several that commercially and recreationally harvested such as American lobster (Table 5.2.3). Perkins and Larsen (1975) and Trott (2004) provide lists of nearly 800 marine invertebrates documented along coastal Maine areas and in Cobscook Bay, ME, respectively. Marine invertebrates play significant roles in the GOM ecosystems creating essential habitats and providing forage for finfish and marine mammals (Kenney et al. 1997, Bowman et al. 2000, Fountain et al. 2019). Life history information, habitat requirements, and distribution are generally known for the commercially harvested species in Table 5.2.3, however, this information in unavailable for the majority of invertebrate species found in the GOM.

Species composition and distribution patterns have been determined for several regional fish assemblages (Overholtz and Tyler 1985, Gabriel 1992, Chen et al. 2006, Chang et al. 2010, Stokesbury et al. 2010). Seasonal and interannual variation in species diversity and abundance are common in the RFI Area. Fish migrate seasonally inshore/offshore and north/south due to the seasonal differences in water temperatures. This is illustrated by Figure 5.2.1 through Figure 5.2.4 showing differences between spring and fall total biomass and species richness from the 2010 - 2019 NMFS Northeast Fisheries Science Center (NEFSC) spring and fall trawl surveys.

Migratory routes have been documented for several finfish including Atlantic Cod, Pollock, and White Hake (*Urophycis tenuis*; Ames and Lichter 2013). American lobsters are also known to undertake long migrations (> 100 km; Chen et al. 2006). Total biomass and interpolated biomass for 81 fish from the NEFSC spring and fall trawl surveys can be found on the Northeast Ocean Data Portal (https://www.northeastoceandata.org/).

Linkages between fish and habitat characteristics and/or features have been discussed in several summary and multidisciplinary publications including USFWS Species Profiles (1983-1989), Collette and Klein-MacPhee (2002), the NOAA Technical Memorandum NMFS-NE series: EFH Source Documents, and NMFS (2017). The NOAA NMFS-NE EFH Source Documents provide life histories and habitat characteristics including geographical distribution at time of publication for commercially harvested finfish and invertebrate species managed by the New England and Mid-Atlantic Fishery Management Councils. Fish assemblage distribution patterns and species composition in the GOM have changed over time due to several factors including invasive species, overfishing, and increases in water temperatures related to climate change (Harris and Tyrrell 2001, Kleisner et al 2017, Nye et al. 2009, Pershing et al. 2021). For example, many cold-water species are shifting northward and deeper to remain in preferred water temperatures as water temperatures have increased throughout the region (Nye et al. 2009, Sorte et al. 2017).

Endangered, Threatened, and Protected species

Three federally endangered finfish species listed under the ESA occur in the GOM, Atlantic Salmon (*Salmo salar*), Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*), and Shortnose Sturgeon (*Acipenser brevirostrum*; Table 5.2.1). Critical habitats have been designated for Atlantic Salmon and Atlantic Sturgeon, however, these habitats do not overlap with the GOM RFI Area. Critical habitat has not been designated for the Shortnose Sturgeon and is not required. The Giant Manta Ray (*Manta birostris*) is listed as a federally threatened species and is an occasional summer visitor to the GOM.

Atlantic Salmon - Atlantic Salmon is an anadromous species that is native to the North Atlantic Ocean basin from the Arctic Circle to Portugal in the eastern Atlantic, from Iceland and southern Greenland, and from northern Quebec south to the Connecticut River in the western Atlantic. In the United States, Atlantic Salmon historically ranged from Maine to Long Island Sound (Collette and Klein-MacPhee 2002). The GOM distinct population segment (DPS) of Atlantic Salmon was officially listed as a federally endangered species on November 17, 2000 (65 FR 69459) and was expanded on June 19, 2009 (74 FR 29344). The GOM DPS represents the last wild population of U.S. Atlantic Salmon. Critical habitat for GOM DPS of Atlantic Salmon was designated by NMFS in 2009 (74 FR 29300).

Atlantic Sturgeon - Atlantic Sturgeon is a long-lived, late maturing, estuarine dependent, anadromous fish that ranges from Hamilton River, Labrador, and George River, Ungava Bay, to Port Canaveral and Hutchinson Island, Florida (Collette & Klein-MacPhee 2002, ASSRT 2007). The NMFS listed five DPSs of Atlantic Sturgeon under the Endangered Species Act on February 6, 2012; the New York Bight, Chesapeake Bay, Carolina, and South Atlantic populations were listed as endangered, while the GOM population was listed as threatened (77 FR 5880). Critical habitat for these Atlantic Sturgeon DPSs was designated on August 17, 2017, and includes the following rivers of Maine, New Hampshire, and Massachusetts: Penobscot, Kennebec, Androscoggin, Piscataqua, Cocheco, Salmon Falls, and Merrimack (82 FR 39160). Atlantic Sturgeon utilize a wide variety of habitats. Subadult (> 76 cm to < 150 cm TL) Atlantic Sturgeon emigrate out of their natal estuarine habitats in the fall and migrate long distances in the marine environment (Greene et al. 2009, GARFO 2017). Subadult and adult (> 150 cm TL) Atlantic Sturgeon frequently congregate in upper estuary habitats around the saltwater interface (Greene et al. 2009). In nearshore Atlantic coastal shelf areas subadult and non-spawning adult Atlantic Sturgeon have been documented in moderately shallow (7 m to 50 m) sand and gravel habitats (Stein et al. 2004, Laney et al. 2007, Greene et al. 2009, Dunton et al. 2010). Studies have shown that Atlantic Sturgeon aggregate in areas off the Penobscot River, and the Kennebec River System (Kennebec, Androscoggin, and Sheepscot Rivers).

Shortnose Sturgeon - Shortnose Sturgeon is a demersal, amphidromous species that inhabits most large coastal rivers along the Atlantic coast from Saint John River, New Brunswick to the St. Johns River, Florida (Collette & Klein-MacPhee 2002, SSSRT 2010). Shortnose Sturgeon was officially listed as a federally endangered species on March 11, 1967 (32 FR 4001). NMFS assumed jurisdiction of this species in 1974. Shortnose Sturgeon is also listed as an endangered species by the State of New Hampshire. Recent genetic analysis has identified three metapopulations of Shortnose Sturgeon: the Acadian Province (northern metapopulation) consisting of the GOM rivers; the Virginian Province (mid-Atlantic metapopulation) consisting of the Connecticut River, Hudson River, and Delaware River-Chesapeake Bay; and the Carolinian Province (southern metapopulation) consisting of the South Carolina rivers to the Altamaha River, GA (Wirgin et al 2010, SSSRT 2010, King et al. 2014). Shortnose Sturgeon prefer slower moving riverine, estuarine, and nearshore marine habitats of large river systems, although inter-river migrations to neighboring rivers through marine habitats have been documented within the GOM metapopulation. They are not expected to occur in the RFI Area (Dadswell et al. 1984, Fernandes et al. 2010, Wippelhauser et al. 2015).

Giant Manta Ray – The Giant Manta Ray is a long-lived, late maturing, filter-feeding cartilaginous fish that occurs offshore in oceanic waters at or near the surface over or near the continental or insular shelves. They occur in the western Atlantic from southern New England and Georges Bank to North Carolina. Off the eastern U.S., manta rays are commonly found at thermal fronts in productive, warm (20 to 30°C [68 to 86°F]) nearshore, and shelf-edge waters (Collette & Klein-MacPhee 2002, Farmer et al. 2022). The Giant Manta Ray was officially listed as a federally threatened species throughout its range on February 21, 2018 (83 FR 2916). Critical habitat has not been designated at this time due to a lack of data sufficient to perform the required analyses. Sufficient information is not currently available to identify physical or biological features that are essential to the conservation of the Giant Manta Ray within areas under U.S. jurisdiction (83 FR 2916).

Table 5.2.1. New Hampshire and Federally Listed Threatened and Endangered Fish Species, species of special concern, and candidate species in the Gulf of Maine RFI Area (NHFG 2017a, 2017b).

Species		Conservation Status
Common Name	**Scientific Name**	
Alewife (sea run only)	*Alosa pseudoharengus*	NH: Species of Special Concern (Category 1R[1])
American Eel	*Anguilla rostrata*	NH: Species of Special Concern (Category 1)
American Shad	*Alosa sapidissima*	NH: Species of Special Concern (Category 1)
Atlantic Salmon (Gulf of Maine DPS)	*Salmo salar*	Federal: Endangered NH: Wild Populations are Extinct
Atlantic Sturgeon	*Acipenser oxyrinchus oxyrinchus*	Federal: Endangered NH: Threatened
Blueback Herring	*Alosa aestivalis*	NH: Species of Special Concern (Category 1R)
Cusk	*Brosme brosme*	Federal: Candidate[2] (2007)
Giant Manta Ray	*Manta birostris*	Federal: Threatened
Rainbow Smelt (sea run only)	*Osmerus mordax*	NH: Species of Special Concern (Category 1)
Sea Lamprey	*Petromyzon marinus*	NH: Species of Special Concern (Category 1)
Shortnose Sturgeon	*Acipenser brevirostrum*	Federal: Endangered NH: Endangered

[1] Category 1 - 'Near-Threatened Species': Species that could become Threatened in the foreseeable future if action is not taken. Existing threats are such that the species could decline to Threatened status if conservation actions are not taken. In addition, the use of an "R" appended to a category, denotes that the species is designated "regional responsibility species". These are species for which at least 50% of their continental range occurs in the northeastern United States (United States Fish and Wildlife Service Region 5, consisting of all states between Maine and West Virginia plus the District of Columbia). Due to this high regional responsibility, actions to protect these species and/or their habitat will benefit the species' global population (NHFG 2017b).

[2] A candidate species is any species whose status is currently under review to determine whether it warrants listing under the Endangered Species Act.

Table 5.2.2. Commercially and recreationally harvested finfish species reported by New Hampshire fishermen from 2015-2022 (Data from NOAA NMFS 2023a, 2023b).

Species		Commercial Fishery	Recreational Fishery	Managed By
Common Name	Scientific Name			
Acadian Redfish	*Sebastes fasciatu*	X	X	NEFMC
Alewife	*Alosa pseudoharengus*	X	X	ASMFC
American Eel	*Anguilla rostrata*		X	ASMFC
American Plaice	*Hippoglossoides platessoides*	X		NEFMC
American Shad	*Alosa sapidissima*		X	ASMFC
Atlantic Bonito	*Sarda sarda*		X	NMFS
Atlantic Chub Mackerel	*Scomber colias*	X	X	MAFMC
Atlantic Cod	*Gadus morhua*	X	X	NEFMC
Atlantic Halibut	*Hippoglossus hippoglossus*	X	X	NEFMC
Atlantic Herring	*Clupea harengus*	X	X	NEFMC and NMFS in federal waters, ASMFC in state waters
Atlantic Mackerel	*Scomber scombrus*	X	X	MAFMC
Atlantic Menhaden	*Brevoortia tyrannus*	X	X	ASMFC
Atlantic Wolffish	*Anarhichas lupus*		P[1]	NEFMC
Barndoor Skate	*Dipturis laevis*	X	X - P	NEFMC
Black Sea Bass	*Centropristis striata*		X	MAFMC, ASMFC
Blue Shark	*Prionace glauca*		X	NMFS HMS Division
Blueback Herring	*Alosa aestivalis*		X	ASMFC
Bluefin Tuna	*Thunnus thynnus*	X	X	NMFS HMS Division
Bluefish	*Pomatomus saltatrix*	X	X	ASMFC
Butterfish	*Peprilus triacanthus*	X	X	MAFMC
Clearnose Skate	*Raja eglanteria*			NEFMC
Common Thresher Shark	*Alopias vulpinus*		X	NMFS HMS Division
Cunner	*Tautogolabrus adspersus*	X	X	—
Cusk	*Brosme brosme*	X	X	NMFS
Fourspot Flounder	*Hippoglossina oblonga*	X		—
Haddock	*Melanogrammus aeglefinus*	X	X	NEFMC
Little Skate	*Leucoraja erinacea*	X		NEFMC
Longhorn Sculpin	*Myoxocephalus octodecemspinosus*	X	X	—

Table 5.2.2. Continued.

Species		Commercial Fishery	Recreational Fishery	Managed By
Common Name	Scientific Name			
Monkfish	*Lophius americanus*	X	X	NEFMC and MAFMC
Northern Searobin	*Prionotus carolinus*		X	—
Ocean Pout	*Zoarces americanus*		X - P	NEFMC
Pollock	*Pollachius virens*	X	X	NEFMC
Red Hake	*Urophycis chuss*	X	X	NEFMC
Red Snapper	*Lutjanus campechanus*	X		NMFS, MAFMC, and GMFMC
Scup	*Stenotomus chrysops*	X	X	ASMFC
Sea Raven	*Hemitripterus americanus*		X	—
Shortfin Mako	*Isurus oxyrinchus*		X	NMFS HMS Division
Shorthorn Sculpin	*Myoxocephalus scorpius*		X	—
Silver Hake	*Merluccius bilinearis*	X	X	NEFMC
Smooth Skate	*Malacoraja senta*	X	P	NEFMC
Spiny Dogfish	*Squalus acanthias*	X	X	NEFMC, MAFMC, and NMFS
Striped Bass	*Morone saxatilis*		X -P	ASMFC
Summer Flounder	*Paralichthys dentatus*	X	X	MAFMC and ASMFC
Swordfish	*Xiphias gladius*	X		NMFS HMS Division
Tautog	*Tautoga onitis*		X	ASMFC
Thorny Skate	*Amblyraja radiata*		X - P	NEFMC
Weakfish	*Cynoscion regalis*		X	ASMFC
White Hake	*Urophycis tenuis*	X	X	NEFMC
Windowpane	*Scophthalmus aquosus*		X - P	NEFMC
Winter Flounder	*Pseudopleuronectes americanus*	X	X	NEFMC, ASMFC
Winter Skate	*Leucoraja ocellata*	X		NEFMC
Witch Flounder	*Glyptocephalus cynoglossus*	X		NEFMC
Yellowfin Tuna	*Thunnus albacares*	X		NMFS HMS Division
Yellowtail Flounder	*Limanda ferruginea*	X		NEFMC

[1] P denotes that recreational fishing is prohibited in federal waters for these species.

Table 5.2.3. Commercially and recreationally harvested marine invertebrate species reported by New Hampshire fishermen from 2015-2021 (Data from NOAA 2023a, 2003b).

Species		Commercial Fishery	Recreational Fishery	Managed By
Common Name	Scientific Name			
American Lobster	*Homarus americanus*	X	X	ASMFC
Atlantic Deep-sea Red Crab	*Chaceon quinquedens*	X		NEFMC
Atlantic Northern Shrimp	*Pandalus borealis*	X		ASMFC
Atlantic Rock Crab	*Cancer irroratus*	X		—
Atlantic Sea Scallop	*Placopecten magellanicus*	X		NEFMC
Channeled Whelk	*Busycotypus canaliculatus*	X		State Agencies
Eastern Oyster	*Crassostrea virginica*	X		State Agencies
Green Crab	*Carcinus maenas*	X		—
Jonah Crab	*Cancer borealis*	X		ASMFC
Knobbed Whelk	*Busycon carica*	X		State Agencies
Longfin Inshore Squid	*Doryteuthis (Amerigo) pealeii*	X		MAFMC, NMFS
Shortfin Squid	*Illex illecebrosus*	X		MAFMC
Spider Crabs	*Majidae*	X		—
Waved Whelk	*Buccinum undatum*	X		State Agencies

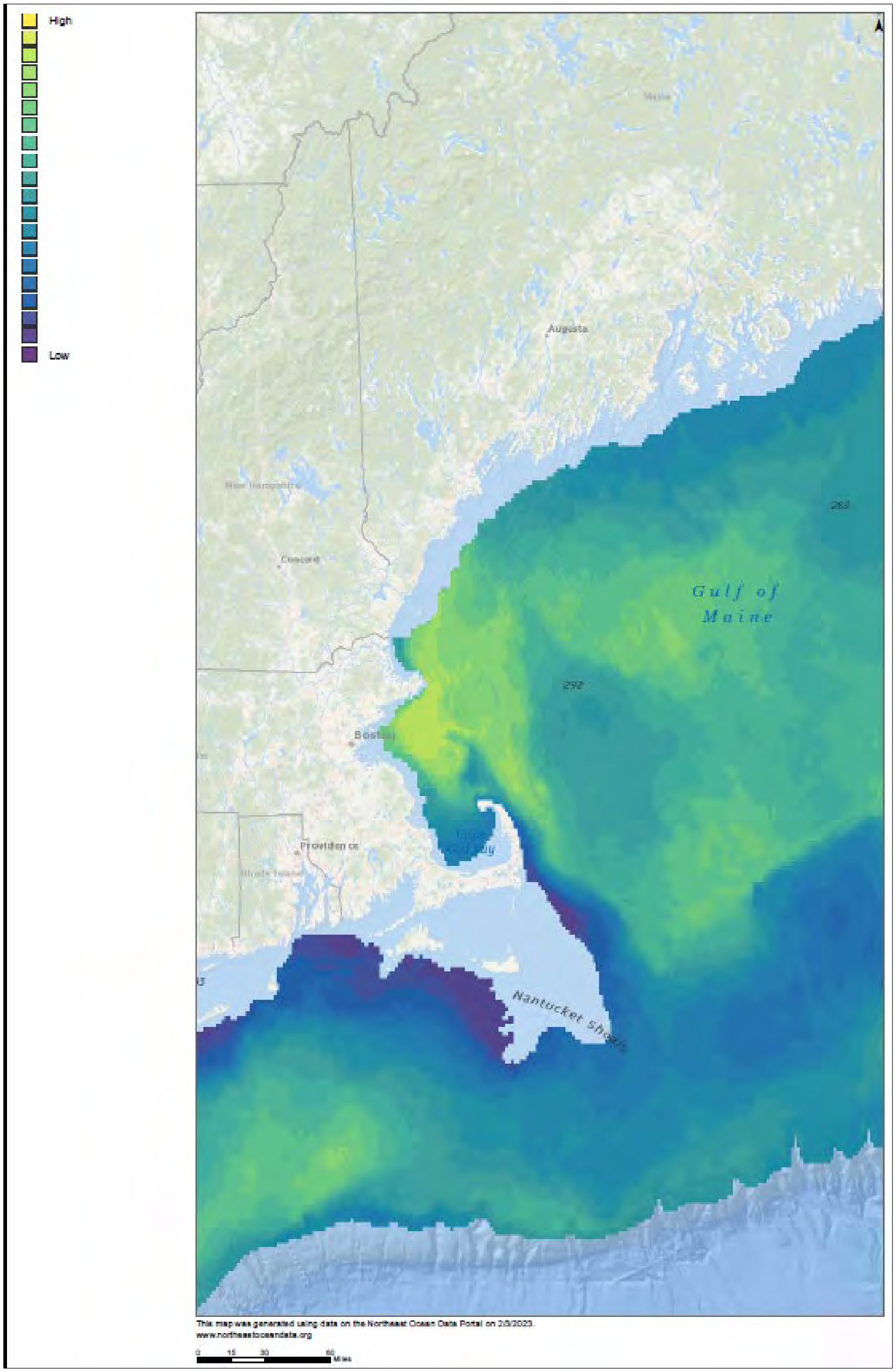

Figure 5.2.1. Total spring biomass of all fish species, 2010 through 2019 (Curtice et al. 2019, Ribera et al. 2021, MDAT 2023).

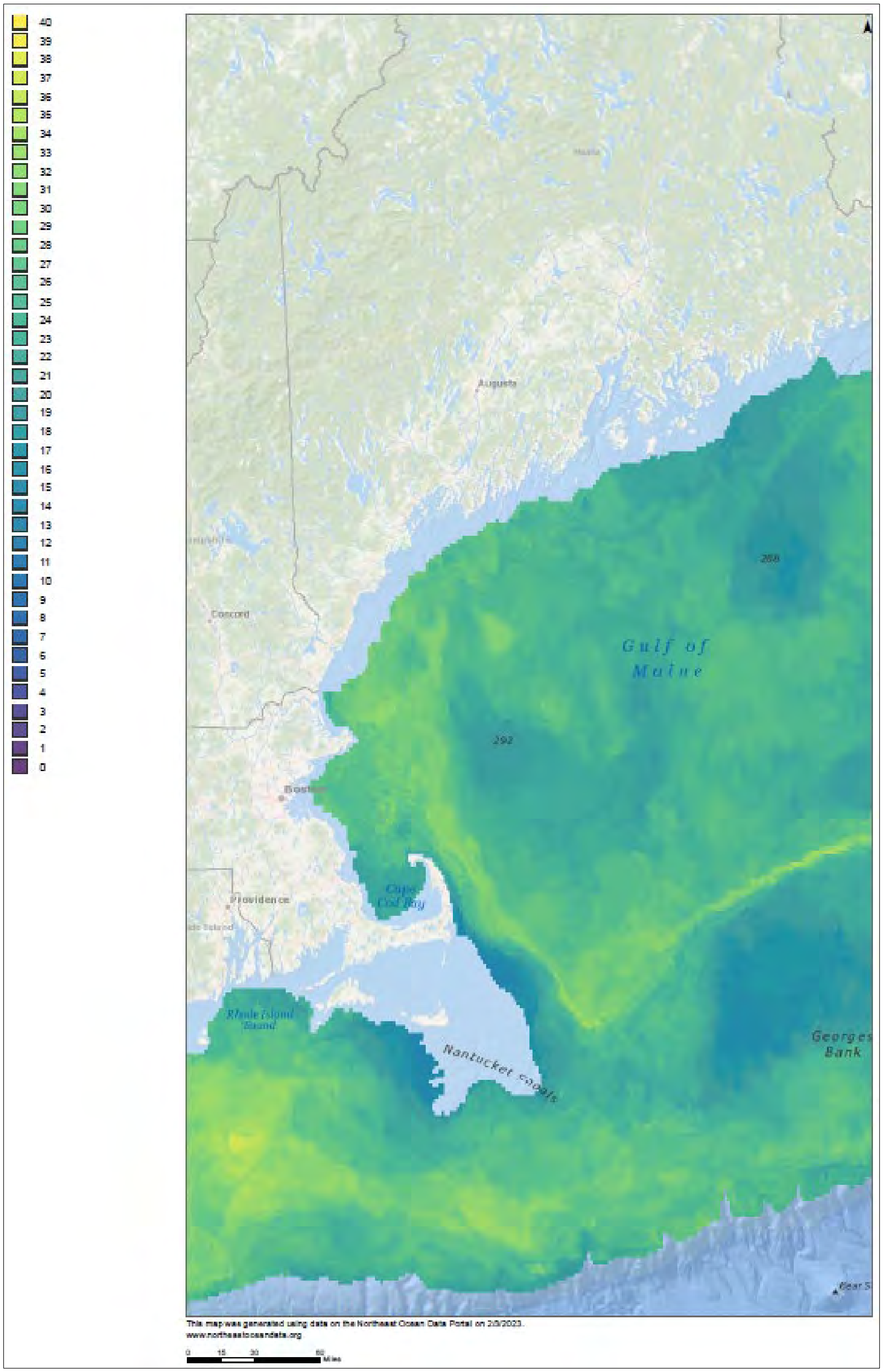

Figure 5.2.2. Spring species richness for all fish species, 2010 through 2019 (Curtice et al. 2019, Ribera et al. 2021, MDAT 2023).

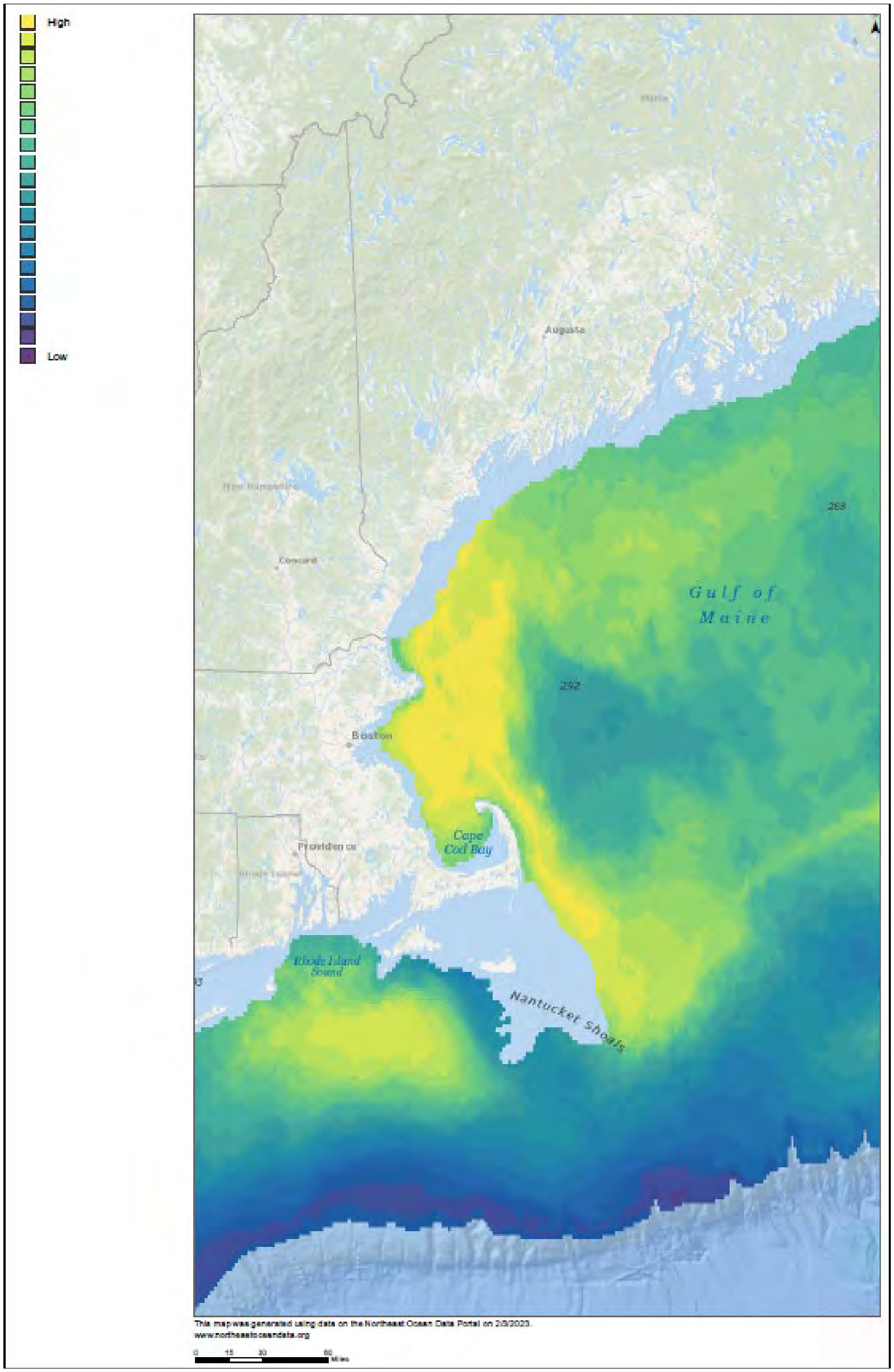

Figure 5.2.3. Total fall biomass of all fish species, 2010 through 2019 (Curtice et al. 2019, Ribera et al. 2021, MDAT 2023).

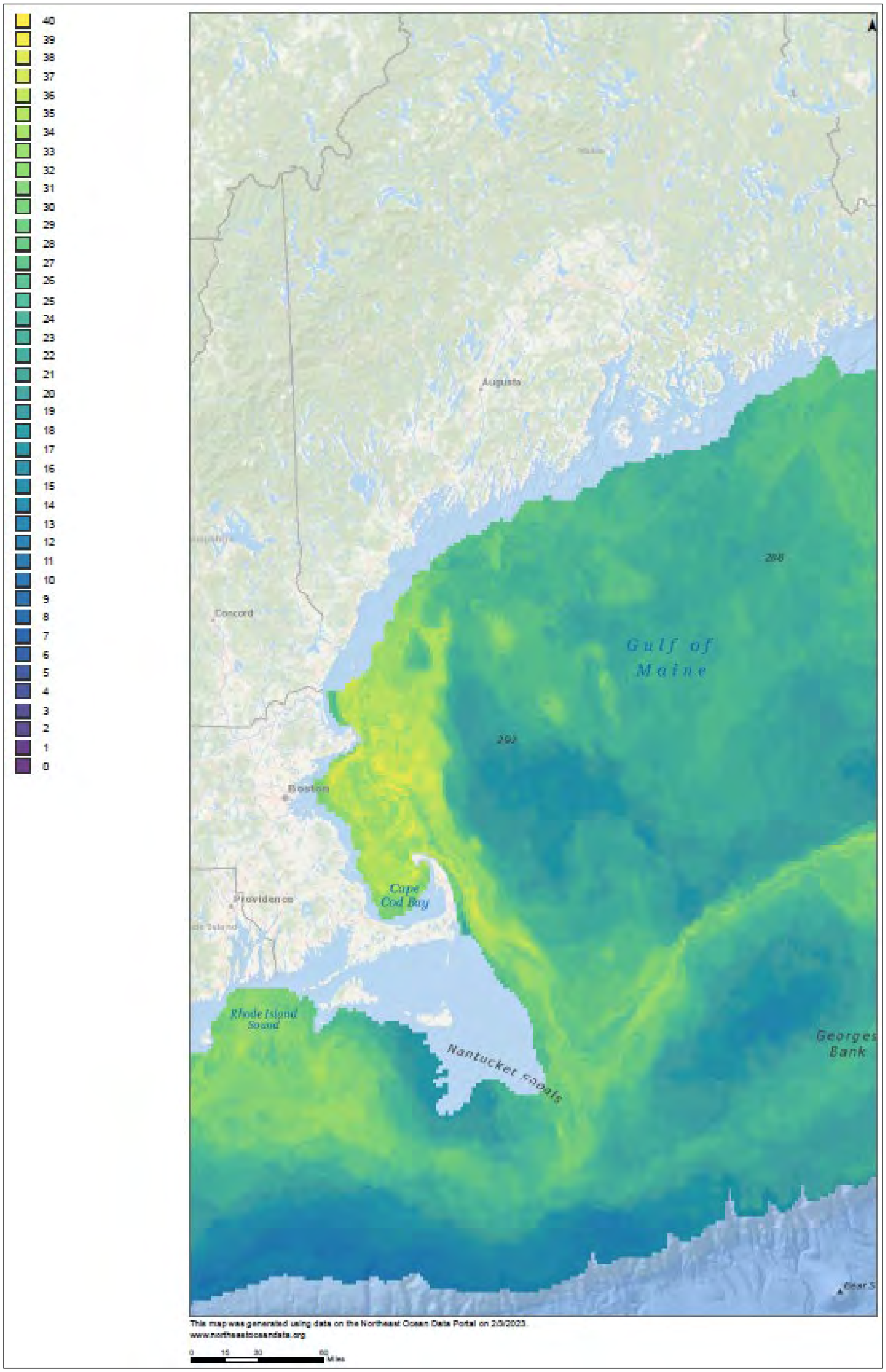

Figure 5.2.4. Fall species richness for all fish species, 2010 through 2019 (Curtice et al. 2019, Ribera et al. 2021, MDAT 2023).

Potential Impacts

Currently, robust empirical study of the effects of FOWT is not possible due to the limited number of FOWT in operation (Farr et al. 2021). Floating turbines are likely to have many impacts in common with fixed-bottom turbines, however there are potentially different impacts associated with FOWT that are less established than for fixed-bottom turbines due to the relative newness of the technology (Maxwell et al. 2022). The types of effects and their potential magnitudes can be estimated and reviewed through the scientific literature on appropriate analogues (e.g., fixed-foundation turbines, land-based wind energy facilities, and oil and gas platforms; Farr et al. 2021, Maxwell et al. 2022). FOWT may have less of a direct effect on fish species and habitats due to the limited vertical profile of the floating foundation and smaller footprint associated with mooring and anchoring than fixed-bottom turbines (SEER 2022a). Impacts associated with FOWT on fish may include entanglement, noise effects, electromagnetic fields (EMF) effects, habitat displacement, habitat alteration or destruction, and vessel collision (Bailey et al. 2014, Benjamins et al. 2014, Farr et al. 2021, Maxwell et al. 2022, SEER 2022a).

Entanglement

Entanglement risks exist during the operation stage of FOWT and are one the key potential risk differences between floating turbines and fixed-bottom foundations. The risks result from the presence of lines and cables required to operate FOWT such as mooring lines, inter-array cables, and export cables. The entanglement risks may include primary entanglement, where fish are entangled in the lines or cables themselves, secondary entanglement, where other materials such as fishing gear becomes entangled in the lines or cables and this material entangles a fish, or tertiary entanglement, where a fish already entangled in gear swims through a floating offshore wind farm and the gear becomes entangled with a facility component (Farr et al. 2021, Maxwell et al. 2022). Entanglement risks at FOWT are likely influenced by several factors including the configuration, type, and drape of the mooring lines or cables, fish behavior near turbines, detection of mooring lines or cables by fish, abundance of derelict fishing gear and other materials in the area, and the proximity to fishing grounds (Benjamins et al. 2014, Parton et al. 2019, Maxwell et al. 2022).

Benjamins et al. (2014) provided an in-depth qualitative assessment of relative primary entanglement risk, considering both biological risk parameters (e.g., body size, flexibility, ability to detect moorings, and foraging style) and physical risk parameters of mooring elements (e.g., tension characteristics, swept volume, and mooring curvature). Primary entanglement risks with FOWT for large sharks and bony fish (e.g., Basking Shark [*Cetorhinus maximus*], Ocean Sunfish [*Mola mola*]) are considered low as mooring lines and cables have a large diameter and are sufficiently heavy and taut which prevents them from entangling marine life (Bailey et al. 2014, Benjamins et al. 2014, Maxwell et al. 2022). This is consistent with the absence of entanglement records in similar moorings or other infrastructure for offshore oil and gas platforms (Benjamins et al. 2014). Additionally, no primary entanglement has been reported for FOWT elements at the Hywind Scotland since operation began in October 2017 (Maxwell et al. 2022). Catenary moorings with nylon rope and chains or accessory buoys present the greatest risk relative to other mooring designs (Benjamins et al. 2014, Harnois et al. 2015).

Marine animals including finfish and mobile invertebrates (e.g., American lobster, crabs) are more likely to be at risk from secondary and tertiary entanglement that may result in severe injury or mortality from tissue damage, starvation, or suffocation (Farr et al. 2021). As most floating turbines will be placed in remote offshore areas, if entanglements should occur, the opportunities to release any entangled animal would be unlikely (Benjamins et al. 2014). Finish, invertebrates, and other animals caught in ghost gear could also serve as bait for larger predators bringing them closer to the debris and increasing their entanglement risk (Maxwell et al. 2022). Secondary entanglement could have population-level impacts if vulnerable life stages of taxa are more susceptible to entanglement (e.g., juvenile elasmobranch species) or highly endangered species occur in the areas around FOWT (Parton et al. 2019, Maxwell et al. 2022). Currently, little is known about the actual risks posed by FOWT mooring lines or cables for secondary and tertiary entanglement (Farr et al. 2021, Maxwell et al. 2022).

Several recommendations to reduce secondary entanglement risk to marine animals in floating offshore wind infrastructure have been developed by collaboration of environmental organizations. The recommended measures are designed first to avoid and then minimize and mitigate potential impacts and are based on the most up-to-date scientific and technological information currently available (CLF et al. 2022). The recommendations include: a) siting offshore wind projects in areas that avoid sensitive habitats and biologically important areas, b) continuous monitoring of any unexpected weight or strain on mooring lines or cables using load cells or other appropriate sensors, c) daily remote visual inspection of the mooring lines and cables close to the platforms in order to detect an entanglement event within at least a 24-hour period, and d) monthly acoustic or remote visual inspections of the full length of the submerged structures (CLF et al. 2022). Additional recommended avoidance and minimization measures include: a) mooring lines and inter-array cables should be designed and maintained in configurations that minimize the potential for entanglement of marine animals, b) infrastructure should be designed to facilitate visual or acoustic detection of ensnared marine debris at depths where marine debris is most likely to occur, c) development of protocols for when ensnarement and/or entanglements are identified, and d) the return or disposal of the ghost gear or marine debris prioritizing the physical recycling of materials (CLF et al. 2022). Lastly, all incidences of observed ensnarements of marine debris on floating offshore wind infrastructure and entanglements of marine animals shall quickly be made publicly available (CLF et al. 2022).

Noise effects

Underwater noise produced by turbines may be an important stressor during all phases of offshore wind energy development, generation, and decommissioning (Mooney et al. 2020). Anthropogenic noise sources have the potential to displace, cause hearing threshold shift, physically injure, and/or negatively affect many marine animals' ability to communicate, forage, select habitat, and migrate (Götz et al. 2009, Popper et al. 2014, Popper and Hawkins 2019, Farr et al. 2021). These effects can have considerable consequences to individuals and populations (Popper and Hawkins 2019). Floating turbine-bearing structures are expected to produce mainly lower-frequency sounds with dominant frequencies of about 1 kHz or less based on fixed-foundations turbines (Tougaard et al. 2020, Maxwell et al. 2022). Noise from fixed-foundation turbines is highly variable depending on wind speed, the size of the turbine, the type of foundation used, and other factors related to the ambient environment (Mooney et al. 2020, Tougaard et al. 2020). Cumulative noise levels from fixed-foundation wind farms can extend a few kilometers in low ambient noise conditions (Tougaard et al. 2020). Additionally, there is a particle motion component to the sounds generated by wind turbines, accompanying substrate transmission although this has rarely been monitored (Popper and Hawkins 2019). It is largely unknown how noise levels differ for floating versus fixed-foundation turbines, although it is likely to be dependent on the type of mooring used, the size and number of turbines, and site weather and oceanographic conditions among other factors (Maxwell et al. 2022). The cumulative contribution to the ocean soundscape from multiple wind turbines may be significant in areas with low natural ambient noise and low ship traffic levels, and large enough to raise concern for negative effects on marine animals (Tougaard et al. 2020).

A sound source characterization study was conducted at the Hywind Scotland floating offshore wind farm from October 2020 to January 2021 using in situ acoustic recorders placed on the seafloor (Burns et al. 2022). The study found that continuous tonal noise, associated with rotating rotor and generator components below 500 Hz, was perceptible and showed correlation with wind speed. Temporal variability in similar frequency tones suggested different concurrent signatures for individual Hywind turbines arrived simultaneously. The other main feature of the overall Hywind noise was the presence of frequent broadband transient sounds with a median duration of 1.5 seconds (Burns et al. 2022). These transient noises were audibly associated with strain and friction in the mooring system and showed a strong positive correlation in occurrence with wave height. Directional analysis of transient noise indicated that the mooring noise was predominantly generated in mooring components close to the floating spar and not from components farther down each mooring cable (Burns et al. 2022). The total noise levels (tonal and transient) from turbine HS1 were extracted and back propagated to attain decidecade (one-third octave) band source levels for a single Hywind Scotland system at five winds speeds between 5 and 25 kn. The resulting median broadband source levels ranged from 162.5 to 167.2 dB re 1 $\mu Pa^2 m^2$ with the maximum 95th percentile at 25 kn of 172 dB re 1 $\mu Pa^2 m^2$ (Burns et al. 2022). These source levels were used to model a basic noise footprint for the entire five turbine windfarm. The modelling showed that the distance to the averaged background SPL level (110 dB re1μPa) from the center of the farm (i.e., where the radiating noise decays to approximately the broadband ambient level) at the quietest state (10 kn of wind) was approximately 4 km, and in maximum state (25 kn of wind) was 13 km (Burns et al. 2022).

All finfish (including elasmobranchs) detect and use particle motion, principally at frequencies below several hundred Hz, therefore particle motion is integral to hearing in all fishes (Popper and Hawkins 2019). Most fishes detect sounds from less than 50 Hz (as low as 10-30 Hz) to about 300–500 Hz. Finfish that can detect sound pressure hear to about 1,000 Hz, with a smaller number of species able to detect sounds to 3–4,000 Hz (Popper and Hawkins 2019). FOWT operational noise, which would be continuous, may be detectable to some finfish however it is unlikely that the noise levels would result in physiological damage (Wahlberg and Westerberg

2005, Marmo et al. 2013, Farr et al. 2021). The particle motion (the back-and-forth motion of the medium) component to sounds generated by turbines has received little research attention and remains uncertain (Popper and Hawkins 2019). Additionally, differential effects of operational noise on fish with and without a swim bladder (used in sound frequency detection) is unknown (Farr et al. 2021). Based on modeled scenarios presented in Marmo et al. (2013) for fixed-foundation turbines, fish behavioral responses to operational FOWT noise are expected to be minimal, indicating low potential for displacement (Farr et al. 2021).

Relatively few studies have been conducted on marine invertebrates, including crustacean species (e.g., American lobster), regarding the effects of underwater noise, although research has increased in recent years (Edmonds et al. 2016, Hawkins and Popper 2017). There is limited information available on the ability of marine invertebrates to detect sounds (Popper and Hawkins 2018). The sound-detecting structures in various invertebrates are diverse and are less well studied than in finfish, however, most appear to be responsive to particle motion rather than to sound pressure (Budelmann 1992, Popper and Hawkins 2018, Jézéquel et al. 2021). Additionally, there is evidence that invertebrates are capable of detecting sounds traveling through and on the substrate (substrate vibration), however, there is very limited knowledge of the way in which invertebrates detect and respond to substrate transmission (Popper and Hawkins 2018, Hawkins et al. 2021). Exposure to shipping noise has been found to significantly alter the foraging and antipredator behaviors of marine invertebrates. Marine invertebrate physiological responses (e.g., respiration rate, heat shock proteins, and initiation of the defense system) also indicated increased stress to shipping noise (Murchy et al. 2019). Crustaceans are more perceptive to low-frequency particle motion compared to sound pressure (Leiva et al. 2021). Several key crustacean behaviors, such as foraging, antipredator responses, shell searching behavior, and grouping behavior, are altered by low-frequency (<500 Hz) anthropogenic noise (Wale et al. 2013, Tidau and Briffa, 2019, Leiva et al. 2021). FOWT are expected to produce lower-frequency sounds and may have impacts on marine invertebrates including American lobster, although the extent is currently unknown. Thresholds for harmful sound exposure levels and/or injury criteria have not been developed for marine invertebrates (Edmonds et al. 2016, Hawkins and Popper 2017). An in-depth examination of the acoustic propagation characteristics of floating substructures and their associated moorings, along with the overall noise levels of operational floating OWFs would enhance the understanding of the interactions of these facilities and marine animals (Farr et al. 2021).

Electromagnetic fields (EMF) effects

The generation of electromagnetic fields (EMF) is of concern for finfish and invertebrate species in proximity with floating offshore wind farms (Farr et al. 2021, Maxwell et al. 2022, SEER 2022a). Natural magnetic, electric, and electromagnetic fields provide important ecological cues to magneto- and/or electro-sensitive species. Studies have shown that some fishes (e.g., elasmobranchs, sturgeons, salmonids, cods) and invertebrates (including decapods) use the Earth's geomagnetic field for navigational and orientation purposes and bioelectric fields for prey, conspecific, or predator detection (Peters et al. 2007, Normandeau et al. 2011, Bedore and Kajiura 2013, Gill et al. 2014, Hutchison et al. 2020a). Distortions of these fields by anthropogenic EMF may have important ecological consequences (Hutchison et al. 2020b). Anthropogenic EMF effects can alter the ability of some fishes to detect or respond to natural magnetic signatures, potentially altering feeding, survival, migratory patterns, and or reproductive success (Normandeau et al. 2011). Long-lived slow reproducing species (e.g., elasmobranchs, sturgeons) are of particular concern (Maxwell et al. 2022). Currently, the research on fish is limited and observed responses are often species-specific or even individual-dependent (Gill et al. 2014). EMF sensitivity (based on detection and sensory ability) likely varies through a species' life history and movement ecology likely affects exposure (based on encounter rate). Knowledge of these species' characteristics are required to understand potential population-level effects of EMF (Hutchison et al. 2020b).

Little is known about the effects of EMF on marine benthic invertebrates (e.g., molluscs, worms, crustaceans, and echinoderms). Fundamental data about the magneto-sensitivity of some invertebrate groups are lacking, creating a knowledge gap regarding the impact assessment of magnetic field exposure especially in burrowing and epibenthic species that live in or near the seafloor where frequency of encounter and exposure to submarine cable-generated EMF is highest (Albert et al. 2020). For a marine animal to detect EMF from a submarine cable, the animal's range of detection must overlap with the intensity and frequency of the EMF emitted from the cable. Distinct detection ranges of electric and magnetic fields are not well known for many species (SEER 2022a). However, American lobster are able to detect EMF based on an exploratory response when exposed to a HVDC cable EMF compared to the ambient geomagnetic field (Hutchison et al. 2020a).

The current data gaps pose challenges for managers of OSW developments and fishery resources. The effects of EMF on commercially and recreationally important species are an understudied aspect of OSW environmental impact assessments. There are currently no policies or regulations related to EMF (Hutchison et al. 2020b).

Sources of anthropogenic EMF at floating OWF will include inter-array cables between floating turbines and substations, and export cables. Project-specific properties will define the cable types and routes through multiple ecosystems (Hutchison et al. 2020b). Several factors may influence the strength of EMF generated from subsea cables including the distance between conductors, balance of the load, and the type of cable. Three-phase AC cables, which produce both electric and magnetic fields, are the most commonly used cables in offshore wind farms, although the magnetic fields emitted are typically low (Gill et al. 2014, Farr et al. 2021). As floating OWF are further from shore, the longer transport distances may require the use of HVDC cables, which typically emit higher intensity magnetic fields over a larger spatial scale (Gill et al. 2014). A model developed for existing submarine cables found that the strongest EMF was within the first 2 meters (7 feet) of the cable and then decreased to lower levels beyond 10 meters (33 feet) from the cable (SEER 2022a). Additionally, FOWT configuration will include inter-array cables in the water column (dynamic cables), instead of solely on the seafloor as for fixed-foundation turbines, and introduce EMF into the water column potentially affecting a greater diversity and abundance of marine animals (Hutchison et al. 2020b, Farr et al. 2021).

There is a limited understanding of the EMF impacts of cables suspended in the water column (Hutchison et al. 2020b). The most likely effects of anthropogenic electric and magnetic field emissions for submarine and dynamic cables associated with floating offshore wind include physiological impacts, such as altered development, and behavioral effects, such as attraction, avoidance, and impaired navigation and/or orientation (Gill et al. 2014, Farr et al. 2021).

Field and laboratory studies have shown measurable effects and responses (behavioral, physiological, developmental and genetic) to electric and/or magnetic fields on a small number of individual species, but not at the EMF intensities associated with renewable energy systems (Gill and Desender 2020). A response to EMF does not necessarily mean there are impacts. Current evidence is insufficient to determine if impacts from submarine cable emitted EMF are occurring on individuals or populations. Additional data about sensitive species at various life stages, exposure to different EMF (sources, intensities), and determination of the EMF environment at specific deployment sites are needed (Gill and Desender 2020, SEER 2022a). Hutchison et al. (2020b) suggests that understanding EMF needs to move from individual effects to population-level impacts. For invertebrate EMF research, Albert et al. (2020) suggest future studies should target a restricted number of species with the highest probability of exposure, in both duration (mobile versus sessile) and location (epifauna versus infauna) to assess the effects electric and magnetic fields have on basic ecological functions (e.g., reproduction, feeding, or habitat selection) before studies are conducted at the population level. As uncertainties are a significant barrier to research progress, there needs to be better communication of electric and magnetic fields and in situ measurements in relation to the power production cycle. Data collection should facilitate experiments that will be more relevant both at the ecological and technical level (Albert et al. 2020).

As the numbers of submarine cables from future OSW farm projects and other marine industries increase, cumulative effects could occur in heavily developed regions. EMF from a single cable needs to be considered in the context of other cables in the area (i.e., existing and proposed cables) and other activities that may occur in the region (SEER 2022a). Cumulative effects could be both physical and biological. Physically, more numerous cables, their orientation, and cable type may influence the EMF encountered by marine animals (Hutchison et al. 2020b, SEER 2022a). For example, the addition of new cables in an area could increase the number of submarine cables a migratory species would encounter along its migratory route. Biologically, behavioral and physiological effects may interact, and early life history experiences may influence later life stages (Hutchison et al. 2020b). The potential for cumulative EMF effects has not been characterized by current studies or research. These types of scenarios need to be studied to understand the actual interactions that may occur from multiple OSW projects in an area or region. (SEER 2022a). Careful baseline studies are essential in evaluating EMF at various scales of potential impact, including cumulative impacts (Hutchison et al. 2020b).

Habitat displacement

Changes in fish movements or assemblages around FOWT will likely be species-dependent, difficult to generalize, and may occur during any stage of offshore wind development (Maxwell et al. 2022). Any significant changes in fish behavior as a result of avoidance or displacement due to FOWT (e.g., noise, EMF) may increase energy expenditure (Maxwell et al. 2022). This behavior could cause alterations to aggregations, spawning events, migration patterns, and may influence the ecological community structure if ecologically-important species avoid impacted areas (Maxwell et al. 2022). Connections between species in ecological communities are extremely complex and impacts on one species in a community can often impact other species. Reduced coastal and pelagic fish species abundance in impacted areas could have impacts on upper trophic level populations, including large predatory finfish, seabirds, and marine mammals (Golet et al 2007, Cury et al. 2011, Maxwell et al. 2022).

Habitat alteration or destruction

The deployment of FOWT components (i.e., mooring anchors and subsea cables) may induce physical changes to seafloor sediments, benthic communities, and habitats that could result in direct temporary and/or permanent habitat alteration or destruction, potentially altering species composition and abundance at the local scale (Farr et al. 2021, Maxwell et al. 2022, SEER 2022a). Deployment of mooring anchors and subsea cables can result in the addition of new hard surfaces to areas with soft sediments, changes to sedimentation regimes, scouring and resuspension of sediment, and impacts to habitat-forming species or structures (Farr et al. 2021, Maxwell et al. 2022, SEER 2022a). However, habitat alterations that may result from floating OWFs are unlikely to present many new challenges that have yet to be observed and addressed with the deployment of other marine structures (Farr et al. 2021).

Mooring anchors and subsea cables associated with FOWT that are not fully buried may function as artificial reefs by introducing hard substrate that can be colonized by algae, invertebrates, and structure-associated finfishes (Langhamer 2012, Farr et al. 2021, SEER 2022a). The “reef effect” of anthropogenic structures has been well-documented at OWFs and oil and gas platforms (Langhamer 2012, Claisse et al. 2014, Degraer et al. 2020). FOWT surface and midwater structures (e.g., floating substructures and mooring lines) may also act as fish aggregation devices (Kramer et al. 2015, Farr et al. 2021). Hundreds of different finfish species from nearly a hundred taxonomic families aggregate around floating structures suggesting that FOWT may attract a variety of species and potentially alter species composition in surface and midwater ecological communities (Castro et al. 2002, Farr et al. 2021). In instances where fishing activity is restricted within and around floating offshore wind farms, they may act as marine protected areas, creating refuges for some marine species, increasing local species abundances, and producing spillover effects to adjacent areas (White et al. 2012, Hammar et al. 2016, Farr et al. 2021). The degree to which this may happen would depend on the location of the wind farm and the level of imposed fishing restriction (Hammar et al. 2016). However, the reef and fish aggregation effects of FOWT components could also promote colonization by non-native (invasive) species across the region, whose threat to marine biodiversity can have far-reaching ecological and economic consequences (Molnar et al. 2008, Farr et al. 2021, SEER 2022a). As floating foundations are generally towed from ports to deployment sites, there could be an increased potential for the introduction of invasive species at the wind farm sites (SEER 2022a).

FOWT may cause increased sedimentation compared to fixed-foundation turbines as a result of scour from anchors and other components that will be impacted by wave action and currents similar to traditional boat anchors (Davis et al. 2016, Maxwell et al. 2022, Watson et al 2022). Increased sedimentation could impact benthic fish populations and may cause the release of sediment contaminants in the seafloor which could impact the benthic spawning habitat quality of some species (Wilber and Clarke 2001, Wenger et al. 2017, Johnson 2018, Maxwell et al. 2022).

Understanding effects of habitat alteration or destruction on highly migratory species (HMS) is difficult, as life histories and historic catch records show a wide distribution within and between species that varies temporally (NOAA NMFS 2017, Maxwell et al. 2022). This makes it difficult to specifically delineate areas of importance at a resolution of the wind lease areas (Maxwell et al. 2022). Habitat use for HMS identified both benthic and water column habitats in offshore areas, although in many cases the particular habitat characteristics that influence species habitat use are not clearly understood or identified (NOAA NMFS 2017). Habitat for HMS appears to be related to water quality, especially water temperature, which can be highly variable between seasons and years (NOAA NMFS 2017, Maxwell et al. 2022). FOWT are unlikely to change local water temperatures significantly, therefore thermal habitat preferences of HMS are not likely to be impacted by the presence of the floating turbines, although hydrodynamics may be altered in the vicinity of the turbines (van Berkel et al. 2020, Maxwell et al. 2022).

Vessel collision

Offshore wind energy installations will result in increased vessel presence in coastal and offshore habitats during construction, operation, and maintenance phases, increasing vessel-wildlife collision risks (Maxwell et al. 2022). A vessel collision or strike is defined as any impact between any part of a vessel and a live animal. Vessel collisions often result in the physical trauma to or death of the animal, may negatively affect wildlife populations, and may seriously damage the vessel placing the people on board at risk of injury and death (Lightsey et al. 2006, Ritter 2012, Moore and Barco 2013, Schoeman et al. 2020). Vessel collisions have led to concerns about animal welfare, species conservation, the safety of people on board the colliding vessel, and economic consequences as a result of vessel damage (Schoeman et al. 2020). Concerns about the effects of vessel strikes on marine animals and their populations mainly began from the extensive and growing utilization of the world’s oceans by commercial and recreational vessels (Schoeman et al. 2020). Based on eye-witness collision reports, necropsy data, and anecdotal accounts, over 75 marine species have been struck by vessels including sharks, sturgeons, sunfish, and manta rays (Jensen and Silber 2004, McGregor et al. 2019, Schoeman et al. 2020). Collision data for smaller marine species are scarce due to underreporting rather than collisions being less frequent. Underreporting is caused by several factors including a lack of awareness of a collision by vessel crew, the quick sinking of carcasses in fatal collisions, consumption by scavengers or decomposition before reaching the shore, and a lack of global encouragement and database. It is unknown if the collisions of small and large species are reported with the same probability, as the public may be less concerned about reporting smaller species than about reporting large whales (Schoeman et al. 2020). There are three main types of consequences from vessel collisions with wildlife: direct (immediate results), long-term (decrease in animal fitness over time), and population-level consequences (Schoeman et al. 2020). Studies regarding vessel collisions specific to offshore wind development have not been conducted to date (Maxwell et al. 2022).

The likelihood of fish collisions with FOWT vessels may be less than with fixed-bottom turbines for two reasons (Maxwell et al. 2022). First, much of the FOWT construction can be done on land with pre-constructed components towed to the deployment site. This reduces the installation time, the number of vessels, and level of offshore construction necessary compared to fixed-foundation turbines. Secondly, in some FOWT platform configurations, the surface area is large enough for helicopter landing pads to be installed. This means that maintenance could be done by helicopter reducing the potential of vessel-fish collision and transit times to the offshore turbines, however the use of helicopters for turbine maintenance would cause a collision risk for birds (Maxwell et al. 2022).

5.2.2 Fisheries

The GOM supports historically and culturally significant and high value commercial and recreational fisheries including American lobster, Northeast Multispecies (groundfish), Atlantic sea scallop, Atlantic Herring, Monkfish (*Lophius americanus*), skates, and Bluefin Tuna. Additionally, a small Maine mahogany quahog fishery exists (NOAA NMFS 2022a). The Northeast Multispecies fishery consists of several species including Acadian Redfish, American Plaice (*Hippoglossoides platessoides*), Atlantic Cod, Atlantic Halibut, Atlantic Pollock, Atlantic Wolffish (*Anarhichas lupus*), Haddock, Ocean Pout (*Zoarces americanus*), Red Hake (*Urophycis chuss*), Silver Hake, White Hake, Windowpane Flounder (*Scophthalmus aquosus*), Winter Flounder, Witch Flounder (*Glyptocephalus cynoglossus*), and Yellowtail Flounder (*Limanda ferruginea*). The lobster, groundfish, and herring fisheries are the largest fisheries by volume and value in the RFI area. The Maine lobster fishery landed 108 million pounds in 2021 worth $725 million. Groundfish landings since 2008 have averaged approximately 30.7 million pounds per year with an average annual value of $40.6 million (NOAA NMFS 2022a). The top 10 species harvested in the RFI area by revenue from 2008 to 2020 were American lobster, Atlantic Herring, Atlantic sea scallop, Pollock, Haddock, Atlantic Cod, Monkfish, White Hake, Acadian Redfish, American Plaice, and Witch Flounder (NOAA NMFS 2022a).

Fishing vessels from Maine to North Carolina operate in the GOM and many are dependent on this area for a significant portion (50-100%) of their annual fishing revenue (NOAA NMFS 2022a). Modeled vessel trip reports (VTR) data indicate an estimated average of 700 vessels took an average of approximately 15,000 expected commercial fishing trips annually from 2008 through 2020 into the RFI area (NOAA NMFS 2022a). The primary ports used by commercial vessels to land their harvest include New Bedford and Gloucester, MA which average approximately $22 million in ex-vessel revenue annually from trips within the RFI area. Additionally, Boston, MA, Portland ME, and Rockland, ME currently average between $9 and $11 million in annual fishing revenues from trips in the RFI area (NOAA NMFS 2022a).

Several commercial gear types operate in the RFI area including bottom trawls, mid-water trawls, gillnets, hook and line (i.e., longline and handline), dredge (i.e., clam and scallop), purse seines, and traps (NOAA NMFS 2022a). Purse seines, trawls, and traps are the prevalent gear in the RFI area, although gillnets are also used in the groundfish and monkfish fisheries, and harpoons are used for Bluefin Tuna (NOAA NMFS 2022a). FOWT are likely to affect the feasibility of fishing with several of these gear types. Vessels using trawl gear, gillnets, traps, and hook and line for tuna may not be able to operate within the FOWT arrays given the potential gear obstructions and entanglement risk from anchor lines and inter array and export cables. For example, in the lobster fishery the maximum length of a lobster trawl is 1.5 miles in most of the GOM but can be as long as 1.75 miles in the offshore portions based on existing regulations. Depending on the spacing of potential future FOWT, it may be difficult to set the trawls among floating turbine arrays. Purse seines may also have difficulty operating in the areas depending on gear length and depth, and the ability of use spotter planes among the FOWT (NOAA NMFS 2022a).

NMFS vessel monitoring system (VMS) data represent the majority of vessel operations in most of the fisheries managed in federal waters with the exception of the lobster fishery. Preliminary assessment indicated 95% of groundfish, herring, monkfish, and scallop landings from 2014 through 2019 were from vessels equipped with VMS. Less than 4% of lobster landings were from VMS vessels (NOAA NMFS 2022a). VMS data are good indicators of the spatial distribution of fishery operations for major fisheries within the RFI area (NOAA NMFS 2022a). Commercial fishing vessel activity in the GOM from January 2015 through December 2019 reported through the NMFS VMS is shown in Figure 5.2.5. These data have some limitations as they do not adequately characterize commercial lobster fishing and vessels targeting HMS, and do not distinguish between areas of fishing activity versus transit.

The recreational fishing industry consists of shore fishing, private or rental boats, party boats or headboats, and charter boats (for-hire vessels). For-hire recreational fishing is dominated by vessels targeting groundfish species and mackerel. Fishing revenue by federally permitted for-hire vessels averaged $4.3 million from 2008 through 2020 but has declined since 2010 with an average of $2.4 million from 2016 through 2020 (NOAA NMFS 2022a). Angler trips per year averaged 38,269 from 2008 through 2020, and for-hire vessel trips averaged 1,880. Both angler trips and for-hire vessel trips have declined since peaking in 2010 (NOAA NMFS 2022a). The majority of these trips originated at New Hampshire ports. For-hire vessels are heavily dependent on fishing within the RFI area for most of their fishing income (NOAA NMFS 2022a). Spatial data on private recreational fishing are not available but it is expected that the species targeted are similar to party and charter operations along with Striped Bass and other regional sportfish. Bluefin Tuna is another important recreational fishery based on the annual Bluefin Tuna tournaments held at Maine, New Hampshire, and Massachusetts ports (NOAA NMFS 2022a).

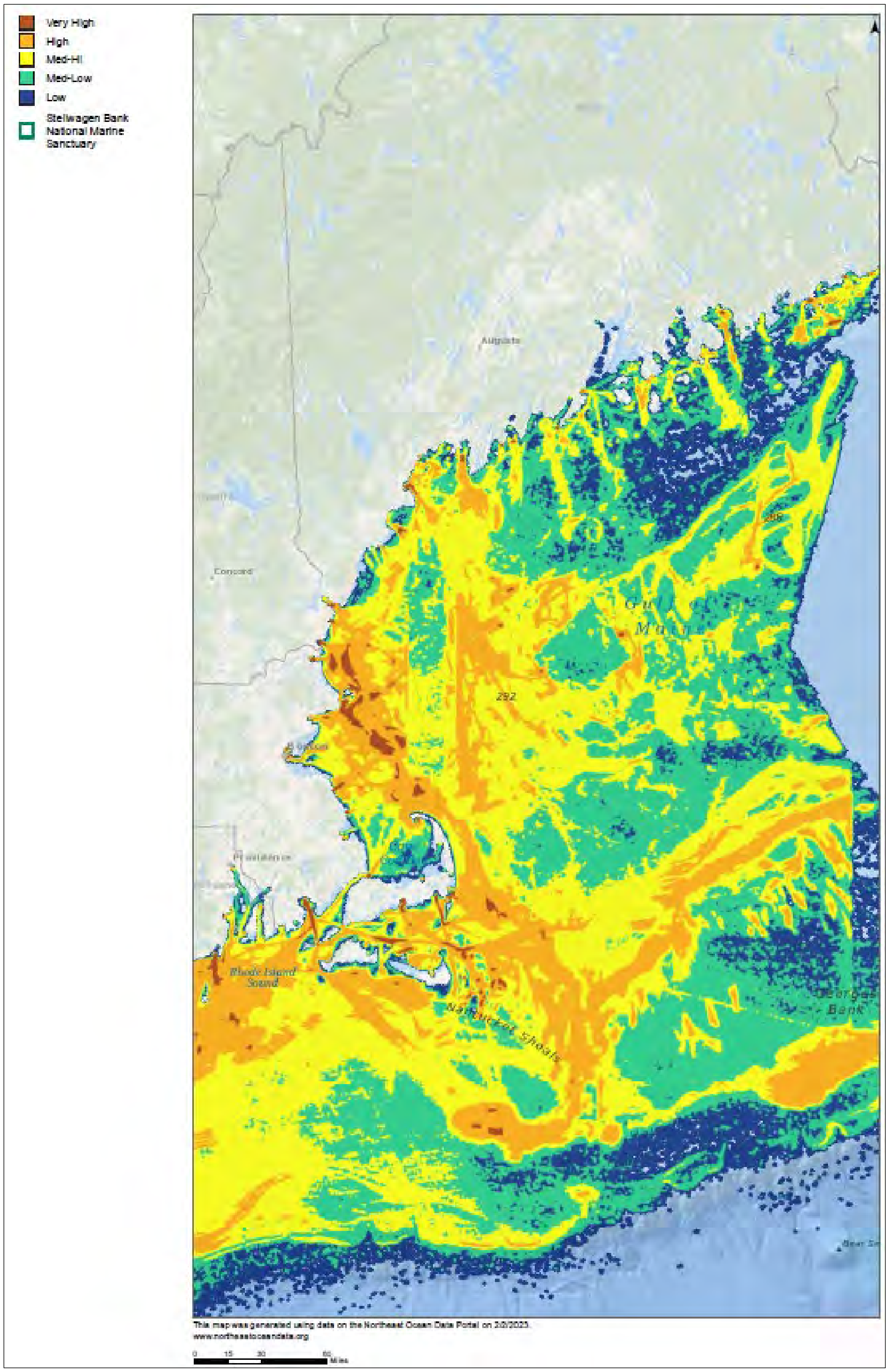

Figure 5.2.5. The density of all commercial fishing vessel activity reported through the NMFS Vessel Monitoring Systems (VMS) in the Gulf of Maine from January 2015 through December 2019 (Northeast Ocean Data 2023). These data do not distinguish between areas of fishing activity versus transit.

New Hampshire Fisheries

Commercial Fisheries

New Hampshire commercial fisheries are the third largest by both landings and revenue in the RFI area. New Hampshire total cumulative landings within the area from 2008 through 2020 were 81.5 million pounds worth $196.7 million (NOAA NMFS 2022a). The main New Hampshire commercial fisheries include American lobster, menhadens, Bluefin Tuna, Northeast Multispecies (e.g., Haddock and Pollock), Monkfish, Atlantic sea scallop, and Atlantic Herring. The New Hampshire lobster fishery landed 5.7 million pounds in 2021 worth $44 million (NOAA NMFS 2023a). The menhaden fishery landed 4.8 million pounds worth $1.6 million in 2021, and the Bluefin Tuna fishery landed 162.4 thousand pounds worth $0.9 million (NOAA NMFS 2023a). New Hampshire also has several small fisheries that harvest Atlantic Halibut, Butterfish, skates, Atlantic rock and Jonah crabs (*Cancer irroratus* and *Cancer borealis*), longfin squid, and whelks along with various other species (Table 5.2.2 and Table 5.2.3). New Hampshire commercial fishermen often fish multiple fisheries in a year. The New Hampshire commercial landings for all species from 2015 through 2021 are presented in Appendix D.

New Hampshire commercial fishermen use a variety of gear types including traps, pots, gill nets, otter trawls, dredges, handlines, and rod and reels. Commercial fishing activity in the RFI area for all gear types from 2004 through 2022 is shown in Figure 5.2.6. Commercial fishing activity from 2004 through 2022 by individual gear type is provided in Appendix E. Commercial fishermen use ports in Hampton, Portsmouth, Rye, Seabrook, and Newington. State-owned commercial fishing piers and facilities are located in Portsmouth, Rye and Hampton Harbors. Berths and slips are only available in Portsmouth Harbor, as physical limitations prevent long-term or overnight berths at Rye or Hampton Harbors (Pease International 2023). As a result, Portsmouth Harbor maintains New Hampshire’s largest number of commercial fishing vessels averaging 1,747 trips per year from 2015 through 2020. In 2020, the harbor’s 20 fishing vessels made 1,559 trips (NOAA NMFS 2022a, Table 5.2.4). The second largest number of fishing vessels is found in Rye Harbor where an average of 9 vessels typically made 387 trips between 2015 and 2020.

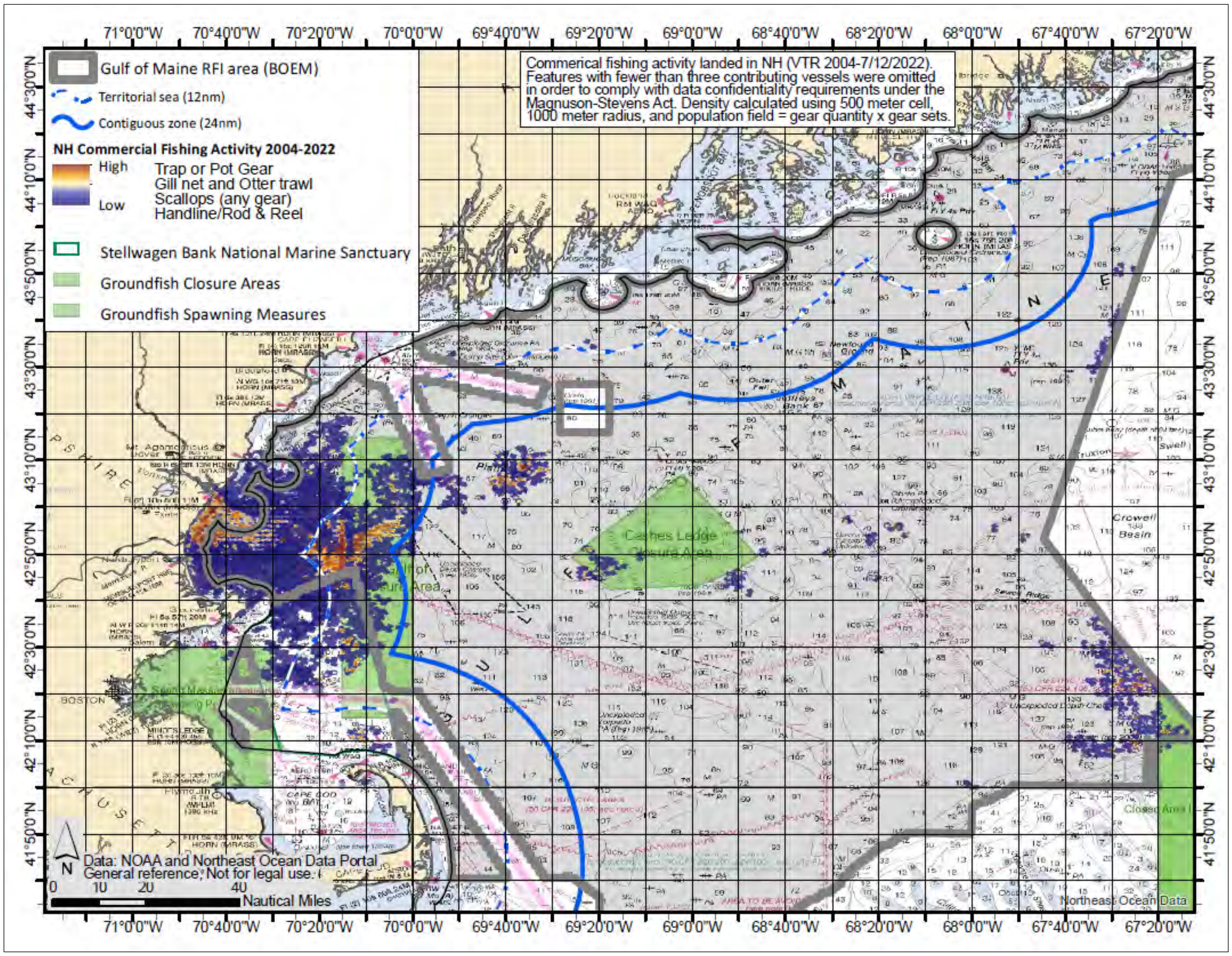

Figure 5.2.6. New Hampshire commercial fishing activity for all gear types from 2004 through 2022 based non-confidential vessel trip reports (NHFG 2022).

Table 5.2.4. Total number of commercial fishing trips and vessels taking the trips from New Hampshire ports from 2015-2020. These trips represent an upper bound on the counts as the data do not consider the probability of these trips actually overlapping the RFI area (NOAA NMFS 2022a).

New Hampshire Port	Year	Number of Commercial Fishing Trips	Number of Vessels
Hampton	2015	148	8
	2016	141	5
	2017	-	-
	2018	150	3
	2019	74	4
	2020	123	5
Portsmouth	2015	1,589	24
	2016	1,852	27
	2017	1,967	25
	2018	1,941	24
	2019	1,571	21
	2020	1,559	20
Rye	2015	698	9
	2016	387	10
	2017	317	8
	2018	264	9
	2019	299	9
	2020	359	12
Seabrook	2015	634	17
	2016	708	17
	2017	666	15
	2018	629	16
	2019	-	-
	2020	-	-
Newington	2015	-	-
	2016	-	-
	2017	626	12
	2018	-	-
	2019	-	-
	2020	-	-

Recreational Fisheries

New Hampshire recreational fishermen harvested a cumulative total of 14.7 million pounds of fish from 2015 through 2021 with an annual average of 2.1 million pounds (NOAA NMFS 2023b). Atlantic Mackerel, Haddock, and Pollock are the main species caught by recreational fishermen in New Hampshire. In 2021, 434,121 pounds of Haddock, 324,338 pounds of Atlantic Mackerel, and 183,941 pounds of Pollock were caught (NOAA NMFS 2023b). Striped Bass is one of the most sought-after fish in New Hampshire coastal waters, although several other species are targeted including Cusk, Bluefin Tuna, Atlantic Cod, and Bluefish (NHFG 2021; Table 5.2.2). The New Hampshire recreational landings for all species from 2015 through 2021 are presented in Appendix F.

Recreational fishing for several species is prohibited in federal waters (ocean waters greater than 3 nautical miles [nm] from shore [EEZ]), including Striped Bass, Atlantic Sturgeon, Shortnose Sturgeon, Atlantic Salmon, Ocean Pout, Wolffish, Windowpane Flounder, Red Drum, several skate species, and Atlantic sea scallop. All for-hire recreational fishing vessels operating in federal waters must follow current reporting requirements and submit a vessel trip report for each fishing trip. New Hampshire recreational hand line and rod and reel fishing activity in the RFI area from 2004 through 2022 is shown in Figure 5.2.7. New Hampshire recreational anglers fishing by all modes (i.e., charter boat, party boat, and private/rental boats) in federal waters made 719,076 trips between 2015 and 2021. During this timeframe, charter vessels averaged 6,268 trips, party boats averaged 26,962 trips, and private or rental boats averaged 69,495 trips. Annual New Hampshire recreational fishing trips by mode in EEZ waters from 2015 through 2021 are presented in Table 5.2.6 (NOAA NMFS 2022c).

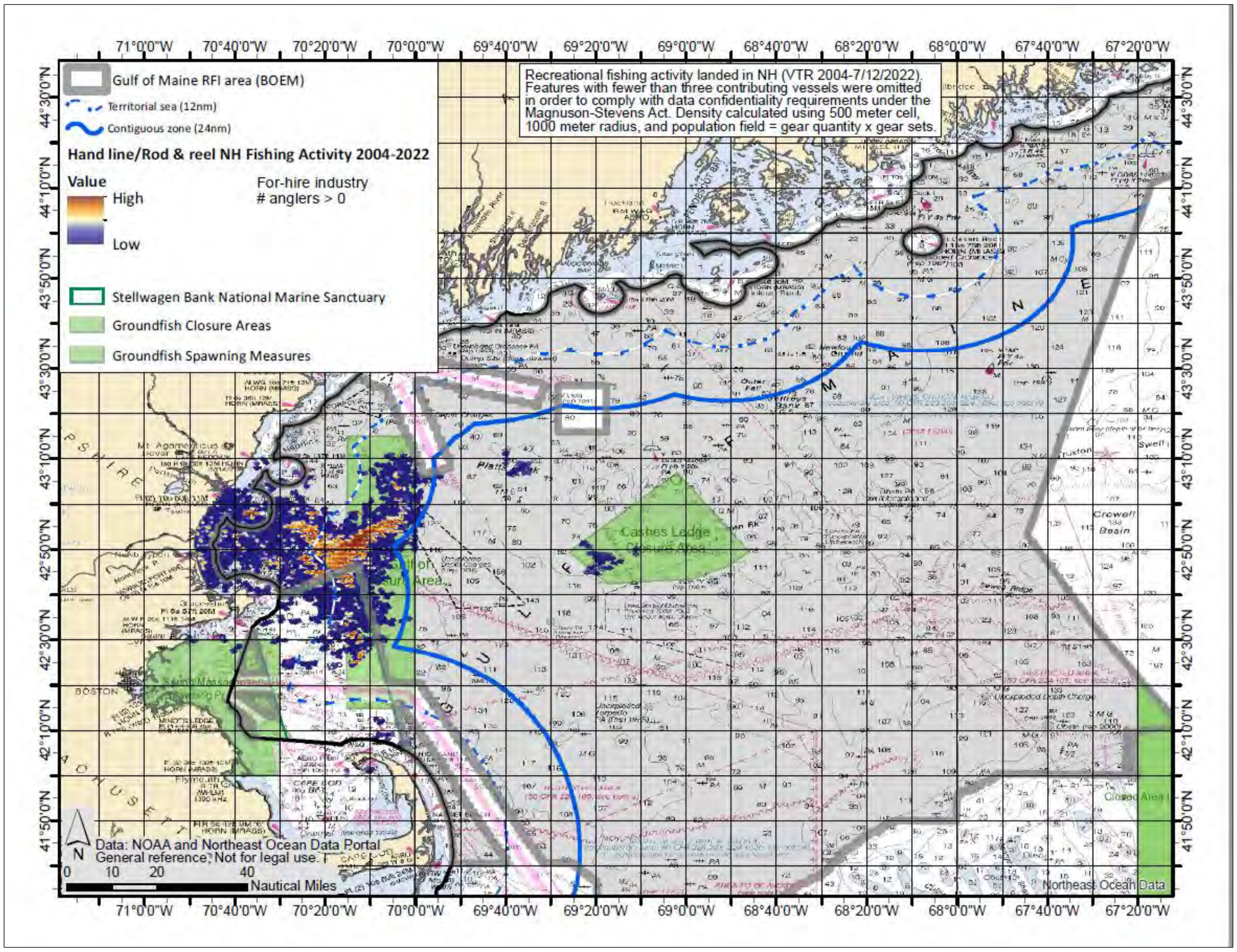

Figure 5.2.7. New Hampshire recreational hand line and rod and reel fishing activity for 2004 through 2022 on for-hire vessels based on non-confidential vessel trip reports (NHFG 2022).

Table 5.2.5. Number of recreational fishing trips by fishing mode in the federal EEZ (> 3 nm from shore) from 2015-2021 (NOAA NMFS 2022c).

Recreational Fishing Mode	Year	Angler Trips
Charter Boat	2015	16,013
	2016	1,567
	2017	6,770
	2018	2,349
	2019	6,470
	2020	4,956
	2021	5,752
Party Boat/ Headboat	2015	45,692
	2016	25,946
	2017	22,773
	2018	20,190
	2019	25,097
	2020	27,999
	2021	21,040
Private/Rental Boat	2015	104,633
	2016	99,554
	2017	93,438
	2018	57,117
	2019	37,542
	2020	36,451
	2021	57,727

Many data gaps exist in understanding commercial and recreational fishing activities, their infrastructure support, and the critical habitats and ecosystem interactions to provide for these fisheries and supporting shoreside communities (NHFG 2022).

Potential Impacts

The proposed development of U.S. offshore wind energy resources will change the ocean landscape (Twigg et al. 2020). Currently, all the leased areas are partially or completely opened to commercial and recreational fishing and are expected to remain accessible to fishing after construction of offshore wind farms (Pol and Ford 2020, Methratta et al. 2020). However, there are several logistical challenges associated with operating vessels near and in wind farms particularly for vessels using mobile fishing gear including difficulties with navigation, physical obstruction, traffic, safety, gear loss, and possible insurance changes (Methratta et al. 2020). Commercial and recreational fisheries most likely will be affected by offshore wind development, despite efforts to minimize conflict and reduce overlap of Wind Energy Areas (WEAs) with other users (Twigg et al. 2020, Pol and Ford 2020). The potential impacts could include direct effects on commercial fishermen and their supporting communities and changes through regional fishery management. Direct impacts to commercial fishermen and their communities include the potential increased risk of collision with wind farm infrastructure and other vessels, interruption of fishing by wind farm development and construction activities, and loss of fishing areas and/or changes in fishing locations. Potential impacts associated with changes through regional fishery management could include changes to fishing regulations, management measures at specific areas or new management areas, and impacts to the scientific fishery resource surveys used for stock assessments (Methratta et al. 2020).

The direct potential impacts to commercial fishermen and their communities could arise from the logistical challenges associated with operating vessels near and in wind farms. As floating wind turbines are a developing technology, these challenges are even less well understood for operating around dynamic cables. These potential obstacles together with shifts in target stock distribution, from climate change or other causes, could make wind farms effectively fishery exclusion areas, potentially leading to redistribution of fishing effort. Such exclusions would not only have direct effects on the excluded vessels but could also have indirect effects on vessels as well as ecosystems at other locations as displaced effort could increase competition in the remaining fishable locations (Methratta et al. 2020). Fishing exclusion and its effect on the benthic habitat could also have significant effects on target population indicators, including increases in abundance and size, functioning similar to closed areas (Roach et al. 2018). These compounding effects could ripple through coastal businesses, communities, and the downstream seafood trade. Finer-scale fisheries data are necessary to understand these concerns and to better understand the economic value of seafood once it enters the supply chain (Methratta et al. 2020).

Offshore wind facilities could directly benefit the recreational fishing community by providing new fishing locations and opportunities to catch different species than those available from shore or nearshore areas (Smythe et al. 2021). Studies have not yet indicated that the habitat provided at OWFs will provide actual benefits to fish at local or regional population levels (Methratta et al. 2020). Gill et al. (2020) identified a critical data gap, the need to understand how changes in population at local scales may impact productivity at regional scales and the fishermen that harvest them.

Under current U.S. law, regional fishery management councils will continue to manage fisheries in WEAs. Potential impacts associated with management actions by regional fishery management councils could include changes or closures of fishing areas, stockwide changes in quotas or catch limits, and changes in gear types (Methratta et al. 2020). The New England and Mid-Atlantic Fishery Management Councils have developed management measures to specific areas (e.g., Western Gulf of Maine Groundfish Closure and Habitat Areas, Cashes Ledge Groundfish Closure and Habitat Areas, Eastern Maine and Jeffreys Bank Habitat Management Areas). Changes to the management of these areas or the implementation of new site-specific regulations could be necessary in and around WEAs. Additionally, competition between commercial and recreational fishing could have implications for fisheries management that might need to be addressed by the councils (Methratta et al. 2020).

Fisheries management involves establishing catch levels that are based on stock assessments. Scientific fishery resource surveys are one of several data sources used in the development of stock assessments. In the Northeast United States, these scientific resource surveys represent more than 315 years of cumulative survey effort, supported by NOAA ship and aircraft resources. Information gathered from these surveys represents some of the world's most comprehensive data on marine ecosystems. The surveys support fisheries and protected species assessments and management actions, ecosystem-based fisheries management, and regional and national climate assessments (Methratta et al. 2020). A number of these scientific surveys overlap with wind development areas. As a result, these surveys will be impacted by the development of offshore wind energy and accordingly the scientific and management products generated for a wide variety of users. Survey operations could be reduced or eliminated within offshore wind areas under current vessel and aircraft capacity limits, safety requirements, and assessment protocols. If wind farms are not sited to minimize impact to the scientific surveys, and the data collection and analysis programs are not modified to account for offshore wind development, the programs could suffer from survey bias, a reduction in information, and increased uncertainty in stock assessments. Uncertainty in the stock assessments could result in poorly informed management decisions. Less well-informed management decisions in turn increase the likelihood of inappropriate management actions which could lead to either the overfishing or underfishing of stocks causing population-level impacts to the stocks and significant economic impacts on commercial and recreational fishing communities (Methratta et al. 2020).

5.3 Marine Mammals and Sea Turtles

There are 21 species of cetaceans (whales, dolphins, and porpoises), 4 species of seals, and 4 species of sea turtles that inhabit the GOM (Hayes et al. 2022; Halpin et al. 2009). Among the 21 species of cetaceans, 5 whales (blue [*Balaenoptera musculus*], fin, North Atlantic right (NARW), sei [*Balaenoptera borealis*], and sperm [*Physeter macrocephalus*]) are designated as endangered under the Endangered Species Act (ESA). In July 2020, NARWs' status was changed from endangered to critically endangered by the International Union for Conservation of Nature (IUCN) due to a declining population since 2010, increased mortality rate, and larger interval between calving (Cooke 2020). Green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) sea turtles are listed as threatened, and Kemp's ridley (*Lepidochelys kempii*) and leatherback (*Dermochelys coriacea*) sea turtles are listed as endangered under the ESA.

Marine mammals and sea turtles utilize the habitat in the GOM for many purposes including foraging, migrating, resting, mating, and socializing (Wynne and Schwartz 1999). Some species including NARW also use the area as a nursery, with mother and calf pairs observed (CCS 2022) In general, the distribution of marine mammals is greatly influenced by upwelling along the continental shelf break and the Gulf Stream (Wynne and Schwartz 1999). Both oceanographic features result in the concentration of prey species including zooplankton, fish, and squid. Whale distribution is likely guided by prey availability or social behaviors but may also result from predator avoidance. A recent study on acoustic detections of baleen whales along the eastern seaboard indicates that baleen whale movement patterns are considerably more complex than previously thought (Davis et al. 2020).

Climate change has caused the GOM to warm more rapidly than most other oceans (Pershing et al. 2015). Over the past decade, the warmer temperatures have resulted in changes in some marine mammals' prey distribution including NARW's primary food source, a cold-water copepod, *Calanus finmarchicus* (Meyer Gutbrod et al. 2021). Because of these changes, NARW distribution has shifted, in some cases dramatically, both spatially and temporally (Quintana-Risso et al. 2021; Pettis et al. 2022). These shifts into areas with little or no protective measures have resulted in an increase in exposure to anthropogenic impacts including vessel strike and entanglement in fishing gear (Davies and Brillant 2019).

This section summarizes marine mammal and sea turtle habitat in the GOM RFI Area and potential impacts from floating offshore wind technology. Below is a summary of the queries made for this report and overview of passive acoustics monitoring for whales. Section 5.3.1 includes an overview of all marine mammal species separated out by Endangered Species Act (ESA)-listed species, with a particular emphasis on NARW and its shift in habitat use in the past decade, and non-ESA species that occur in the RFI Area. There are three maps for each of the ESA-listed species (abundance, density, and acoustic presence) to provide the best account, except blue whale with two maps. Section 5.3.2 summarizes sea turtle species in the GOM, and Section 5.3.3 is an overview of impacts from floating offshore wind farms.

Data Queries

Web-based queries resulted in multiple data sources including published papers, reports, and interactive maps (Table 5.3.1). Each source provides slightly different information including data used, survey method (aerial/vessel or passive acoustic), time frame, species represented, and specific to the interactive maps, data layers. For example, the OBIS SEAMAP interactive mapper has the most inclusive species list and includes distribution data for all 20 species of marine mammals and 4 species of turtles from 1992 through 2016, with periodic updates to the data (Roberts et al. 2018). The two published papers by Davis et al. (2017 and 2020) include passive acoustic data collected from 2004 to 2014 on 281 bottom-mounted recorders, totaling 35,033 days for the entire eastern seaboard. The acoustic surveys fill in data gaps in whales' presence that previous aerial and vessel-based surveys could not detect (i.e., during night and/or heavy sea conditions). The Passive Acoustic Cetacean Map 2022 provides the most current acoustic data (2004 through 2022) for NARW, blue, humpback, fin, sei whales and has a very useful feature allowing the user to capture data by the month(s) or year(s) and animate the distribution data on the map in real-time, which is informative for detecting habitat shifts over time and season. Lastly, the Northeast Ocean Data Portal interactive map provides data for 19 species of marine mammals and loggerhead sea turtles from 1992 through 2016 collected from aerial and shipboard surveys and passive acoustic monitors for NARW since 2010. In addition, there are several very useful data layers including proposed passive acoustic monitoring (PAM) locations in the GOM, marine transportation, commercial fishing, and habitat among others.

Table 5.3.1. Data Queried for Marine Mammal and Sea Turtle Occurrence in the Gulf of Maine RFI Area

Source	Description	Format	Species/Group Results	Survey Type	Time Frame	Reference
AMAPPS: NMFS, BOEM, USFWS, U.S. Navy	Atlantic Marine Assessent Program for Protected Species	Report	ESA Hot Spot Index maps; cetacean diversity map	Shipboard and aerial line transect	2010 - 2014	Palka et al. 2017
AMAPPS: NMFS, BOEM, USFWS, U.S. Navy	Marine Mammal Model Viewer	Interactive map	13 whale and dolphin species across season	Shipboard and aerial line transect	2010 - 2017	Palka et al. 2021
Davis et al. 2020	Changing distribution pattern of baleen whales in Western North Atlantic	Peer-reviewed Literature	Fin, blue, sei, and humpback whales	Passive acoustic monitoring (PAM); animal tagging	2004 - 2014	Davis et al. 2020
BOEM and NOAA	Marine Cadastre National Viewer	Interactive map	Biologically Important Area (BIA) maps; Marine mammal total abundance map; NARW density maps	Aerial and shipboard data from multiple organizations, platforms, time periods	1992 - 2016	BOEM and NOAA 2022; Van Parijs et al. 2015; Curtice et al. 2019
NMFS NEFSC	US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments 2021	Report	25 species of whales, dolphins, and seals	NA	NA	Hayes et al. 2022
OBIS SEMAP	World data center for marine mammals, seabirds, and sea turtles	Interactive map	23 species/groups of whales, dolphins, seals, and sea turtles	Aerial and shipboard data from multiple organizations, platforms, time periods	1992 - 2016	Halpin et al. 2009; Curtice et al. 2019; Roberts et al. 2016; Roberts et al. 2017

Table 5.3.1. Continued.

Source	Description	Format	Species/Group Results	Survey Type	Time Frame	Reference
NOAA Cetsound	Cetacean and Sound Mapping	Interactive map	BIA maps for 6 marine mammal species	NA	NA	https://cetsound.noaa.gov/biologically-important-area-map
NOAA NEFSC	Passive Acoustic Cetacean Map 2022	Interactive map	NARW, blue, humpback, fin, sei whales	PAM	2004 - 2022	Passive Acoustic Cetacean Map. 2022
NOAA NEFSC	Northeast Ocean Data Portal	Interactive map	19 species of marine mammals; strandings; sea turtles; various useful data layers	Aerial and shipboard (1992 – 2016); PAM (NARW 2010 - 2022); NARW strandings (2000 – 2020); proposed PAM locations	1992-2016	MDAT 2022; Curtice et al. 2019; Roberts et al. 2016; Roberts et al. 2017
Tlusty et al. 2017	Maps overlapping fisheries, shipping, and large pelagic animals in Gulf of Maine	Pier-reviewed Literature	Baleen whales and sea turtles	Shipboard and aerial	1978 - 2009	Tlusty et al. 2017
NOAA Cetsound	Cetacean and Sound Mapping	Interactive map	BIA maps for 6 marine mammal species	NA	NA	https://cetsound.noaa.gov/biologically-important-area-map
NOAA NEFSC	Passive Acoustic Cetacean Map 2022	Interactive map	NARW, blue, humpback, fin, sei whales	PAM	2004 - 2022	Passive Acoustic Cetacean Map. 2022

Passive Acoustic Monitoring

The most accurate record possible of cetacean presence is obtained by the combination of visual surveys and passive acoustic monitoring, providing information on both species' presence and behavior. Passive acoustic monitoring can include moored surface buoys, wave gliders, bottom mounted acoustic recorders, Slocum gliders, towed hydrophone arrays, archival tags fixed onto animals, and free-floating acoustic recorders, among others (Van Parijs et al 2021). An example of some passive acoustic monitor locations used in studies in this report are shown in Figure 5.3.1 (NEFSC bottom-mounted recorders in the GOM deployed from 2006 through 2021; Passive Acoustic cetacean Map 2022). Passive acoustic data products used in other mappers and reports vary depending on the specific data requirements by species, time frame, and monitor type (e.g., surface buoy and Slocum glider data for NARWs).

The range of detection for whale calls is dependent on many factors including the type and quality of the call, water depth, physical oceanographic conditions (temperature, salinity, etc.), the type and structure of the ocean bottom, and ambient noise (Johnson 2019). General guidelines for acoustic detection ranges by species groups are as follows: harbor porpoise ([*Phocaena phocaena*] 0.5 km), dolphins (6 km), sperm whales and baleen whales including NARW (10 km), and other baleen whales (fin, blue, and sei whales; 20 -200 km; Van Parijs et al. 2021). Placement of the NEFSC monitors provides full coverage of the RFI for baleen whales as the distance between the monitors along the north and south boundaries of the GOM are less than 200 km, with overlap between several monitors.

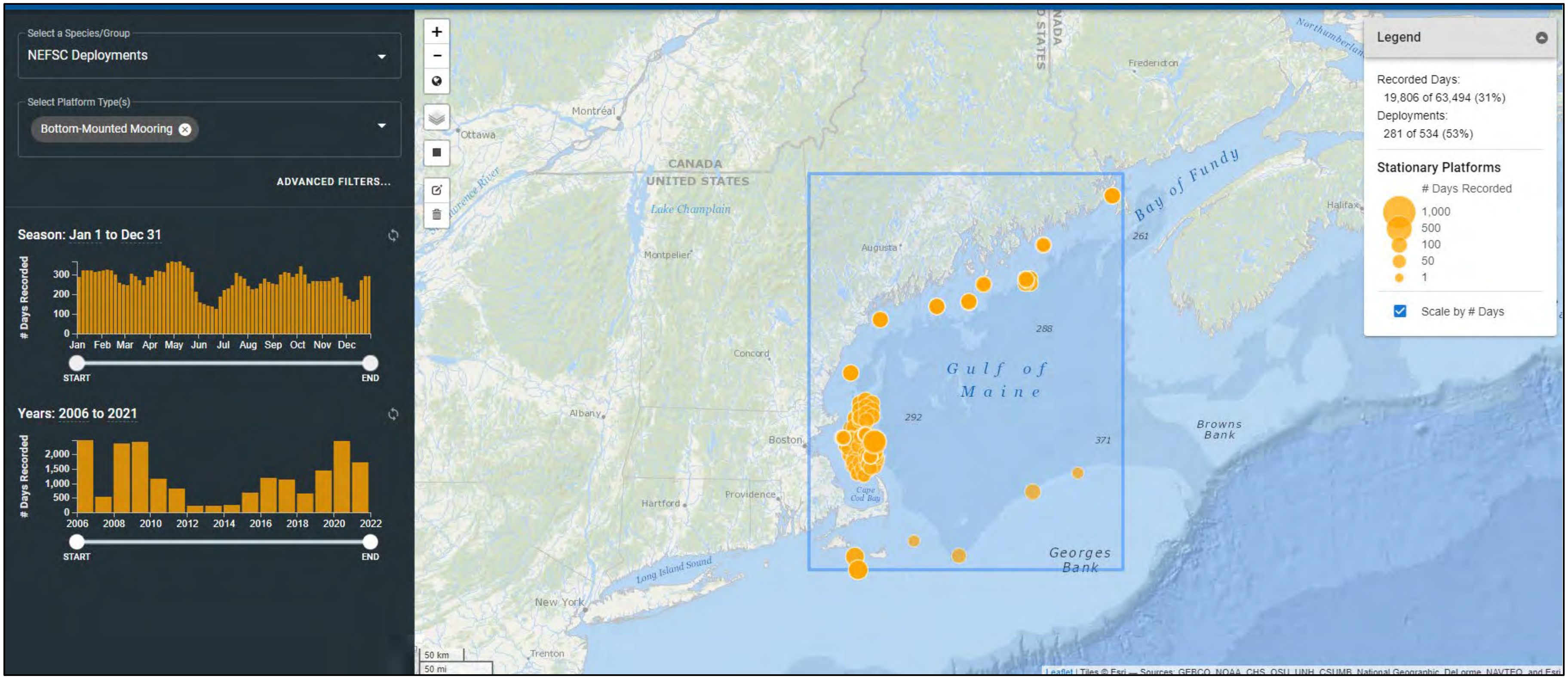

Figure 5.3.1. NEFSC bottom-mounted mooring locations in the Gulf of Maine. Size of the bubble indicates number of days with recordings from 2006 through 2021 (Passive Acoustic Cetacean Map 2022).

5.3.1 Marine Mammals

Overview Marine Mammals in the Gulf of Maine RFI Area

Twenty one species of marine mammals occur in the GOM RFI Area: seven whales, nine delphinids (killer whales [*Orca orcinus*] and pilot whales are members of the Delphinidae (dolphin family), one porpoise, and four seals (Table 5.3.2; Hayes et al 2022; Halpin et al. 2009).

Figure 5.3.2 represents the annual total predicted abundance (ranging from 0.04 to 458.71 animals per 100 sq km) of all individuals of the 17 cetacean species in Table 5.3.2. The total annual predicted abundance for baleen whales is relatively high (6.85 animals per 100 sq km) along the coast and shelf waters from northern Maine to Jeffreys Ledge (southern Maine to Massachusetts), Stellwagen Bank, Cape Cod Bay, Great South Channel, along northern George's Bank, and the Scotian Shelf (Figure 5.3.3; Curtice et al 2019).

Table 5.3.2. Marine Mammals in the Gulf of Maine RFI Area

Species		Status ESA[1]	Occurrence
Common Name	Scientific Name		
North Atlantic right whale (NARW)	*Eubalaena glacialis*	E	Yearround
Fin whale	*Balaenoptera physalus*	E	Yearround
Sei whale	*Balaenoptera borealis*	E	Potentially yearround
Minke whale	*Balaenoptera acutorostrata*		Yearround
Humpback whale	*Megaptera novaeangliae*		Yearround
Blue whale	*Balaenoptera musculus*	E	Low, yearround
Sperm whale	*Physeter macrocephalus*	E	Summer/fall potentially yearround
Killer whale	*Orca orcinus*	E	Rare
Long-finned/short-finned Pilot whale	*Globicephala melas/macrorhynchus*		Spring to fall
Risso's dolphin	*Grampus griseus*		Summer
Atlantic white-sided dolphin	*Lagenorhynchus acutus*		Yearround
Common dolphin	*Delphinus delphis*		Summer/fall potentially yearround
White-beaked dolphin	*Lagenorhynchus albirostris*		Low
Common bottlenose dolphin Western North Atlantic Northern Migratory Coastal stock	*Tursiops truncatus*	Strategic[2]	Low

Table 5.3.2 Continued.

Species		Status ESA[1]	Occurrence
Common Name	Scientific Name		
Common bottlenose dolphin Western North Atlantic Offshore stock	*Tursiops truncatus*		Low
Striped dolphin	*Stenella coeruleoalba*		Rare
Harbor porpoise	*Phocaena phocaena*		Yearround
Harbor seal	*Phoca vitulina*		Yearround
Gray seal	*Halichoerus grypus*		Yearround
Harp seal	*Pagophilus groenlandica*		Winter
Hooded seal	*Crystophora cristata*		Low

Source: Hayes et al. 2022; Halpin et al. 2009

E = endangered under the ESA

[1]All marine mammals are protected undet the Marine Mammal Protection Act (MMPA). [2]Strategic under the MMPA

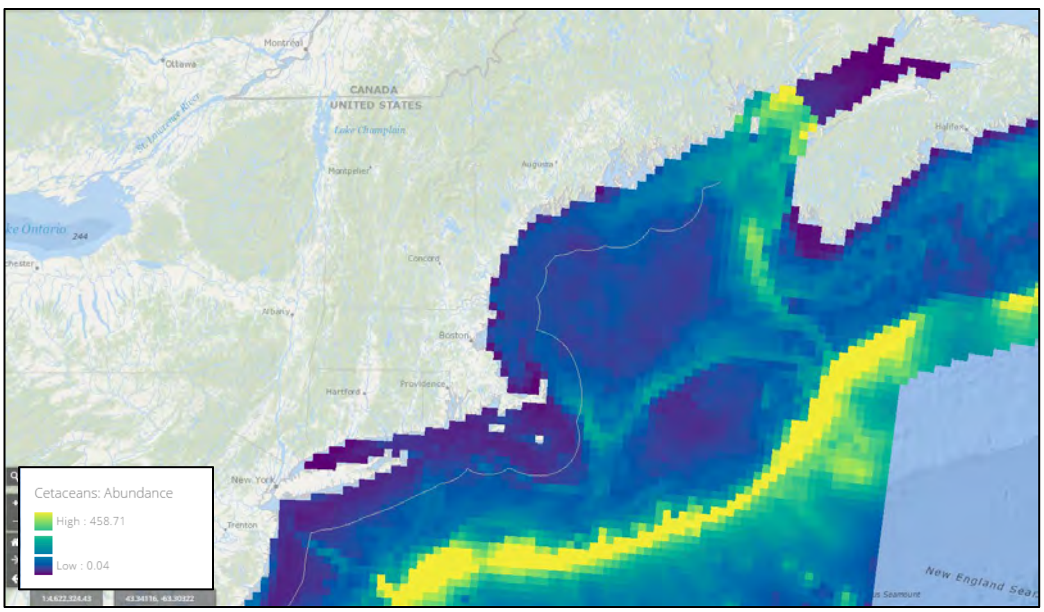

Figure 5.3.2. Marine mammal total abundance (High = yellow/green (458.71 animals per 100 sq km), Low = dark blue/purple (0.04 animals per 100 sq km); Curtice et al (2019).

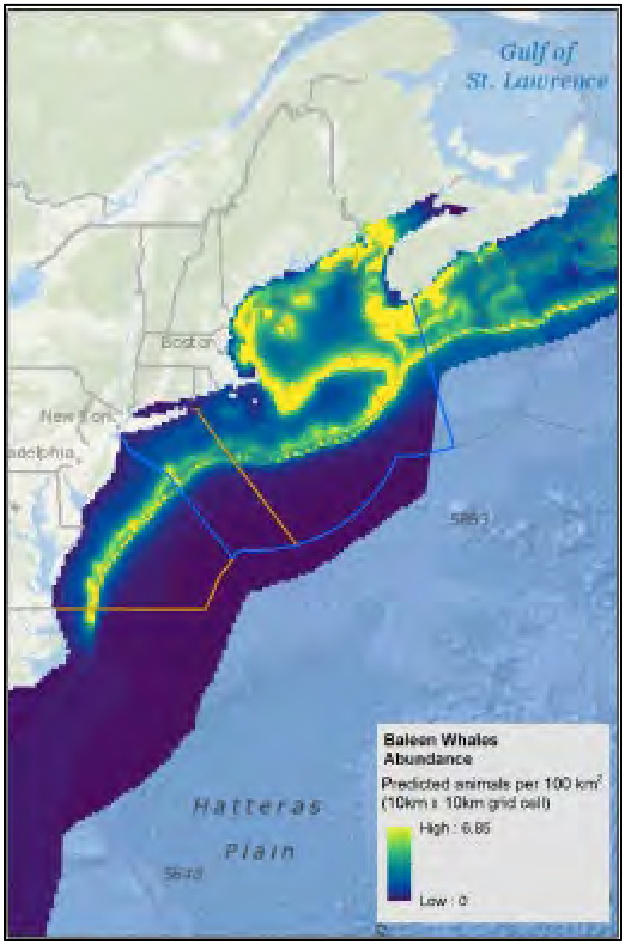

Figure 5.3.3. Total predicted annual abundance (animals per 100 sq km) for baleen whales (blue, fin, humpback, minke, NARW,and sei whales; High = yellow/green (6.85 animals per 100 sq km), Low = dark blue (0 animals per 100 sq km Curtice et al. 2019).

Biologically Important Areas

The GOM is an important habitat for whales, dolphins, harbor porpoise, and seals. Some areas have been delineated as Biologically Important Areas (BIA). BIAs are reproductive areas, feeding areas, migratory corridors, and areas in which small and resident populations are concentrated (Van Parijs et al. 2015). BIAs are meant to be used as a tool to help inform analyses and planning in offshore waters. BIAs include some, though not all, areas important to cetaceans and when combined with cetacean densities provide a more robust account of cetacean's use of the area than either could alone (Van Parijs et al. 2015).

BIAs are available in two formats, habitat use (Marine Cadastre 2022) and individual species (Cetacean and Sound Mapping; Cetsound 2022). The BIA for cetacean feeding includes a large proportion of the RFI along the Maine to Massachusetts coastal and shelf waters and along the northern Great South Channel and George's Bank (Figure 5.3.4a). The BIA for cetacean migration is represented as a relatively small proportion of the RFI in the southern boundary to the east of Cape Cod (blue shaded area in Figure 5.3.4b) and the BIA for reproduction is located essentially in the center of the RFI (green shaded area in Figure 5.3.4b).

BIAs for individual species are available for six species: harbor porpoise, humpback whale, minke whale, sei whale, fin whale, and NARW (Figure 5.3.4c-h; Cetsound 2022). The BIA for each species is as follows:

- harbor porpoise foraging encompasses the northern Maine coastal and shelf waters
- humpback whale foraging BIA is within the same footprint as the foraging BIA for cetaceans along the western coastal and shelf waters and along the northern Great South Channel and George's Bank
- minke whale foraging BIA includes the coastal waters off southern Maine, New Hampshire, the area east of Cape Cod including northern George's Bank, and a patch in the center of the RFI
- sei whale foraging BIA includes the area along the coastal and shelf waters of central Maine to Cape Cod and northern George's Bank
- fin whale foraging BIA area is encompassed within the coastal and shelf waters of northern and southern Maine, Cape Cod, the Great South Channel, and northern George's Bank
- NARW migratory and foraging habitat includes Cape Cod Bay and Stellwagen Bank National Marine sanctuary in Massachusetts Bay and the mating BIA is located in the center of the GOM (Cetsound 2022).

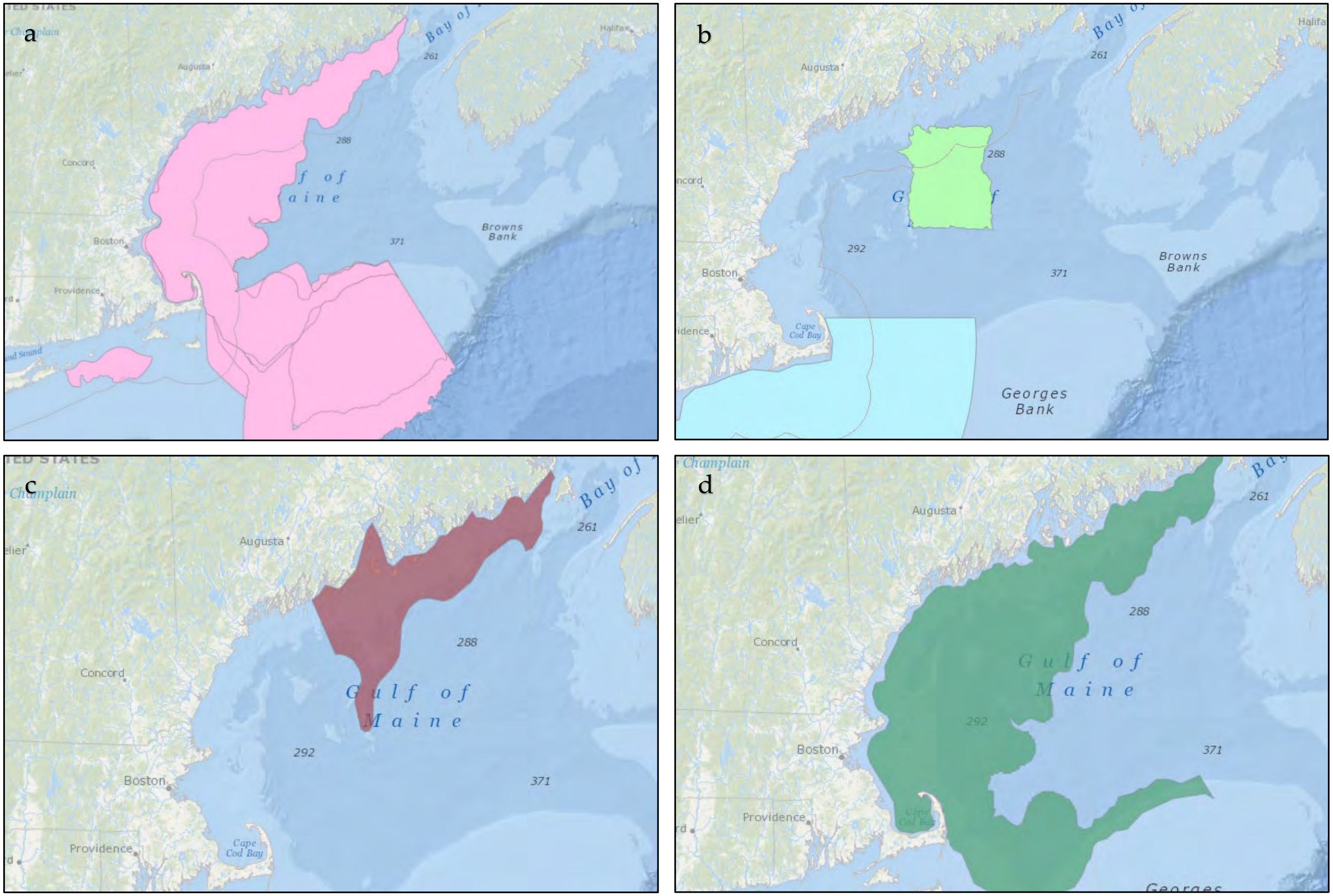

Figure 5.3.4. Biologically Important Areas (BIA) in the Gulf of Maine for (a) cetacean feeding, (b) migratory corridor [blue] and reproduction [green]. (c) BIA for harbor porpoise, (d) humpback whale, (e) minke whale, (f) sei whale, (g) fin whale, and (h) North Atlantic right whale (Cetsound 2022, Marine Cadastre 2022; Van Parijs et al. 2015).

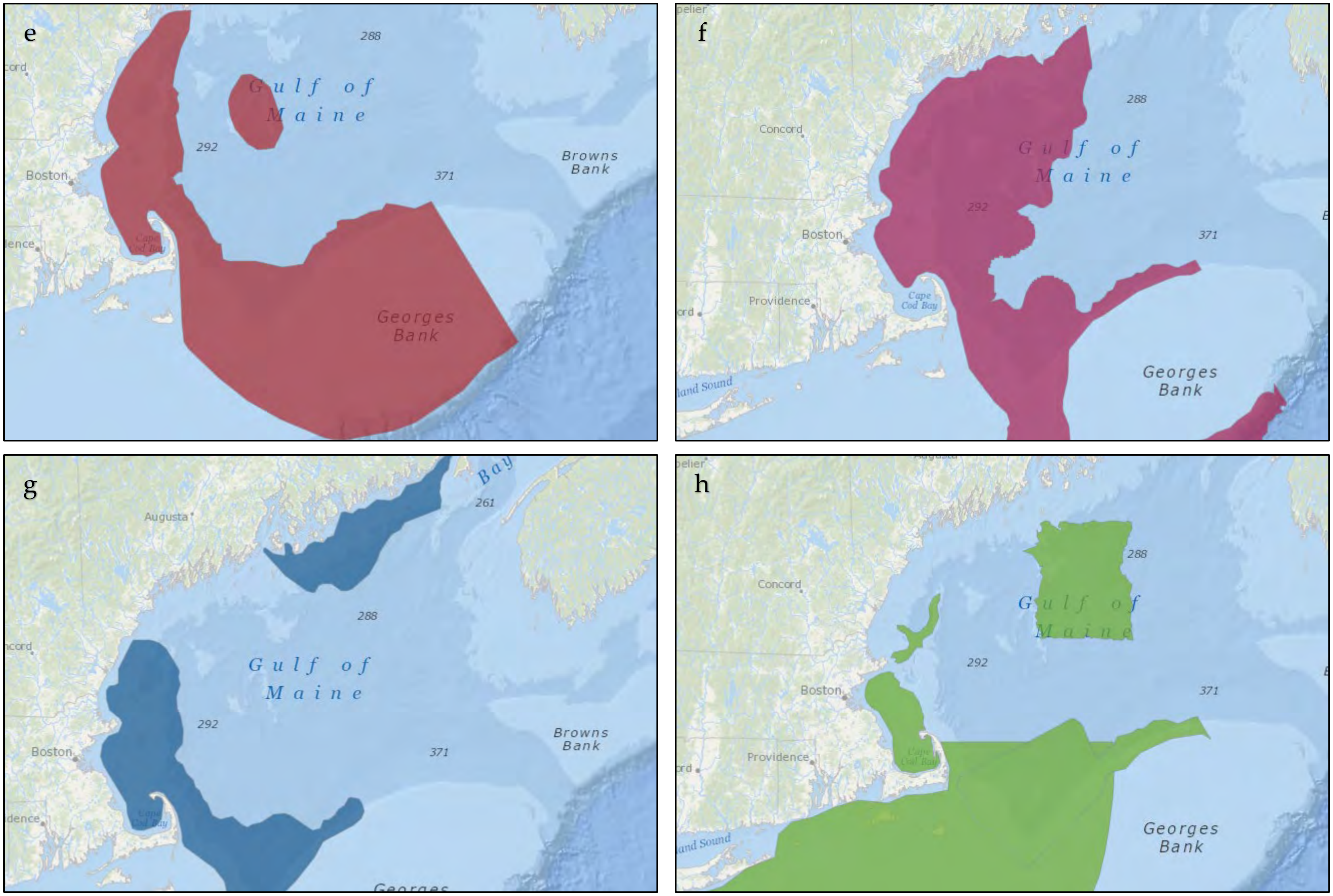

Figure 5.3.4 Continued.

Combining all individual species' BIA indicate that the coastal and shelf waters from Maine to Massachusetts and along George's Bank is biologically important habitat for cetaceans (Figure 5.3.5; Cetsound 2022). Although shelf waters in the eastern section of the RFI is clear of BIAs, the abundance data for ESA-listed species indicate relatively high occurrence in that area, more specifically along northeastern Georges' Bank, the Northeast Channel, Browns Bank, and the western Scotian Shelf (Figure 5.3.6; Halpin et al. 2009).

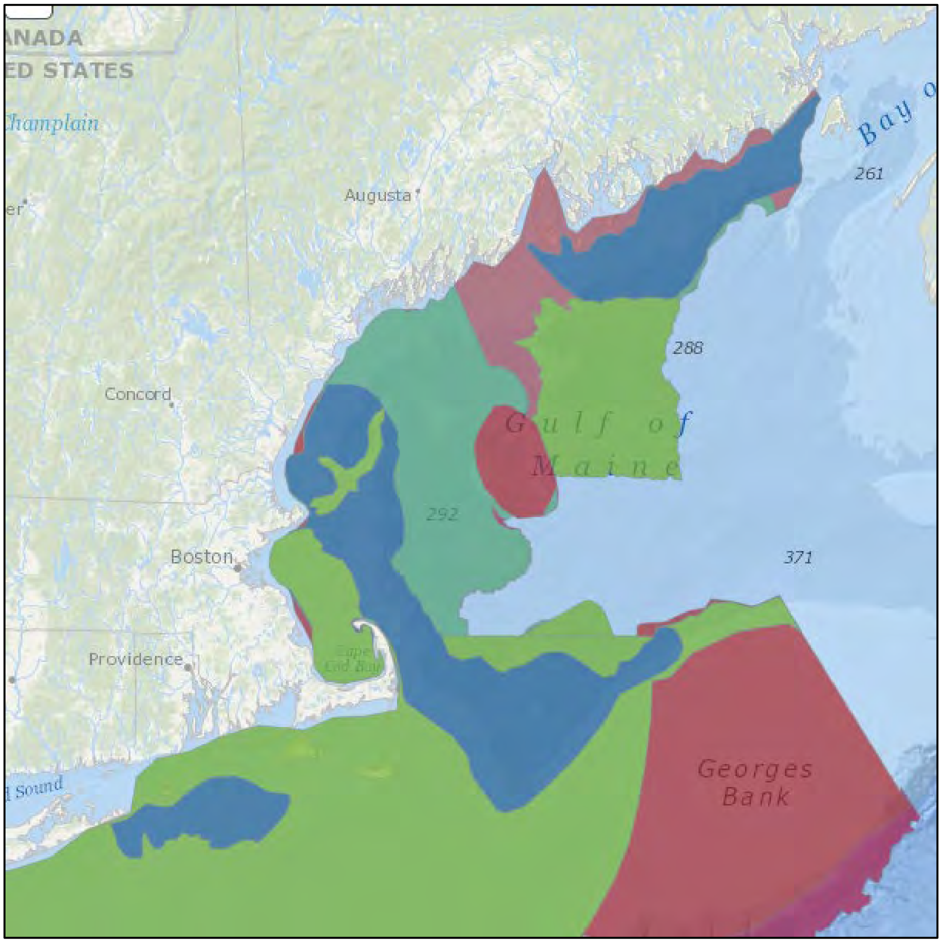

Figure 5.3.5. BIAs for all cetaceans combined (Cetsound 2022).

ESA Whales

Visual surveys from 1992 through 2016 indicate that ESA whale species' (NARW, fin, sei, blue, and sperm whales) abundance is relatively high in Jeffrey's Ledge, Stellwagen Bank, Wilkinson Basin, the Great South Channel, George's Bank, Northeast Channel, Jordan Basin, and the Scotian Shelf (Figure 5.3.6; Halpin et al. 2009). Fin whales had the highest number of recorded observations (7,318 records) followed by NARW (5,364 records; Table 5.3.3; Halpin et al. 2009). Sperm whales and blue whales had the fewest number of observations (54 and 16 records, respectively). When combining all ESA whales, the seasons in which the most animals were observed were spring (11,777 animals) and summer (10,017 animals; Halpin et al. 2009; Table

5.3.3). The lowest number of animals were observed in the winter (1,676 animals). Information regarding each ESA species' distribution in the GOM is in the following sections below.

Table 5.3.3. OBIS SEAMAP Data Summary ESA Whales in the Gulf of Maine* 1992 – 2016.

Whale Species	Total number of records	Total number of animals: Spring	Total number of animals: Summer	Total number of animals: Fall	Total number of animals: Winter
NARW	5,364	4,747	2,514	765	1,107
Sei	2,186	2,409	1,946	93	21
Fin	7,318	4,603	5,520	2,170	545
Blue	16	5	2	17	1
Sperm	54	13	35	6	2

Halpin et al. 2009. *Data include Stellwagen Bank and Traffic Separation Scheme even though these areas are excluded from the RFI.

Fin whale

Fin whales occur singly or in groups of 2 to 10 whales and feed on small schooling fish in large aggregations in deep coastal and continental shelf waters (Wynne and Schwartz 1999). With 7,318 total records from 1992 – 2016, they are the most abundant whale species in the GOM, and thus their distribution pattern in

Figure 5.3.7 is very similar to the above Figure 5.3.6 for all ESA species. Their abundance is highest in the summer and spring when they are foraging, followed by fall, and lowest in winter (Halpin et al. 2009). Average summer densities in the region from 2010 to 2017 range from 0.003 to 0.011 animals per sq km (Figure 5.3.8; Palka et al. 2021). It is unknown where calving, mating, and wintering occur for most of the population (Hayes et al. 2022). Acoustic data from 2004 to 2022 indicate a year-round presence in the GOM, and a presence of up to 100% of days recorded in several areas including Stellwagen Bank, Jeffrey's Ledge, and George's Bank (Figure 5.3.9 and Figure 5.3.10; Passive Acoustic Cetacean Map 2022; Davis et al. 2020).

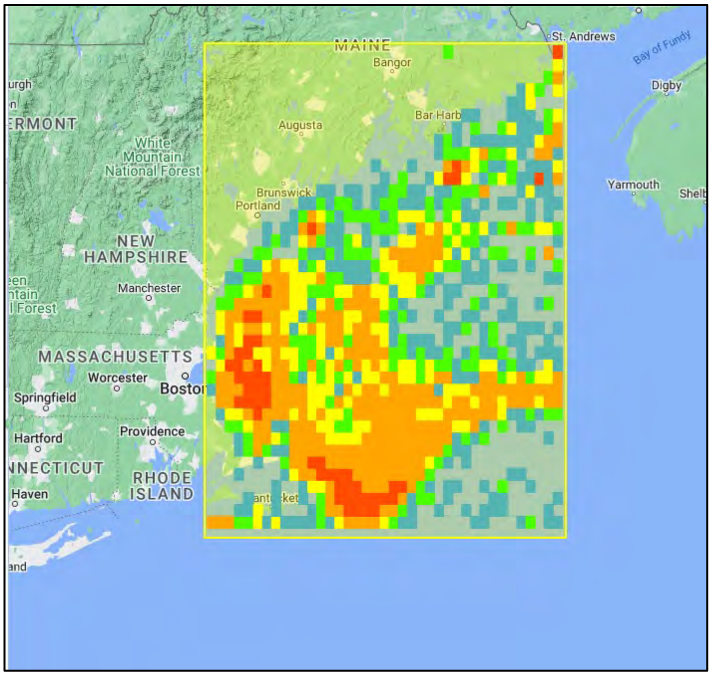

Figure 5.3.6. All ESA species (NARW, fin, sei, blue, and sperm) in the Gulf of Maine (Colored Squares = Records per 0.1 degree grid resolution: Blue = 1-2, Green = 3-5, Yellow = 6-10, Orange = 11-50, and Red > 50; Halpin et al. 2009).

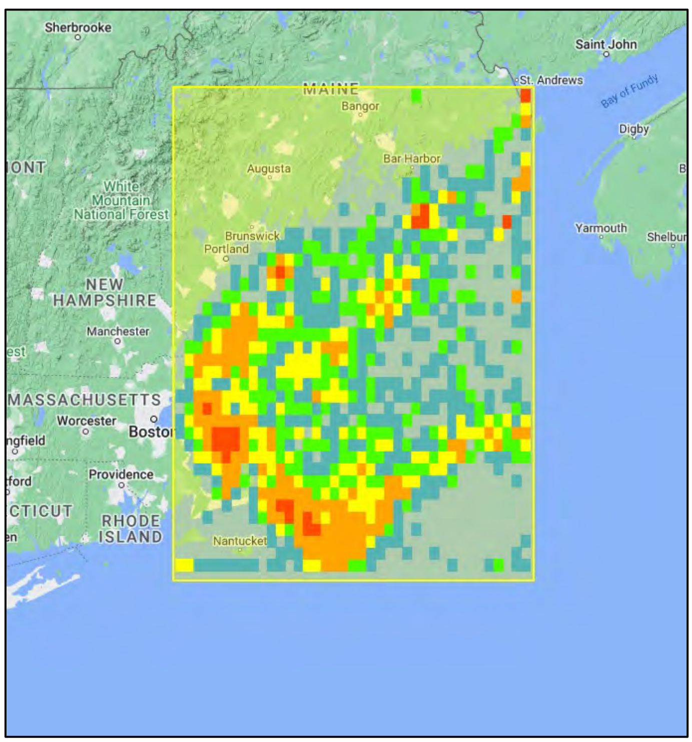

Figure 5.3.7. Fin whale abundance (number of records from 1992 – 2016) in the Gulf of Maine (Colored Squares = Records per 0.1 degree grid resolution: Blue = 1-2, Green = 3-5, Yellow = 6-10, Orange = 11-50, and Red > 50; Halpin et al. 2009).

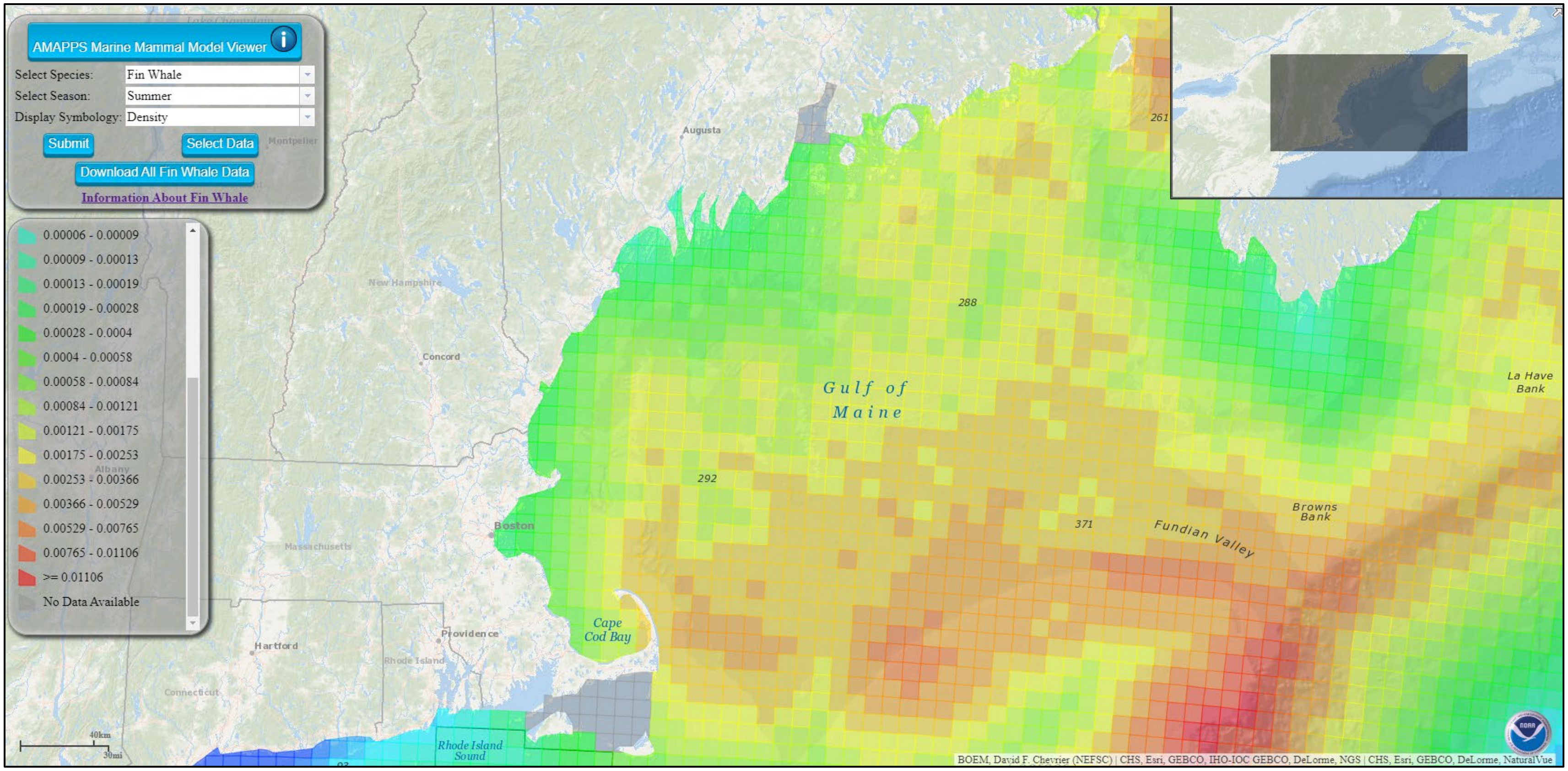

Figure 5.3.8. Average summer fin whale density in the Gulf of Maine (2010 – 2017; animals per sq km; Palka et al. 2021).

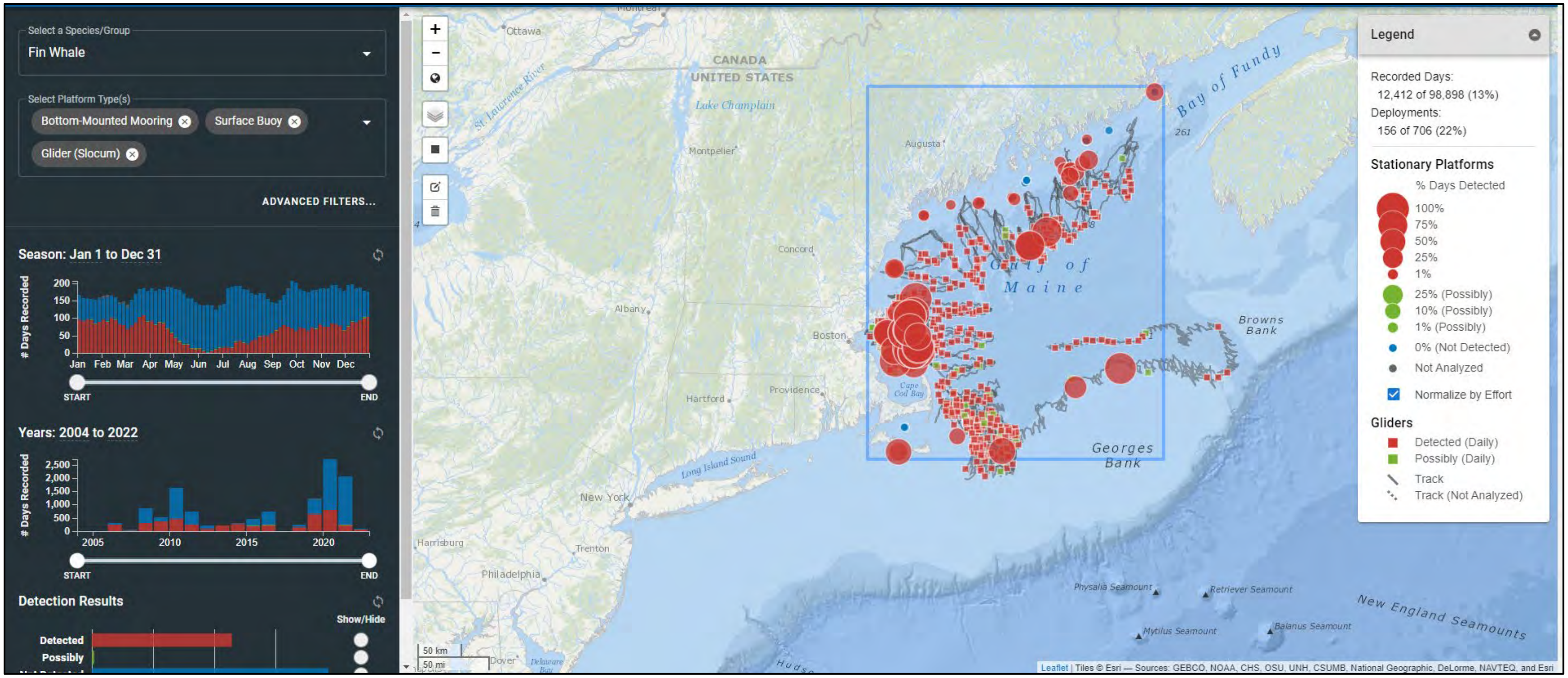

Figure 5.3.9. Acoustic detection of fin whales in the Gulf of Maine 2004 – 2022 (Passive Acoustic Cetacean Map 2022).

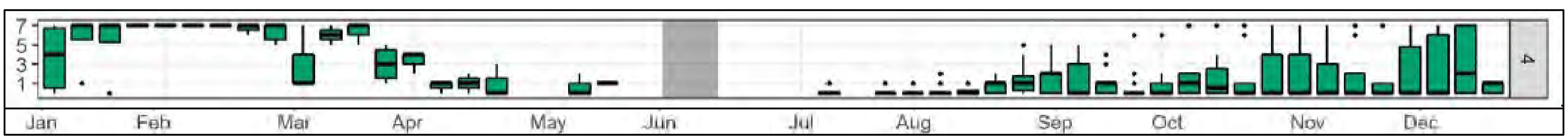

Figure 5.3.10. Fin whale: monthly acoustic presence in the Gulf of Maine (Area 4 on secondary y-axis; 2004–2014; Davis et al. 2020). The y-axis is number of days per week.

Sei Whale

Sei whales can be found in groups of 2 to 5 whales and may associate with humpback and fin whales when foraging on copepods and euphausids (Wynne and Schwartz 1999). They are generally pelagic, most often found near the shelf edge, but may also follow prey inshore (Wynne and Schwartz 1999). Sei whales are most abundant primarily on Jeffrey's Ledge, the Great South Channel, and George's Bank (Figure 5.3.11; Halpin et al. 2009). Visual surveys from 1992 to 2016 indicate higher abundance in the spring and summer (Table 5.3.3; Halpin et al. 2009), but average seasonal densities from 2010 to 2017 indicate slightly higher densities in the winter (greater than 0.009 animals per sq km; Figure 5.3.12) over a larger area in the Great South Channel compared to the spring and summer average densities over the same time period (Palka et al. 2021). Sei whales had an acoustic presence year-round in the GOM with detections of up to 100% of days (Figure 5.3.13 and Figure 5.3.14; Passive Acoustic Cetacean Map 2022; Davis et al. 2020). Most acoustic presence has been observed between April and June (Figure 5.3.13; Passive Acoustic Cetacean Map 2022).

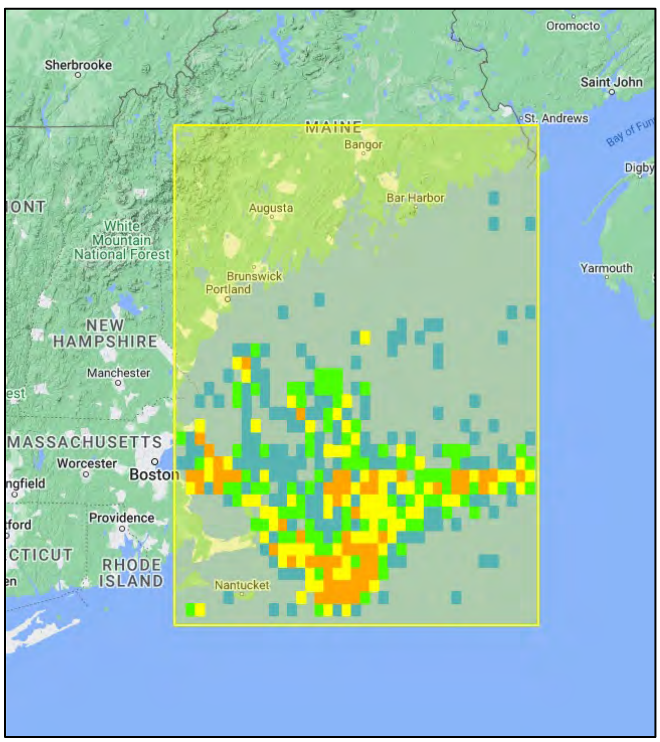

Figure 5.3.11. Sei whale abundance (number of records from 1992 – 2016) in the Gulf of Maine (Colored Squares = Records per 0.1 degree grid resolution: Blue = 1-2, Green = 3-5, Yellow = 6-10, Orange = 11-50, and Red > 50; Halpin et al. 2009).

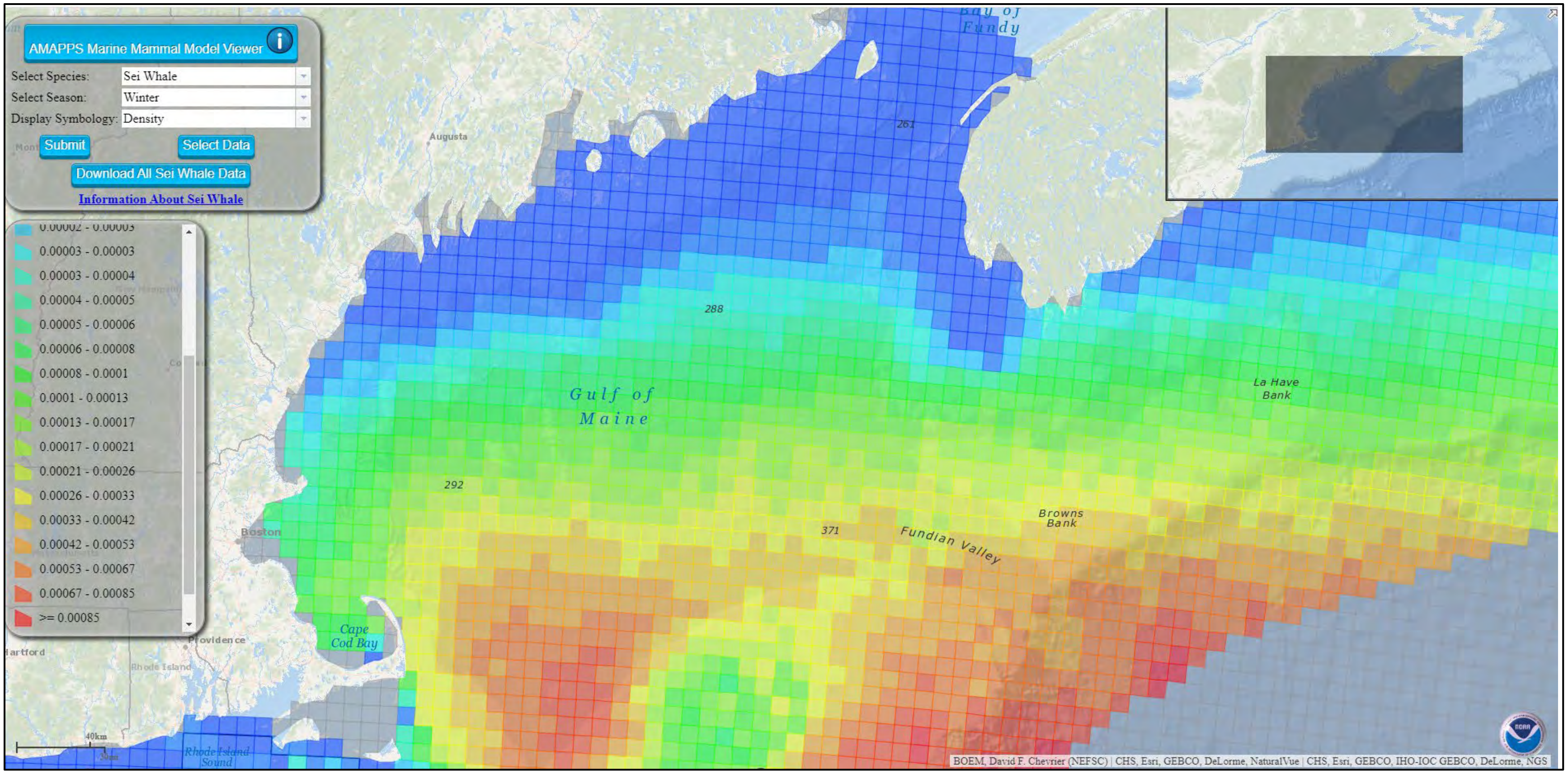

Figure 5.3.12. Average winter Sei whale density in the Gulf of Maine (2010 – 2017; animals per sq km; Palka et al. 2021).

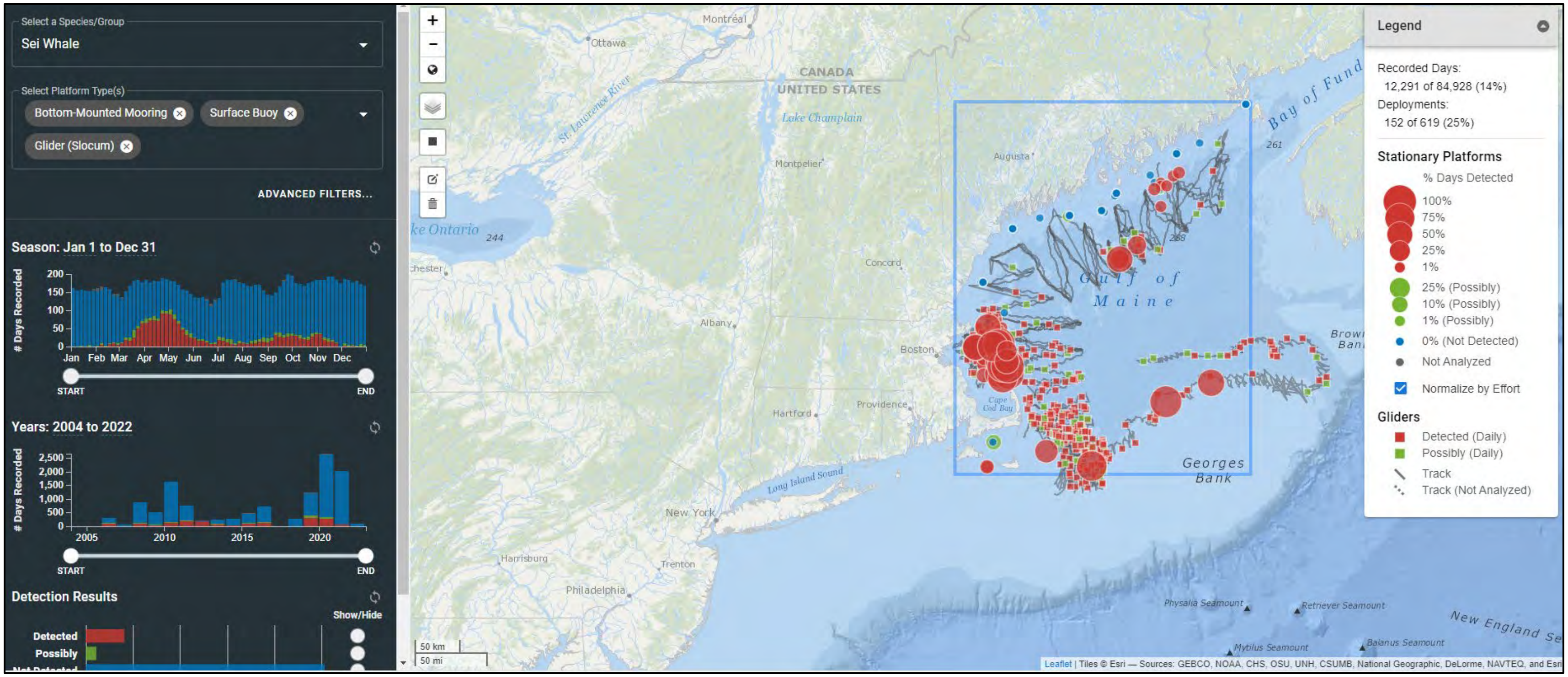

Figure 5.3.13. Acoustic presence of sei whales in the Gulf of Maine 2004 – 2022 (Passive Acoustic Cetacean Map 2022).

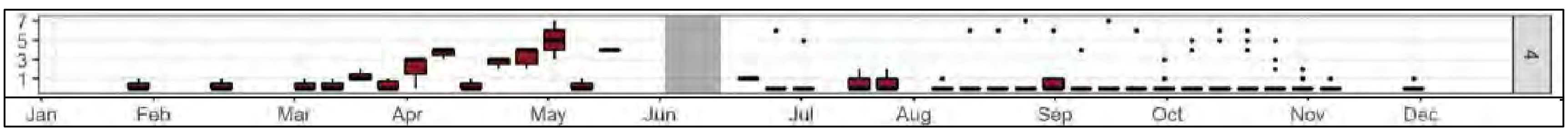

Figure 5.3.14. Sei whale: monthly acoustic presence in the Gulf of Maine (Area 4 on secondary y-axis; 2004–2014; Davis et al. 2020). The y-axis is number of days per week.

Blue whale

Blue whales are generally pelagic but can be found seasonally in areas on the continental shelf and may congregate in areas where dense patches of krill exist (Davis et al. 2020; Wynne and Schwartz 1999). They occur singly or in pairs. Abundance data are scarce in the GOM, with visual records of 1 to 2 whales (Figure 5.3.15; Halpin et al. 2009) and acoustic presence distributed throughout the area (Figure 5.3.16; Passive Acoustic Cetacean Map 2022). From 2004 through 2014, blue whales had a low acoustic presence in the GOM (two dates in February; Figure 5.3.17; Davis et al. 2020).

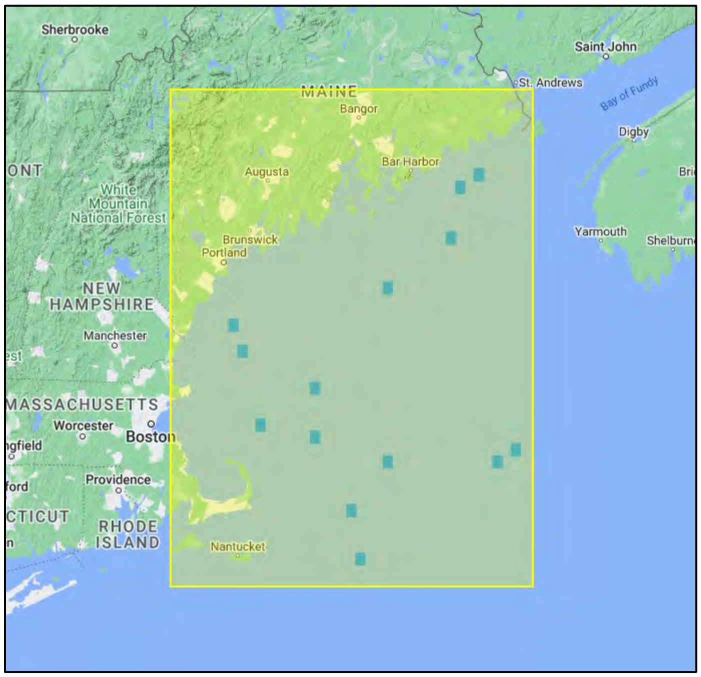

Figure 5.3.15. Blue whale abundance (number of records from 1992 – 2016) in the Gulf of Maine (Colored Squares = Records per 0.1 degree grid resolution: Blue = 1-2, Green = 3-5, Yellow = 6-10, Orange = 11-50, and Red > 50; Halpin et al. 2009).

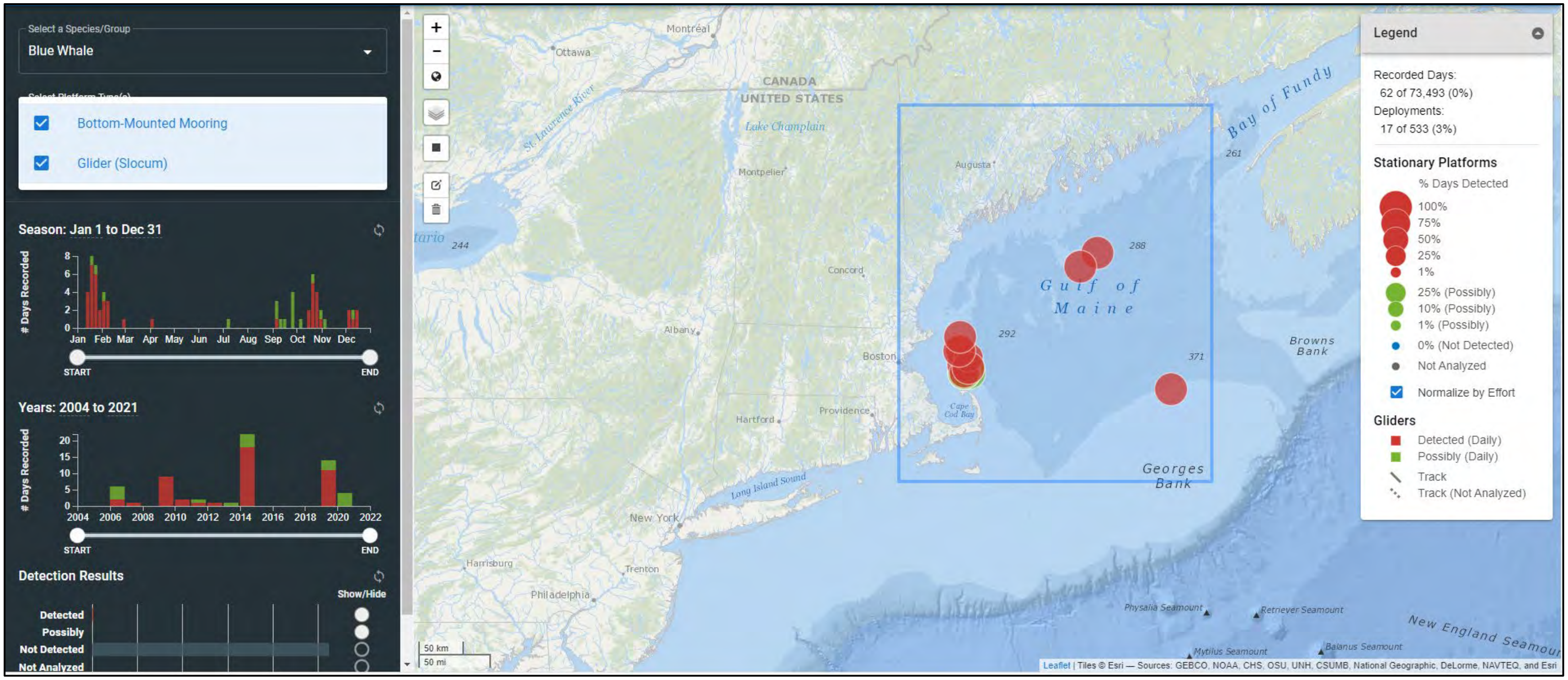

Figure 5.3.16. Acoustic presence of blue whales in the Gulf of Maine 2004 – 2022 (Passive Acoustic Cetacean Map 2022).

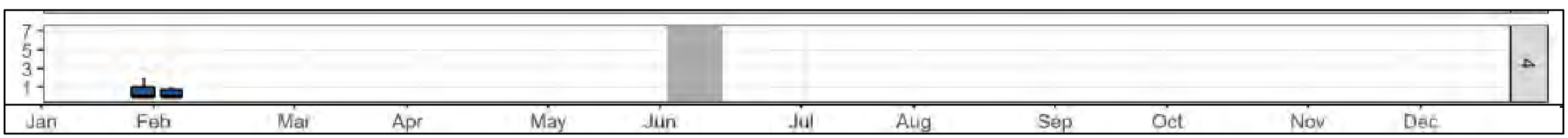

Figure 5.3.17. Blue whale: monthly acoustic presence in the Gulf of Maine (Area 4 on secondary y-axis; 2004–2014; Davis et al. 2020). The y-axis is number of days per week.

Sperm whale

Sperm whales generally occur in deep waters near the shelf edge and slope but may also occur in waters less than 200 m deep in spring and fall (Wynne and Schwartz 1999; Figure 5.3.18; Halpin et al. 2009). Their presence in the GOM is relatively low, with the highest abundance and density in the RFI found in the shelf slope off George's Bank (Figure 5.3.18 and Figure 5.3.19; Halpin et al. 2009; Palka et al, 2021). Sperm whales form groups based on sex and reproductive status. Females form breeding schools of 10 to 80 whales, sexually inactive males form bachelor schools, and sexually active males may join the bachelor schools during mating season but are typically solitary (Wynne and Schwartz 1999). Sperm whales' diet consists of squid and fish.

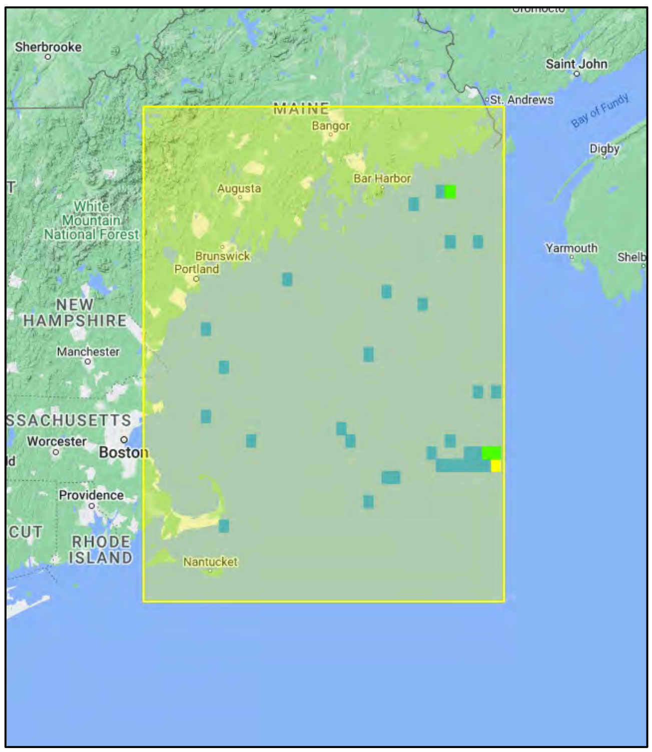

Figure 5.3.18. Sperm whale abundance (number of records from 1992 – 2016) in the Gulf of Maine (Colored Squares = Records per 0.1 degree grid resolution: Blue = 1-2, Green = 3-5, Yellow = 6-10, Orange = 11-50, and Red > 50; Halpin et al. 2009).

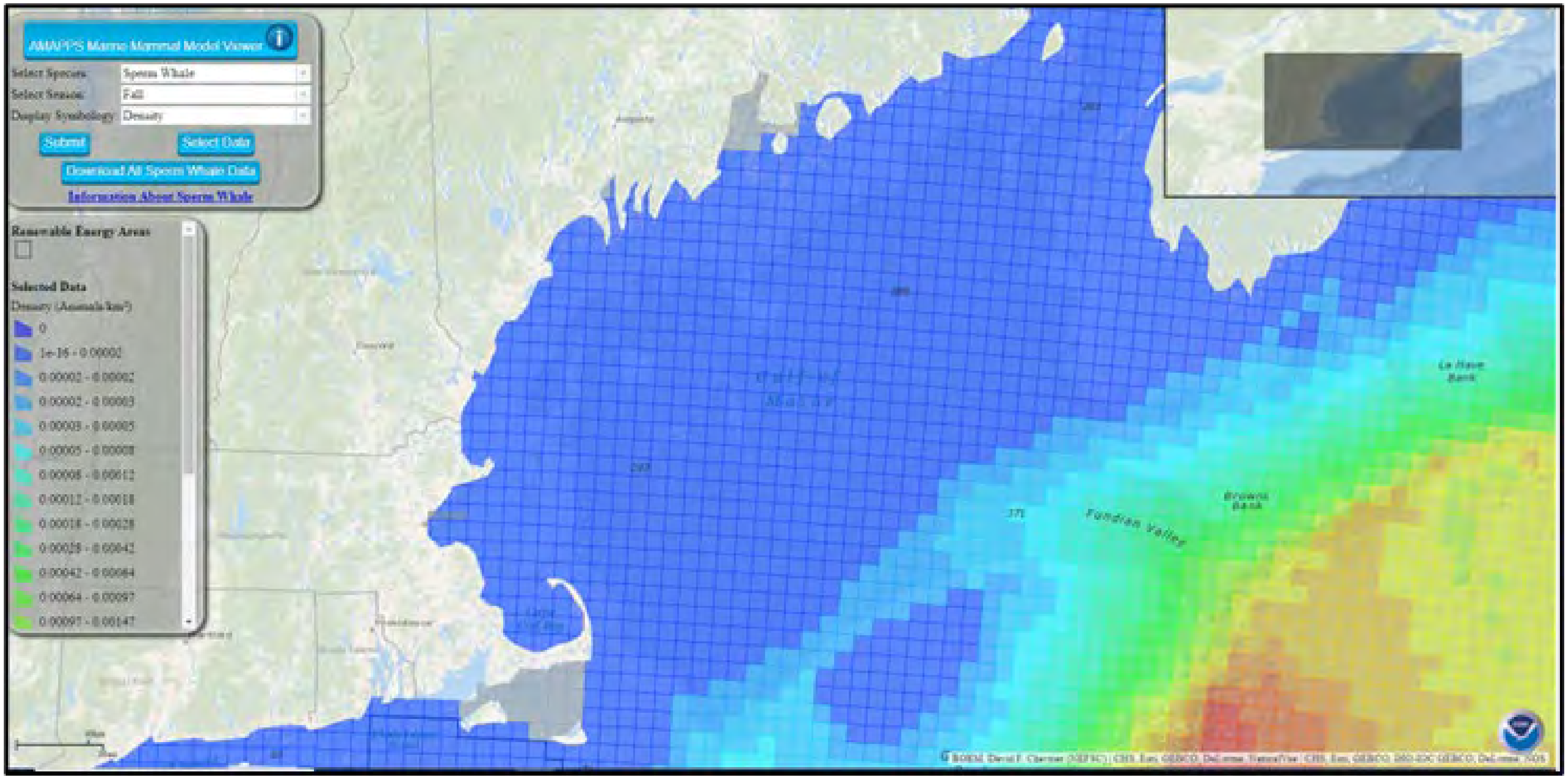

Figure 5.3.19. Average summer and fall Sperm whale density in the Gulf of Maine (2010 – 2017; animals per sq km; Palka et al. 2021).

North Atlantic Right Whale

North Atlantic right whales are currently one of the most endangered marine mammals on the planet. The most current population estimate for 2020 is 336 whales (95% confidence range +/-14 whales) using data as of September 7, 2021 (Pettis et al. 2022). This estimate is an 8% decline from the 2019 estimate. Due to declining numbers, the International Union for Conservation of Nature (IUCN) red listed the North Atlantic right whale changing its status from endangered to critically endangered in July 2020 (Pettis et al. 2022). A species is designated as critically endangered when it is at a high risk for global extinction. NARW critical foraging habitat encompasses the entire RFI footprint (Figure 5.3.20; NOAA NMFS 2022b).

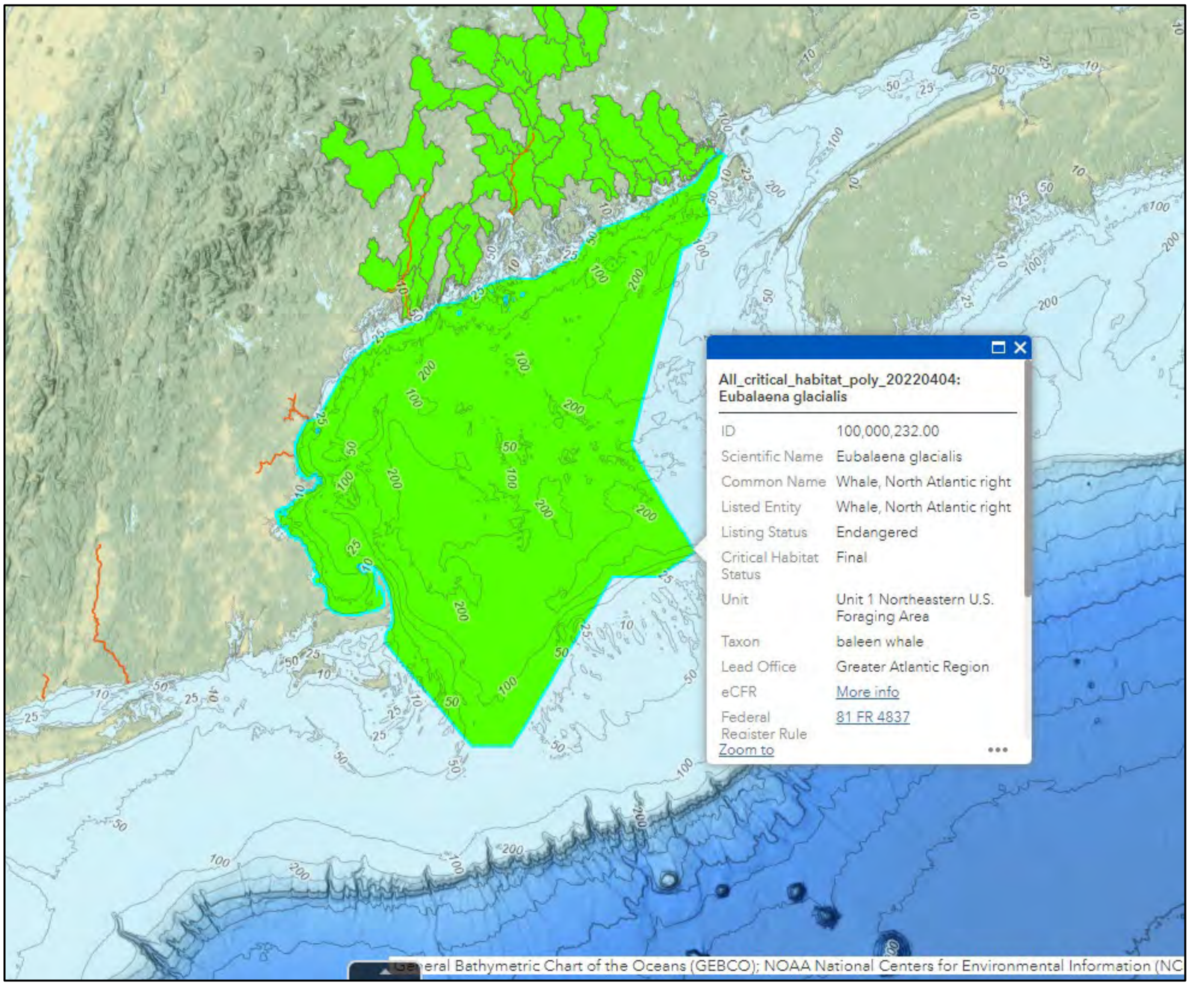

Figure 5.3.20. NARW Critical Foraging Habitat (NOAA NMFS ESA Critical Habitat Mapper 2022).

NARWs inhabit coastal and offshore waters from Florida to the Gulf of St. Lawrence, Canada (Hayes et al. 2022). NARWs feed on calanoid copepods (*Calanus finmarchicus* and *Centropages* sp. (Quintana-Rizzo et al. 2018) and can swim hundreds of miles in a period of a week looking for dense patches of the lipid-dense stage of *Calanus finmarchicus* (Pershing and Pendleton 2021).

Studies have shown that a high average biomass of copepods is not adequate to support the whales' dietary requirements. They need dense compressed patches of copepods, which is accomplished by the complex bottom features, currents, and upwellings found in the GOM (Pershing and Stameszkin 2020). Individual NARW dive behavior is strongly correlated with the depth of maximum *Calanus* abundance between 100 and 150 m (Baumgartner and Mate 2003; Baumgartner et al. 2017). NARW seasonal distribution in the GOM is summarized from acoustic presence (number of days detected) from 2004 through 2014 as follows:

- Winter (November – February): Stellwagen Bank (just north of Cape Cod Bay), Nantucket Shoals south of Cape Cod, and Jordan Basin
- Spring (March – April): Stellwagen Bank, Jeffrey's Ledge, Great South Channel, with some presence in Jordan Basin and George's Bank
- Summer (May – July): Nantucket Shoals and George's Bank, with some presence in Jordans Basin, the Northeast Channel, and Browns Bank
- Fall (August – October): Stellwagen Bank, offshore mid-Maine, coastal northern Maine, and Scotian Shelf (Davis et al. 2017; Figure 5.3.21).

Recent warming due to climate change has caused a decline in the abundance of the cold-water copepod species *C. finmarchicus* in the GOM (Record et al. 2019). The decline in their primary forage species has resulted in a shift in historical distribution both spatially and temporally. Beginning in 2010 NARW spent less time in the GOM in the summer and more time in the Gulf of St. Lawrence (Davis et al. 2017; Pershing and Pendleton 2021) and their presence in the mid-Atlantic region increased while decreasing in the eastern GOM (Ross et al. 2021). Right whale sightings per unit effort (SPUE) have also increased in Cape Cod Bay in the fall, winter, and spring since 2010 (Meyer-Gutbrod et al. 2021). Although Cape Cod Bay is not included in the RFI, whales travelling to Cape Cod Bay will need to swim across the RFI to get there.

NARW historic distribution patterns in the GOM are well known due to more than 30 years of intensive studies. Recent and rapid changes in the quality of foraging habitat for NARW have prompted researchers to attempt to predict where suitable habitat will be in the future, which is vitally important information needed for resource management planning. Ross et al. (2021) have synthesized species distribution algorithms, historic whale abundance data and environmental covariate data to build monthly models that project NARW distribution into the year 2050 for a range of climate scenarios. The models indicate decreased foraging habitat across the GOM except for the area along the Scotian Shelf (Ross et al. 2021). However, these projections represent climatological 30-year means, and in any given year, historical foraging grounds could still be important habitat (Ross et al. 2021). Pershing and Pendleton (2021) also indicate that the shift in habitats could result in a decreased fitness while they learn to forage successfully in the new habitats.

There are several interactive maps that represent historic monthly NARW distribution in the GOM RFI (see Table 5.3.1). The most current maps are through 2016 and so include the 2010 habitat shift. For example, in December, NARW densities are highest (6.8 – 10 animals per 100 sq km) in the deep basins including Jordan Basin, Jeffrey's Ledge, Wilkinson Basin, and the Great South Channel (Figure 5.3.22; Roberts et al. 2016; Roberts et al. 2017; Roberts et al. 2018; Curtice et al. 2019). In June, NARW distribution covers most offshore waters from mid-Maine to Nova Scotia (except eastern GOM), with the highest densities (6.8 – 10 animals per 100 sq km) in Jordan Basin, Georges Basin, the Great South Channel and off Browns Bank (Figure 5.3.23; Roberts et al. 2016; Roberts et al. 2017; Roberts et al. 2018; Curtice et al. 2019). More recent acoustic data (2004 – 2022) indicate NARW presence in Jordan Basin Great, South Channel, and Georges Bank similar to visual surveys, but their presence was also detected in the nearshore Maine waters that was not detected in the visual surveys from 1992 – 2016 (Figure 5.3.24; Passive Acoustic Cetacean Map 2022). An important feature of the Passive Acoustic Cetacean Interactive Map (2022) is that the user can animate the acoustic presence of a species in real time by month or year, making this mapper useful to detect shifts in NARW habitat use over time or season.

Finally, the Northeast Ocean Data map combines several data layers into monthly density maps for the GOM (Figure 5.3.25). This interactive mapper is very useful for viewing the visual and acoustic data together for the most complete account of NARW presence each month. For example, visual surveys indicated the highest average densities for NARW (>10 animals per 100 sq km) in the RFI in April were east of Cape Cod and in the Great South Channel (MDAT 2022; Curtice et al. 2019; Roberts et al. 2016; Roberts et al. 2017). NARW were however also detected acoustically in the Jordan Basin and Jeffrey's Ledge, presence that was not detected by the visual surveys (MDAT 2022; Curtice et al. 2019; Roberts et al. 2016; Roberts et al. 2017).

In summary, due to the recent shifts in *C. finmarchicus* and NARW distribution, historical seasonal migratory patterns should not be used alone to assess their presence and potential impacts from floating offshore wind farms. Development and management of resources in the GOM should be adapted and reevaluated continually in relation to right whales' use of the area (Quintana-Rizzo et al. 2021).

Habitat shifts have also been detected for sei, fin, and blue whales in the GOM (Davis et al. 2020). The expected number of days with sei, fin, and blue whale acoustic presence increased from 2011 – 2014 compared to 2004 – 2010 in the GOM (Figure 5.3.26; Davis et al. 2020). Acoustic presence of NARW decreased in the GOM over the same time periods (Figure 5.3.26; Davis et al. 2020).

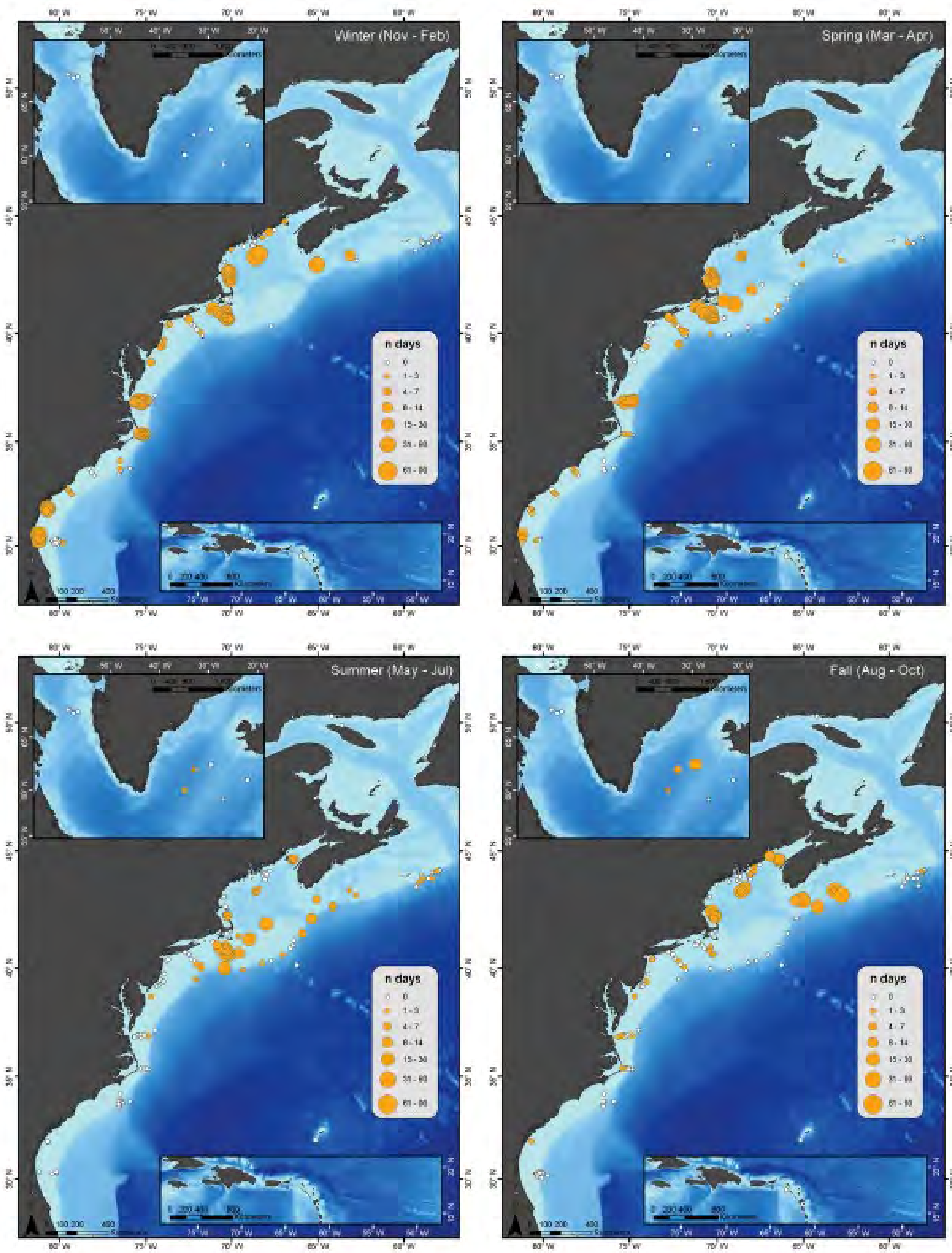

Figure 5.3.21. Seasonal occurrence Maps: The number of days per season with confirmed NARW upcall acoustic detections, summarized for all available recordings locations (2004 – 2014). Filled orange circles indicate NARW acoustic presence, and circle size indicates number of days with NARW acoustic detections during a season. White dots indicate recorder locations with no NARW acoustic presence for any year during that season (Davis et al. 2017).

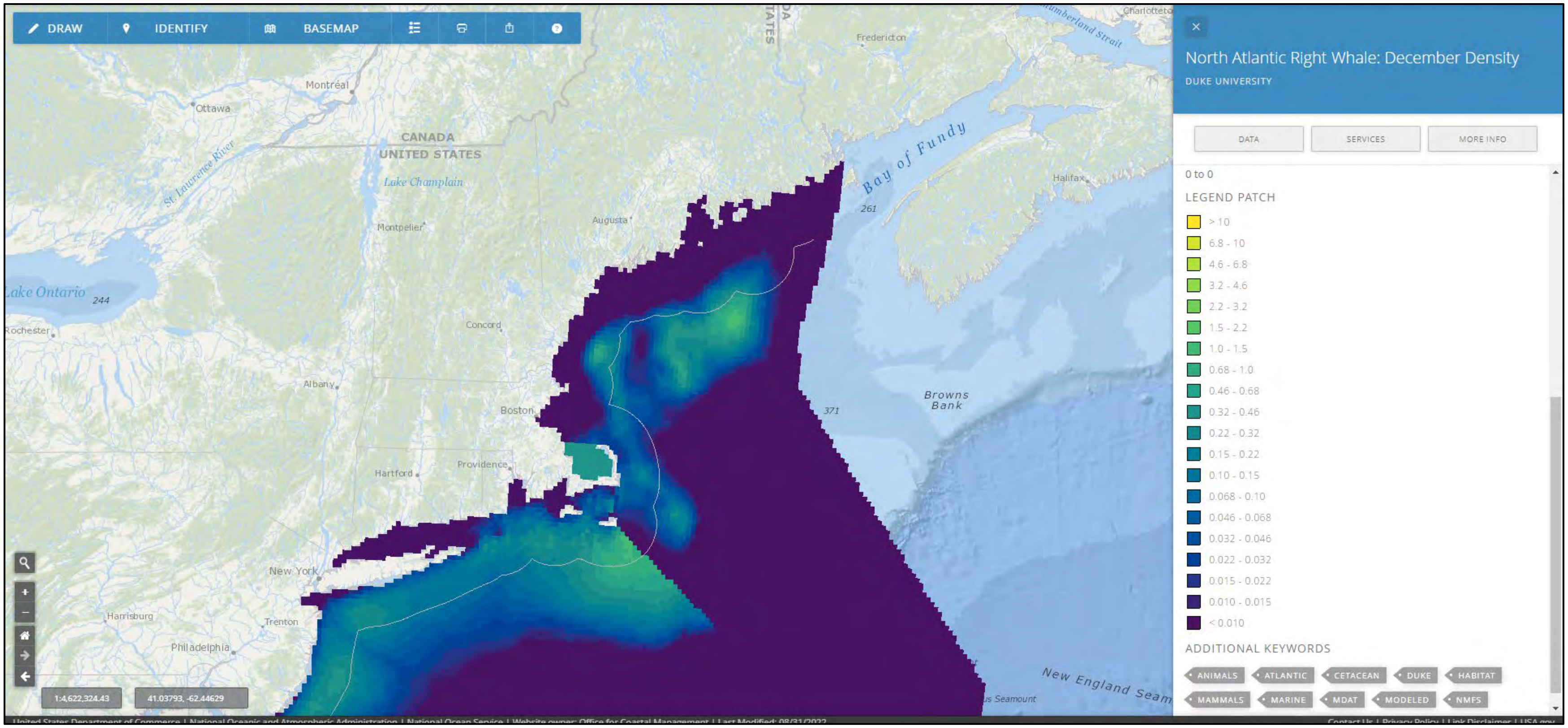

Figure 5.3.22. December Density of NARW in the Gulf of Maine from 1992 - 2016 (number of animals per 100 sq km; Roberts et al. 2016; Roberts et al. 2017; Roberts et al. 2018; Curtice et al. 2019).

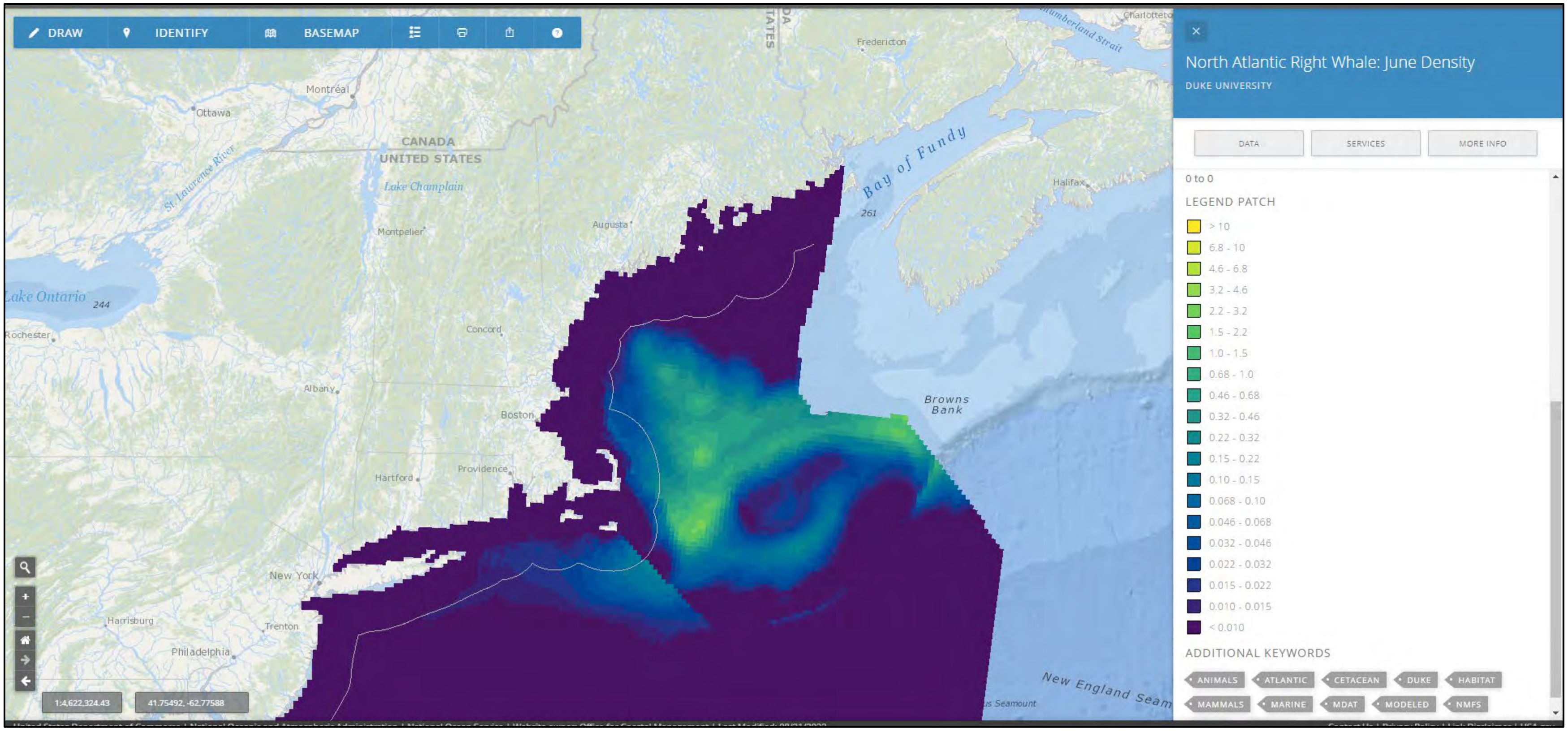

Figure 5.3.23. June Density of NARW in the Gulf of Maine from 1992 – 2016 (number of animals per 100 sq km; Roberts et al. 2016; Roberts et al. 2017; Roberts et al. 2018; Curtice et al. 2019).

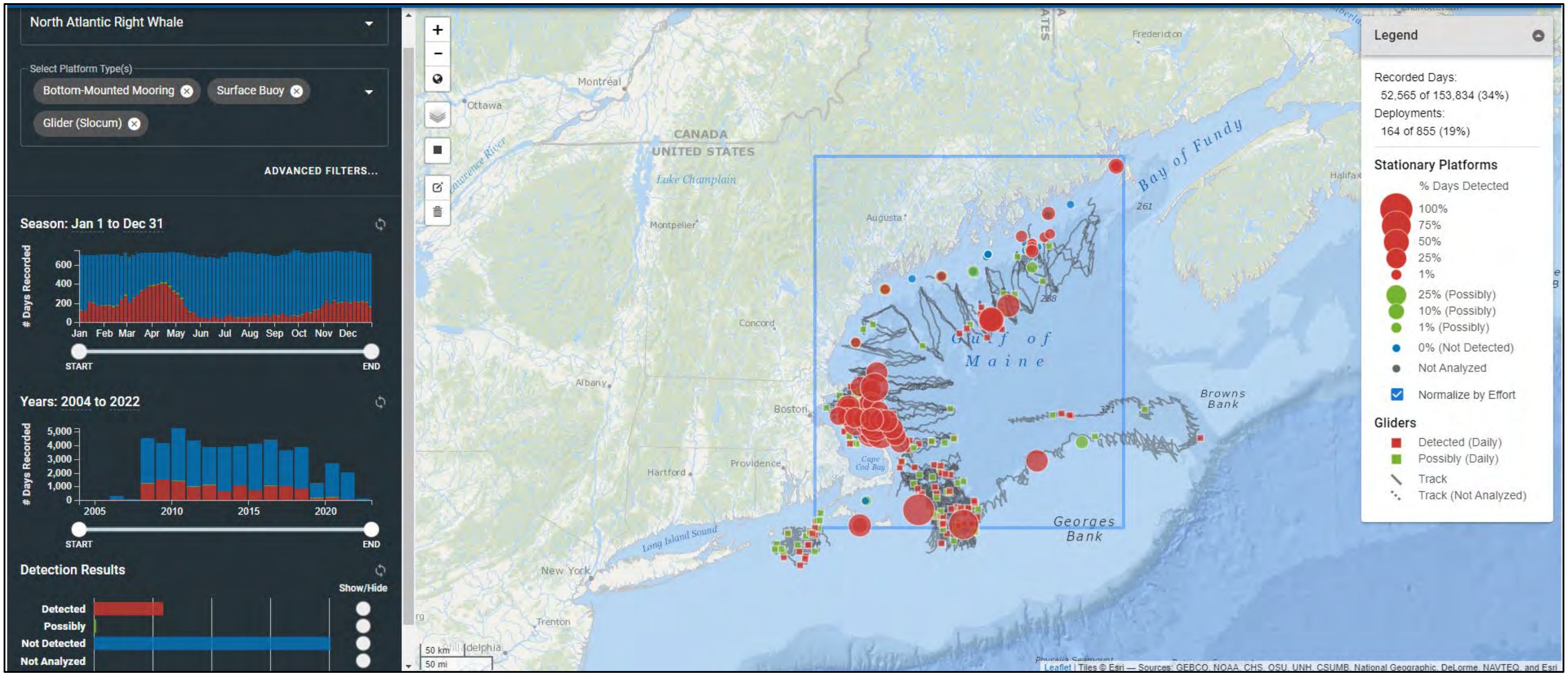

Figure 5.3.24. Acoustic presence of NARW in the Gulf of Maine 2004 – 2022 (Passive Acoustic Cetacean Map 2022).

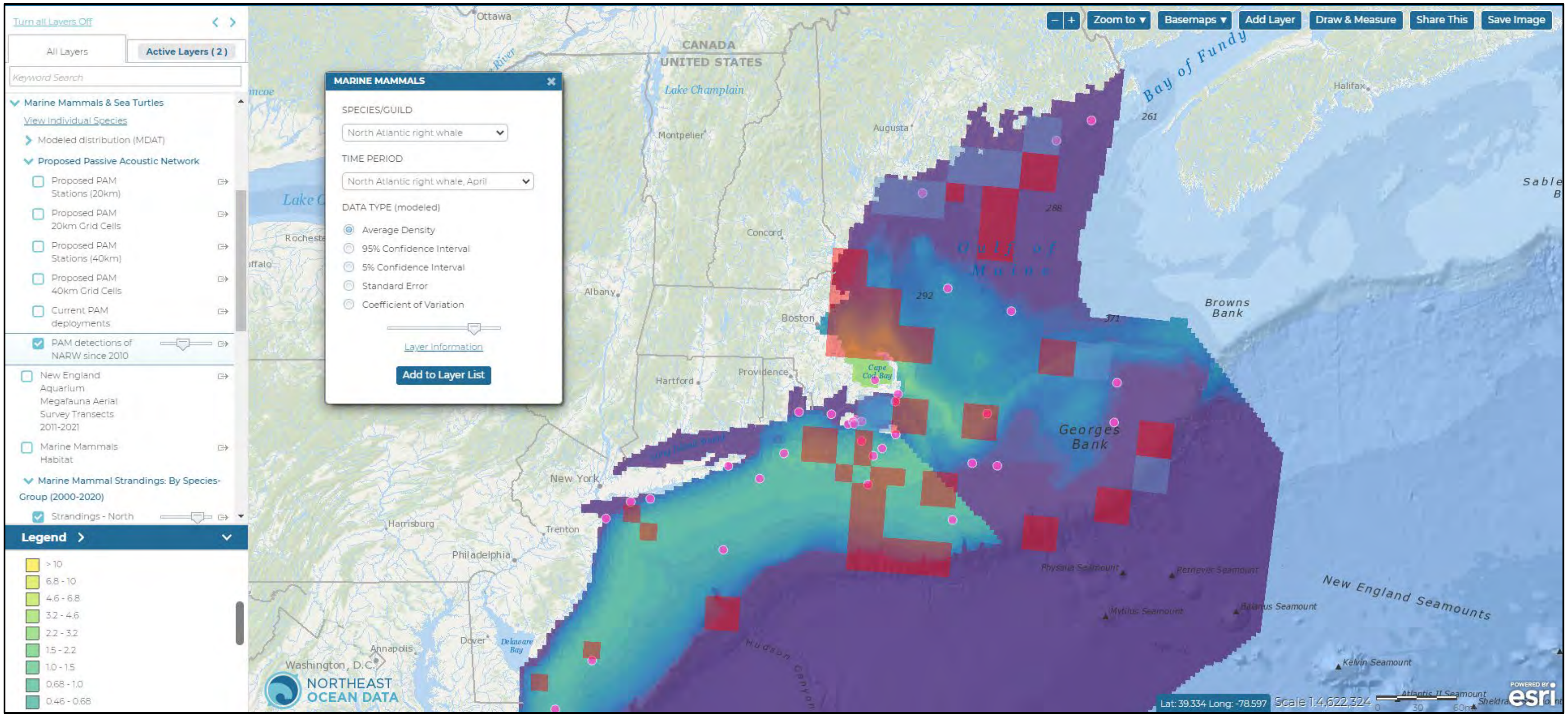

Figure 5.3.25. NARW average April density (animals per 100 sq km); Pink circle = strandings (2000 – 2020); red squares = PAM monitored and detected (2010 – 2022); blue squares = PAM monitored not detected (2010 – 2022); MDAT 2022; Curtice et al. 2019; Roberts et al. 2016; Roberts et al. 2017).

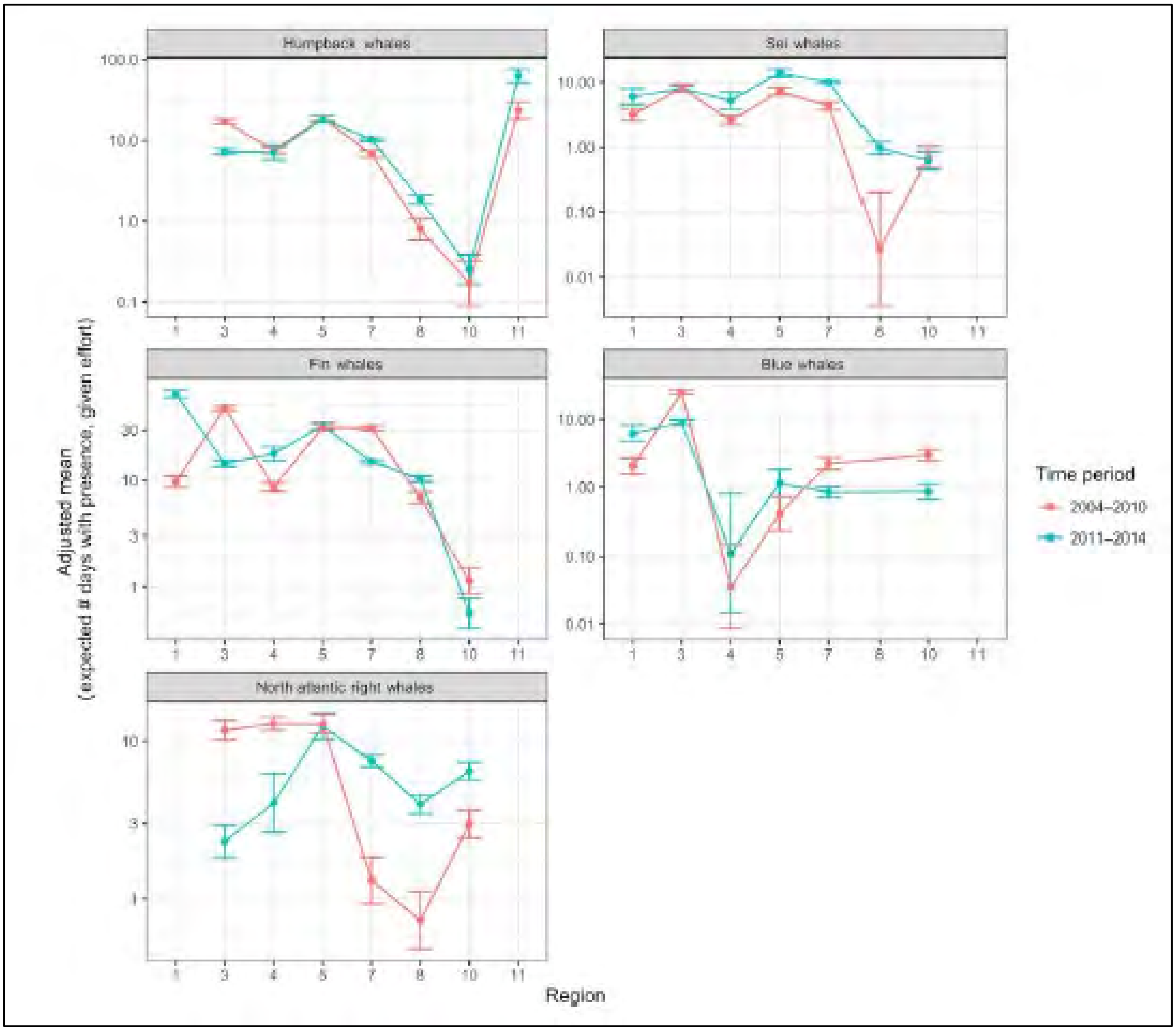

Figure 5.3.26. Adjusted means of acoustic occurrence for each time period (2004–2010 in red, 2011–2014 in blue), for each region indicated on the x-axis, for each species. Vertical bars represent 95% confidence intervals. The y-axis represents the expected number of days with acoustic presence, given the average number of recording days for that region and time period. The y-axis is on a logarithmic scale (base 10) and is different for each species. Data for North Atlantic right whales are taken from Davis et al. (2017; Davis et al. 2020).

Non-ESA Marine Mammals

Cetaceans

Examples of current (2010 – 2017) average density maps for seven non-ESA cetaceans indicate the relatively high use of the entire GOM (Figure 5.3.27– Figure 5.3.29; Palka et al. 2021). Maps of each of the species were available for winter, spring, summer, and fall. The season in which the highest abundance was indicated was presented (summer in all cases except Atlantic white-sided dolphin, which was most abundant in the spring; Palka et al. 2021). Average densities for these species in the RFI are summarized as follows:

- Harbor porpoise: High (>1.63 animals per sq km) in the northern quadrant, and gradually decreasing toward the southern boundary (Figure 5.3.27)
- Common dolphin (*Delphinus delphis*): Moderately high in the southern quadrat (0.27 – 0.48 animals per sq km; Figure 5.3.28)
- Atlantic white-sided dolphin: Moderate (>0.05 animals per sq km) in all areas except north and mid coastal Maine (Appendix Figure G-1)
- Longfin pilot whale (*Globicephala melas*): Relatively low (0.004 – 0.02 animals per sq km) throughout the GOM (Appendix Figure G-2)
- Minke whale: Relatively low (0.002 animals per sq km) throughout most of the RFI, with higher densities on George's Bank (0.005 – 0.007 animals per sq km; Appendix Figure G-3)
- Risso's dolphin (*Grampus griseus*): Moderate (0.05 – 0.08 animals per sq km) in central GOM and the Fundian Valley and Northeast Channel (Appendix Figure G-4)
- Humpback whales: Moderate (0.007 – 0.10 animals per sq km) around the GOM, especially along northern George's Bank (Figure 5.3.29; Palka et al. 2021).

Passive acoustic surveys also indicate that humpback whales are present year-round in the GOM (Figure 5.3.30; Davis et al. 2020; Murray et al. 2014). and in winter months off the Scotian Shelf (Kowarski et al. 2018). The Passive Acoustic Cetacean Map (2022) shows moderately high presence in the northwest quadrant of the GOM along the north and mid Maine coastal and shelf waters with whales detected year-round ranging from 1 to 100% of the days detected. The areas in and near Stellwagen Bank and Great South Channel had the highest presence, with whales detected 100% of the days at most locations (Figure 5.3.31).

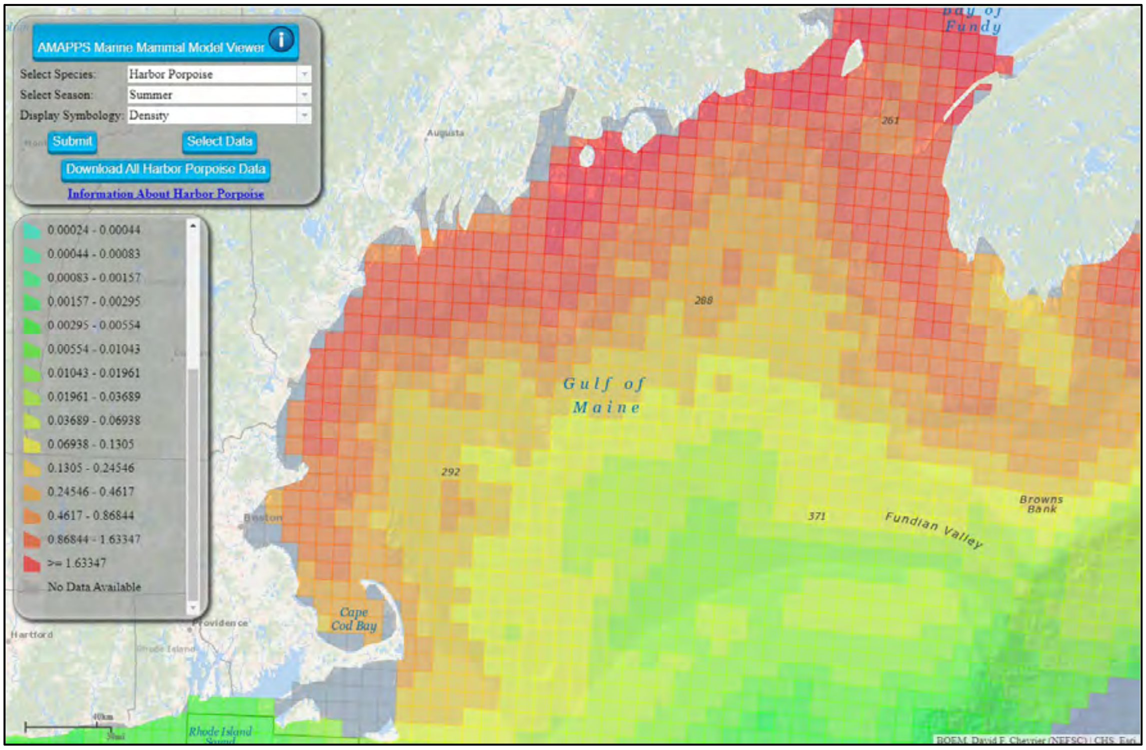

Figure 5.3.27. Harbor porpoise average summer density (red colored squares >1.63 animals per sq km (Palka et al. 2021).

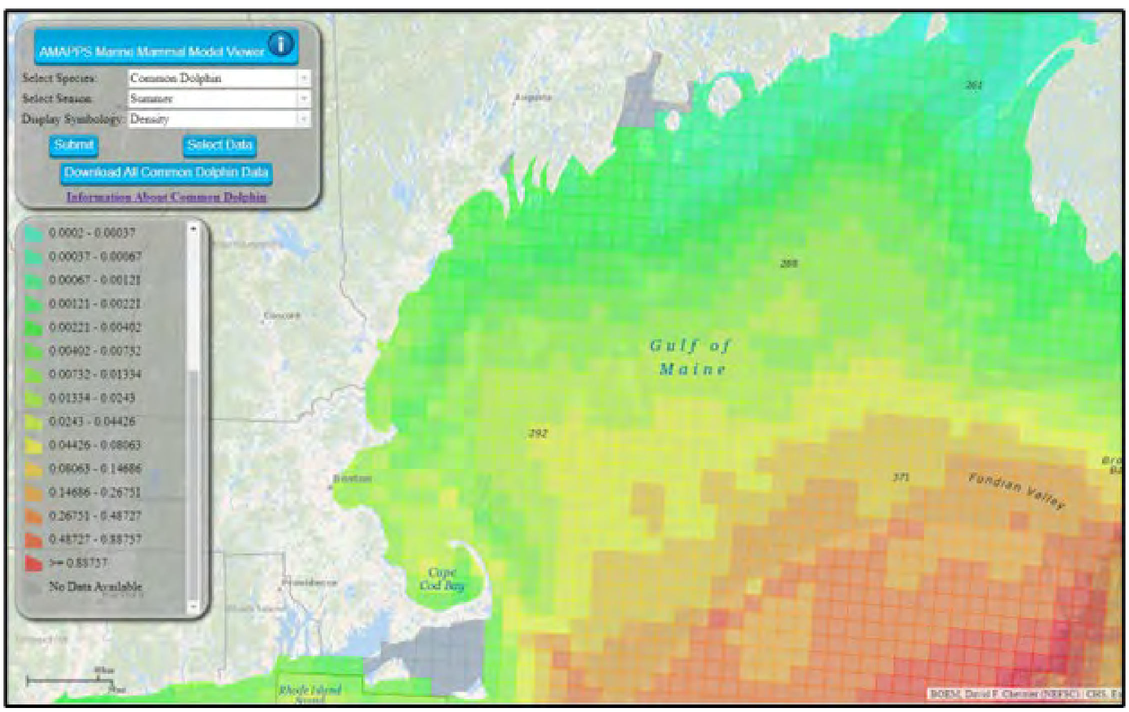

Figure 5.3.28. Common dolphin average summer density (orange squares 0.27 – 0.48 animals per sq km; Palka et al. 2021).

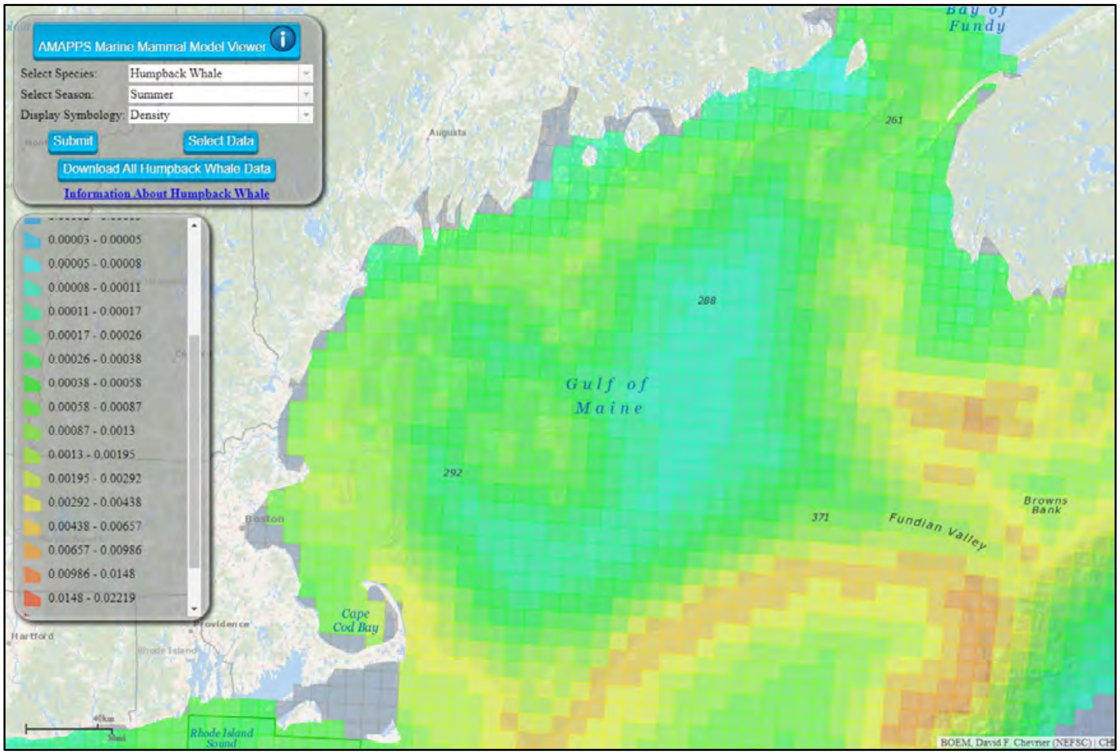

Figure 5.3.29. Humpback whale average summer density (orange squares = 0.007 – 0.10 animals per sq km; Palka et al. 2021).

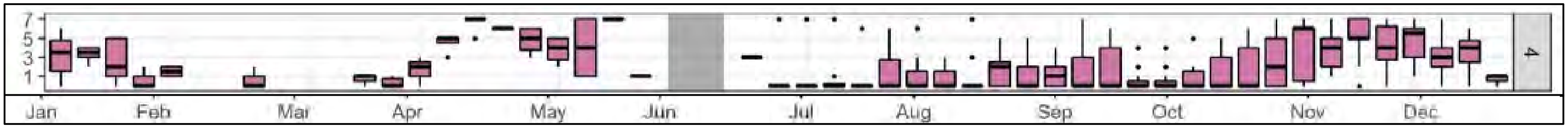

Figure 5.3.30. Humpback whale acoustic presence in the Gulf of Maine (2004–2014; Area 4 in Davis et al. 2020). The y-axis is number of days per week.

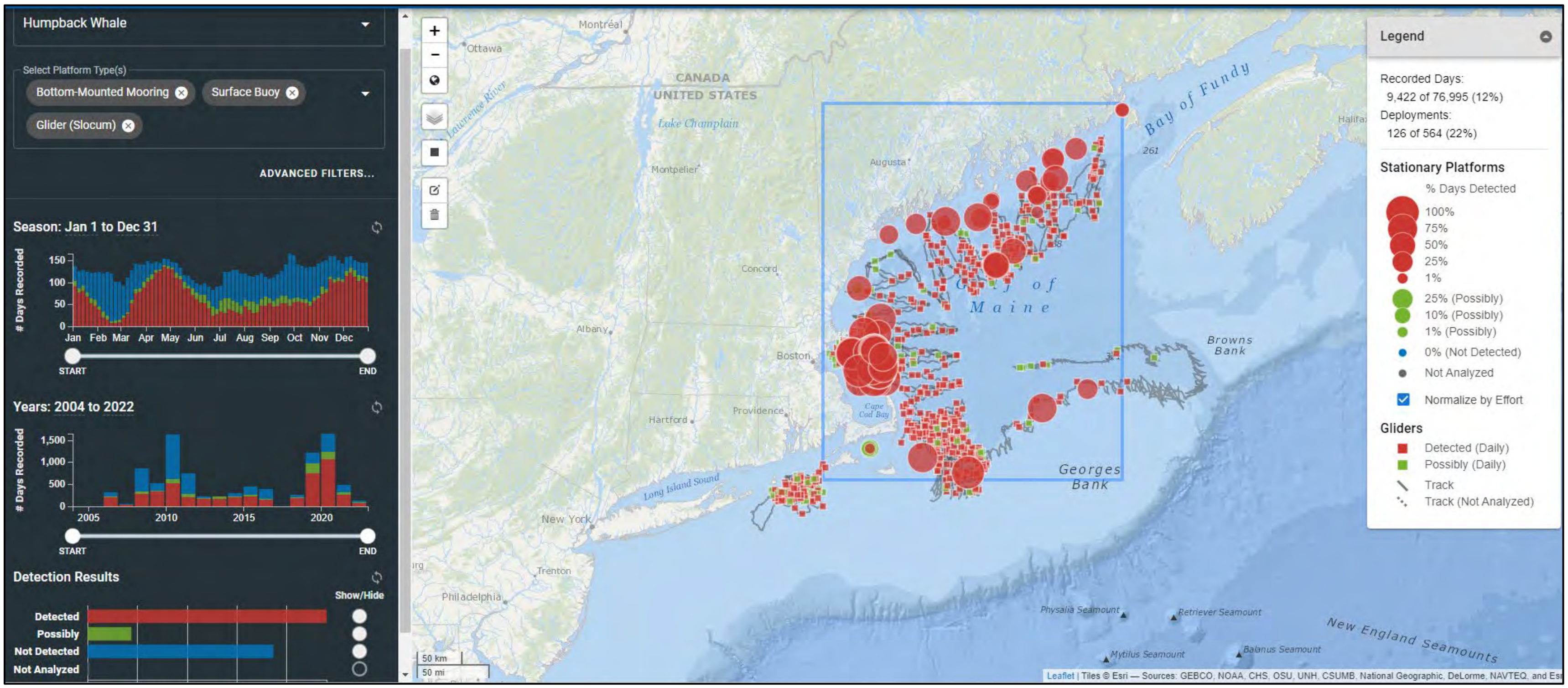

Figure 5.3.31. Passive acoustic detection results for humpback whales in the Gulf of Maine 2004 – 2022 (Passive Acoustic Cetacean Map 2022).

Seals

Four species of seals inhabit the GOM. Atlantic gray (*Halichoerus grypus*) and harbor (*Phoca vitulina*) seals are year-round residents, with the highest numbers observed along the Maine coast during spring and summer (Figure 5.3.32; Hayes et al 2022; Halpin et al. 2009). Harbor and gray seals' habitat includes haul out areas for resting on protected beaches, rocky outcrops, and coves and offshore coastal and shelf waters for foraging on fish species (Hayes et al. 2022). Hooded (*Crystophora cristata*) and harp (*Pagophilus groenlandica*) seals prefer deep offshore waters. Hooded seals occur in the GOM from December through March and juvenile harp seals can occur offshore from January through May (Wynne and Schwartz 1999). Figure 5.3.33 shows the very wide range of tagged gray seals off the coast of Cape Cod and their foraging range into the GOM (Palka et al. 2017).

The most current stranding data for seals (2015 through 2019) are summarized in Table 5.3.4. Stranding data indicate that harbor seals are most abundant in Maine and New Hampshire, and gray seals an harbor seals are abundant in Massachusetts (Hayes et al. 2022).

Table 5.3.4. Numbers of stranded seals in Maine, New Hampshire, and Massachusetts from 2015 – 2019.

State	Species			
	Harbor Seal[1]	Gray Seal	Harp Seal	Hooded Seal
Maine	1,273 (323)	53	14	0
New Hampshire	266 (152)	17	4	0
Massachusetts	490 (142)	589	176 (2)	3

Hayes et a. 2022. [1]Subtotal number of pups in parentheses.

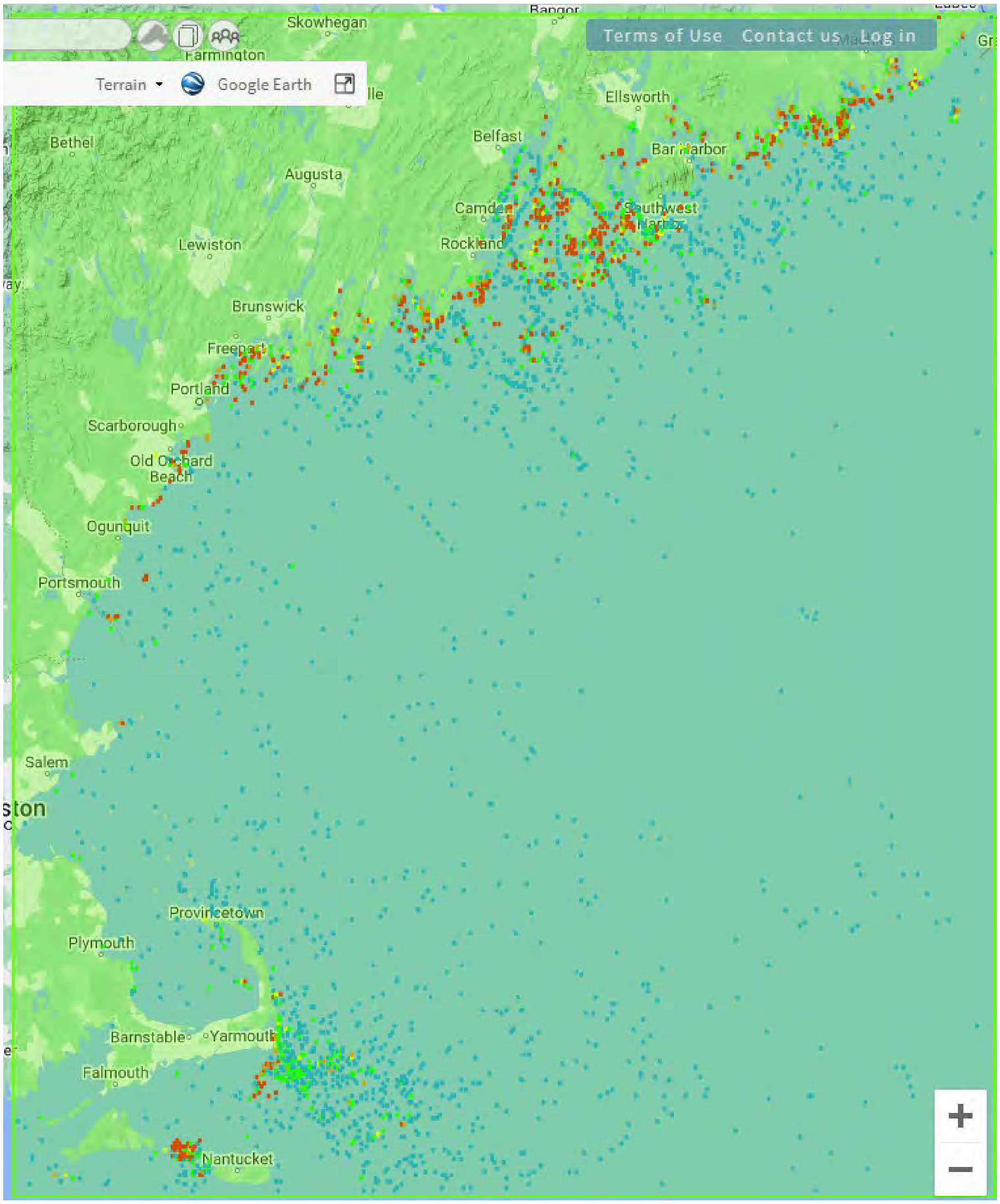

Figure 5.3.32. Seals (Phocidae, pinnipeds, gray seal, and harbor seals) in the Gulf of Maine (Colored Squares = Records per 0.01 degree grid resolution: Blue = 1, Green = 2-5, Yellow = 6-10, Orange = 11-20, and Red > 20; Halpin et al. 2009).

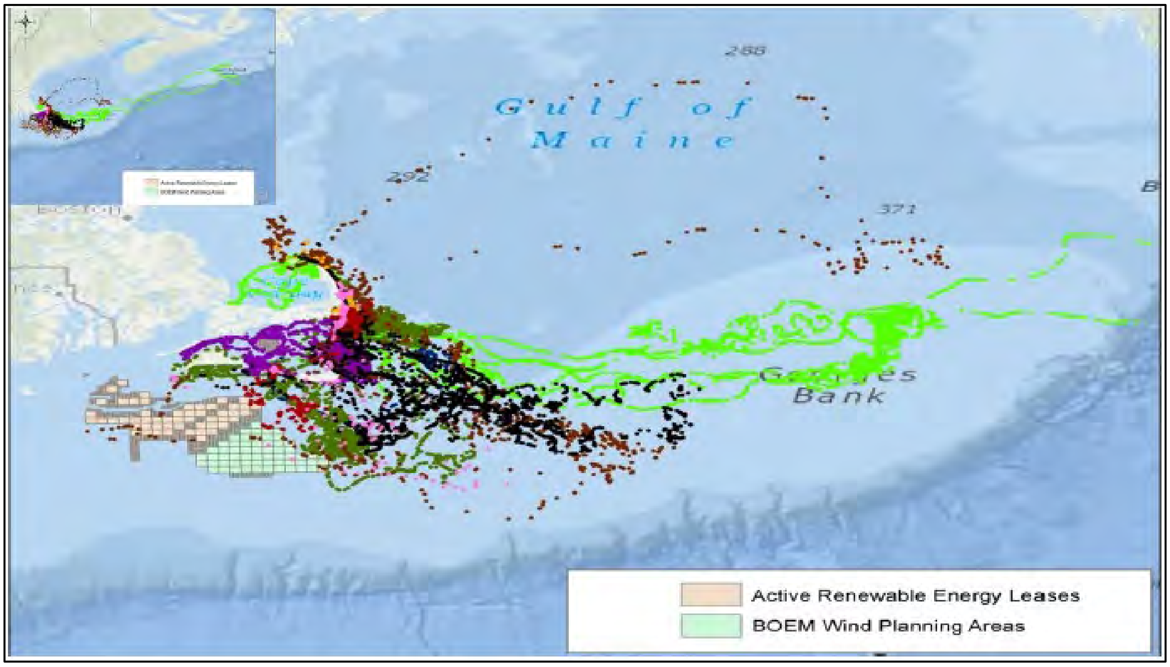

Figure 5.3.33. Location of gray seals tagged in Chatham, MA 2013. Each color is a different animal. Orange and green cells are the wind energy areas off MA. Cell phone tag data courtesy J. Moxley, Duke University (as cited in Palka et al. 2017).

5.3.2 Sea Turtles

Four species of federally listed threatened or endangered sea turtles may occur seasonally in the GOM. These species include the threatened Northwest Atlantic Ocean distinct population segment (DPS) of loggerhead sea turtles, the threatened North Atlantic DPS of green sea turtles, and the endangered Kemp's ridley and leatherback sea turtles. Sea turtles are generally distributed in coastal Atlantic waters from Florida to New England. These four species are highly migratory and may occur in the RFI from May through November feeding and migrating (Kenney and Vigness Raposa 2010).

Sightings data for sea turtles are difficult to obtain in part because they are typically underwater for an average of 92% of each day (Morreale et al. 1992). However, sightings and stranding data from three sources indicate that although they are concentrated near Cape Cod, they also occur in coastal waters and offshore of Massachusetts, New Hampshire, and Maine (Halpin et al. 2009; STSH 2022; STSSN 2022). The species with the most sightings in the RFI from 2002 to 2020 was leatherback turtle (Figure 5.3.34; STSH 2022), but the species with the highest number of strandings was Kemp's ridley sea turtles (Figure 5.3.35; STSSN 2022). Unlike leatherback turtles, who are endothermic and able to regulate their body temperature, the other three species of sea turtles are ectothermic, and susceptible to cold-stunning in the fall and winter months.

Green sea turtle abundance is relatively low, with few sightings mostly south of Cape Cod, but with one turtle sighted off Bar Harbor, ME (Halpin et al. 2009). Loggerhead abundance is moderate and predominantly in the southern quadrant of the GOM from the coast to George's Bank (Figure 5.3.36; Halpin et al. 2009; STSH 2022). Kemp's ridley sea turtle sightings are mostly around Cape Cod, with some sightings off northern Massachusetts and New Hampshire (Figure 5.3.34; STSH 2022). Strandings data for the GOM from 2012 – 2022 indicate that a majority of strandings were Kemp's ridley sea turtle (n=5,494), followed by loggerhead sea turtle (n=698), leatherback sea turtle (n=444), green sea turtles (n=241), and hawksbill sea turtle (n=1; STSSN 2022).

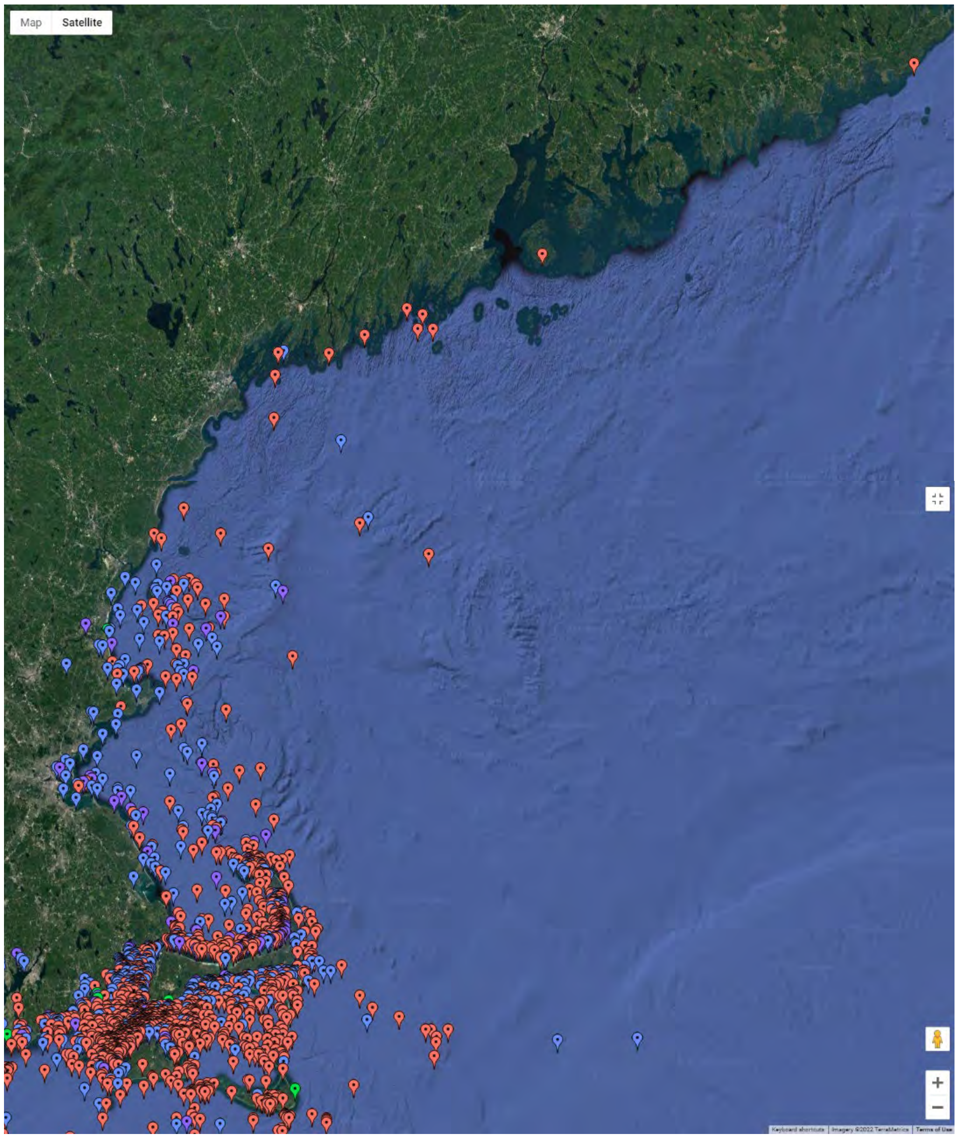

Figure 5.3.34. Sea turtle sightings in the Gulf of Maine from 2002 – 2022. Red marker = leatherback sea turtle, blue = loggerhead, purple = Kemp's ridley, and green = green sea turtle; STSH 2022).

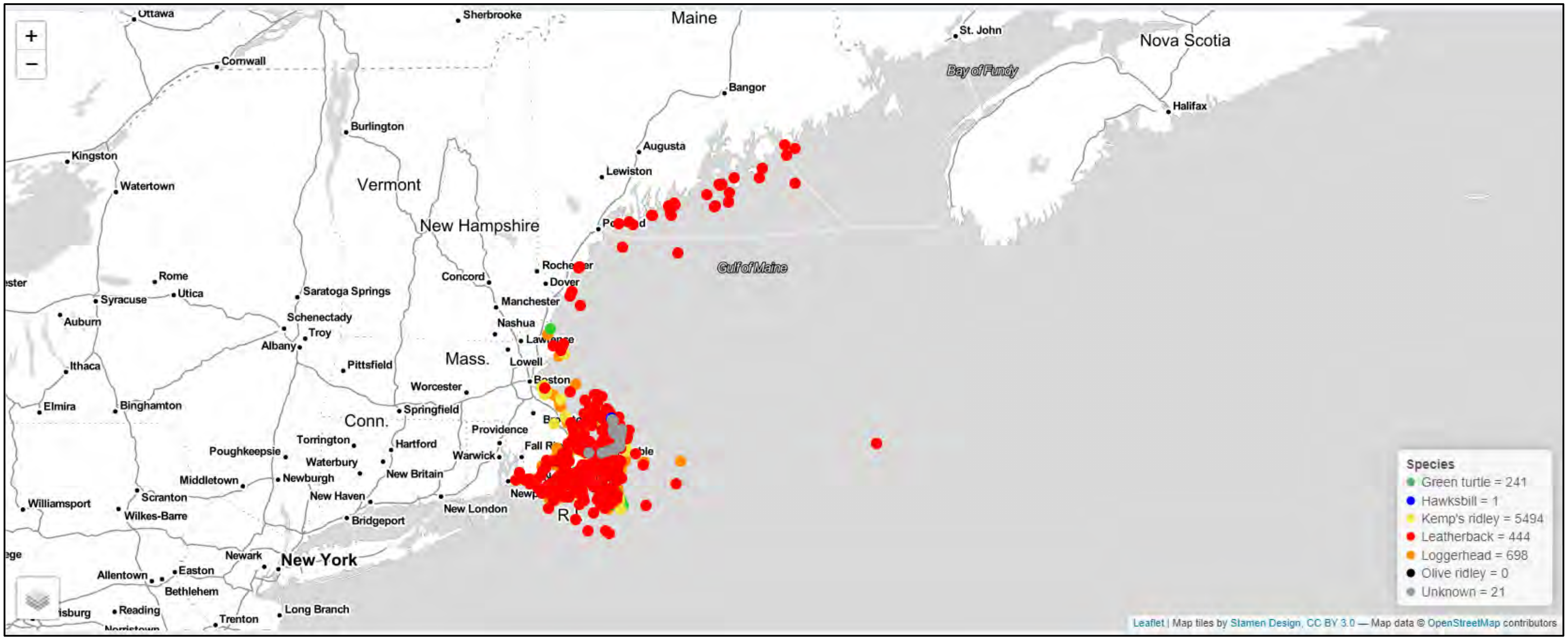

Figure 5.3.35. Sea turtle strandings: Green sea turtles (n=241), Hawksbill sea turtle (n=1), Kemp's ridley sea turtle (n=5,494), Leatherback sea turtle (n=444), Loggerhead sea turtle (n=698), Unknown (n=21) from 2012 - 2022 (STSSN 2022).

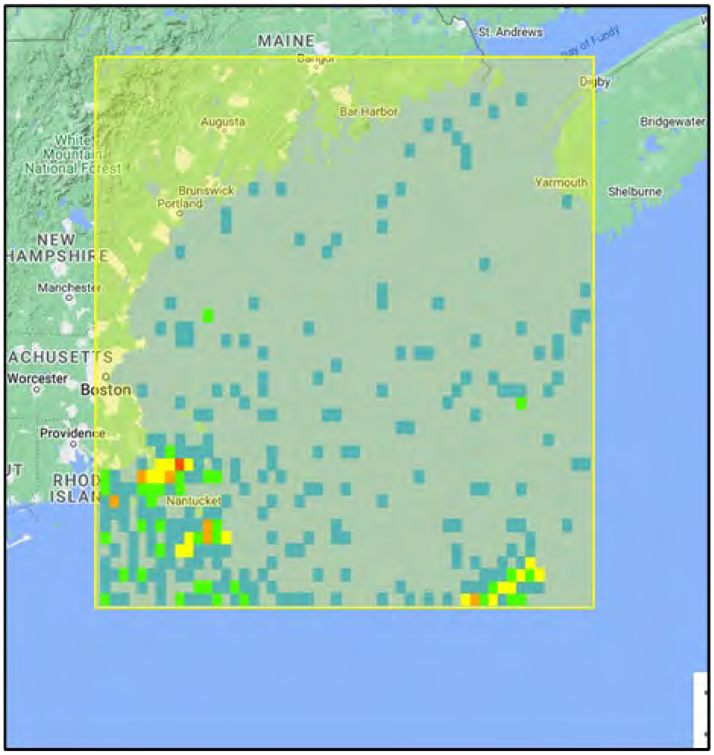

Figure 5.3.36. Sea turtles (Loggerhead, leatherback, green, and Kemp's ridley) sightings in the Gulf of Maine (Colored Squares = Records per 0.1 degree grid resolution: Blue = 1-2, Green = 3-5, Yellow = 6-10, Orange = 11-50, and Red > 50; Halpin et al. 2009).

5.3.3 Impacts on Marine Mammals and Sea Turtles

Floating wind platform designs to date may include spar, semisubmersible, barge, and tension leg configurations (see Section 1.4.2). An example of turbine orientation and spacing with a single platform anchored bythree mooring lines is depicted in Figure 5.3.37 (Copping and Grear 2018). Each row of three platforms is offset from the next row by about 410 m, the distance turbine platforms within a row is about 820 m and about 1640 m between rows. There are few floating wind arrays in the world and thus data for impacts to marine mammals are not available. Potential impacts that may occur are listed below, but as more specific design information becomes available, other impacts may become relevant.

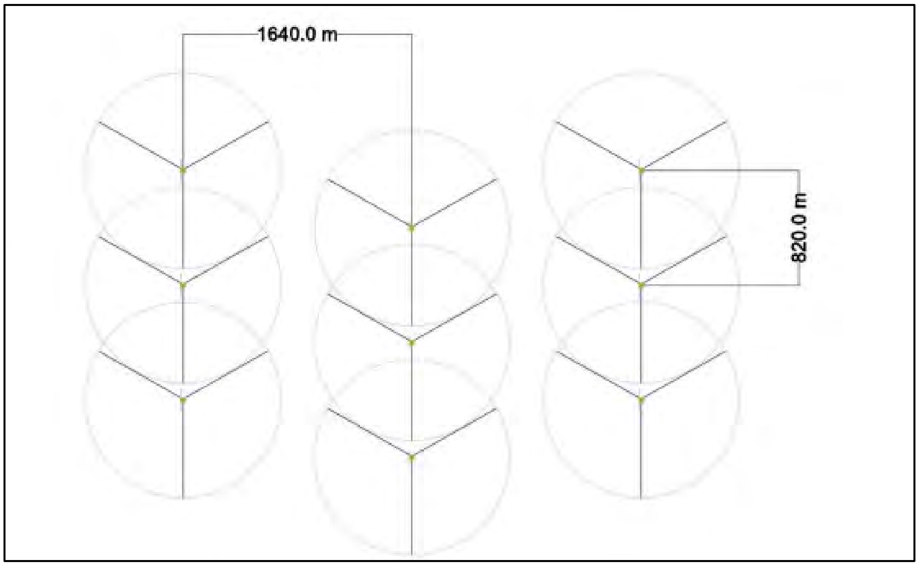

Figure 5.3.37. Scale drawing of floating wind farm array. Light blue circles respresent the effective diameter of the turbine platform based on where the mooring lines are anchored to the seabed (Copping and Grear 2018).

Potential impacts to marine mammals and sea turtles during site characterization surveys, construction, and operation of floating offshore wind farms in the RFI include:

- Noise:
    - High-resolution geophysical (HRG) site characterization surveys
    - Fisheries/hydrographic sonar monitoring surveys,
    - Installation of electrical service platform (ESP) foundations using impact and vibratory hammer pile driving, and drilling
    - Installation of mooring line anchors using pile driving
    - Vessel noise from monitoring surveys, construction, and operation/maintenance vessels
    - Trenching for export and inter-array cable installation
    - Acoustic shock waves from high-order detonation of unexploded ordnances (UXO)
    - Operation noise
- Increased vessel traffic and risk of vessel strike:
    - Fisheries/hydrographic sonar monitoring surveys,
    - HRG surveys,
    - Construction traffic
    - Operation/maintenance traffic
- Allision (defined as a violent strike (such as in a collision) with a fixed object) with turbine platforms, ESP foundations, export and inter-array cables

- Entanglement:
    - Abandoned, lost, or discarded fishing gear or marine debris caught on cables or platforms entrapping an animal
    - Ingestion of gear entangled on cables or platforms
    - Secondary entanglement: abandoned, lost, or discarded fishing gear and other marine debris that becomes ensnared in mooring lines and cables where it may entangle animals
    - Tertiary entanglement: the trailing gear attached to an entangled, swimming animal may become caught on cables, mooring lines, or platforms
- Turbidity from export and inter-array cable installation (trenching and burial)
- Electromagnetic Field (EMF) from inter-array and export cables
- Potential reduction of wind speed resulting in:
    - less mixing, lower current speeds, higher surface water temperatures (Afshrian et al. 2019),
    - detectable changes in the water column (Christiansen and Hasager 2005; Broström 2008),
    - and increased turbidity (Vanhellemont and Ruddick 2014) downwind of the wind farm.
- Displacement or avoidance of habitat: fish and marine animals may avoid floating offshore wind farms due to noise, vessel traffic, or the presence of the platforms, mooring lines, and cables (NRDC 2021)

In addition to pile driving, other sources of noise are associated with the construction, operation, and maintenance of offshore wind farms, although at relatively lower source levels (SEER 2022b). For example, vessel noise can mask important communication (Parks et al. 2007; Parks et al. 2008), negatively affect response to predators and foraging, and cause physiological stress (Rolland et al. 2012). HRG surveys involve multibeam, side-scan sonar, sub-bottom profilers, and other technologies that may cause impacts to animals within hearing range of the activities. Operation of the turbines produces nearly continuous relatively low-amplitude underwater sound, that is variable depending on wind speed, turbine size, and bathymetric conditions (SEER 2022b). Operation noise is not high enough to cause physical injury but may cause behavioral changes in animals (see Section 5.9.5; SEER 2022b).

Due to the potential risk of entanglement of whales and lack of data for interactions with offshore platforms, cables and mooring lines, the U.S. Department of Energy/Pacific Northwest National Laboratory created a hypothetical animated video. The authors used morphometrics data, swim speed and dive behavioral data for humpback whales to illustrate how this species would potentially swim through the mooring lines and electrical cables to scale (Copping and Grear 2018). The video simulates a mother and calf humpback whale during migration, approaching, transiting through, and foraging within the wind farm array. The mother and calf pair enter the farm and the mother dives while the calf remains at the surface (Figure 5.3.38A). During this dive, the mother forages at higher speeds and travels by the mooring lines, buoys, and inter-array cables (Figure 5.3.38B-E). This video shows humpbacks foraging on a school of small fish about 50 m deep. It should be noted that NARW individual dive behavior is strongly correlated with the depth of maximum *Calanus* abundance between 100 and 150 m (Figure 5.3.39; Baumgartner and Mate 2003; Baumgartner et al. 2017), and thus this species may encounter the electrical cables while foraging.

North Atlantic Right Whales- Impacts

Impacts to NARW from offshore wind development are not known (Madsen et al. 2006). However, the effect of large-scale wind farms in NARW critical habitat, specifically the RFI in this report, but also when cumulatively added to other habitats along the U.S. east coast, could negatively impact right whales at a time when they are difficult to monitor as they search for suitable foraging habitat, with more unpredictable movements between habitats (Quintana-Rizzo et al. 2021). Construction, operation, and maintenance of hundreds of turbines could amplify shifts already occurring in oceanographic conditions, water column stratification, and shifting zooplankton assemblages due to climate warming (Pershing and Pendleton 2020). Construction and maintenance activities may expose NARW to higher levels of vessel traffic, vessel noise, and increased stress levels (Rolland et al. 2012), which may in turn negatively affect their reproductivity, in a time when the average calving interval has changed from 1 calf/female every 3–4 years to 1 calf/female every 7–10 years (Pettis et al. 2022). In addition, low frequency noise from large ships (20 – 200 Hz) and operation noise of offshore wind turbines (below 500 Hz; Burns et al. 2022) overlaps with acoustic communication signals (Hatch et al. 2012). When combined, these impacts may negatively affect the foraging, migratory, nursery, and socializing habitat in the GOM.

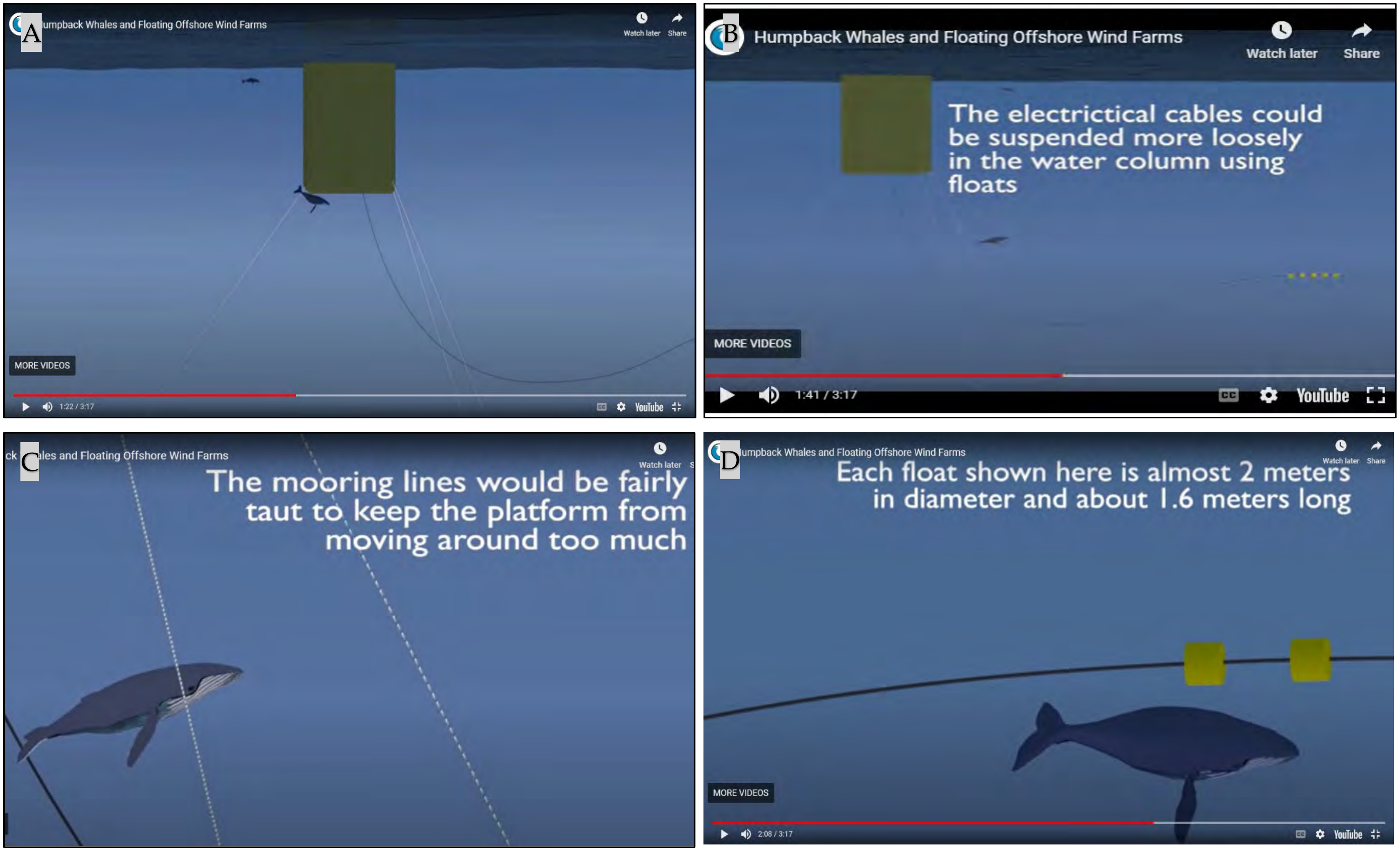

Figure 5.3.38. Video simulation of mother and calf humpback whale: A) enter a floating wind farm; B) swimming through mooring lines; C) swimming near horizontal electrical cable; D) swimming near electrical cable floats (Copping and Grear 2018).

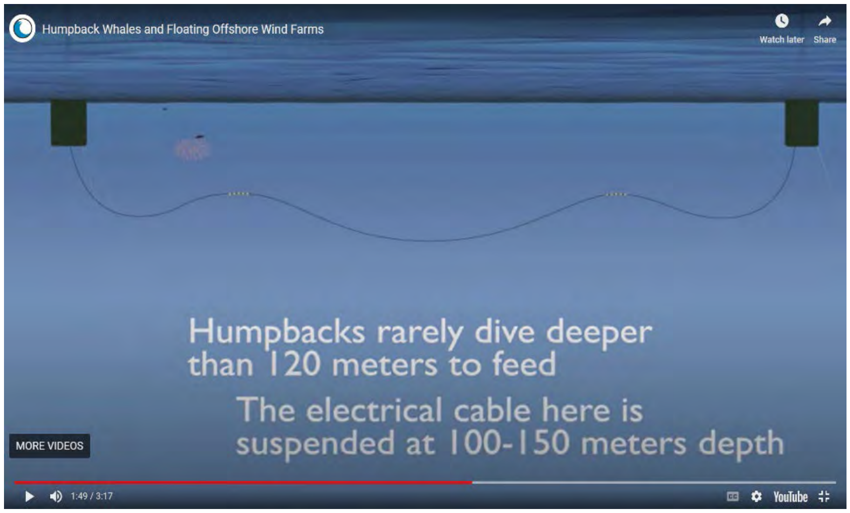

Figure 5.3.38. Continued. Mother and calf humpback whales foraging above electrical cable (Copping and Grear 2018).

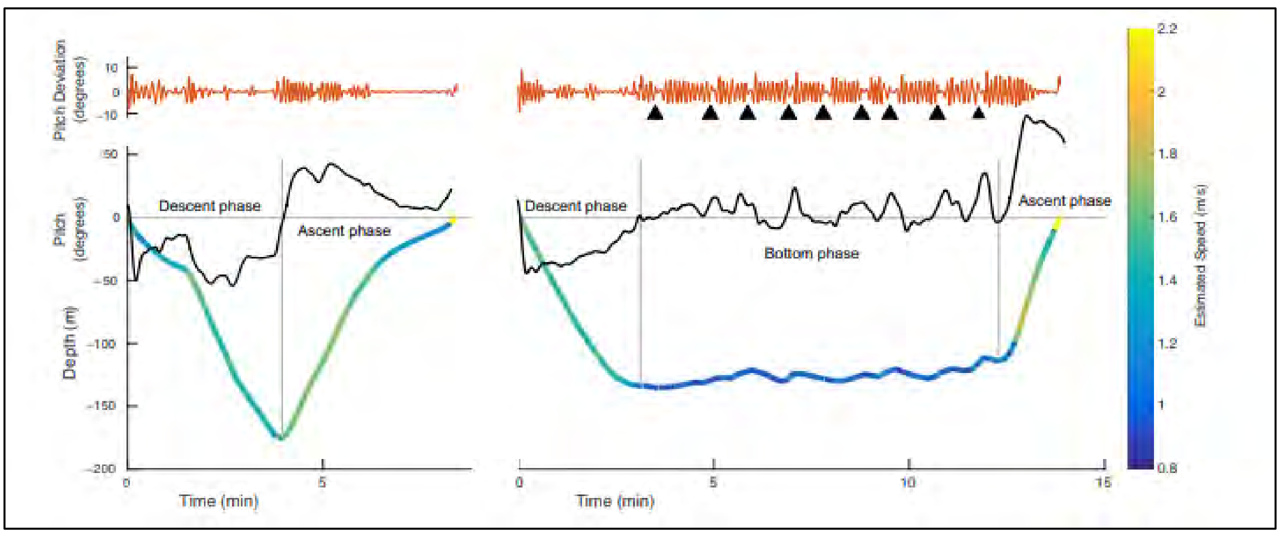

Figure 5.3.39. Example V-shaped non-foraging (left) and U-shaped foraging (right) dive profiles of NARW. Diving depth is colored by estimated speed (m/s), overlaid with total body pitch (degrees, black). Pitch deviation (degrees, orange) is plotted above each dive, with triangles indicating the start of pauses between fluking bouts detected in the foraging dive. Dive phases of descent, bottom, and ascent, as determined from the pitch record are also noted (Van Der Hoop et al. 2019).

Ongoing Studies

There are several ongoing studies that will provide relevant information on potential impacts from offshore floating wind farms when completed. For example, 1) Development of Computer Simulations to Assess Entanglement Risk to Whales and Leatherback Sea Turtles in Offshore Floating Wind Turbine Moorings, Cables, and Associated Derelict Fishing Gear Offshore California (BOEM 2019 – 2022; https://www.boem.gov/pr-19-ent-profile/ Infographic: https://www.boem.gov/PR-19-ENT-Infographic) and 2) A Vulnerability Index to Scale Effects of Offshore Renewable Energy on Marine Mammals and Sea Turtles of the U.S. West Coast (VIMMS; Southall Environmental Associates (SEA), Inc. 2021-2023; https://www.boem.gov/pc-21-04). This study will provide levels of concern for relevant species or groups, prioritizing which of these species need to be considered in assessments of risk from offshore renewable energy infrastructure, and inform the selection of renewable energy sites.

5.4 Birds and Bats

5.4.1 Birds

The potential impacts of offshore wind on the GOM's environment and wildlife are shared interests within the region and along the Atlantic coast. Strategic committees in multiple states are discussing the current state of the science surrounding the potential impacts to birds and bats, and future research needs and strategies to monitor, minimize, and/or mitigate impacts are under consideration. Eighteen construction and operation plans have been submitted to BOEM for the Atlantic coast, each of which describes potential impacts to birds and bats that might be caused by development of offshore wind within each represented project area. Analyses of the potential impacts to birds and bats consider the species within the area of impact and the "impact producing factors" associated with development that might have direct or indirect effects on the species of interest.

Direct effects are expected to occur within the same location and timeframe as the project activity. These include collision causing injury or mortality and displacement or attraction due to visible infrastructure, lighting, noise, and vessel traffic. Indirect effects may occur after the project activity and influence a different or larger area than the project site alone, which could include displacement associated with avoidance of visible infrastructure. Avoidance behaviors could result in increased energy expenditure or reduced fitness, influencing survival and breeding success if the species is displaced from preferred foraging habitat or late arriving to breeding or overwintering grounds thus losing access to prime breeding and foraging sites. Impacts may be short-term (temporary) or long-term (reoccurring or permanent).

This section seeks to define the species of birds potentially exposed to activities associated with the development of offshore wind in the GOM and to assess their risk of short- and long-term impact factors.

We performed a literature review to understand species composition and abundance of birds likely to occur in the GOM and the impact factors that could affect birds in the same area. Multiple datasets were queried (Table 5.4.1) to create a master list of species that could occur in the RFI Area. The geographic scope searched focused on the RFI Area and a buffer (data selection range) to capture species observed outside the RFI Area that could occur in the RFI Area (Figure 5.4.1). This was done because pelagic bird datasets often are not as comprehensive as those focused on terrestrial areas because of limited accessibility. We provide monthly relative abundance information along with qualitative descriptions of seasonal occurrences in the RFI Area for bird species groups. Each season corresponds to approximately the following months:

- Winter: January–March
- Spring: April–June
- Summer: July–September
- Fall: October–December

We also discuss the impact factors likely to affect birds in the RFI Area as floating offshore wind development begins and becomes more frequent.

Figure 5.4.1. Gulf of Maine RFI and buffer (data selection range).

Table 5.4.1. Data Queried for Bird Occurrence in the Gulf of Maine RFI.

Source	Description	Format	Species/Group Results	Survey Type	Timeframe
OBIS-SEAMAP	Aerial survey of upper trophic level predators on Platts Bank, Gulf of Maine	Spatial Dataset	Individual observation count	Aerial Visual	2005
OBIS-SEAMAP	Atlantic Canada Conservation Data Centre Rare Species in Atlantic Canada and Adjacent Marine Waters	Spatial Dataset	Individual observation count	Boat Visual	2000–2001
Northwest Atlantic Seabird Catalog	AMAPPS USFWS Aerial	Spatial Dataset	Individual observation count	Aerial Visual	2011–2018
Northwest Atlantic Seabird Catalog	AMAPPS NOAA/NMFS Boat Surveys	Spatial Dataset	Individual observation count	Boat Visual	2011, 2013–2016
Northwest Atlantic Seabird Catalog	Audubon Christmas Bird Counts	Spatial Dataset	Individual observation count	Point Counts	2000–2003
Northwest Atlantic Seabird Catalog	Bar Harbor Whale Watching – Seabird Surveys During Transit	Spatial Dataset	Individual observation count	Boat Visual	2006–2010
OBIS-SEAMAP	Beacon Wind Digital Aerial Wildlife Surveys for BOEM Lease Area OCS-A 0520	Spatial Dataset	Individual observation count	Aerial Digital	2019–2021

Table 5.4.1. Continued.

Source	Description	Format	Species/Group Results	Survey Type	Timeframe
Northwest Atlantic Seabird Catalog	Aerial Surveys for Roseate and Common Terns South of Tuckernuck and Muskeget Islands	Spatial Dataset	Individual observation count	Aerial Visual	July–September 2013
Northwest Atlantic Seabird Catalog	BOEM pilot studies using nanotags for tracking local and regional movements of tern species	Spatial Dataset	Nanotag tern species	Tags	2013
Northwest Atlantic Seabird Catalog	Ecosystems Monitoring Surveys on NOAA Research Vessels	Spatial Dataset	Individual observation count	Boat Visual	2009–2019
Northwest Atlantic Seabird Catalog	USFWS Atlantic Wind Seaduck Surveys	Spatial Dataset	Individual observation count	Aerial Visual	2008
Northwest Atlantic Seabird Catalog	Seabird Surveys during NOAA/National Marine Fisheries Service Acoustic Herring Surveys in the Gulf of Maine	Spatial Dataset	Individual observation count	Boat Visual	2009–2012
Northwest Atlantic Seabird Catalog	Massachusetts Audubon Nantucket Sound Aerial Seabird Surveys	Spatial Dataset	Individual observation count	Aerial Visual	2002–2006

Table 5.4.1. Continued.

Source	Description	Format	Species/Group Results	Survey Type	Timeframe
Northwest Atlantic Seabird Catalog	MassCEC	Spatial Dataset	Individual observation count	Aerial Visual	2011–2014
OBIS-SEAMAP	NOAA Southeast Fishery Science Center (SEFSC) Commercial Pelagic Observer Program (POP) Data	Spatial Dataset	Individual observation count	Boat Visual	2000
Northwest Atlantic Seabird Catalog	NOAA/National Marine Fisheries Service (NMFS)/Northeast Fishery Science Center (NEFSC) Seasonal Ecosystems Boat Surveys	Spatial Dataset	Individual observation count	Boat Visual	2004, 2007, 2014, 2018, 2019
Northwest Atlantic Seabird Catalog	NOAA Bycatch Surveys	Spatial Dataset	Individual observation count	Boat Bycatch	2000–2005
Northwest Atlantic Seabird Catalog	Aerial survey of Upper Trophic Level Predators on Platts Bank, Gulf of Maine	Spatial Dataset	Individual observation count	Aerial Visual	2005
Northwest Atlantic Seabird Catalog	Rhode Island Ocean Special Area Management Plan Aerial Surveys	Spatial Dataset	Individual observation count	Aerial Visual	2009–2010

Table 5.4.1. Continued.

Source	Description	Format	Species/Group Results	Survey Type	Timeframe
Northwest Atlantic Seabird Catalog	RISAMP Rhode Island Ocean Special Area Management Plan Boat Surveys Boat	Spatial Dataset	Individual observation count	Boat Visual	2009–2010
Northwest Atlantic Seabird Catalog	Statoil Surveys Offshore Boothbay Harbor, Maine	Spatial Dataset	Individual observation count	Boat Visual	2012–2013
Northwest Atlantic Seabird Catalog	Stellwagen Bank National Marine Sanctuary Surveys	Spatial Dataset	Individual observation count	Boat Visual	2012–2015
Northwest Atlantic Seabird Catalog	Woods Hole Oceanographic Institution Sept 2010	Spatial Dataset	Individual observation count	Boat Visual	2010
eBird.org	eBird Basic Dataset	Spatial Dataset	Individual observation count	Point Counts	2000–2022

Bird Species and Relative Abundance in the Gulf of Maine

Species Groups with Potential Exposure in the RFI Area

Geese, swans, ducks, mergansers, and grebes are most abundant during the winter months (October–March), but species such as Canada goose (*Branta canadensis*), mallard (*Anas platyrhynchos*), and common eider (*Somateria mollissima*) can be found in the RFI Area throughout the year (Table 5.4.2). Across these species groups, ducks, geese, and swans have low collision sensitivity while scaup, eiders, scoters, and mergansers have high collision susceptibility (Robinson Willmott et al. 2013). The same is true for displacement, except mergansers have low displacement sensitivity.

Nightjars are small nocturnal bird species that forage out in the open for insects on the wing during the spring, summer, and fall (Table 5.4.2). They are primarily terrestrial; however, they have been recorded in small numbers in pelagic environments in studies using aerial digital surveys (Robinson Willmott et al. 2021). This species group could be exposed to offshore wind turbines in small numbers given their aerial foraging tendencies.

The chimney swift (*Chaetura pelagica*) is the only member of the swift species group to occur in the RFI Area. Chimney swifts are a diurnal aerial insectivore that occurs over both terrestrial and nearshore habitats during the spring, summer, and fall (Steeves et al. 2014; Table 5.4.2). This species' tendency to forage in flight could expose it to offshore wind turbines.

Shorebirds are a large taxonomically diverse group that can be found in the RFI Area throughout the year; however, the highest number of shorebirds occur in this area during their spring and fall migration (Table 5.4.2). Other species such as the sanderling (*Calidris alba*), dunlin (*Calidris alpina*), and purple sandpiper (*Calidris maritima*) occur in the fall, winter, and spring (Table 5.4.2). While shorebirds do not forage in open water habitats, they do forage along the mudflats of the coastal areas and fly among the islands and other land areas to find new foraging areas. These inter-island flights could expose this species group to offshore wind turbines. Some shorebirds such as red knot (*Calidris canutus*) migrate over the open ocean, which could further expose them to offshore wind turbines. Shorebirds have moderate collision sensitivity and low displacement sensitivity (Robinson Willmott et al. 2013). Two members of this species group (piping plover [*Charadrius melodus*] and red knot) are federally threatened species and are of high conservation concern.

Phalaropes are a small-bodied pelagic species that primarily occurs in the RFI Area during the spring, summer, and fall migratory periods (Table 5.4.2). This species group forages on the open water and sometimes in large flocks, which could expose them to offshore wind turbines. Red-necked phalarope (*Phalaropus lobatus*) and red phalarope (*Phalaropus fulicarius*) have high collision sensitivity; displacement sensitivity is thought to be low for red-necked phalarope and moderate for red phalarope (Robinson Willmott et al. 2013).

Skuas and jaegers are medium-sized birds that can occur in the RFI Area during fall migration (Table 5.4.2). These species occur over the open water in the RFI Area and either can be found sitting on the water's surface or harassing other birds for their prey. The occurrence of this species group both on the water's surface and in the air could expose this species group to offshore wind turbines. Skuas and jaegers have high collision sensitivity, but low displacement sensitivity (Robinson Willmott et al. 2013).

Auks are a species group consisting of small to medium-sized birds that mainly occur in the RFI Area during winter but some species such as the black guillemot (*Cepphus grylle*) and Atlantic puffin (*Fratercula arctica*) occur in the RFI Area during the spring and summer months (Table 5.4.2). During this time, these species typically remain in flocks and forage by diving underwater to catch small animals, including crustaceans and fish. Foraging in the water column and resting on the water's surface means this species group could be exposed to underwater mooring lines and to offshore turbines during flights. Auks have moderate to high collision and displacement sensitivity (Robinson Willmott et al. 2013).

Gulls are a diverse taxonomic group in the RFI Area, and many species such as ring-billed gull (*Larus delawarensis*) and herring gull (*Larus argentatus*) occur year-round (Table 5.4.2). Body size of species of gull ranges from small to large, and these species commonly occur both on the water's surface and in flight above the water. These behaviors could expose this species group to offshore wind turbines. Given the species diversity of gulls, both collision and displacement sensitivity ranges from low to high depending on the species (Robinson Willmott et al. 2013).

Terns are small to medium-sized birds that occur in the RFI Area during the spring, summer, and fall (Table 5.4.2). These species commonly forage for small fish by hovering above the water and plunge-diving to catch their prey just below the water's surface. Some species will also attempt to steal food from other species or conspecifics, and members of this species group will forage together in small flocks. These behaviors could expose this species group to offshore wind turbines. The roseate tern (*Sterna dougallii*) is a federally endangered species and is of high conservation concern. Terns have a wide range of collision and displacement sensitivity from low to high depending on the species of interest (Robinson Willmott et al. 2013).

The black skimmer (*Rhynchops niger*) is the only member of the skimmer species group to occur in the RFI Area. This species occurs in the RFI Area during the summer and fall (Table 5.4.2) and forages in small groups by flying just above water level with their bill in the water, capturing fish and crustaceans (Gochfeld and Burger 1994). Their flight behavior could expose this species to offshore turbines, primarily during non-foraging periods. Black skimmers have moderate collision sensitivity and low displacement sensitivity (Robinson Willmott et al. 2013).

Tropicbirds are seabirds that catch prey by hovering above the water's surface and plunge-diving for fish and squid. Birds in this species group could be exposed to offshore wind turbines during flight while foraging and to mooring cables while diving. Tropicbirds have been recorded in very small numbers during summer and fall in the RFI Area (Table 5.4.2). Tropicbirds have high collision sensitivity and low–moderate displacement sensitivity (Robinson Willmott et al. 2013).

Loons are medium-sized birds that spend most of their time on the water's surface and periodically dive to catch fish. They occur in the RFI Area mainly during the winter months though isolated records can be found throughout the year, especially for common loon (*Gavia immer*; Table 5.4.2). Robinson Willmott et al. (2013) found that loons have high collision and displacement sensitivity.

Storm-petrels are usually only seen in the spring, summer, and fall in the RFI Area (Table 5.4.2). These birds occur in small groups while feeding on plankton from the water's surface (Sibley 2014). Exposure to offshore wind turbines is most likely when the bird is traveling among foraging areas, but its rarity is likely to make overall exposure low. This species group typically has high collision sensitivity and moderate displacement sensitivity (Robinson Willmott et al. 2013).

Fulmars and petrels can be found throughout the year, though minimally in July and August (Table 5.4.2). Northern fulmar (*Fulmarus glacialis*) forage by capturing fish, squid, and crustaceans at or just below the water's surface (Mallory et al. 2012). Given the tendency to forage on the water's surface, this behavior could expose them to offshore wind turbines during flight and to the mooring cables when making shallow dives. Members of this species group have high collision sensitivity and moderate–high displacement sensitivity (Robinson Willmott et al. 2013).

Shearwaters can occur in the RFI Area from spring through fall, with the largest numbers in the summer and fall (Table 5.4.2). These medium-sized birds forage by swimming or diving for fish and marine invertebrates. This behavior could expose this species group to mooring lines when diving. This species group also spends significant time flying above the water, which could expose them to offshore wind turbines. Shearwaters have a high collision sensitivity and low–high displacement sensitivity depending on the species (Robinson Willmott et al. 2013).

The magnificent frigatebird (*Fregata magnificens*) is the only member of the frigatebird species group observed within the buffer (data selection range) but not within the RFI Area (Figure 5.4.1). This species is uncommon in the area and forages by grabbing fish from the water's surface without landing on the water (Diamond and Schreiber 2002). This behavior could cause this species to be exposed to offshore wind turbines though its rarity in the area suggests the likelihood of exposure is low.

The brown booby (*Sula leucogaster*) is the only member of the booby species group observed in the RFI Area and is rare in the area, though other species have been observed in the buffer (data selection range; Figure 5.4.1). They forage by soaring over the open water and then diving to catch fish and squid (Schreiber and Norton 2002). This behavior could expose this species to offshore wind turbines in the RFI Area along with mooring lines. Brown boobies have high collision sensitivity and moderate displacement sensitivity (Robinson Willmott et al. 2013).

The northern gannet (*Morus bassanus*) is the only member of the gannet species group observed in the RFI Area. This species is most common in the winter and less common in other seasons

(Table 5.4.2). Gannets forage by diving deep into the water in large flocks to catch fish (Mowbray 2002). This foraging and flocking behavior could expose them to offshore wind turbines and to underwater mooring lines. Northern gannets have a high collision and displacement sensitivity (Robinson Willmott et al. 2013).

Cormorants occur in the RFI Area throughout the year, and double-crested cormorants (*Phalacrocorax auritus*) are abundant from April to November (Table 5.4.2). They spend time on the water's surface and diving underwater to catch fish and crustaceans. This foraging behavior could expose them to offshore wind turbines and mooring cables underwater. Cormorants have high collision sensitivity and moderate to high displacement sensitivity (Robinson Willmott et al. 2013).

Pelicans are large birds that spend time on the water's surface and diving from aerial positions to catch fish. They occur in small numbers, primarily in the fall and winter (Table 5.4.2). While their behavior could expose them to wind turbine infrastructure the rarity of this species group in the RFI Area makes collisions unlikely. Brown pelicans (*Pelecanus occidentalis*) have high collision sensitivity and moderate displacement sensitivity; however, this has not been quantified for the American white pelican (*Pelecanus erythrorhynchos*; Robinson Willmott et al. 2013). Only the brown pelican has been observed in the RFI Area.

Vultures, raptors, and owls can occur in the RFI Area throughout the year (Table 5.4.2) and primarily use terrestrial environments for foraging and nesting. The two exceptions are osprey (*Pandion haliaetus*) and bald eagle (*Haliaeetus leucocephalus*), in which fish are a significant portion of their diets, and these species are more likely to occur over open water (Buehler 2000, Poole et al. 2002). Other raptor species are likely to only use the open water areas of the RFI Area while commuting among islands and other landmasses. The foraging and nesting preferences of most species in this group suggest exposure to offshore wind turbine infrastructure should be minimal. Robinson Willmott et al. (2013) quantified collision and displacement sensitivity for falcons (members of the raptor family) and found that they showed moderate collision sensitivity and low displacement sensitivity.

The belted kingfisher (*Megaceryle alcyon*) is the only member of the kingfisher species group observed in the RFI Area and occurs in small numbers throughout the year (Table 5.4.2). While this species is small, it forages by diving into open water for prey (Kelly et al. 2009) and could be exposed to offshore wind turbines and mooring lines.

Passerines are the most diverse species group in the RFI Area throughout the year (Table 5.4.2). Passerines are terrestrial and thus only use the open water areas of the RFI Area while commuting among islands and other landmasses; therefore, they should have minimal exposure to offshore wind turbines. Some species with low population sizes migrate over the open ocean such as Kirtland's warbler (*Setophaga kirtlandii*) and Bicknell's thrush (*Catharus bicknelli*) have moderate collision vulnerability, but otherwise most passerines have low collision and displacement sensitivity (Robinson Willmott et al. 2013).

Species Groups with Minimal Potential Exposure in the RFI Area

Members of the Galliformes are large terrestrial land birds such as turkeys and grouse that can occur throughout the year in the RFI Area (Table 5.4.2). This species group is not commonly observed over open water, thus exposure to offshore wind turbines should be low.

Pigeons and doves are primarily terrestrial species that would only use aquatic habitats when flying among the islands and mainland in the RFI Area. Mourning doves (*Zenaida macroura*) and rock pigeons (*Columba livia*) occur year-round while other members of this species group are much less abundant (Table 5.4.2). Exposure to offshore wind turbines is unlikely given this species group uses aquatic habitat infrequently and only during flight among terrestrial areas.

Cuckoos are small terrestrial forest-dwelling birds that primarily occur in the RFI Area during summer and fall (Table 5.4.2). Their tendency to inhabit woodlands means they are unlikely to be exposed to offshore wind turbines in the RFI Area.

The ruby-throated hummingbird (*Archilochus colubris*) is the only member of the hummingbird family to have been observed in the RFI Area, though other hummingbird species have been observed in the buffer (data selection range; Figure 5.4.1, Table 5.4.2). The ruby-throated hummingbird occurs in the RFI Area during the spring, summer, and fall (Table 5.4.2) and is primarily terrestrial as it feeds on nectar and small insects (Weidensaul et al. 2013). This species is only likely to use open aquatic environments during travel among islands in the RFI Area or during migration thus exposure to turbines should be low.

Rail species commonly inhabit marsh habitats with large amounts of emergent aquatic vegetation. Only the sora (*Porzana carolina*) has been observed in the RFI Area during the spring, summer, and fall (Table 5.4.2), though other rail species have been observed in the buffer (data selection range; Figure 5.4.1). As this species group occurs less frequently in open water compared to geese and ducks (Brisbin et al. 2002), they are less likely to be exposed to offshore wind in the RFI Area. Rails have moderate collision sensitivity and low displacement sensitivity (Robinson Willmott et al. 2013).

The sandhill crane (*Grus canadensis*) is the only member of the crane species group to occur in the buffer (data selection range) but not the RFI Area; it is most abundant during the fall (Table 5.4.2). Their occurrence in the open waters of the buffer (data selection range) only occurs while traversing among islands within the area; they do not forage in open pelagic waters (Gerber et al. 2014), thus their exposure to offshore wind turbines should be low.

Members of the long-legged wading birds (bitterns, herons, ibis, storks) can be found in the RFI Area throughout the year with abundance being the lowest during the winter (Table 5.4.2). Most members of these species groups are medium to large-size birds that forage in shallow water or wetlands while feeding on everything from insects to crustaceans to fish. These species groups rely on the open water areas of the RFI Area when commuting between terrestrial foraging areas. While these species groups will occur along the coast, they will spend most of their time nearer to shore rather than in the open water areas. Species in this group have moderate collision sensitivity but low displacement sensitivity (Robinson Willmott et al. 2013).

Woodpeckers are a mostly small-bodied group of birds that occur in the RFI Area throughout the year (Table 5.4.2). This species group is strongly associated with woody vegetation for foraging and nesting and only uses open water areas while commuting among islands and landmasses. These tendencies mean the time spent flying over open water is low, thus exposure to offshore wind turbines should be minimal.

Table 5.4.2. Bird Species' Abundance per Month (Birds/Count).

The monthly columns display gray bars showing the abundance of each species per month scaled to the abundance of all the species, not individually. Long bars indicate higher abundance while shorter bars indicate lower. Cells are colored to highlight the most abundant months for each species individually with the highest month indicated by the darkest color and a thick border. The orange bar charts show the relative abundance by month within a species.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Overall	JFMAMJJASOND	Species has been observed within RFI boundary
Ducks, Geese, and Waterfowl															
Black-bellied Whistling-Duck													0.001072		
Snow Goose													0.015484		
Ross's Goose													0.000539		
Graylag Goose													4.19E-06		
Greater White-fronted Goose													0.001457		
Pink-footed Goose													0.000751		
Brant													1.09354		yes
Barnacle Goose													0.000433		
Cackling Goose													0.000669		
Canada Goose													7.401201		yes
Mute Swan													0.327683		yes
Trumpeter Swan													7.97E-05		
Tundra Swan													0.000159		
Common Shelduck													0.000107		
Muscovy Duck													4.61E-05		
Wood Duck													0.083656		yes
Garganey													1.68E-06		
Blue-winged Teal													0.02921		yes
Northern Shoveler													0.028677		
Gadwall													0.303062		
Eurasian Wigeon													0.003556		
American Wigeon													0.239732		yes
Mallard													3.4514		yes
American Black Duck													3.794823		yes
Northern Pintail													0.192804		
Green-winged Teal													0.561433		yes
Canvasback													0.021721		
Redhead													0.008644		
Ring-necked Duck													0.203793		
Tufted Duck													0.000596		
Greater Scaup													0.722066		yes
Lesser Scaup													0.082692		
King Eider													0.004577		
Common Eider													20.82943		yes
Harlequin Duck													0.29045		yes
Surf Scoter													1.859874		yes
Velvet Scoter													0.003744		yes
White-winged Scoter													2.699449		yes
Black Scoter													2.876807		yes
Long-tailed Duck													5.347815		yes

Table 5.4.2. Continued.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Overall	JFMAMJJASOND	Species has been observed within RFI boundary
Bufflehead													1.939003		yes
Common Goldeneye													0.604563		yes
Barrow's Goldeneye													0.005157		yes
Hooded Merganser													0.245264		yes
Common Merganser													0.128945		yes
Red-breasted Merganser													1.856263		yes
Ruddy Duck													0.175077		
New World Quail															
Northern Bobwhite													0.003553		
Pheasants, Grouse, and Allies															
Wild Turkey													0.237237		yes
Ruffed Grouse													0.005773		
Willow Ptarmigan													8.39E-07		
Spruce Grouse													0.00069		yes
Ring-necked Pheasant													0.011095		
Chukar													8.39E-07		
Grebes															
Pied-billed Grebe													0.014476		yes
Horned Grebe													0.16455		yes
Red-necked Grebe													0.127752		yes
Eared Grebe													0.000621		
Western Grebe													0.000454		
Clark's Grebe													1.68E-06		
Pigeons and Doves															
Rock Pigeon													1.490615		yes
Eurasian Collared-Dove													4.53E-05		
White-winged Dove													0.000416		yes
Mourning Dove													1.114296		yes
Cuckoos															
Yellow-billed Cuckoo													0.004275		yes
Black-billed Cuckoo													0.004795		
Nightjars and Allies															
Common Nighthawk													0.014379		yes
Chuck-will's-widow													0.000375		
Eastern Whip-poor-will													0.005303		
Swifts															
Chimney Swift													0.155085		yes
Hummingbirds															
Ruby-throated Hummingbird													0.075964		yes
Black-chinned Hummingbird													1.34E-05		
Calliope Hummingbird													1.76E-05		
Rufous Hummingbird													0.000305		
Allen's Hummingbird													1.93E-05		
Broad-billed Hummingbird													2.85E-05		
Rails, Gallinules, and Coots															
King Rail													0.000534		
Clapper Rail													0.003166		
Virginia Rail													0.009994		

Table 5.4.2. Continued.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Overall	JFMAMJJASOND	Species has been observed within RFI boundary
Corn Crake													8.39E-07		
Sora													0.004574		yes
Common Gallinule													0.001292		
American Coot													0.11981		
Purple Gallinule													8.39E-05		
Yellow Rail													3.27E-05		
Cranes															
Sandhill Crane													0.000723		
Shorebirds															
Black-necked Stilt													0.000412		
American Avocet													0.002291		
American Oystercatcher													0.091243		yes
Black-bellied Plover													1.457042		yes
European Golden-Plover													8.98E-05		
American Golden-Plover													0.006842		yes
Pacific Golden-Plover													7.38E-05		
Northern Lapwing													0.000309		
Snowy Plover													1.68E-06		
Wilson's Plover													9.31E-05		
Common Ringed Plover													0.000126		
Semipalmated Plover													2.608925		yes
Piping Plover													0.118784		
Killdeer													0.165381		yes
Mountain Plover													8.39E-07		
Upland Sandpiper													0.001725		
Whimbrel													0.03513		yes
Bar-tailed Godwit													4.95E-05		
Black-tailed Godwit													2.10E-05		
Hudsonian Godwit													0.015086		
Marbled Godwit													0.002712		yes
Ruddy Turnstone													0.259401		yes
Great Knot													1.68E-06		
Red Knot													0.180177		yes
Surfbird													9.23E-05		
Ruff													0.000302		
Stilt Sandpiper													0.01141		
Curlew Sandpiper													0.000194		
Red-necked Stint													4.53E-05		
Sanderling													2.12942		yes
Dunlin													1.102909		yes
Purple Sandpiper													0.266468		yes
Baird's Sandpiper													0.002532		
Little Stint													0.0002		
Least Sandpiper													0.599499		yes
White-rumped Sandpiper													0.088745		yes
Buff-breasted Sandpiper													0.001384		
Pectoral Sandpiper													0.016517		
Semipalmated Sandpiper													4.721138		yes
Western Sandpiper													0.003047		
Short-billed Dowitcher													0.941439		yes

Table 5.4.2. Continued.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Overall	JFMAMJJASOND	Species has been observed within RFI boundary
Long-billed Dowitcher													0.006689		
American Woodcock													0.013119		
Common Snipe													2.52E-06		
Wilson's Snipe													0.0208		yes
Wilson's Phalarope													0.001832		
Red-necked Phalarope													0.177373		yes
Red Phalarope													0.085429		yes
Spotted Sandpiper													0.094763		yes
Solitary Sandpiper													0.010728		yes
Gray-tailed Tattler													1.17E-05		
Greater Yellowlegs													0.707169		yes
Willet													0.347209		yes
Lesser Yellowlegs													0.196617		yes
Great Skua													0.001071		yes
South Polar Skua													0.001461		yes
Pomarine Jaeger													0.016931		yes
Parasitic Jaeger													0.028914		yes
Long-tailed Jaeger													0.000812		yes
Auks															
Dovekie													0.079676		yes
Common Murre													0.127472		yes
Thick-billed Murre													0.026459		yes
Razorbill													1.525144		yes
Black Guillemot													1.184112		yes
Ancient Murrelet													1.17E-05		
Atlantic Puffin													1.27628		yes
Tufted Puffin													2.43E-05		
Gulls, Terns, and Skimmers															
Black-legged Kittiwake													0.456794		yes
Ivory Gull													0.000114		
Sabine's Gull													0.00027		yes
Bonaparte's Gull													1.353133		yes
Black-headed Gull													0.001678		yes
Little Gull													0.001504		yes
Ross's Gull													3.36E-06		yes
Laughing Gull													2.293727		yes
Franklin's Gull													8.05E-05		yes
Black-tailed Gull													4.19E-06		
Heermann's Gull													1.17E-05		
Common Gull													0.000229		
Short-billed Gull													9.39E-05		
Ring-billed Gull													3.224299		yes
California Gull													8.39E-06		
Herring Gull													13.99616		yes
Iceland Gull													0.048249		yes
Lesser Black-backed Gull													0.04554		yes
Slaty-backed Gull													5.03E-05		
Glaucous Gull													0.005352		yes

Table 5.4.2. Continued.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Overall	JFMAMJJASOND	Species has been observed within RFI boundary
Great Black-backed Gull													4.335366		yes
Sooty Tern													6.71E-06		
Bridled Tern													3.10E-05		
Little Tern													2.52E-06		
Least Tern													0.534301		yes
Gull-billed Tern													0.000248		
Caspian Tern													0.003275		yes
Black Tern													0.024664		yes
White-winged Tern													1.68E-06		
Roseate Tern													0.315526		yes
Common Tern													6.802033		yes
Arctic Tern													0.521678		yes
Forster's Tern													0.045499		yes
Royal Tern													0.000465		
Sandwich Tern													7.72E-05		
Elegant Tern													9.23E-06		
Black Skimmer													0.009137		
Tropicbirds															
White-tailed Tropicbird													8.39E-07		yes
Red-billed Tropicbird													0.001103		yes
Loons															
Red-throated Loon													0.370761		yes
Pacific Loon													0.000858		yes
Common Loon													0.612205		yes
Yellow-billed Loon													0.000181		
Albatrosses															
Yellow-nosed Albatross													1.17E-05		
Storm-Petrels															
Wilson's Storm-Petrel													0.841305		yes
White-faced Storm-Petrel													8.64E-05		yes
Black-bellied Storm-petrel													8.39E-07		yes
Leach's Storm-Petrel													0.035943		yes
Band-rumped Storm-Petrel													2.77E-05		yes
Tristram's Storm-Petrel													8.39E-07		
Least Storm-petrel													1.68E-06		yes
Shearwaters and Petrels															
Northern Fulmar													0.098605		yes
Fea's Petrel													5.03E-06		
Bermuda Petrel													8.39E-07		
Black-capped Petrel													9.23E-06		
White-chinned Petrel													8.39E-07		yes
Cory's Shearwater													0.759635		yes
Great Shearwater													2.785532		yes
Sooty Shearwater													0.318007		yes
Manx Shearwater													0.092935		yes
Little Shearwater													1.59E-05		
Barolo Shearwater													8.39E-07		yes
Audubon's Shearwater													0.000111		yes
Storks															
Wood Stork													8.14E-05		

Table 5.4.2. Continued.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Overall	JFMAMJJASOND	Species has been observed within RFI boundary
Frigatebirds															
Magnificent Frigatebird													3.61E-05		
Boobies and Gannets															
Masked Booby													2.52E-06		
Brown Booby													0.000179		yes
Red-footed Booby													1.68E-06		
Northern Gannet													2.182321		yes
Cormorants and Shags															
Great Cormorant													0.200195		yes
Double-crested Cormorant													7.444411		yes
Pelicans															
American White Pelican													0.000312		
Brown Pelican													0.000174		yes
Herons, Egrets, and Bitterns															
American Bittern													0.003448		yes
Least Bittern													0.00266		
Great Blue Heron													0.297597		yes
Gray Heron													2.52E-06		
Great Egret													0.556046		yes
Little Egret													0.000868		
Western Reef-Heron													2.43E-05		
Snowy Egret													0.560805		yes
Little Blue Heron													0.01354		
Tricolored Heron													0.002006		
Cattle Egret													0.001523		
Green Heron													0.020002		
Black-crowned Night-Heron													0.064702		yes
Yellow-crowned Night-Heron													0.008178		
Ibises and Spoonbills															
White Ibis													0.002318		
Glossy Ibis													0.223214		yes
White-faced Ibis													0.000931		
New World Vultures															
Black Vulture													0.004435		
Turkey Vulture													0.172134		yes
Osprey															
Osprey													0.265864		yes
Hawks, Eagles, and Kites															
Swallow-tailed Kite													2.43E-05		
Golden Eagle													8.56E-05		
Mississippi Kite													0.000127		
Eurasian Marsh-Harrier													4.78E-05		
Northern Harrier													0.087672		yes
Sharp-shinned Hawk													0.032837		yes
Cooper's Hawk													0.046877		yes
Northern Goshawk													0.000666		yes
Bald Eagle													0.088029		yes
Steller's Sea-Eagle													0.000865		
Great Black Hawk													0.000602		

Table 5.4.2. Continued.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Overall	JFMAMJJASOND	Species has been observed within RFI boundary
Red-shouldered Hawk													0.009808		
Broad-winged Hawk													0.03654		yes
Swainson's Hawk													5.87E-06		
Zone-tailed Hawk													8.39E-07		
Red-tailed Hawk													0.141022		yes
Rough-legged Hawk													0.00665		
Owls															
Barn Owl													0.000825		
Eastern Screech-Owl													0.007356		
Snowy Owl													0.021077		
Great Horned Owl													0.008534		
Northern Hawk Owl													8.39E-07		
Barred Owl													0.007909		
Long-eared Owl													0.000445		
Short-eared Owl													0.003978		yes
Boreal Owl													2.52E-06		
Northern Saw-whet Owl													0.001829		
Kingfishers															
Belted Kingfisher													0.070985		yes
Woodpeckers															
Yellow-bellied Sapsucker													0.028093		yes
Red-headed Woodpecker													0.001018		
Red-bellied Woodpecker													0.137375		
Black-backed Woodpecker													0.000229		
Downy Woodpecker													0.361131		yes
Hairy Woodpecker													0.105969		
Pileated Woodpecker													0.024993		yes
Northern Flicker													0.262261		yes
Falcons and Caracaras															
Crested Caracara													1.43E-05		
Eurasian Kestrel													1.09E-05		
American Kestrel													0.034268		yes
Red-footed Falcon													3.44E-05		
Merlin													0.037963		yes
Eurasian Hobby													5.03E-06		
Peregrine Falcon													0.03676		yes
Passerines															
Olive-sided Flycatcher													0.001505		
Western Wood-Pewee													6.71E-06		
Eastern Wood-Pewee													0.035272		
Yellow-bellied Flycatcher													0.003976		yes
Acadian Flycatcher													0.000662		
Alder Flycatcher													0.01895		
Willow Flycatcher													0.025043		
Least Flycatcher													0.019034		yes
Hammond's Flycatcher													1.17E-05		
Gray Flycatcher													3.36E-06		
Eastern Phoebe													0.17405		yes
Say's Phoebe													6.21E-05		

Table 5.4.2. Continued.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Overall	JFMAMJJASOND	Species has been observed within RFI boundary
Vermilion Flycatcher													5.03E-06		
Ash-throated Flycatcher													0.000375		
Great Crested Flycatcher													0.060929		yes
Tropical Kingbird													0.000175		
Couch's Kingbird													1.68E-06		
Cassin's Kingbird													8.39E-07		
Western Kingbird													0.000958		
Eastern Kingbird													0.142048		yes
Gray Kingbird													0.000282		
Scissor-tailed Flycatcher													0.000194		
Fork-tailed Flycatcher													0.00015		
White-eyed Vireo													0.003591		
Bell's Vireo													0.000137		
Yellow-throated Vireo													0.00158		
Cassin's Vireo													5.87E-06		
Blue-headed Vireo													0.056016		yes
Philadelphia Vireo													0.00478		
Warbling Vireo													0.032626		
Red-eyed Vireo													0.15624		yes
Yellow-green Vireo													6.71E-06		
Black-whiskered Vireo													8.39E-07		
Loggerhead Shrike													5.87E-06		
Northern Shrike													0.002904		
Canada Jay													0.000363		
Blue Jay													1.161153		yes
American Crow													2.096225		yes
Fish Crow													0.091863		yes
Common Raven													0.061388		yes
Black-capped Chickadee													1.748066		yes
Boreal Chickadee													0.000693		
Tufted Titmouse													0.549924		
Horned Lark													0.211147		yes
Northern Rough-winged Swallow													0.036766		yes
Purple Martin													0.142954		yes
Tree Swallow													20.2085		yes
Violet-green Swallow													7.55E-06		
Bank Swallow													0.084714		yes
Barn Swallow													0.53503		yes
Cliff Swallow													0.008597		yes
Cave Swallow													0.000304		
Ruby-crowned Kinglet													0.104249		yes
Golden-crowned Kinglet													0.191049		yes
Red-breasted Nuthatch													0.276858		yes
White-breasted Nuthatch													0.29439		yes
Brown Creeper													0.048006		yes
Blue-gray Gnatcatcher													0.027153		
Rock Wren													0.000223		
House Wren													0.059941		yes
Winter Wren													0.027603		yes
Sedge Wren													0.000229		

Table 5.4.2. Continued.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Overall	JFMAMJJASOND	Species has been observed within RFI boundary
Marsh Wren													0.047615		yes
Carolina Wren													0.203737		
European Starling													5.058877		yes
Gray Catbird													0.824515		yes
Brown Thrasher													0.035719		yes
Sage Thrasher													4.70E-05		
Northern Mockingbird													0.216894		yes
Eastern Bluebird													0.173636		
Mountain Bluebird													0.000223		
Townsend's Solitaire													0.000471		
Varied Thrush													5.96E-05		
Veery													0.028072		
Gray-cheeked Thrush													0.000258		
Bicknell's Thrush													5.87E-06		
Swainson's Thrush													0.024048		yes
Hermit Thrush													0.102058		yes
Wood Thrush													0.016575		yes
Redwing													0.000469		
American Robin													3.376322		yes
Northern Wheatear													0.000185		
Bohemian Waxwing													0.01935		
Cedar Waxwing													0.858354		yes
House Sparrow													1.797263		yes
White Wagtail													1.93E-05		
American Pipit													0.036144		yes
Sprague's Pipit													8.39E-07		
Evening Grosbeak													0.01027		
Pine Grosbeak													0.005852		yes
House Finch													0.670086		yes
Purple Finch													0.106901		yes
Common Redpoll													0.067636		yes
Hoary Redpoll													0.00018		
Red Crossbill													0.047398		
White-winged Crossbill													0.047696		
Pine Siskin													0.135319		yes
American Goldfinch													1.525096		yes
Lapland Longspur													0.006415		
Chestnut-collared Longspur													3.52E-05		
Smith's Longspur													0.000152		
Snow Bunting													0.310077		yes
Cassin's Sparrow													2.01E-05		
Grasshopper Sparrow													0.005698		
Chipping Sparrow													0.347636		yes
Clay-colored Sparrow													0.003998		yes
Field Sparrow													0.038315		
Brewer's Sparrow													2.10E-05		
Black-throated Sparrow													5.37E-05		
Lark Sparrow													0.001924		yes
Lark Bunting													5.12E-05		
American Tree Sparrow													0.111647		yes

Table 5.4.2. Continued.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Overall	JFMAMJJASOND	Species has been observed within RFI boundary
Fox Sparrow													0.010882		
Dark-eyed Junco													0.596778		yes
White-crowned Sparrow													0.029663		yes
Golden-crowned Sparrow													4.70E-05		
Harris's Sparrow													6.29E-05		
White-throated Sparrow													0.631163		yes
Vesper Sparrow													0.001969		
LeConte's Sparrow													4.45E-05		
Seaside Sparrow													0.00363		yes
Nelson's Sparrow													0.018799		
Saltmarsh Sparrow													0.047863		
Savannah Sparrow													0.25027		yes
Henslow's Sparrow													0.000299		
Song Sparrow													1.576812		yes
Lincoln's Sparrow													0.010634		yes
Swamp Sparrow													0.094952		yes
Green-tailed Towhee													3.61E-05		
Spotted Towhee													0.000117		
Eastern Towhee													0.292989		yes
Yellow-breasted Chat													0.003136		yes
Yellow-headed Blackbird													0.000242		
Bobolink													0.132386		yes
Western Meadowlark													1.59E-05		
Eastern Meadowlark													0.019418		yes
Orchard Oriole													0.021058		
Bullock's Oriole													0.000291		
Baltimore Oriole													0.158446		yes
Red-winged Blackbird													1.727813		yes
Bronzed Cowbird													8.39E-07		
Brown-headed Cowbird													0.246336		yes
Rusty Blackbird													0.008661		yes
Common Grackle													1.802296		yes
Great-tailed Grackle													1.68E-06		
Ovenbird													0.134156		yes
Worm-eating Warbler													0.001868		
Louisiana Waterthrush													0.001096		
Northern Waterthrush													0.021426		yes
Golden-winged Warbler													0.000131		
Blue-winged Warbler													0.007797		
Black-and-white Warbler													0.150449		yes
Prothonotary Warbler													0.000426		
Swainson's Warbler													3.19E-05		
Tennessee Warbler													0.007294		yes
Orange-crowned Warbler													0.004299		
Nashville Warbler													0.02809		yes
Virginia's Warbler													6.71E-06		
Connecticut Warbler													0.000261		
MacGillivray's Warbler													0.000115		
Mourning Warbler													0.002142		yes
Kentucky Warbler													0.000424		

Table 5.4.2. Continued.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Overall	JFMAMJJASOND	Species has been observed within RFI boundary
Common Yellowthroat													0.387586		yes
Hooded Warbler													0.001021		yes
American Redstart													0.184508		yes
Cape May Warbler													0.01577		yes
Cerulean Warbler													0.000284		
Northern Parula													0.195392		yes
Magnolia Warbler													0.092069		yes
Bay-breasted Warbler													0.012419		yes
Blackburnian Warbler													0.02816		yes
Yellow Warbler													0.35177		yes
Chestnut-sided Warbler													0.048515		yes
Blackpoll Warbler													0.084033		yes
Black-throated Blue Warbler													0.043663		yes
Palm Warbler													0.081212		yes
Pine Warbler													0.126145		yes
Yellow-rumped Warbler													0.851		yes
Yellow-throated Warbler													0.000493		
Prairie Warbler													0.021892		
Black-throated Gray Warbler													5.79E-05		
Townsend's Warbler													0.000278		
Hermit Warbler													1.68E-06		
Black-throated Green Warbler													0.171038		yes
Canada Warbler													0.014144		yes
Wilson's Warbler													0.020491		yes
Painted Redstart													2.52E-06		
Summer Tanager													0.000846		
Scarlet Tanager													0.020513		yes
Western Tanager													0.000467		
Northern Cardinal													0.785875		
Rose-breasted Grosbeak													0.027599		yes
Black-headed Grosbeak													6.96E-05		
Blue Grosbeak													0.001426		
Lazuli Bunting													8.30E-05		
Indigo Bunting													0.013793		
Painted Bunting													0.000258		
Dickcissel													0.005414		yes

ESA Listed Species

The federally endangered and threatened bird species likely to occur in the RFI Area include roseate tern, red knot, and piping plover. There is no critical habitat designated for roseate tern and no critical habitat overlaps the RFI Area for piping plover. There is proposed critical habitat for red knot in Massachusetts (MA-1 Pleasant Bay and MA-2 Monomoy National Wildlife Refuge), but these areas, while adjacent to the RFI Area, do not overlap it (50 CFR Part 17 2021).

Piping Plover

Piping plover are migratory shorebirds with nesting populations that breed along the U.S. Atlantic coast and winter in the southeastern U.S. and Caribbean (Burger et al. 2011). Piping plovers have not been observed in the RFI Area but have been detected in the buffer (data selection range; Figure 5.4.1). Most piping plover exposures to offshore wind turbines occur when birds are moving among shorelines or small islands. Movements during migration may also pass through the RFI Area as piping plovers use offshore habitat during this time; although, most of this occurs while flying above the rotor swept zone (RSZ; Loring et al. 2019). As piping plovers are mostly a coastal species, they will likely be minimally exposed to turbines in the RFI Area.

Roseate Tern

Roseate tern are colonial seabirds with nesting populations on coastal strips and islands of the northeastern U.S. Atlantic coast (Gochfeld and Burger 2020). Roseate terns use migratory staging sites along the U.S. Atlantic coast and migrate to South America for the non-breeding period. In New Hampshire, roseate terns can be expected off the coast from May to September. Some data collected using radio-tracking describe offshore movements of roseate terns; they may occur over 54 nm (100 km) from shore. Offshore usage is considered higher during morning hours and in high barometric conditions (i.e., fair weather) as activity is higher during these conditions (Goyert 2014, Loring et al. 2019). Despite the activity in the offshore environment, Loring et al. (2019) found roseate terns flights generally below the RSZ (25–250 m).

Red Knot

Red knots are a migrant shorebird that breed in the artic and make long-, mid-, and short-distance migrations, wintering in the southern coastal regions of South America as far south as Tierra del Fuego (Piersma et al. 2005). They use staging areas along the northeast coast of the US, departing by late August to early September towards staging areas farther south. During the southbound migration in fall, stopover sites within the U.S. Atlantic coast include Cape Cod and sites in New York and New Jersey. During northbound migration in spring birds arrive along the Atlantic coast with the highest concentration of red knots in the Delaware Bay due to the abundant horseshoe crab eggs, a critical food supply (Buehler and Piersma 2008, Loring et al. 2018, Baker et al. 2020). Red knots do not breed in the RFI Area but are most abundant from July through October.

Potential Impacts on Birds

Collisions and Displacement

Collisions occur when a bird collides with part of a structure, usually expected to be a moving turbine blade but for some species could include the monopole or other offshore structures such as meteorological towers or substations while in flight (Fox et al. 2006). Some bird behaviors potentially increase exposure to turbine blades and cause individuals to spend more time in the RSZ. Such behaviors include foraging on prey items at the turbine such as insects, fish, or other birds. Other factors thought to influence collision risk are low visibility from adverse weather and nighttime lighting limitations and activity in high wind speeds that influence the behavior of dynamic soaring birds such as petrels and shearwaters (Fox and Peterson 2019, Johnston 1955, Crawford and Engstrom 2001). Factors such as foraging opportunities, attraction to the physical structure of the turbine (including for perching from which to make foraging flights), and nighttime attraction to light also increase the potential for collision risk exposure.

Bird displacement is an avoidance response to a wind farm or wind turbine. While avoidance behavior can reduce collision risk, it can also increase the duration of a migratory movement with resulting energetic costs, reduced foraging, and resting opportunities. These can reduce the habitats to which birds have access, again increasing energy expenditures to find suitable alternatives (Fox and Peterson 2019). Negative effects of extra energy expenditure are exacerbated when birds often fly between feeding areas and nesting colonies, thus potentially impacting the fitness of not only adult birds but their offspring (Robinson Willmott et al. 2013). During construction, wet storage areas that house turbine components in the water could also cause bird displacement.

Avoidance behavior is a strong influence on collision and displacement risk at wind facilities. Species attracted to wind turbines can have a higher collision risk while species that avoid turbines have a higher displacement risk (Robinson Willmott et al 2013). There are three scales of avoidance: macro-avoidance (beyond a windfarm perimeter), meso-avoidance (within the turbine array footprint), and micro-avoidance (birds responding to the proximity of the WTG blades; Skov et al. 2018, SNH 2010).

Lighting

Artificial lighting is associated with vessels, vehicles, equipment, and structures and may affect birds depending on lighting color, brightness, and frequency of emission (Kerlinger et al. 2010). Moisture and cloud cover can also influence lighting effects on birds by altering visibility (Cochran and Graber 1958, Caldwell and Wallace 1966, Avery et al. 1976, Poot et al. 2008). Birds migrating between summer and winter ranges are heavily reliant on visual cues and are most vulnerable to artificial lighting's effects (Van Doren et al. 2017). In addition, short-term, localized effects from artificial lighting on birds' navigation ability are possible.

Operational turbines require lighting that complies with Federal Aviation Administration, U.S. Coast Guard, and BOEM guidelines. It is possible to minimize the impacts by using lighting only when necessary for work crews and by using down-lighting or down-shielding lighting, where practicable. Construction and decommissioning activities temporarily increase duration of artificial lighting from construction equipment and vessels with navigational lights, deck lights, and interior lights. During operations, vessel traffic occurs but at lower frequency than construction and decommissioning. Other temporary lighting can be expected for safety purposes.

Noise

Noise can affect birds' ability to conduct normal breeding, foraging, and resting activity (Ortega 2012). Though the noise intensity of each source varies considerably, birds have the potential to be affected by noise from sources such as aircraft, vehicle and vessel traffic, and onshore and offshore construction equipment. Pile-driving, a source of noise with traditional fixed-foundation wind, is not typically an issue with floating offshore wind (Maxwell et al. 2022).

Vessel Traffic

Vessels operating in the ocean have the potential to disturb birds on the water or in flight. These disturbances can cause incremental increased energy expenditure as birds take flight to avoid the vessel. Vessel disturbance impacts vary widely among bird species groups with loons considered the most sensitive to ship traffic (Schwemmer et al. 2011).

Entanglements

Derelict fishing line or fishing gear caught on structures can increase the likelihood of bird entanglements (Ryan 2018, Schrey and Vauk 1987). This is easily minimized by removing derelict gear. Public education on the deleterious effects of derelict fishing gear could further reduce impacts. An additional entanglement risk with floating offshore wind is entanglements with mooring lines. For seabirds, secondary entanglements with derelict gear are more likely than primary entanglements with mooring lines, though our knowledge about this is low (Maxwell et al. 2022).

Reef Effects

Offshore structures such mooring lines, scour protection, cable protection, buoys, and meteorological towers could have beneficial and negative effects on local bird populations. Beneficial effects could include increases in fish aggregations near structures due to created habitat for structure-orientated and hard-bottom fish species, which has the potential to increase foraging opportunities for piscivorous birds (Taormina et al. 2018). Attraction to this created foraging resource could also cause increases in bird exposure to turbine blades.

5.4.2 Bats

The aim of this section is to assess the possible impacts on New Hampshire bats from offshore deployment of wind energy facilities in the GOM.

There are eight bat species known to occur in NH (Table 5.4.3). The same species group occupies the rest of New England and southeastern Canada, all areas potentially impacted by offshore wind deployment in the GOM. As "ground zero" for the spread of the fungal pathogen causing white nose syndrome in North America, bat populations of most New England species have suffered drastic declines over the past 10-15 years, leading to many of them being state or federally listed.

Table 5.4.3. Bat species of New Hampshire, their migratory behavior, and federal and state listing.

Common Name	Scientific Name	Migratory	Federal Conservation Status	NH State Conservation Status
Eastern red bat	*Lasiurus borealis*	Yes	Not listed	Special Concern
Hoary bat	*Lasiurus cinereus*	Yes	Not listed	Special Concern
Silver-haired bat	*Lasionycteris noctivagans*	Yes	Not listed	Special Concern
Northern long-eared bat	*Myotis septentrionalis*	Yes, regional	Endangered	Endangered
Eastern small-footed bat	*Myotis leibii*	Yes, regional	Not listed	Endangered
Little brown bat	*Myotis lucifugus*	Yes	Not listed (currently under review)	Endangered
Tricolored bat	*Perimyotis sublfavus*	Yes, regional	Not listed (proposal to reclassify as Endangered underway)	Endangered
Big brown bat	*Eptesicus fuscus*	Yes, regional	Not listed	SGCN

Wind turbines are recognized as a major cause of excess bat mortality worldwide (Arnett et al. 2016) and in the U.S. (Choi et al. 2020; Smallwood 2013) that may lead to significant population declines and risk of extinction (Friedenberg and Frick 2021). The rate of mortality caused by individual turbines or a farm as a whole, varies according to risk factors related to the facility's location and size, environmental conditions, and bat biology and behavior. For example, wind energy facilities located in the midst of migration routes or reproduction swarming sites would have a much larger impact than those located near low quality foraging sites (Thompson et al. 2017). Likewise, it is well established that weather conditions and time in season create large variations in bat activity and therefore risk of mortality. Many bats are less active when wind speeds are high and many bat species show seasonal peaks and troughs of activity (e.g., high during spring migration and fall reproductive activity, low during winter), providing the rationale for many acceptable mitigation policies (Adams et al. 2021; Bennett et al. 2022; Friedenberg and Frick 2021). Since these factors are often intertwined, we will regard them together in this section. Bat mortality risk factors include occurrence, behavior, altered behavior, weather, and facility characteristics.

Occurrence

The GOM RFI is located within flight distance from the nearest shore of all species found in NH. Moreover, three of these species are migratory tree-dwelling bats – Eastern red bat (*Lasiurus borealis*), Hoary bat (*Lasiurus cinereus*), and Silver-haired bat (*Lasionycteris noctivagans*). These species are deemed especially at risk for wind energy-related mortality and together comprise up to 79% of the mortalities reported in wind energy facilities (Allison and Butryn 2020; Friedenberg and Frick 2021). These species are strong fliers and routinely cover greater distances than the distance between shore and the RFI (McGuire et al. 2012; Morningstar and Sandilands 2019). Though bats are generally regarded as terrestrial, they have been reported over sea, and technological limitations as well as lack of sampling effort have likely caused significant underestimation of bat activity over open water. Recent advances in methods and increased interest have led to multiple observations of bats not only in coastal areas (Santec, 2016) but also in the marine environment (Ahlén et al. 2009; Hatch et al. 2013; R. H. Thompson et al. 2015). Of the eight bat species found in NH four have been recorded on offshore structures or boats in the GOM (Eastern red bat, Hoary bat, Silver-haired bat, and Little brown bat [*Myotis lucifugus*]; Pelletier et al. 2013; R. H. Thompson et al. 2015) and one more was recorded on small and medium islands in the GOM (Big brown bat [*Eptesicus fuscus*]; Pelletier et al. 2013), and another (Tricolored bat [*Perimyotis sublfavus*]) was recorded at buoys up to 26 km from shore in the GOM (Santec 2016). Normandeau has recorded Silver-haired bats above buoys up to 100 km offshore the Hudson Bay, Eastern red bats and Silver-haired bats above boats up to 30 km offshore Northeastern USA (Normandeau Associates, Inc. unpublished data), and Eastern red bats, Hoary bats, and Silver-haired bats above offshore wind turbines up to 43 km offshore Virginia (Normandeau Associates, Inc. 2022). All of the above offshore records show a very strong seasonal signal, with the vast majority of the records during autumn (late July to early November, depending on location), a season that correlates with the bats' migration and reproductive swarming behavior, and to a lesser degree in the spring (during spring migration) - periods in the bats' life cycle characterized by long distance flight and a concentration of many individuals in high densities. This increased occurrence in areas where wind turbines operate inherently increases the risk of collisions and mortality.

Behavior

Certain behaviors increase the likelihood of bat interaction with wind turbine and hence the risk of collision. Many bat species specializing in open-air environments take advantage of food patches such as insect swarms and migrating moths. When a bat engages a target there is a tell-tale change to its echolocation behavior that can be heard by conspecifics (and probably heterospecifics) and attract other individuals to the food patch, which greatly increases their density in that area (Cvikel et al. 2015). A concentration of insects around the rotor-swept zone (RSZ) can therefore increase collision risk of foraging bats. As mentioned above, migration and reproductive swarming are also behaviors associated with increased collision risk. All three species most-often recorded offshore (Eastern red bat, Hoary bat, Silver-haired bat) share these risk-increasing characteristics (Allison and Butryn 2020). Another behavioral factor that is tightly connected to collision risk is flight height, specifically whether bats fly in the altitude of the RSZ. Accurate measurements of bat flight altitudes are hard to generate and the literature is therefore lacking in this regard, but an increasing amount of data shows that bats often fly at altitudes of 20-120 meters (as well as lower and higher), which includes the RSZ of most modern turbines (Hatch et al. 2013; Voigt et al. 2018).

Altered Behavior

It is becoming evident that the mere presence of a wind turbine (or multi-turbine facility) can alter bat behavior in the area in ways that can either increase collision risk due to attraction, or increase energetic costs due to avoidance. For that reason, pre-construction risk assessments are often not sufficient and post-construction assessments are necessary to reveal the full impact of wind energy on bat populations. There are three possible reasons offshore turbines may attract bats even to places they were not frequenting prior to construction: 1. The turbines are both novel and stand out in the environment, thus promoting investigatory behavior and "beaconing" (attraction to noticeable landmarks) behavior. 2. The turbine towers are used by the bats for roosting – either day roosts during migration or permanent roosts. 3. The turbines attract insects that in turn attract bats foraging on them. Wind turbines, both land-based and offshore, have been shown to attract both insects and bats (Ahlén et al. 2009, Foo et al. 2017, Jansson et al. 2020, Rydell et al. 2010, 2016). Data obtained by Normandeau supports this notion as activity levels at operating offshore turbines are greater by an order of magnitude than those recorded at buoys or boats, even though the latter were much nearer to shore (albeit at a more northerly location; Normandeau Associates, Inc. 2022). Moreover, bats are known to investigate novel man-made structures both on land and at sea (Figure 5.4.2; Normandeau Associates, Inc. unpublished data, Ahlén et al. 2007), and to use them as roosts, especially during migration (Thompson et al. 2015). Man-made structure may also be used as navigational aids (Harten et al. 2020) and thus increase interaction with turbines.

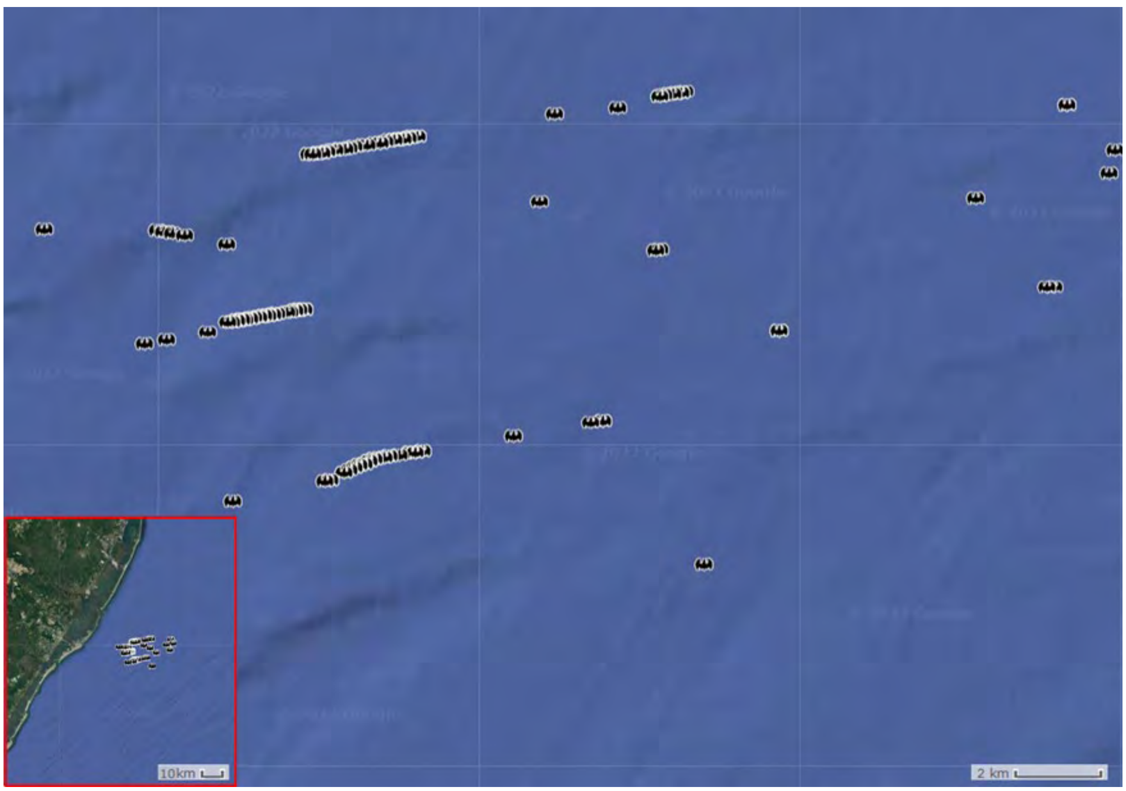

Figure 5.4.2. Bats are attracted to and investigate boats offshore. The symbols depict bat echolocation sequences recorded by boat-borne detector up to 30 km offshore Northeastern US. The lines of symbols are a result of the recorded bat following the boat, sometimes for more than 2 km.

Weather

Weather conditions are an important factor influencing bat activity level, behavior, and presence. Both high wind and low temperature are known to decrease insect activity and so decrease bat foraging activity (Amorim et al. 2012, Erickson and West 2002), though not necessarily migration or commute. Conversely, high winds may be conductive to migration and so increase bat activity along migration routes (Dechmann et al. 2017, Pettit and O'Keefe 2017). On land, curtailment regimes relying on both cut in speeds greater than 5-6 m/s have been shown to successfully mitigate much of collision-associated mortality (Adams et al. 2021, Arnett et al. 2011, Friedenberg and Frick 2021), and seasonal nocturnal shut-offs during peak migration season should be beneficial as well (Boonman 2018). Not much is known about specific bat migration routes, especially offshore, but at least some of the above-mentioned species likely span the GOM during migration based on timing of offshore observations (Hatch et al. 2013, Thompson et al. 2015). If little is known about bat migration routes, even less is known about the migration of nocturnal insects such as moths that many bat species prey upon, and more research is necessary to assess more accurately the impact of both these factor on collision risk of bats with offshore turbines. Light and moderate rain has no large impact on bat activity, but during heavy rain bat activity is reduced, either because of reduced insect activity or because of sensory issues as the raindrops create ambiguous echo returns.

Facility characteristics

The characteristics of any given wind energy facility are of course very important in assessing risk. Height, RSZ, and number of turbines are directly connected to collision risk. While the size of the RSZ and the number of turbines are both positively correlated with increased risk, the height is less straightforward, as some species tend to fly lower and are thus more affected by lower turbines, and other species tend to fly at higher altitudes and thus be more affected by higher turbines, but overall turbine height was not correlated with bat mortality (Thompson et al. 2017). (Ahlén et al. 2007) recorded bat commute flights at very low altitudes over sea (presumably to increase flight energetic efficiency), and at higher altitudes (at nacelle height or higher) while foraging around turbine blades. Since facility characteristics are intertwined, a possible proxy is energy production: installed capacity (in megawatts, MW) has been shown to be positively correlated with bat mortality (MacGregor and Lemaître 2020) though the correlation was not a simple linear one and other environmental and spatial factors are important: facilities located on migration routes or in the vicinity of maternity colonies extracted a much heavier toll per MW compared to ones that were situated in less critical locations. Since maternity colonies are unlikely to be near offshore turbines it is critically important to understand offshore migration and movement patterns over the GOM (see below). Other facility characteristics should be considered: lights at night on turbines may attract insect and the bats that hunt them, or even attract bats directly, depending on light color (Voigt et al. 2017). The color of the turbine tower and blades may also attract insects (Long et al. 2011), and the noise produced by the turbines, while not directly interfering with bat echolocation, may encourage investigative behavior and thus increase interaction with the turbines (Guest et al. 2022).

As is the case for many aspects of bat biology and ecology, there are serious knowledge gaps with regards to occurrence and risk-increasing behaviors of bats in the context of offshore wind energy in general, and specifically in the GOM. To try and bridge this gap a much deeper understanding of the movement ecology of susceptible species is needed. Hoary bats, silver-haired bats, Eastern red bats (NH: Special Concern), and little brown bats and tricolored bats (NH: Endangered) have all been documented at significant distances offshore and are of special interest. Movement studies using miniature GPS technology for the larger species and MOTUS radio-telemetry technology for smaller ones should be considered around the gulf, as bats are highly mobile animals that perform seasonal long-distance migrations. It is important to understand bat movement over the water and not only the locations where bats go out to sea or back in over land, so installing MOTUS towers offshore is highly recommended to gather this information. This approach, in combination with on-site studies of bat behavior at turbines using regular and thermal videography are especially important since post-construction mortality surveys at offshore facilities are almost impossible to conduct as the remains quickly sink or are washed away.

5.5 Sand and Gravel Resources

The morphology of the RFI area comprising a large portion of the GOM is incredibly complex and diverse, and thus difficult to accurately describe. This area is characterized by relatively cold waters and deep basins, with extensive marine-modified glacial features and deposits creating a patchwork of sediment types and seafloor features which tend to change dramatically over very short distances (Figure 5.5.1; Belknap et al. 2002, NOAA NMFS 2022a, Ward et al. 2021b). Coastal areas include rocky habitats, with bedrock as the predominant substrate and fine sediments such as mud and silt in coastal valleys and basins (Uchupi & Bolmer 2008). Sandy areas are relatively rare along the inner shelf of the GOM, but are more common south of Casco Bay, particularly off sandy beaches and estuaries; large sand deposits can also be found on Stellwagen Bank along with boulder ridges and gravel deposits (GEO 2022, NOAA NMFS 2022a). Gravel is common adjacent to bedrock outcrops and in rock fractures and is most abundant in depths of 20-40m, with the exception of a large gravel-covered plain off the eastern (southern) coast of Maine reaching depths of 100 m (Watling & Skinder 2007).

Historical efforts to review and characterize the sand and gravel resource in the GOM have indicated in general terms where the majority of sand and gravel deposits tend to lie, but it takes a significant concerted effort to accurately map in detail even just a fraction of the area covered by the RFI. However, with the advancement of GIS mapping tools and the consolidation of historical data, an overall characterization of the sediment types throughout the GOM may be generated as a starting point (Figure 5.5.2), and recent focused studies have been successful in preliminarily identifying with much higher resolution areas of sand and gravel resource potential in select study areas (TNC 2022). However, these focused efforts to date cover only relatively small areas of the GOM (NOAA NMFS 2022a; Figure 5.5.3). This section will review one such study for the waters off the coast of New Hampshire, using it as an example for the type of research necessary to accurately characterize the potential sand or gravel resource at the selected offshore wind site as the potential area size narrows.

As is the case in the entirety of the GOM, the continental shelf off the New Hampshire coast is extremely complex, including extensive bedrock outcrops, marine-modified glacial deposits, marine-formed shoals, and seafloor plains which are composed of a range of sediment types. Ward et al. (2021a, 2021b) evaluated sand and gravel deposits based on a synthesis of high-resolution bathymetry models, surficial sediment data, geoform maps, and a historical data archive including thousands of data points from vibracores, seismic profiles, and grain size analyses. The study area extended from the New Hampshire coast out seaward approximately 50 km to Jeffreys Ledge (Figure 5.5.4). Through the combination of historical data coupled with high-resolution surficial sediment mapping, bathymetry, and seismic stratigraphy the authors were able to perform a first order evaluation of four promising sand and gravel resources on the seafloor, all located relatively near the coast within the study area (Figure 5.5.5). The four sites identified in the analysis indicated sites of promising deposits of sand and fine gravel which may be extracted for use in beach restoration and nourishment efforts, all of which are located several kilometers landward of Jeffreys Ledge.

Beyond just identification of promising deposits, these focus areas require a multifaceted effort to accurately describe the extent of the resource. To that end, Ward et al. (2021a) developed and reviewed the surficial sediment and bathymetry maps against a systematic review of seismic stratigraphy and analyses of vibracores taken from the New Hampshire shelf. From this effort the authors were able to describe each of the sites in accurate detail. For example, the northern sand body (NSB) was found to be composed of primarily sand and gravelly sand, with surrounding sediments consisting of coarser gravel mixes believed to be the remnants of glacial deposits (Figure 5.5.6). Seismic profiles indicated relative thicknesses of transects throughout the NSB, and when integrated into a 3D GIS mapping tool, allowed the authors to estimate a total resource volume of approximately 17.3 million m^3. However, this was only an area estimate, not a composition estimate, so further analyses of the extent to which sediment mixture changes with depth would be necessary to categorize how much of that estimated volume would be targeted as ideal for beach nourishment efforts.

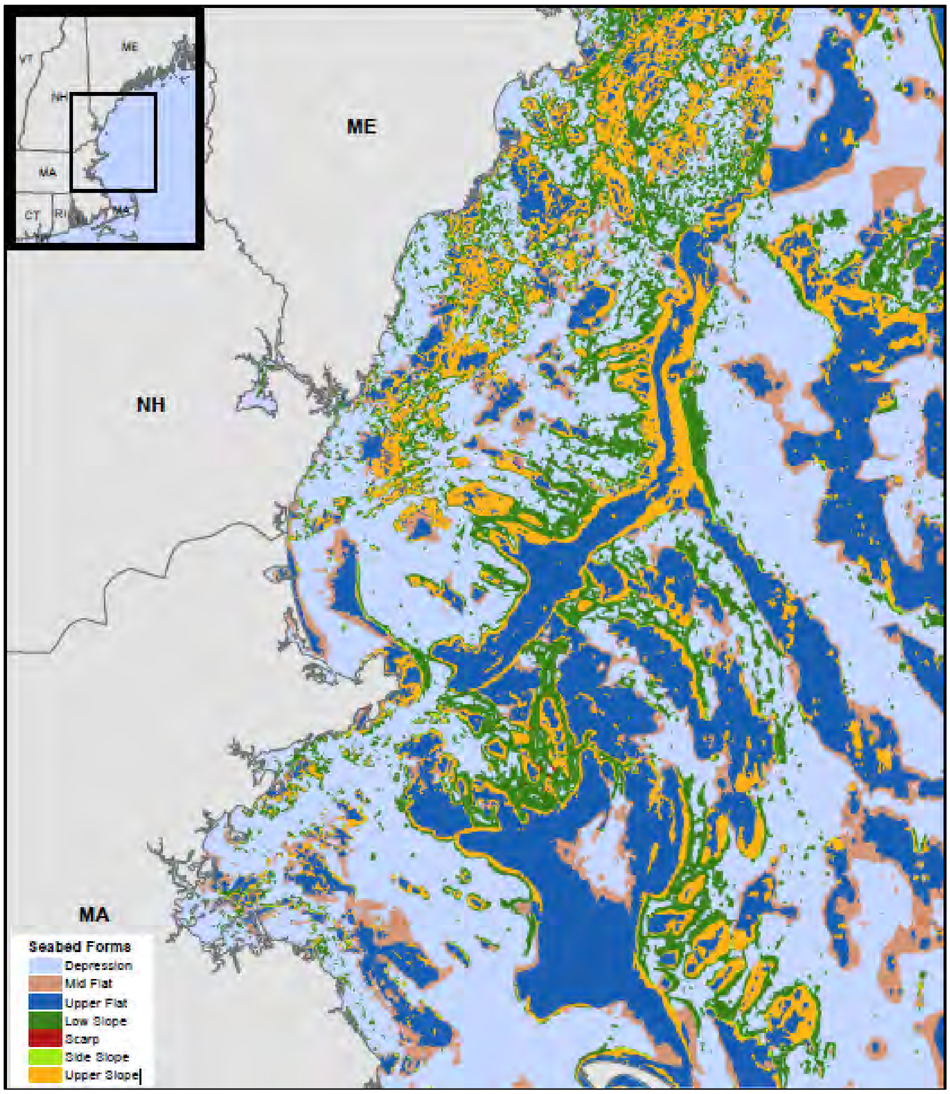

Figure 5.5.1. Map of seabed forms of the RFI waters in the Gulf of Maine generated with data from the NE Ocean Data Portal (accessed 14 December 2022).

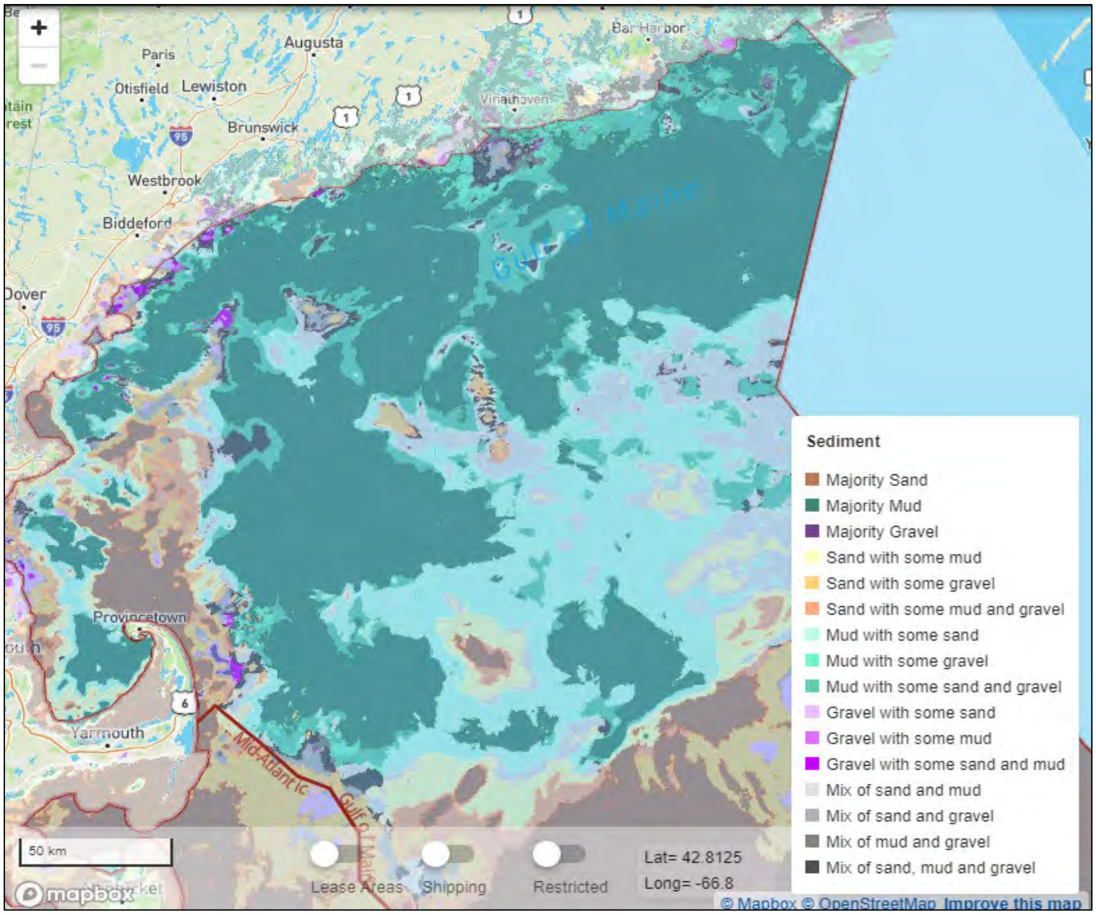

Figure 5.5.2. Sediment map generated for the entirety of the RFI area using TNC Marine Mapping Tool (accessed December 2, 2022). Areas classified as majority mud, sand, and gravel compose 43%, 3%, and <1% of the RFI area respectively (TNC 2022).

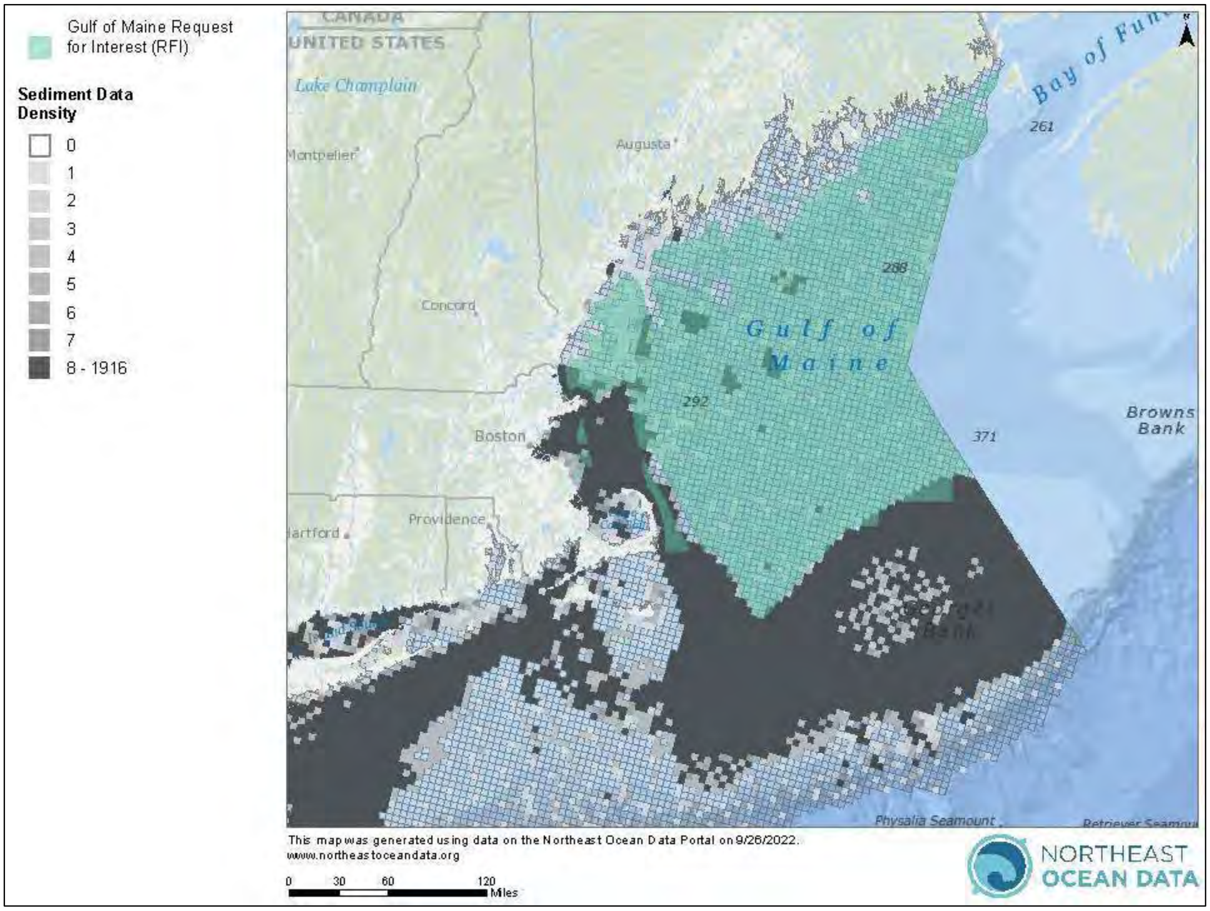

Figure 5.5.3. RFI area overlaid with sediment data collection density for each 5x5km grid cell (NOAA NMFS 2022a).

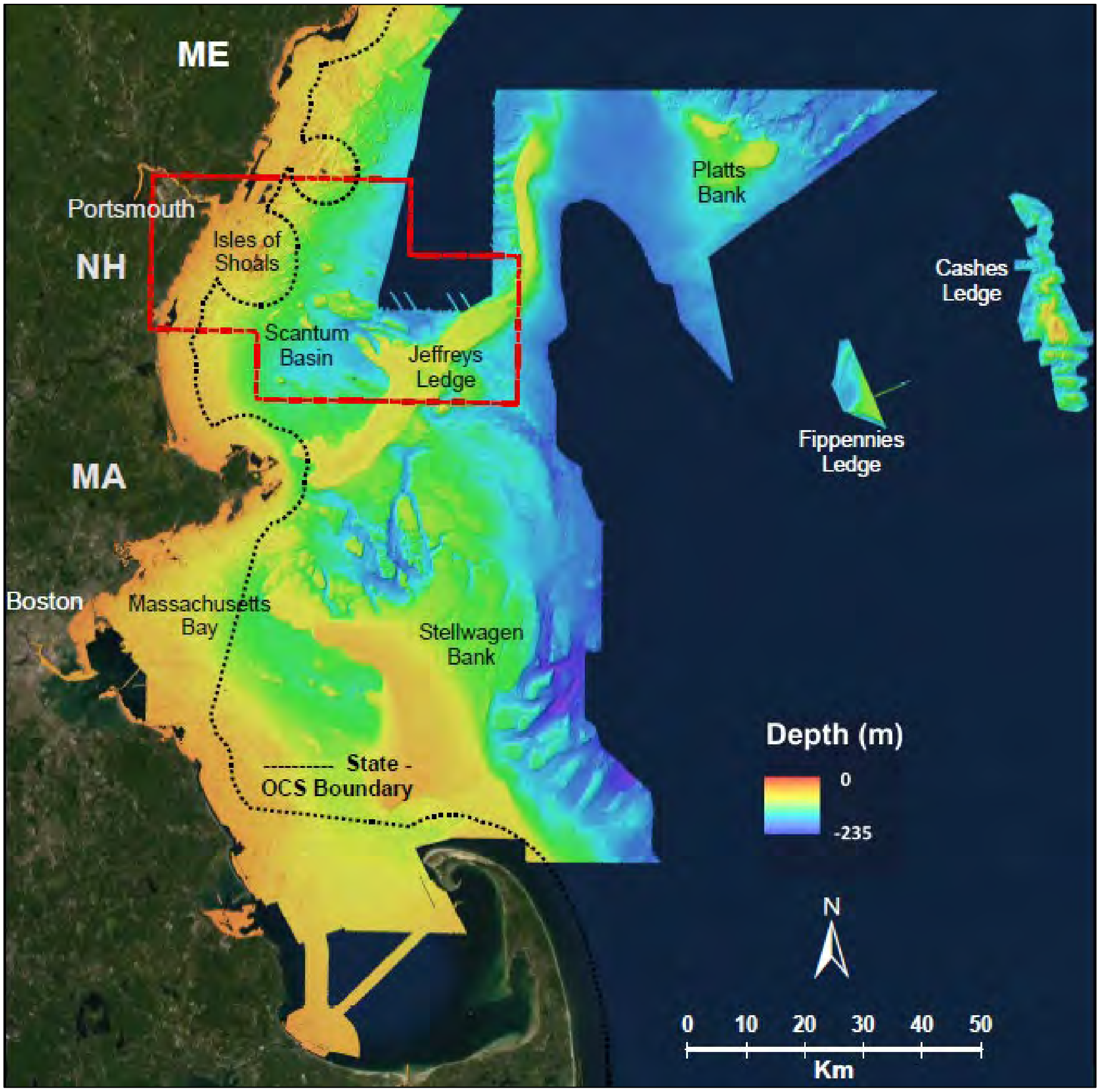

Figure 5.5.4. Bathymetric contour map of the Gulf of Maine, with the study area defined by the dotted red line (Ward et al. 2021b).

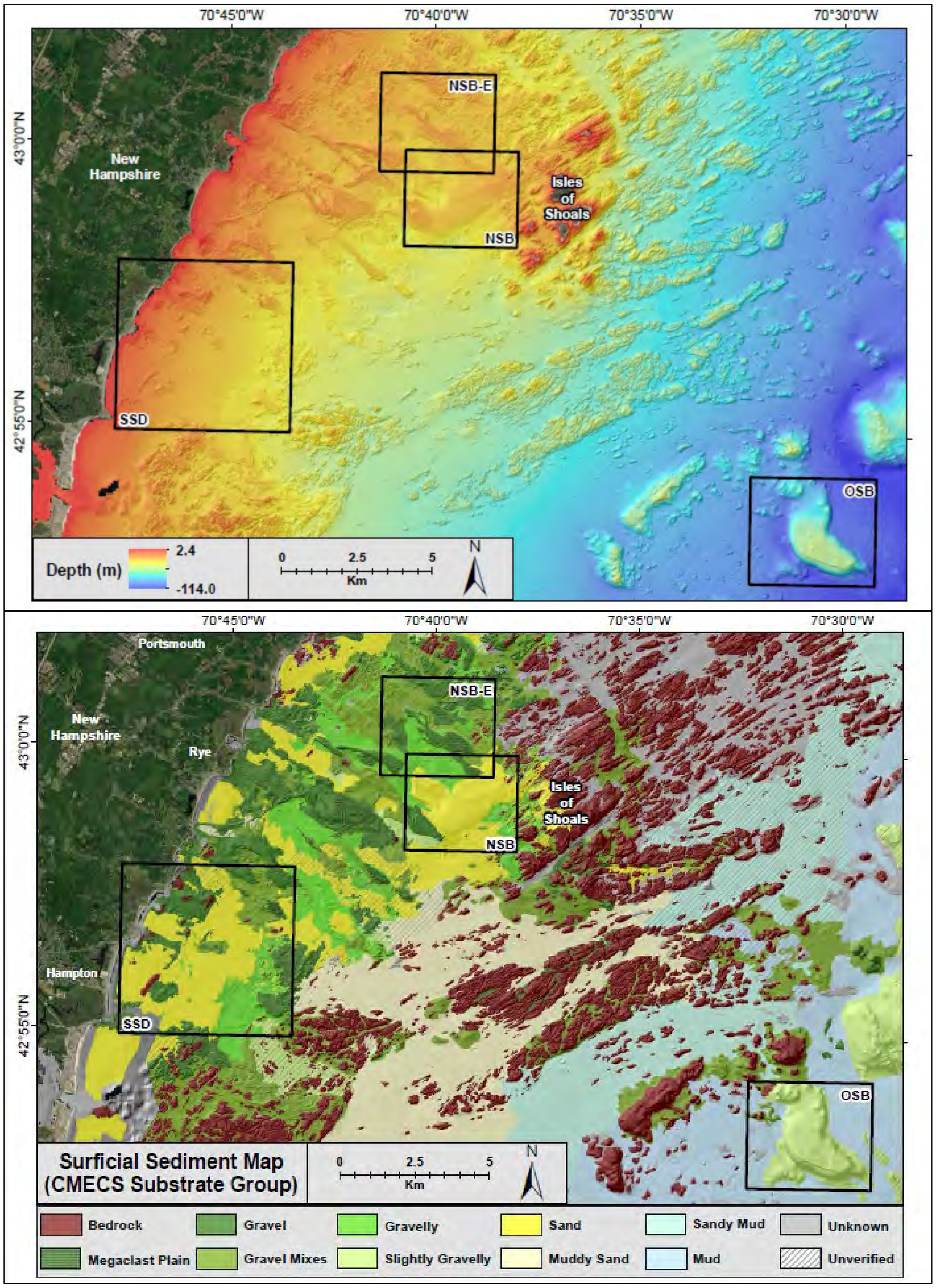

Figure 5.5.5. Bathymetric location map (top) and surficial sediment map (bottom) of the four focus areas (outlined in black) where sand and gravel deposits on the New Hampshire continental shelf were identified. SSD=southern sand deposit; NSB=northern sand body; NSB-E=northern sand body extension; OSB=offshore sand body (Ward et al. 2021a).

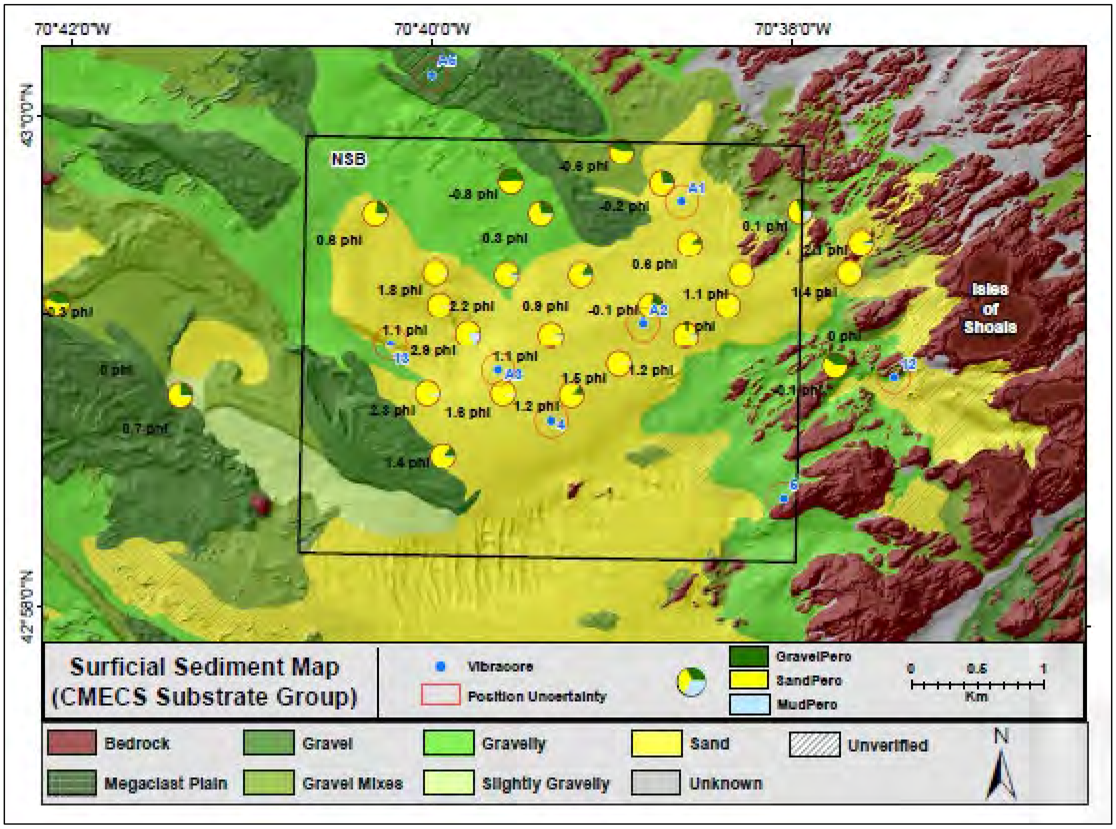

Figure 5.5.6. Surficial sediment map, grain size data, and locations of vibracores for the NSB site. Pie charts show distribution of gravel, sand, and mud, with mean grain size given as phi units (Ward et al. 2021a).

These efforts to map just a small fraction of the sediment deposited on the seafloor in one localized study area shed light on the extent of the effort required to accurately categorize the true resource potential of sand and gravel within the GOM. It is impractical to conduct a study which covers an area as vast as the RFI, so it will require focused analyses to be conducted as potential lease areas for offshore wind are pinpointed further down the line.

Sand and Gravel Resources off the Coast of New Hampshire

The BOEM Marine Minerals Program identifies Atlantic OCS sediment aliquots with sand resource areas identified in a block grid. These OCS blocks represent areas within the OCS protraction grid where sand resources have been identified through reconnaissance and/or design-level OCS studies. Access to and identification of potential OCS sand resources is crucial for the long-term management of coastal restoration, beach nourishment, and habitat reconstruction to mitigate future coastal erosion, land loss, flooding, and storm damage along the U.S. Atlantic Coast including New Hampshire.

BOEM maintains leased sand and gravel borrow areas on the OCS and has identified Atlantic OCS aliquots with sand resources within the RFI Area, south of Small Point, Maine. As storm effects and storm-preparedness efforts have reached critical levels in recent years, identifying these resources has become a priority. These polygons define the areas where leaseholders can dredge sand, gravel, or shell material from the OCS for use in beach and coastal restoration and protection projects undertaken by the federal government, or in a construction project funded in whole or in part by the federal government; and should be carefully considered for avoidance during offshore wind development especially in export cable routing.

An initial assessment indicates three sand resource areas denoted off the coast of New Hampshire (Figure 5.5.7). The resource areas are classified as "Unverified", which are defined as those hypothesized to exist based on indirect evidence (e.g., seismic profiles, bathymetry, or side-scan sonar). Inferred sediment types, unit thicknesses and lateral extents have not been confirmed through direct sampling methods. Three modeled shoals coincide with these sand resource areas, whose avoidance should be considered (BOEM 2019a, Ward et al. 2021a).

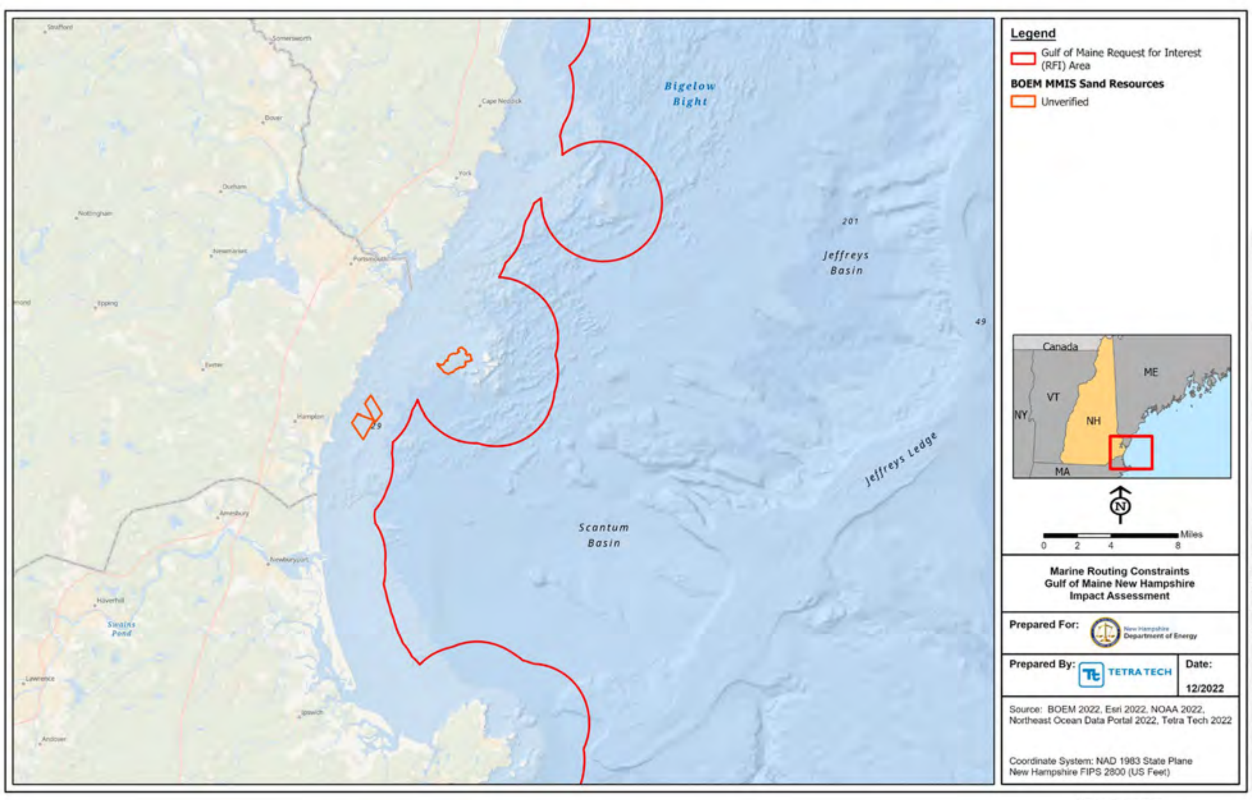

Figure 5.5.7. Sand resources off the coast of New Hampshire.

B Other Environmental Topics of Concern

5.6 Environmental Justice

In accordance with Executive Order 12898 (59 FR 7629), federal agencies are responsible to ensure that environmental justice is part of their projects' goals and that all disproportionate environmental or human health effects on minority and low-income populations must be addressed to the most precise degree that is legally possible. More recently, Executive Order 14008 (86 FR 7619) established several new environmental justice initiatives, including the establishment of:

- The White House Environmental Justice Interagency Council.
- The White House Environmental Justice Advisory Council.
- Government-wide "Justice40 Initiative" (aims to provide 40% of the overall benefits of federal investments relating to climate change, clean energy, and other areas to disadvantaged communities).
- Climate and Economic Justice Screening Tool.
- Environmental Justice Scorecard.

These actions also include agency-specific strategies to strengthen environmental justice policies. Remedial actions may be necessary to compensate for impacts on communities that may have previously felt the effects of environmental projects or degradations compared to their counterparts. Furthermore, environmental justice concerns may arise because of poor communication among parties and a lack of transparency between agencies and affected communities. Therefore, environmental justice concerns should be considered early in the project planning stage. Environmental justice practices are in place not only to protect the health of individuals in impacted communities but also their livelihoods and traditions.

Environmental justice is becoming an increasing concern for coastal communities and fisheries stakeholders. This is in part due to the historical lack of environmental justice consideration for these stakeholders in the past. In contrast, development of the offshore wind industry in the United States has the potential for direct and indirect socioeconomic benefits for coastal communities, as identified by various project developers (e.g., jobs, port upgrades, etc.). However, the delivery of such benefits to environmental justice communities needs to be tracked throughout the life of a project to determine if benefits are realized.

5.6.1 Rockingham County Demographics

Rockingham County, New Hampshire has a population of 314,176 (2020 U.S. Census) and contains 37 municipalities, five of which are included in the study area (Hampton, Rye, Seabrook, Newington, and Portsmouth), as shown in Table 5.6.1. Most census data is gathered every ten years. From the census survey in 2010 to the survey in 2020, the county's population rose by almost 19,000 people and this trend is continuing. 94.6% of the population identifies as white alone and of that 91.6% are white alone not including Hispanic or Latino ethnicities. The rest of the population is 1.2% Black or African American, 0.2% American Indian, 2.4% Asian, 0.1% Pacific Islander, 1.6% two or more races, and 3.8%

Hispanic or Latino. Approximately 95.5% of the households in Rockingham County have a computer and 95.4% are a high school graduate or higher.

Understanding a city or town's race and ethnicity is necessary for an environmental justice evaluation. Minorities and marginalized populations have historically been impacted by environmental hazards at disproportionate rates before Environmental Justice became a requirement for the review/permitting process associated with a development project. It is important to understand whether the study area's residents have been exposed to a disproportionate level of environmental or social impacts.

Household data is relevant to the study as it indicates the economic status of a given town or region (

Geography	Households	Persons per household	Median Income
Statewide	539,116	2.44	$77,923
Rockingham County	122,520	2.5	$93,962
Hampton	7,058	2.18	$81,519
Portsmouth	10,097	2.07	$78,712
Rye	2,304	2.35	$108,750
Seabrook	3,870	2.29	$76,540
Newington	423	2.3	$134,494

). This helps the developer, agencies, and stakeholders understand if a particular community that is part of a proposed project area may be at an economic disadvantage compared to other regions in the study. The median income of Rockingham County is $93,962, ranging from $76,540 to $134,494 in the five municipalities in the study area, with only Seabrook falling below the State median income level.

Percent of the population below the poverty line is an important indicator of sensitive communities that may require environmental justice consideration. Of the five municipalities, Portsmouth and Seabrook have the highest percentage of their populations in poverty, but neither fall below the statewide average, and therefore are not anticipated to be disproportionately impacted or experience substantial environmental justice impacts from a potential offshore wind project (Table 5.6.3).

Similar to poverty levels, education level in a community is associated with overall economic security and wellbeing. Of the five municipalities within the study area, Seabrook has the highest percent of residents without a high school diploma; higher than the statewide average, and the percentage of the population with a bachelor's degree or higher is lower than the Statewide average by over 15% (Table 5.6.4).

Table 5.6.1. Race and Ethnicity Percentages by Town & City.

Geography	Population	White	African American	Native American	Asian	Pacific Islander	Other	Two or more races	Hispanic or Latino	Percent Minority	White Alone
Statewide	1,388,992	92.8	1.9	0.3	3.1	0.1	0	1.8	4.4	11.3	89.1
Rockingham County	314,176	94.6	1.2	0.2	2.4	0.1	0	1.6	3.6	8.9	91.6
Hampton	16,333	96.3	0.5	0.2	1	0.2	0	1.7	1.8	5.2	94.9
Portsmouth	22,277	89.5	2	0	4.8	0	0	2.7	2.4	11.9	87.7
Rye	5,554	98.1	0	0	0.9	0	0	1	0	1.9	98.1
Seabrook	8,437	92.1	2.2	0	0.9	0	0	4.8	1.6	9.5	90.7
Newington	1,006	91	0.6	0	6	0.1	0	0.6	1.8	9.1	91

Table 5.6.2. Household Data.

Geography	Households	Persons per household	Median Income
Statewide	539,116	2.44	$77,923
Rockingham County	122,520	2.5	$93,962
Hampton	7,058	2.18	$81,519
Portsmouth	10,097	2.07	$78,712
Rye	2,304	2.35	$108,750
Seabrook	3,870	2.29	$76,540
Newington	423	2.3	$134,494

Table 5.6.3. Percentage of Population Below the Poverty Line.

Geography	Percent in Poverty
Statewide	7.2
Rockingham County	4.6
Hampton	4.4
Portsmouth	6.6
Rye	4.1
Seabrook	5.6
Newington	4.0

Table 5.6.4. Education Level by Percentage of Population that has Obtained a Certain Degree.

Geography	No High School Diploma	High School Diploma or Higher	Bachelor's Degree or Higher
Statewide	6.7	93.3	37.6
Rockingham County	4.6	95.4	41.9
Hampton	3.7	96.3	44.5
Portsmouth	3.6	96.4	61.4
Rye	3.3	96.7	60.5
Seabrook	8.6	91.4	20.8
Newington	3.3	97.8	60.4

5.6.2 Reliance on Marine and Coastal Economic Activities.

The total economy in Rockingham County makes up 22.7% of the state's employment. This consists of 10,990 establishments, 177,573 total jobs, $8 billion in wages and $20 billion of gross domestic product (GDP). While not all of Rockingham County is coastal, the five municipalities comprise the entire coastline of New Hampshire. In Rockingham County, 6.6% of the economy is accounted for by marine employment. The marine economy is made up of 559 establishments, 10,149 jobs, $286 million in wages, and $660 million of GDP. Of the total maritime job numbers, 8,308 are in the tourism and recreation sector.

5.6.3 Disproportionately Impacted Groups

Disproportionately impacted tract groups are summarized in the 2020 U.S. Census data shown in Table 5.6.5 are based on data provided by the EPA Environmental Justice (EJ) Index. Regions above 50% are subject to the largest exposures, which can be used to identify high concern regions such as the following regions or tract groups in the study area that may warrant extra consideration.

Seabrook has the highest exposure to potential environmental hazards, largely due to the presence of the Seabrook Station nuclear power plant. In nearly every category on the EJ Index provided by the

EPA, there is disproportionate exposure surrounding Seabrook Station. In the demographic categories, Seabrook is also substantially below the state average for members of their community with a bachelor's degree or higher, and slightly above average in the category of not having a high school education. As a result of existing exposures of Seabrook residents to potential environmental hazards associated with Seabrook Station and the potential for sea level rise and flooding associated with climate change, Seabrook is expected to require a focused stakeholder coordination effort associated with a potential offshore wind project.

Hampton (specifically, Hampton Beach as census tract number 650.08) is disproportionately exposed to the following Environmental Justice Indices: Wastewater Discharge, Underground Storage Tanks, Hazardous Waste Proximity, RMP FACILITY Proximity, Superfund Proximity, Lead Paint, Traffic and Air Toxins. 13.2% of the region's population is living in poverty compared to Hampton's average of 4.4%, which indicates this region may be disproportionately impacted by negative socioeconomic impacts of a given project or development. Like Seabrook, Hampton is also subject to sea level rise and flooding associated with climate change, which may warrant additional consideration for dredging/trenching associated with a potential cable landfall. These factors indicate that tract 650.08 has been disproportionately impacted by potential environmental exposures and hazards, which should warrant focused stakeholder coordination efforts associated with a potential offshore wind project.

Portsmouth (specifically, Wentworth Acres as census tract 107.01) is a region of concern that warrants attention due to its disproportionate exposure to most Environmental Justice screening categories compared to its surrounding communities. Such categories include a lower percentage of high school graduates (86.2%) and a larger population below the poverty line compared to the rest of Portsmouth. In addition, 15.5% of the population is below the poverty line compared to the average of 6.6% in Portsmouth. According to the EPA's Environmental Justice Index, this region is disproportionately exposed to Diesel Particulate Matter, Lead Paint, Superfund Proximity, Underground Storage Tanks, RMP Proximity, Hazardous Waste Proximity and Wastewater Discharge. It is important to note that these specified areas of above average exposure are not in the two highest national percentiles, but they are outliers of the study area regarding environmental exposures, relative to the rest of Rockingham County. These factors indicate that tract 107.01 has been disproportionately impacted by potential environmental exposures and hazards, which should warrant focused stakeholder coordination efforts associated with a potential offshore wind project.

Table 5.6.5. Areas Identified by the EPA Environmental Justice Index.

Selected Variables	Newington Percentile	Hampton Percentile	Seabrook Percentile	Portsmouth Percentile	Rye Percentile
EJ Index for Particulate Matter 2.5	<50	<50	<50	<50	<50
EJ Index for Diesel Particulate Matter	<50	<50	<50	<50, range from 50-60 near Wentworth Acres and South Cemetery	<50
EJ Index for Air Toxics Cancer Risk	<50	<50	<50	<50	<50
EJ Index for Ozone	<50	<50	<50	<50	<50
EJ Index for Air Toxics Respiratory HI	<50	<50, by Hampton beach 60-70	Mostly 50, higher near Seabrook Station ranging from 50-70	<50, but 50-60 near the Pease Tradeport	<50
EJ Index for Traffic Proximity	<50	<50, portions within Hampton Beach are in the 50-60, 60-70, and 80-90	Regions ranging from <50, 50-60, and 60-70 progressively higher in proximity to Seabrook Station	<50, with regions of 60-70 near Wentworth Acres, Portsmouth Plains, and South Cemetery, area of 70-80 to the west side of Wentworth Acres directly next to Spaulding Turnpike	<50 in almost all areas, 50-60 between Lang Road and Lafayette Road surrounding Bluefish Boulevard
EJ Index for Lead Paint	<50	By Hampton Beach 70-90	<50	<50, near Portsmouth Plains and Pannaway Manor 60-70	<50
EJ Index for Superfund Proximity	<50	Majority of Hampton sits between 60-80 and Hampton Beach is in 80-90	Regions ranging from <50, 50-60, and 60-70 progressively higher in proximity to Seabrook Station	<50, near both Portsmouth Plains, South Cemetery, Pannaway Manor 50-70 & Wentworth acres is 70-80	<50 in almost all areas, 60-70 between Lang Road and Lafayette Road surrounding Bluefish Boulevard

Selected Variables	Newington Percentile	Hampton Percentile	Seabrook Percentile	Portsmouth Percentile	Rye Percentile
EJ Index for RMP Facility Proximity	<50	<50, Hampton Beach has large portion at 50-60	Regions ranging from <50, 50-60, and 60-70 progressively higher in proximity to Seabrook Station	<50, Portsmouth plains 50-60 & Wentworth Acres 60-70	<50
EJ Index for Hazardous Waste Proximity	<50	<50, Hampton Beach 60-70	Regions ranging from <50, 50-60, 60-70, and 70-80, progressively higher in proximity to Seabrook Station	<50, with regions of 50-60 directly above South Cemetery & 60-70 near Wentworth Acres, Portsmouth Plains, with an area of 70-80 to the west side of Wentworth Acres directly next to Spaulding Pike	<50
EJ Index for Underground storage tanks	<50	Regions are <50, by Hampton Beach 60-70	Regions ranging from <50, 50-60, 60-70, and 70-80, progressively higher in proximity to Seabrook Station	<50, with regions of 60-70 directly above South Cemetery, Wentworth Acres & Portsmouth Plains, with an area of 70-80 to the west side of Wentworth Acres directly next to Spaulding Turnpike	<50 in almost all areas, 50-60 between Lang Road and Lafayette Road surrounding Bluefish Boulevard
EJ Index for Wastewater discharge	<50	Further from Waterlines <50, on the beach 70-80 to 80-90	60-70, Near Seabrook Station 80-90	<50, 60-70 to the west of Wentworth Acres on the adjacent side of Spaulding Turnpike overlapping the highway and 70-80 in Wentworth Acres & Portsmouth Plains	<50

5.7 Fossil Fuels Used During Construction and for Lubrication and Equipment for Operations and Maintenance

5.7.1 Fossil Fuels Used During Construction, Operations, and Maintenance

Fossil fuels would be required to operate marine vessels and other combustion equipment needed for construction, operations, and maintenance of an offshore wind project, including:

- Commercial marine vessels,
- Helicopters,
- Stationary diesel generator engines, and
- Portable diesel generator engines.

The majority of the marine vessels would be equipped with either Category 1 or Category 2 engines that qualify as "harbor craft" as defined under the California rule 17 CCR 93118.5. These categories of engines will use only ultra-low sulfur diesel (ULSD) fuel, which has a sulfur content of 15 parts per million by weight. Many of the larger installation vessels could be equipped with Category 3 main engines, and these vessels would likely use marine diesel oil with a sulfur content of 0.1 percent by weight, since fuel could potentially be purchased at overseas ports prior to being employed by a project.

Estimates of fuel usage from a 2,000-3,000 MW offshore wind project ("representative project") currently in development off the East Coast were used to approximate fossil fuel usage for a potential offshore wind project in the GOM (Table 5.7.1).

Table 5.7.1. Fuel Use Summary for Representative Project.

Project Activity	Fuel Type	Fuel Usage (gallons)
Foundation Installation	ULSD or 0.1% S marine fuel	8,000,000
Offshore Substation Installation	ULSD or 0.1% S marine fuel	2,000,000
Export and Inter-array Cable Installation	ULSD or 0.1% S marine fuel	9,000,000
Wind Turbine Installation	ULSD or 0.1% S marine fuel	5,000,000
Wind Farm Commissioning	ULSD or 0.1% S marine fuel	5,000,000
Construction Total		**29,000,000**
Offshore Substation Generator Engine	ULSD	200,000
Offshore Marine Operations	ULSD	2,000,000
Offshore Maintenance	ULSD or 0.1% S marine fuel	800,000
Operations and Maintenance Total (per year)		**3,000,000**

5.7.2 Lubrication, Cooling, and Hydraulic Transmission During Operations and Maintenance

Wind turbines and offshore substations would use oils, greases, and fuels for lubrication, cooling, and hydraulic transmission. However, since they are not burned, these materials would not have a significant contribution to a project's total emissions of greenhouse gas (GHG) or criteria pollutants.

The precise volumes of material required would vary depending on the size and type of the machine selected. Table 5.7.2 below provides representative quantities of oils, greases, and fuels that would potentially be used in wind turbines.

Table 5.7.2. Summary of Wind Turbine Oil/Grease/Fuel for Representative Project.

Oil/Grease/Fuel	Amount Per Wind Turbine (gallons)
Transformer oil	2,500
Main bearing grease	100
Yaw grease	30
Yaw gear oil	100
Hydraulic oil	300
Cooling (water/glycerol)	900
Pitch lubrication (grease)	50
Pitch system hydraulic accumulators (nitrogen)	17,000
Pitch gearbox oil	20
Gearbox oil (gear oil)	1,000

Oils, greases, and fuels will also be required for lubrication, cooling, and hydraulic transmission at onshore and offshore substations. Table 5.7.3 below provides representative quantities of oils, greases, and fuels that would potentially be used at onshore and offshore substations.

Table 5.7.3. Summary of Substation Oil/Grease/Fuel for Representative Project.

Oil/Grease/Fuel	Amount Per Substation (gallons)
Transformer/reactor oil	150,000
Diesel fuel	8,000

Wind turbines would be designed to minimize the potential for spills through containment measures. These materials would have an operational life at the end of which they, or the components that contain them, would be disposed of in accordance with industry guidelines and regulatory requirements.

During construction, water quality has the potential to be impacted through the introduction of constituents of concern, including oil and fuel spills and releases. Project-related construction vessels also have the potential to release oil and fuels. During operation, both the onshore and offshore substations would contain oils, fuels, and/or lubricants. However, since the equipment would be mounted on foundations with associated secondary oil containment or located within buildings, an inadvertent release of oil at these facilities is not expected to impact the quality of the surrounding groundwater, surface water, or ocean water resources.

5.8 Emissions Created by Offshore Wind Operations

Once operational, renewable energy sources such as offshore wind generation, create substantially lower indirect GHG emissions across the life of a project compared to the direct GHG emissions associated with conventional generation facilities (e.g., oil, gas, or coal-fired power plants; Dolan et al. 2012, USDOE 2015). This lack of GHG emissions across large-scale generation sources is a major reason for initiatives in recent years to promote development of offshore wind in New Hampshire (Governor's Executive Orders 2019-06, 2021-03) and at the federal level (President's Executive Order 14008 [86 FR 7619]). GHG emissions in New Hampshire peaked in 2004 and remain lower than targets set in the New Hampshire Climate Action Plan (NHDES 2009), with a total of 15.8 million metric tons of CO_2 equivalents in 2019 (NHDOE 2022). Historical and forward-looking GHG reduction potential of offshore wind in the GOM were evaluated in a report developed by the NHDOE (NHDOE 2022). This section expands on the information from that report, to include specific sources and estimates of air emissions associated with the construction and operations of a hypothetical commercial-scale offshore wind project in the GOM.

The primary emission sources for an offshore wind project would include marine vessel engines and other equipment used during construction, commissioning, operation, and maintenance of the project, as outlined below.

5.8.1 Construction Air Emission Sources

During construction, the potential activities that may generate emissions include:

- Transportation of project-related components to the associated ports, staging locations, and project sites;
- Staging activities and assembly of project components at applicable facilities or areas;
- Construction of the offshore components, including the wind turbines, offshore substations, submarine export cables, and inter-array cables; and
- Construction of the onshore components, including the onshore export and interconnection cables, onshore substations, and O&M facilities.

During construction, project-related air emissions could have short-term impacts to air quality. Primary project emissions sources include marine vessels, which will potentially transit waters of the GOM, with the majority of project-related construction emissions expected to occur offshore within the Lease Area and along the submarine export cable routes. Most of these vessels and the onboard construction equipment will utilize diesel engines burning low sulfur fuel while some larger construction vessels may use marine fuel. Construction staging and laydown for offshore and onshore construction may occur at port facilities along the GOM, as well as the locations for onshore substations and export cable interconnection. Onshore construction activities will primarily utilize diesel-powered equipment that include HDD operations, trenching/duct bank construction, and cable pulling and termination, as well as on-road vehicles for transporting materials and for worker commute trips. In addition, a localized increase in fugitive dust may need to be controlled on-site during onshore construction activities.

5.8.2 Operations and Maintenance Air Emission Sources

During operations and maintenance, the potential activities that may generate emissions include:

- Transportation of project-related components and crew to the associated ports, staging locations, and project site;
- Operations and maintenance of the offshore components, including the wind turbines, offshore substations, submarine export cables, and inter-array cables; and
- Operations and maintenance of the onshore components, including the onshore export and interconnection cables, onshore substations, and O&M facilities.

During operations and maintenance, potential project-related emissions would result from the project-related vessels and potentially helicopters used to service the wind turbines and offshore substation platform(s), the operation of emergency generators at each offshore substation platform and onshore substation, and GHG emissions of sulfur hexafluoride (SF_6) from gas-insulated switchgear installed at the offshore substation platforms, onshore substations, and wind turbines.

Operations and maintenance activities may include routine operational support performed by a service operations vessel along with smaller crew transfer vessels transiting to and from the facility to service the wind turbines and offshore substation(s) over the operational life of an offshore wind facility. Maintenance activities would include a variety of survey and repair vessels that may operate on an infrequent, intermittent basis over the operational life of an offshore wind facility.

Emissions from operations and maintenance activities would not be expected to have a significant impact on regional air quality over the operational life of a project and would generally be expected to be smaller compared to the impacts anticipated during construction activities.

5.8.3 Regulatory Applicability Evaluation

This section describes the regulatory framework for air quality, as applicable to an offshore wind project and the affected air environment. Potential impacts to air quality resulting from construction, and operations and maintenance of an offshore wind project are discussed.

Under the federal Clean Air Act (CAA), the EPA and the states are responsible for developing and enforcing the regulations protecting air quality in the United States. Project emissions associated with construction, operations, and decommissioning would be subject to EPA regulations governing air quality both onshore and offshore.

The federal CAA established the National Ambient Air Quality Standards (NAAQS) for the following common pollutants, known as criteria pollutants: carbon monoxide (CO), lead, nitrogen dioxide (NO_2), ozone, particulate matter, and sulfur dioxide (SO_2). The standards are set by the EPA to protect public health and the environment from harmful air pollutants. To achieve this, the EPA sets both primary and secondary standards. Primary standards are intended to protect human health. Secondary standards are intended to protect public welfare from known or anticipated adverse effects associated with the presence of air pollutants, such as damage to property or vegetation.

Although many of the criteria pollutants are directly emitted into the atmosphere by industrial and combustion processes, some criteria pollutants form in the atmosphere by chemical reactions. Ozone, for example, is formed in the atmosphere by reactions between volatile organic compounds (VOCs) and nitrogen oxides (NO_X), which includes nitric oxide (NO), NO_2, and other NO_X. In this context, VOCs and NO_X, referred to as ozone precursors, are regulated by the EPA to achieve ambient ozone reductions.

Similarly, particulate matter is a mixture of solid particles and liquid droplets of varying size found in the atmosphere. The EPA has established NAAQS for two different particles sizes—particulate matter less than 10 microns in diameter (PM_{10}) and particulate matter less than 2.5 microns in diameter ($PM_{2.5}$). While some particulate matter is emitted directly, $PM_{2.5}$ can form in the atmosphere by chemical reactions from SO_2, NO_X, VOCs, and ammonia. As with ozone, $PM_{2.5}$ precursors are regulated by the EPA to achieve ambient $PM_{2.5}$ reductions.

The NAAQS for each criteria pollutant is presented in Table 5.8.1. Every five years, the EPA conducts a comprehensive review of the NAAQS and revises the standards based on the most recent scientific information available. The EPA monitors compliance with the NAAQS through a state-wide network of air pollution monitoring stations measuring the concentration of each criteria pollutant. If ambient concentrations do not exceed the NAAQS, the area is designated as an attainment area and no further action is required. If ambient concentrations exceed the NAAQS for one or more pollutants, the area is designated as a nonattainment area for those pollutants, and the state is required to develop an implementation plan to achieve compliance with the NAAQS. Once a nonattainment area demonstrates compliance with the NAAQS standard, the EPA will designate the area a maintenance area (EPA 2022a).

In addition to regulating criteria pollutants, the EPA is also responsible for developing and enforcing regulations governing other air pollutants, including hazardous air pollutants (HAPs) and greenhouse gases (GHGs).

HAPs are pollutants known or suspected to cause adverse health and environmental effects. Adverse health effects associated with exposure to HAPs include increased likelihood of developing cancer and other serious impacts to respiratory, reproductive, and immune system health and early childhood development (EPA 2022b).

GHGs are gases that trap heat in the atmosphere and contribute to global warming by retaining heat in the atmosphere (EPA 2022c). Common GHGs include carbon dioxide (CO_2), methane, and nitrous oxide, which can be released into the atmosphere through the production, transportation, and burning of fossil fuels, and through emissions from livestock and other agricultural and industrial practices (EPA 2022c). In the United States, CO_2 accounted for approximately 82% of all GHG emissions in 2017 (EPA 2022d).

Although the EPA has not established ambient air quality standards for HAPs or GHGs, emissions of HAPs and GHGs are regulated through national and state emissions standards and permit requirements.

Table 5.8.1. National Ambient Air Quality Standards.

Pollutant	Average Time	Standard
$PM_{2.5}$	24 hours 1 year 1 year	98th percentile concentration averaged over 3 years ≤ 35 μg/m^3 Annual mean, averaged over 3 years ≤ 12.0 μg/m^3 (primary) Annual mean averaged over 3 years ≤ 15.0 μg/m^3 (secondary)
PM_{10}	24 hours	150 μg/m^3, not to be exceeded more than once per year on average over 3 years
Ozone (2008)	8 hours	4th highest daily maximum value, averaged over 3 years ≤ 0.075 ppm
Ozone (2015)	8 hours	4th highest daily maximum value, averaged over 3 years ≤ 0.070 ppm
NO_2	1 hour 1 year	98th percentile daily maximum, averaged over 3 years ≤ 0.100 ppm Not to exceed 0.053 ppm
SO_2	1 hour 3 hours	99th percentile daily maximum, averaged over 3 years ≤ 0.075 ppm 0.5 ppm, not to be exceeded more than once per year
CO	1 hour 8 hours	35 ppm, not to be exceeded more than once per year 9 ppm, not to be exceeded more than once per year
Lead	Rolling 3-month average	Not to exceed 0.15 μg/m^3
Source: 40 CFR § 50 Notes: μg/m^3 = micrograms per (standard) cubic meter ppm = parts per million (by volume)		

Outer Continental Shelf Air Regulations

The federal CAA authorizes the EPA to regulate air quality on the Outer Continental Shelf (OCS). The EPA has promulgated the OCS air regulations at 40 CFR Part 55, which establish air pollution control and permitting requirements for emission sources and activities occurring on the OCS.

According to Section 328 of the CAA (at 42 U.S.C. § 7627(a)(4)(c)), an OCS source includes the following: (i) any equipment, activity, or facility that emits, or has the potential to emit, any air pollutant; (ii) is regulated or authorized under the OCS Lands Act (43 U.S.C. § 1331); and (iii) is located on the OCS or in or on waters above the OCS. This includes vessels that are permanently or temporarily attached to the seabed (40 CFR § 55.2).

In addition to the federal OCS air regulations, the OCS sources operating within 25 nm (46.3 km) of the seaward boundary of a state are subject to the requirements applicable to the Corresponding Onshore Area (COA), as determined by the EPA. For a project near the coast of

New Hampshire, the COA is likely to be New Hampshire State, in which case the OCS sources associated with project activities would be expected to be subject to the air permitting requirements of the NHDES. Depending on the Nearest Onshore Area and potentially other EPA priorities, the states of Maine and Massachusetts would also have the option to petition the EPA for designation as the COA. If such a petition were successful, the project OCS sources would instead be subject to the air permit requirements of the Maine Department of Environmental Protection (ME DEP) or Massachusetts Department of Environmental Protection (MassDEP), respectively.

Anticipated project emissions would be compared to the EPA's New Source Review (NSR) permitting thresholds to determine the project-specific permitting requirements. NSR is a federal pre-construction permitting program responsible for ensuring new emissions sources do not contribute to a violation of the NAAQS (EPA 2006). Pollutants regulated by the NSR permitting program include the criteria pollutants, VOCs, GHGs, and other HAPs. If a project's anticipated emissions do not exceed the NSR permitting thresholds for one or more pollutants, the project will be considered a minor source and will be subject to minor source permitting. If a project's anticipated emissions exceed the NSR permitting threshold for one or more pollutant, the project will be considered a major source and will be subject to major source permitting for those pollutants. As NSR permitting is pollutant-specific, a project can be considered a major source for some pollutants and a minor source for others.

If a new major stationary source was located in an area designated as nonattainment for a particular pollutant or within the Northeast Ozone Transport Region (OTR), the source would be subject to a Nonattainment New Source Review (NNSR) for that pollutant. Under the NNSR program, a project located in an area designated as nonattainment for ozone or within the OTR must satisfy NNSR requirements for NO_X and/or VOC emissions as ozone precursors if they exceed the NNSR thresholds. New Hampshire is currently in attainment of the NAAQS for all pollutants. However, because it is included in the OTR, it is subject to NNSR requirements. Massachusetts, as well as portions of Maine, are also located within the OTR (40 CFR § 81.457).

General Conformity Applicability and NEPA Review

Under Section 176(c)(4) of the Clean Air Act, certain actions taken by federal agencies are subject to the EPA's General Conformity Rule. The General Conformity rule generally requires federal agencies to demonstrate that proposed actions comply with the NAAQS (EPA 2022a). Section 176(c)(1) of the CAA defines conformity as the upholding of "an implementation plan's purpose of eliminating or reducing the severity and number of violations of the NAAQS and achieving expeditious attainment of such standards." Therefore, in nonattainment or maintenance areas, federal agencies must demonstrate that proposed actions conform to the applicable EPA-approved state implementation plan to achieve and/or maintain the NAAQS (EPA 2022a). In attainment areas without state implementation plans, federal agencies must demonstrate that proposed actions will not cause new violations of the NAAQS and/or increase the frequency or severity of previous violations (EPA 2022a). As a result, a project's emissions should not cause or contribute to new violations of the NAAQS; increase the frequency or severity of a previous violation of the NAAQS; or prevent or delay attainment of the NAAQS or interim emission reductions.

In accordance with 40 CFR Part 51 Subpart W and 40 CFR Part 93 Subpart B, a General Conformity Determination may be required to address whether construction and operation of the project will conform with the applicable state and/or federal implementation plan. The General Conformity thresholds are presented in Table 5.8.2 and only apply to nonattainment areas or maintenance areas.

Table 5.8.2. General Conformity Thresholds.

Pollutant	Designation	Tons per year
Nonattainment Area (NAA) Thresholds		
Ozone (VOCs or NO_X precursors)	Extreme NAA	10
	Severe NAA	25
	Serious NAA	50
	Other ozone NAA outside an ozone transport region	100
	Other ozone NAAs inside an ozone transport region	50 (VOCs)
		100 (NO_X)
CO	All NAAs	100
SO_2	All NAAs	100
NO_2	All NAAs	100
PM_{10}	Moderate NAA	100
	Serious NAA	70
$PM_{2.5}$ (direct emissions, SO_2, NO_X, VOCs, and ammonia)	Moderate NAA	100
	Serous NAA	70
Lead	All NAAs	25
Ozone (VOCs or NO_X precursors)	All Maintenance Areas	100 (NO_X)
	Maintenance areas outside an ozone transport region	100 (VOCs)
	Maintenance areas inside an ozone transport region	50 (VOCs)
CO	All Maintenance Areas	100
SO_2	All Maintenance Areas	100
NO_2	All Maintenance Areas	100
Maintenance Area Thresholds		
PM_{10}	All Maintenance Areas	100
$PM_{2.5}$ (direct emissions, SO_2, NO_X, VOCs, and ammonia)	All Maintenance Areas	100
Lead	All Maintenance Areas	25

Source: 40 CFR § 93.153(b)

Note:
tpy = tons per year

The following are nonattainment and maintenance areas surrounding the GOM (EPA 2022e). Emissions in these nonattainment and maintenance areas would include vessel emissions associated with the transportation of materials and construction and operations activities.

The following jurisdiction is in Ozone Nonattainment Areas (2008 NAAQS):

- Dukes County, MA (Marginal)

The following jurisdictions are in Ozone Maintenance Areas (1997 and 2008 NAAQS):

- Boston-Manchester-Portsmouth (SE), NH Area
- Rockingham County, NH
- Strafford County, NH
- Hillsborough County, NH
- Boston-Lawrence-Worcester (E. Mass), MA Area
- Barnstable County, MA
- Bristol County, MA
- Dukes County, MA
- Essex County, MA
- Middlesex County, MA
- Norfolk County, MA
- Plymouth County, MA
- Suffolk County, MA
- Worcester County, MA
- Portland, ME Area
- Androscoggin County, ME
- Cumberland County, ME
- Sagadahoc County, ME
- York County, ME
- Hancock, Knox, Lincoln and Waldo Counties (Central Maine Coast), ME Area
- Hancock County, ME
- Knox County, ME
- Lincoln County, ME
- Waldo County, ME

The following jurisdictions are in Carbon Monoxide Maintenance Area (1971 NAAQS):

- Manchester and Nashua, NH Area
- Hillsborough County, NH
- Boston, MA Area
- Middlesex County, MA
- Norfolk County, MA
- Suffolk County, MA

The following jurisdictions are in the SO_2 Maintenance Area (2010 NAAQS):

- Central New Hampshire, NH
- Hillsborough County, NH
- Merrimack County, NH
- Rockingham County, NH

5.8.4 Ambient Background Data

The ME DEP, NHDES Air Resources Division, and MassDEP operate ambient air quality monitoring sites at numerous locations throughout their respective states. Since an offshore wind project would be located away from shore in the open water, there would not be any monitoring stations in close proximity. The nearest onshore ambient air quality monitoring sites relative to the GOM were reviewed, including NHDES's monitoring stations at Pierce Island in Portsmouth (for ozone, particles, and sulfur dioxide) and at Odiorne State Park in Rye (for ozone). While an offshore windfarm would not be close to these monitoring sites, land-based offshore wind activities and near shore vessel traffic in the Portsmouth, Rye, Hampton and Kittery areas could be nearby. All of the monitoring sites considered, as well as the pollutants monitored at those sites, are summarized in Table 5.8.3.

Measurements from coastal ambient monitoring sites were assessed to conservatively represent ambient background concentrations. All the monitoring stations are located on land near local sources of pollutants and are representative of urban land use. Table 5.8.4 summarizes the selected monitoring concentrations corresponding to the most conservatively representative monitor for each pollutant for the three most recent years of available data (2019-2021).

Table 5.8.3. Coastal Ambient Monitoring Locations Considered for Representative Ambient Background.

Site ID	State	County	City	Pollutants					
				CO	NO_2	PM_{10}	$PM_{2.5}$	SO_2	O_3
33-015-0016	NH	SEACOAST SCIENCE CENTER	Rye						X
33-015-0014	NH	PORTSMOUTH - PEIRCE ISLAND	Portsmouth			X	X	X	X
23-031-2002	ME	KPW - Kennebunkport Parson'd Way	Kennebunkport						X
23-005-2003	ME	CETL - Cape Elizabeth Two Lights (State Park)	Portland						X
23-005-0029	ME	PDO - Portland Deering Oaks	Portland		X	X	X		X
23-005-0015	ME	TB - Tukey's Bridge	Portland			X	X		
23-013-0004	ME	Marshall Point Lighthouse	Rockland						X
23-009-0102	ME	TOP OF CADILLAC MTN	Bar Harbor			X	X		X
23-009-0103	ME	MCFARLAND HILL Air Pollutant Research Site	Bar Harbor	X		X	X	X	X
23-029-0019	ME	Harbor Masters Office; Jonesport Public Landing	Jonesport						X
25-001-0002	MA	TRURO NATIONAL SEASHORE	Truro						X
25-009-2006	MA	LYNN WATER TREATMENT PLANT	Lynn		X		X		X
25-025-0044	MA	VON HILLERN ST	Boston	X	X		X		

Table 5.8.4. Representative Ambient Background Concentrations.

Pollutant	Averaging Period	Rank	Monitored Design Concentration (µg/m³ unless noted)					NAAQS (µg/m³)	% of NAAQS
			Monitor a/	2019	2020	2021	3-year Design Conc. (µg/m³)		
CO	1-hour	Max. 2nd high	A	1.6 ppm c/	1.5 ppm	1.5 ppm	1832	40,000	5%
	8-hour	Max. 2nd high	A	1.0 ppm	1.1 ppm	1.0 ppm	1260	10,000	13%
NO_2	1-hour	Avg. 98th percentile	A	49 ppb d/	46 ppb	45 ppb	88	188	47%
	Annual	Max. 1st high	A	14.2 ppb	12.5 ppb	12.3 ppb	27	100	27%
PM_{10}	24-hour	Max. 2nd high	B	67	59	53	67	150	45%
$PM_{2.5}$	24-hour	Avg. 98th percentile	A	17	16	18	17	35	49%
	Annual	Avg. 1st high	A	7.6	8.3	8.2	8	12	67%
SO_2	1-hour	Avg. 99th percentile	C	10 ppb	6 ppb	9 ppb	22	196	11%
	3-hour b/	Max. 2nd high	C	14.5 ppb	6.6 ppb	15.6 ppb	41	1,300	3%
	24-hour	Max. 2nd high	C	3.5 ppb	3.3 ppb	2.6 ppb	9	365	2%
	Annual	Max. 1st high	C	1.4 ppb	1.2 ppb	1.2 ppb	4	80	5%
O_3	8-hour	Avg. 4th high	D	0.064 ppm	0.060 ppm	0.070 ppm	127	137	93%

Notes:
a/ Ambient Monitoring Sites:
A = Site 25-025-0044 Von Hillern St. Boston, MA
B = Site 23-005-0015 TB - Tukey's Bridge Portland, ME
C = Site 33-015-0014 Peirce Island, Porstmouth, NH
D = Site 23-031-2002 Parson'd Way, Kennebunkport, ME
b/ 1-hour highest second-high concentration conservatively used as a surrogate for 3-hour highest second-high concentration.
c/ parts per million
d/ parts per billion

5.8.5 *Emissions Estimates*

There are five categories of emissions sources for an offshore wind project:

- Commercial marine vessels,
- Helicopters,
- Stationary diesel generator engines,
- Portable diesel generator engines, and
- Gas-insulated switchgear.

For the purposes of presenting emissions estimates from a potential or theoretical offshore wind project in the GOM, emissions calculated for a representative 2,000-3,000 MW offshore wind project currently in development off the East Coast are presented here. Emission sources and calculations are described below.

Commercial Marine Vessels

The emission calculations were based on assumed typical vessels representative of the types, configurations, and sizes that a project may employ during the construction, operations, and maintenance phases of a project. Where specific vessel specifications were unavailable, vessel specifications were selected to represent a maximum design scenario with respect to the potential emissions of the identified vessel category. Vessel operating durations were selected to represent a maximum design scenario with respect to potential emissions (i.e., conservative estimates).

Helicopter Emissions

Helicopters may be used to perform crew transfers during the foundation, wind turbine, and submarine export cable installation tasks. BOEM has produced a technical document, *BOEM Offshore Wind Energy Facilities Emission Estimating Tool – Technical Documentation* (BOEM 2017), to assist in estimating emissions for construction and operations of offshore wind energy facilities, including emissions from helicopters.

Emissions for helicopter crew transfers during construction were estimated assuming a large twin-engine helicopter capable of carrying 20-30 passengers. Travel distances and durations were estimated using a local airport as the assumed departure location.

Offshore Substation Generator Engines

Each offshore substation may be equipped with one diesel generator engine. The offshore substation generator engines may be used both for emergency and non-emergency generation, including readiness testing and maintenance purposes. Potential emissions were estimated by conservatively assuming up to 2,000 operating hours per year for each engine.

Portable Diesel Generator Engines

Portable diesel generator engines may be required during construction and commissioning of a project, as well as during potential unplanned emergency events during operations and maintenance of a project. Each of the portable diesel generators would be lifted onto each offshore substation or wind turbine prior to use and retrieved from each substation or wind turbine after use.

Gas-Insulated Switchgear

The offshore substations and wind turbines would be equipped with high-voltage circuit breakers (“switchgear”) that use SF_6 as an insulating material. SF_6 is a GHG that is designed to allow minimal outflow from the sealed switchgear housings into the air. Emissions of SF_6 from the wind turbine switchgear were estimated using the switchgear counts and storage quantities and assuming an annual leakage rate of 0.5 percent by weight per year (IEC 2004, as cited in EPA 2022a). For perspective, calculated SF_6 emissions would only contribute about 2% of the total GHG emissions during the operational phase, on a CO_2 equivalent basis.

Currently, the higher-voltage switchgear used for both onshore and offshore substations still require the use of SF_6. However, developers are evaluating switchgear designs that use air as the insulating gas, rather than SF_6. Some turbine manufacturers are beginning to offer SF_6-free switchgear, while others are still researching the feasibility of this. Therefore, it is possible that SF_6 emissions will not be a factor in future projects. However, for the purpose of this assessment, they have been included the estimate of potential emissions.

Global Warming Potentials

The GHG emissions from an offshore wind project would result from the combustion of diesel fuel that produces emissions of CO_2, CH_4, and N_2O, as well as leakage of SF_6 from gas-insulated switchgear. GHGs are typically presented as CO_2 equivalent or “CO_2e”, based on the specific Global Warming Potential (GWP) for each gas.

Each GHG constituent has a different heat trapping capability. The corresponding GWP has been calculated by the EPA to reflect how long the gas remains in the atmosphere, on average, and how strongly it absorbs energy compared to CO_2. Gases with a higher GWP absorb more energy per pound, than gases with a lower GWP.

Factors used to calculate CO_2e (GWP) were taken from Table A-1 of 40 CFR Part 98, Subpart A. The GWPs are 25 for CH_4, 298 for N_2O, and 22,800 for SF_6.

Therefore, the equation to calculate CO_2e for each source is:

Equation 2

$$\mathrm{CO2e} = \left[\mathrm{CO2}\,\frac{\mathrm{tons}}{\mathrm{yr}}\ \mathrm{x\ CO2\ GWP(1)}\right] + \left[\mathrm{CH4}\,\frac{\mathrm{tons}}{\mathrm{yr}}\ \mathrm{x\ CH4\ GWP(25)}\right] + \left[\mathrm{N2O}\,\frac{\mathrm{tons}}{\mathrm{yr}}\ \mathrm{x\ N2O\ GWP(298)}\right] + \left[\mathrm{SF6}\,\frac{\mathrm{tons}}{\mathrm{yr}}\ \mathrm{x\ SF6\ GWP(22{,}800)}\right] \quad (3)$$

Summary of Potential Emissions

Table 5.8.5 presents the potential emissions for a representative offshore wind project by calendar year for the activities that are subject to an OCS air permit application. OCS air permit emissions include those from OCS sources, vessels meeting the definition of OCS Source (40 CFR § 55.2), and vessels traveling to and from the Project when within 25 nm (46.3 km) of the Lease Area's perimeter. The emissions include total emissions from three years of construction, and from operations and maintenance.

Table 5.8.5. Combined Potential Emissions for Representative Offshore Wind Project (tons per year).

Calendar Year	VOC	NO_x	CO	PM/ PM_{10}	$PM_{2.5}$	SO_2	Total HAP	GHG (CO_2e)
Year 1 - Construction	10	200	80	5	5	2	1	10,000
Year 2 - Construction	100	2,000	700	60	50	50	10	150,000
Year 3 - Construction plus partial O&M	50	700	600	30	20	10	5	80,000
Year 4 and Onward – Full O&M	20	300	200	10	10	2	1	30,000

Estimated air emissions from operations and maintenance activities are not expected to have a significant impact on regional air quality over the operational life of a project and are generally expected to be smaller compared to the impacts anticipated during construction activities. Additionally, an offshore wind project in the GOM could reduce the need for electricity generation from traditional fossil-fueled electric generation facilities in the New England region.

5.9 Impacts of Sound Created by Turbine Construction and Operations

The sound generated by the construction and operation of offshore wind farms is regulated by NOAA and the BOEM. Both agencies have published guidelines that specify sound thresholds for marine species. The onshore portion of the projects are regulated by state and local agencies. The regulations are also further described below.

NOAA National Marine Fisheries Service issued a Technical Guidance that provides acoustical thresholds and defines the threshold metrics (NOAA NMFS 2018). The International Organization for Standardization (ISO) 18405 Underwater Acoustics – Terminology (ISO 2017) provided a dictionary of underwater bioacoustics for standardized terminology. Table 5.9.1 provides a summary of the relevant metrics from both NOAA NMFS (2018) and ISO (2017) that are used within this section.

Table 5.9.1. Summary of Acoustic Terminology.

Metric	NOAA NMFS (2018)	ISO (2017)		Reference Value
		Main Text	Equations and Tables	
Sound Pressure Level	SPL	SPL	L_p	dB re 1 μPa
Peak Sound Pressure Level	PK	Lpk	$L_{p,pk}$	dB re 1 μPa
Cumulative Sound Exposure Level	SEL_{cum} a/	SEL	L_E	dB re 1 μPa^2·s

Note:
a/ NOAA NMFS (2018) describes the SEL_{cum} metric over an accumulation period of 24-hour period. Following the ISO standard (2017), this is identified as SEL in the text and L_E is used in tables and equations of this report with the accumulation period identified.

5.9.1 Underwater Acoustic Criteria

The Marine Mammal Protection Act (MMPA) of 1972 was implemented for the protection of all marine mammals. The MMPA prohibits, with certain exceptions, the “take” of marine mammals. The term “take,” as defined in Section 3 (16 U.S.C. § 1362 (13)) of the MMPA, means “to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal”. NOAA NMFS (also known as NOAA Fisheries) has jurisdiction for overseeing the MMPA regulations as they pertain to most marine mammals; however, the U.S. Fish and Wildlife Service (USFWS) has jurisdiction over a select group of marine mammals – none of which occur in New Hampshire, or in the GOM (e.g., manatees, otters, walruses, and polar bears). Generally, NOAA Fisheries is responsible for issuing take permits under MMPA upon a request for authorization of incidental but not intentional “taking” of small numbers of marine mammals by U.S. citizens or agencies who engage in a specified activity (other than commercial fishing) within a specified geographical region. “Harassment” was further defined in the 1994 amendments to the MMPA, with two levels: Level A and Level B. By definition, Level A harassment is any act of pursuit, torment, or annoyance that has the potential to injure a marine mammal or marine mammal stock, while Level B harassment is any act of pursuit, torment, or annoyance which has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering. NOAA Fisheries defines the threshold level for Level B harassment at 160 dB SPL for impulsive sound, averaged over the duration of the signal and at 120 dB SPL for non-impulsive sound, with no relevant acceptable distance specified.

NOAA Fisheries provides guidance for assessing the impacts of anthropogenic sound on marine mammals including whales, dolphins, porpoises, seals, and sea lions (NOAA NMFS 2018). The guidance specifically defines marine mammal hearing groups; develops auditory weighting functions; and identifies the received levels, or acoustic threshold levels, above which individual marine mammals are predicted to experience changes in their hearing sensitivity (permanent threshold shift [PTS] or temporary threshold shift [TTS]) for acute, incidental exposure to underwater sound. Under this guidance, any occurrence of PTS constitutes a Level A, or injury take. Sound emitted by anthropogenic sources may induce TTS or PTS in an animal in two ways: (1) peak sound pressure levels (Lpk) may cause damage to the inner ear, and (2) the accumulated sound energy the animal is exposed to (SEL) over the entire duration of a discrete or repeated noise exposure has the potential to induce auditory damage if it exceeds the relevant threshold levels.

Research shows that the frequency content of the sound would play a role in causing damage. Sound outside the hearing range of the animal would be unlikely to affect its hearing, while the sound energy within the hearing range could be harmful. Since all marine mammal species do not have equal hearing capabilities, the following five hearing groups have been defined:

- **Low-frequency (LF) Cetaceans**—this group consists of the baleen whales (mysticetes) with a collective generalized hearing range of 7 hertz (Hz) to 35 kilohertz (kHz);
- **Mid-frequency (MF) Cetaceans**—includes most of the dolphins, all toothed whales except for Kogia spp., and all the beaked and bottlenose whales with a generalized hearing range of approximately 150 Hz to 160 kHz (renamed High-frequency cetaceans by Southall et al. [2019] because their best hearing sensitivity occurs at frequencies of several tens of kHz or higher);
- **High-frequency (HF) Cetaceans**—incorporates all the true porpoises, the river dolphins, plus Kogia spp., *Cephalorhynchid* spp. (genus in the dolphin family Delphinidae), and two species of *Lagenorhynchus* (Peale's and hourglass dolphins) with a generalized hearing range estimated from 275 Hz to 160 kHz (renamed very high-frequency cetaceans by Southall et al. [2019] since some species have best sensitivity at frequencies exceeding 100 kHz);
- **Phocids Underwater**—consists of true seals with a generalized underwater hearing range from 50 Hz to 86 kHz (renamed Phocid carnivores in water by Southall et al. [2019]); and
- **Otariids Underwater** —includes sea lions and fur seals with a generalized underwater hearing range from 60 Hz to 39 kHz (termed "other marine carnivores" in water by Southall et al. [2019]) and includes otariids, as well as walrus [Family Odobenide], polar bear [*Ursus maritimus*], and sea and marine otters [Family Mustelidae]).

Within these generalized hearing ranges, the ability to hear sounds varies with frequency, as demonstrated by examining audiograms of hearing sensitivity (NOAA NMFS 2018; Southall et al. 2019)., Auditory weighting functions were developed for each functional hearing group to reflect higher noise sensitivities at particular frequencies (NOAA NMFS 2018). These weighting functions are applied to individual sound received levels to reflect the susceptibility of each hearing group to noise-induced threshold shifts, which is not the same as the range of best hearing (Figure 5.9.1).

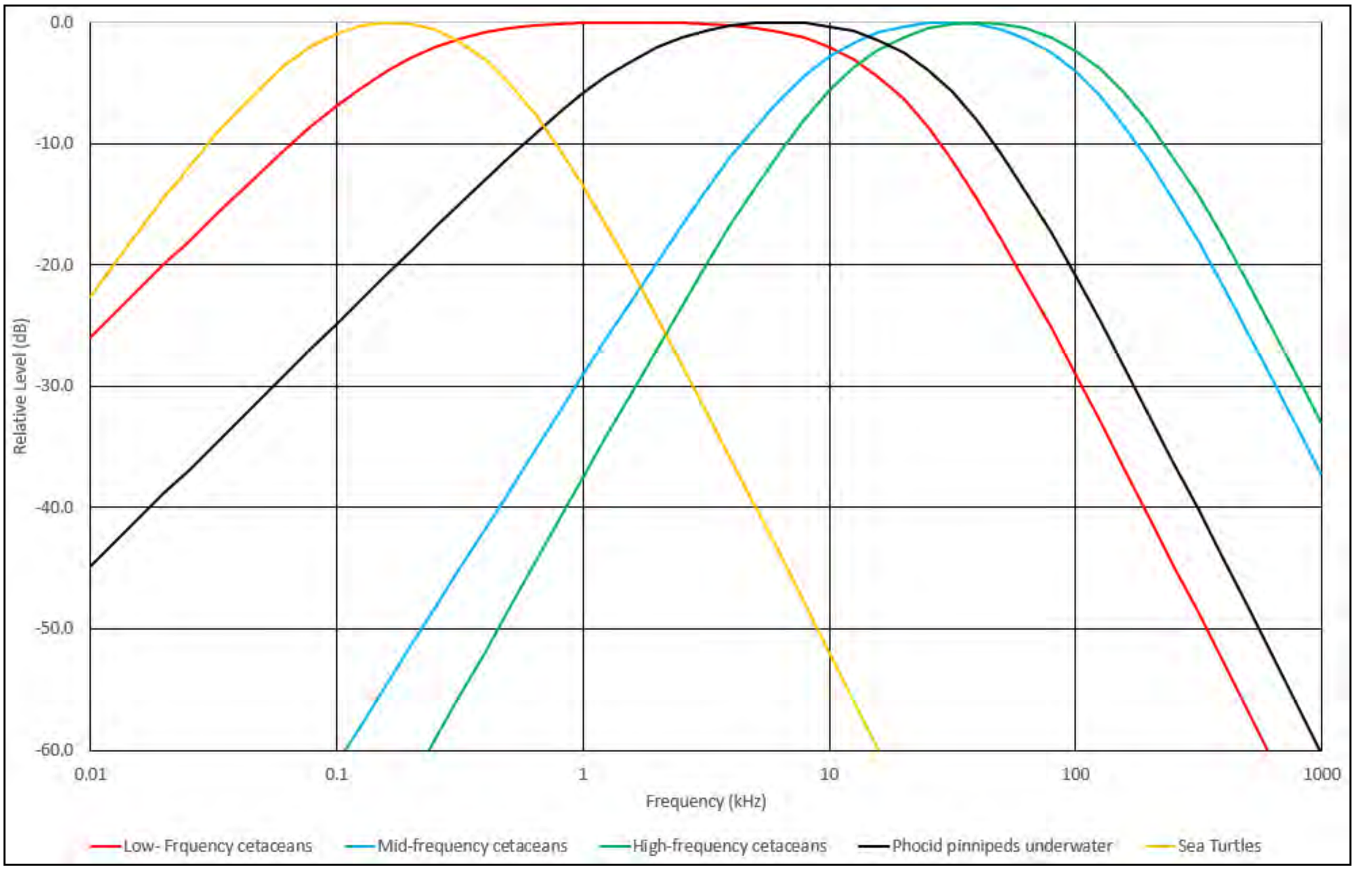

Figure 5.9.1. Auditory weighting functions for cetaceans (Low-frequency, Mid-frequency, and High-frequency Species), Pinnipeds in water (PW), and Sea Turtles (NOAA NMFS 2018, U.S. Navy 2017).

NOAA NMFS (2018) defined acoustic threshold levels at which PTS and TTS are predicted to occur for each hearing group for impulsive and non-impulsive signals (Table 5.9.2), which are presented in terms of dual metrics; SEL and Lpk. The Level B harassment thresholds are also provided in Table 5.9.2.

Table 5.9.2. Acoustic Threshold Levels for Marine Mammals.

Hearing Group	Impulsive Sounds: Permanent Threshold Shift Onset	Impulsive Sounds: Temporary Threshold Shift Onset	Impulsive Sounds: Behavior	Non-Impulsive Sounds: Permanent Threshold Shift Onset	Non-Impulsive Sounds: Temporary Threshold Shift Onset	Non-Impulsive Sounds: Behavior
Low-frequency cetaceans	219 dB ($L_{p,pk}$) 183 ($L_{E,\ LF,\ 24h}$)	213 dB ($L_{p,pk}$) 168 dB ($L_{E,\ LF,\ 24h}$)	160 dB (L_p)	199 dB ($L_{E,\ LF,\ 24h}$)	179 dB ($L_{E,\ LF,\ 24h}$)	120 dB (L_p)
Mid-frequency cetaceans	230 dB ($L_{p,pk}$) 185 dB ($L_{E,\ MF,\ 24h}$)	224 dB ($L_{p,pk}$) 170 dB ($L_{E,\ MF,\ 24h}$)		198 dB ($L_{E,\ MF,\ 24h}$)	178 dB ($L_{E,\ MF,\ 24h}$)	
High-frequency cetaceans	202 dB ($L_{p,pk}$) 155 dB ($L_{E,\ HF,\ 24h}$)	196 dB ($L_{p,pk}$) 140 dB ($L_{E,\ HF,\ 24h}$)		173 dB ($L_{E,\ HF,\ 24h}$)	153 dB ($L_{E,\ HF,\ 24h}$)	
Phocid pinnipeds underwater	218 dB ($L_{p,pk}$) 185 dB ($L_{E,\ PW,\ 24h}$)	212 dB ($L_{p,pk}$) 170 dB ($L_{E,\ PW,\ 24h}$)		201 dB ($L_{E,\ PW,\ 24h}$)	181 dB ($L_{E,\ PW,\ 24h}$)	

Sources: Southall et al. 2019; NOAA NMFS 2018
Note:
$L_{E,\ 24h}$ = cumulative sound exposure over a 24 hour period (dB re 1 μPa^2·s);
$L_{p,pk}$ = peak sound pressure (dB re 1 μPa);
L_p = root mean square sound pressure (dB re 1 μPa)

NOAA Fisheries anticipates behavioral response for sea turtles from impulsive sources such as impact pile-driving to occur at SPL 175 dB (Table 5.9.3; Blackstock et al. 2017). There is limited information available on the effects of noise on sea turtles, and the hearing capabilities of sea turtles are still poorly understood. In addition, the U.S. Navy introduced a weighting filter appropriate for sea turtle impact evaluation in their 2017 document titled "*Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III).*" That weighting has been applied to impulsive criterion for PTS (204 dB SEL), impulsive criterion for TTS (189 dB SEL), and non-impulsive criteria for TTS (200 dB SEL and 226 dB Lpk) and PTS (220 dB SEL and 232 dB Lpk). The weighting for sea turtles is presented in Figure 5.9.1.

In a cooperative effort between federal and state agencies, interim criteria were developed to assess the potential for injury to fishes exposed to pile-driving sounds. These noise injury thresholds have been established by the Fisheries Hydroacoustic Working Group, which was assembled by NOAA Fisheries with thresholds subsequently adopted by NOAA Fisheries. The NOAA Fisheries Greater Atlantic Regional Fisheries Office (GARFO) has applied these standards for assessing the potential effects of ESA-listed fish species exposed to elevated levels of underwater sound produced during pile-driving, which were just recently updated (NOAA NMFS 2019). These noise thresholds have been adopted by GARFO and are based on sound levels that have the potential to produce injury or illicit a behavioral response from fishes (Table 5.9.3).

Table 5.9.3. Acoustic Threshold Levels for Fishes and Sea Turtles.

Hearing Group	Impulsive Signals		Non-impulsive Signals		Behavior (Impulsive and Non-impulsive)
	Injury	Temporary Threshold Shift Onset	Injury	Temporary Threshold Shift Onset	
Fishes	206 dB ($L_{p,pk}$) 187 dB ($L_{E, 24h}$)	--	--	--	150 dB (L_p)
Sea turtles	232 dB ($L_{p,pk}$) 204 dB ($L_{E, TUW, 24h}$)	226 dB ($L_{p,pk}$) 189 dB ($L_{E, TUW, 24h}$)	220 dB ($L_{E, TUW, 24h}$)	200 dB ($L_{E, TUW, 24h}$)	175 dB (L_p)

Sources: Stadler and Woodbury 2009; NOAA NMFS 2019; Blackstock et al. 2017; Department of the Navy 2017
Note:
$L_{E, 24h}$ = cumulative sound exposure over a 24 hour period (dB re 1 μPa^2·s);
$L_{p,pk}$ = peak sound pressure (dB re 1 μPa);
L_p = root mean square sound pressure (dB re 1 μPa)

A Working Group organized under the American National Standards Institute-Accredited Standards Committee S3, Subcommittee 1, Animal Bioacoustics, also developed sound exposure guidelines for fish and sea turtles (Table 5.9.4; Popper et al. 2014). They identified three types of fishes depending on how they might be affected by underwater sound. The categories include fishes with no swim bladder (e.g., flounders, dab, and other flatfishes); fishes with swim bladders in which hearing does not involve the swim bladder or other gas volume (e.g., salmonids); and fishes with a swim bladder that is involved in hearing (e.g., channel catfish).

Table 5.9.4. Acoustic Threshold Levels for Fishes and Sea Turtles.

Hearing Group	Impulsive Sounds			Non-Impulsive Sounds	
	Mortality and Potential Mortal Injury	Recoverable Injury	Temporary Threshold Shift	Recoverable Injury	Temporary Threshold Shift
Fishes without swim bladders	> 213 dB ($L_{p,pk}$) > 219 dB ($L_{E, 24h}$)	> 213 dB ($L_{p,pk}$) > 216 dB ($L_{E, 24h}$)	> 186 dB ($L_{E, 24h}$)	--	--
Fishes with swim bladder not involved in hearing	207 dB ($L_{p,pk}$) 210 dB ($L_{E, 24h}$)	207 dB ($L_{p,pk}$) 203 dB ($L_{E, 24h}$)	>186 dB ($L_{E, 24h}$)	--	--
Fishes with swim bladder involved in hearing	207 dB ($L_{p,pk}$) 207 dB ($L_{E, 24h}$)	207 dB ($L_{p,pk}$) 203 dB ($L_{E, 24h}$)	186 dB ($L_{E, 24h}$)	170 dB (L_p)	158 dB (L_p)
Sea turtles	207 dB ($L_{p,pk}$) 210 dB ($L_{E, 24h}$) 232 dB ($L_{p,pk}$) PTS	(N) High (I) Low (F) Low	226 dB ($L_{p,pk}$)	--	--
Eggs and larvae	207 dB ($L_{p,pk}$) 210 dB ($L_{E, 24h}$)	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	--	--

Hearing Group	Impulsive Sounds			Non-Impulsive Sounds	
	Mortality and Potential Mortal Injury	Recoverable Injury	Temporary Threshold Shift	Recoverable Injury	Temporary Threshold Shift

Sources: Popper et al. 2014
Notes:
$L_{E,\ 24h}$ = cumulative sound exposure over a 24 hour period (dB re 1 μPa^2·s);
$L_{p,pk}$ = peak sound pressure (dB re 1 μPa);
L_p = root mean square sound pressure (dB re 1 μPa)
PTS = permeant threshold shift;
N = near (10s of meters);
I = intermediate (100s of meters);
F = far (1000s of meters);
-- = not applicable

5.9.2 In-air Acoustic Criteria

The State of New Hampshire does not have established regulations for in-air noise impacts and exposure. However, specific counties, cities, and townships typically have established noise regulations. Therefore, the noise regulations will vary depending on the location of the onshore portion of the project, and further review of the applicable noise regulations will be conducted once the project location has been determined.

5.9.3 Impacts of Sound from In-water Construction of Offshore Wind Turbines

Impact Pile Driving

The installation of fixed-bottom offshore wind turbines is typically completed using significant noise generating equipment such as impact hammers, vibratory hammers, and drills. This section focuses on impact pile driving associated with traditional fixed-bottom turbines, since it is not yet clear what extent of pile driving would be required for a floating offshore wind turbine which is expected to rely more on anchoring technologies, rather than pile driving.

Impact pile-driving involves weighted hammers that pile drive foundations into the seafloor. Different methods for lifting the weight associated with the pile driver include hydraulic, steam, or diesel. The acoustic energy is created upon impact; the energy travels into the water along different paths: (1) from the top of the pile where the hammer hits, through the air, into the water; (2) from the top of the pile, down the pile, radiating into the air while traveling down the pile, from air into water; (3) from the top of the pile, down the pile, radiating directly into the water from the length of pile below the waterline; and (4) down the pile radiating into the seafloor, traveling through the seafloorand radiating back into the water. Near the pile, acoustic energy arrives from different paths with different associated stage and time lags, which creates a pattern of destructive and constructive interference. Further away from the pile, the water- and seafloor-born energy are the dominant pathways. The underwater noise generated by a pile-driving strike depends primarily on the following factors:

- The impact energy and type of pile-driving hammer,
- The size and type of the pile,
- Water depth, and

- Subsurface hardness in which the pile is being driven.

For offshore wind facility construction, impact pile driving is typically the loudest activity and is dependent on hammer energy, pile size and penetration depth. Pile driving can be mitigated by implementing a "soft-start" technique. The soft start technique involves initially driving a pile using a low hammer energy. As the pile is driven further into the sediment, the hammer energy is increased as necessary to achieve sediment penetration. This technique gives fish and marine mammals an opportunity to move out of the area before full-powered impact pile-driving begins.

In addition to the application of the soft-start technique, other devices may be considered to mitigate impact pile-driving sound levels. There are several types of sound attenuation devices including bubble curtains, noise mitigation screen (cofferdam type), Hydro Sound Dampers, and the AdBm noise mitigation system. The most commonly considered mitigation strategy is the use of bubble curtains. Bubble curtains create a column of air bubbles rising around a pile from the substrate to the water surface. Because air and water have a substantial impedance mismatch, the bubble curtain acts as a reflector. In addition, the air bubbles absorb and scatter sound waves emanating from the pile, thereby reducing the sound energy. Bubble curtains may be confined or unconfined. These systems may be deployed in series, such as a double bubble curtain with two rings of bubbles encircling a pile. Attenuation levels also vary by type of system, frequency band, and location. Small bubble curtains have been measured to reduce sound levels from approximately 10 dB to more than 20 dB but are highly dependent on depth of water and current, and configuration and operation of the curtain (Koschinski and Lüdemann 2013; Bellmann 2014; Austin et al. 2016). Larger bubble curtains tend to perform better and more reliably, particularly when deployed with two rings. Encapsulated bubble systems and Hydro Sound Dampers are effective within their targeted frequency ranges, e.g., 100 to 800 Hz, and when used in conjunction with a bubble curtain can further reduce noise, resulting in prolonged pulse duration or a reduced impact energy (Koschinski and Lüdemann 2020).

Effectiveness of bubble curtains is variable and depends on many factors, including the bubble layer thickness, the total volume of injected air, the size of the bubbles relative to the sound wavelength, and whether the curtain is completely closed. Decreased noise reduction has been found in cases of strong currents or sub-optimal configuration (Bellmann et al. 2017). As water depth increases, the opportunity for current-based disruption of the bubble curtain increases. In general, bubble curtain effectiveness decreases as the water depth increases (Bellmann et al. 2017).

Vibratory Hammers

Vibratory hammers are typically used to reduce the risk of pile run during the initial installation of piles. They are also used to install nearshore cofferdams supporting the cable transition from underwater to land. Vibratory hammers install pilings into the seafloor by applying a rapidly alternating force to the pile. This is generally accomplished by rotating eccentric weights about shafts. Each rotating eccentric produces a force acting in a single plane and directed toward the centerline of the shaft. The weights are set off-center of the axis of rotation by the eccentric arm. If only one eccentric arm is used, in one revolution a force will be exerted in all directions, giving the system significant lateral whip. To avoid this problem, the eccentric arms are paired so the lateral forces cancel each other, leaving only axial force for the pile. The use of vibratory hammer itself is considered a noise mitigation strategy. The main energy associated with vibratory pile driving is radiated at lower frequencies compared to impact piling, and sound waves below a lower cut-off frequency do not propagate in shallow waters. As a result, high peak levels can be avoided, and continuous sound levels can be kept low. Noise emissions from vibratory pile driving are on the order of 10 to 20 dB ($L_{eq,30s}$) below mitigated impact pile driving at identical monopiles (Koschinski and Lüdemann 2020).

Cable Lay Operations

Specialist vessels designed for laying and burying cables on the seabed would be used to install the Offshore Export and Inter-Array Cables. The cables would be buried using a jet trencher or plough. Throughout the cable lay process, it is assumed that a dynamic positioning (DP)-enabled cable lay vessel would be the maximum design scenario. A DP-enabled cable lay vessel maintains its position (fixed location or predetermined track) by means of its propellers and thrusters using a global positioning system, which describes the ship's position by sending information to an onboard computer that controls the thrusters. DP vessels possess the ability to operate with positioning accuracy, safety, and reliability without the need for anchors, anchor handling tugs, and mooring lines. The underwater noise produced by subsea trenching operations depends on the equipment used and the nature of the seabed sediments, but will be predominantly generated by vessel thruster use.

Thruster sound source levels may vary, in part due to technologies employed and are not necessarily dependent on either vessel size, propulsion power, or the activity engaged. DP positioning thruster noise is non-impulsive and continuous in nature and is not expected to result in harassment. Vessel sound sources are sufficiently low so that no injury is expected. Distances within which injury and/or harassment might occur are generally short.

5.9.4 Impacts of Sound from Onshore Construction of Offshore Wind Turbines

The sound generated from the construction onshore components associated with an offshore wind turbine farm includes HDD associated with the cable installation as well as typical construction activities associated with substations and switching stations. HDD operations are typically conducted at the onshore/in water connection as well as at points where the cable line would go under roads and water. The HDD operations are typically the loudest noise source associated with the onshore cable installation and the most impactful since they typically occur over 24-hour periods. Construction of the substation and switching stations would utilize typical construction equipment. These activities would occur typically during the daytime hours and would result in a less significant impact.

5.9.5 Impacts of Sound from the Operation of Offshore Wind Turbines

Current studies monitoring underwater noise produced by FOW turbine arrays indicate that measured received levels are similar to those measured for operational noise from fixed-bottom offshore wind turbines at comparable distances (Risch et al. 2023). Underwater noise data were collected from two floating offshore wind farms currently in operation off the Scottish east coast: Kincardine and Hywind Scotland. Kincardine comprises five turbines rated at 9.5 MW deployed on semi-submersible foundations, while the five 6 MW-rated turbines at Hywind Scotland were deployed on spar-buoys. Like operational noise of fixed-bottom offshore wind turbines, noise from FOW turbines is low frequency (below 200 Hz), with received levels between 95 and 100 dB re 1 μPa at about 600 m from the closest turbine for both wind farms (Risch et al. 2023). Source levels for turbine operational noise (25 Hz – 20 kHz) increased with wind speed at both recording locations. At a wind speed of 15 m/s operational noise levels were about 3 dB higher at Kincardine (148.8 dB re 1μPa) compared to Hywind Scotland (145.4 dB re 1 μPa; Risch et al. 2023). The difference may be attributed to different power ratings, gear box versus direct drive technology, and/or the difference in mooring structure of the two turbines (i.e., semi-submersible versus spar-buoy). Assuming 15 m/s wind speed, the predicted noise fields for unweighted sound pressure levels were above median ambient noise levels in the North Sea for maximum distances of 3.5 - 4.0 km from the center of the Kincardine 5-turbine array, and 3.0 - 3.7 km for the 5-turbine array at Hywind Scotland (Risch et al. 2023).

The biggest difference between fixed-bottom and floating offshore wind turbines regarding underwater noise generation is the presence of mooring-related noise at floating wind turbines (Risch et al. 2023). The flexible mooring lines (steel cables, chains, or wired ropes) are dependent on water depth and turbine structure type and are a source of noise that does not occur in fixed-bottom offshore wind turbine arrays. During higher wind speeds the number of impulsive sounds or transients from mooring-related structures increased at both Kincardine and Hywind Scotland (Risch et al. 2023). While the long, flexible cables are not likely to produce a lot of strumming noise, periodic tension released along the cables of the mooring system may produce 'snaps', according to data near the Hywind Demo (Martin et al. 2011). At 150 m from the source, measurement of these transient sounds (containing energy over the full recording bandwidth of 0-20 kHz) indicated received peak sound pressure levels could exceed 160 dB re 1μPa (Xodus Ltd. 2015).

The expected wind turbine in-air sound levels are typically below audibility thresholds at all coastal areas due to the distance from the turbines to land. Sound generated by an operating wind turbine is comprised of both aerodynamic and mechanical sound with the dominant sound component from utility scale wind turbines being largely aerodynamic. Aerodynamic sound refers to the sound produced from air flow and the interaction with the wind turbine tower structure and moving rotor blades.

Wind facilities, in comparison to conventional energy projects, are somewhat unique in that the sound generated by each individual wind turbine will increase as the wind speed across the site increases. Wind turbine sound is negligible when the rotor is at rest, increases as the rotor tip speed increases, and is generally constant once rated power output and maximum rotational speed are achieved. Under maximum rotational wind speed the assumed maximum sound power level will be reached, generally occurring at approximately 7 to 9 meters per second depending on wind turbine type and according to manufacturer specifications. It is important to recognize, as wind speeds increase, the background ambient sound level will likely increase as well, resulting in acoustic masking effects. The net result is that during periods of elevated wind when higher wind turbine sound emissions occur, the sound produced from a wind turbine operating at maximum rotational speed may well be largely or fully masked by wind generated sounds of foliage or by increased sound related to waves crashing on the shoreline. In practical terms, this means that a nearby receptor may hear these other sound sources (i.e., foliage, ocean waves) rather than the sound of a wind turbine.

Offshore wind facility operations are unique due to the reflective nature of sounds surrounded by water and the impact of the shoreline on sound attenuation. As sound waves reach the coastline, a modification of the ground boundary occurs. This sudden change produces a supplementary sound attenuation due to the partial reflection of sound waves. In addition, the wind and temperature gradients are modified as the sea and the land are not always at the same temperature, thus generating friction at the ground surface. These effects result in a variation in the speed and curve of the sound waves. Few studies have been made of the shoreline effect and its effect on acoustical propagation. However, an average attenuation for low frequencies has been documented at 3 dB (Johansson 2003) up to 1,000 m, and then increasing with distance.

In addition, sound propagation from offshore wind turbines is different than propagation from land-based wind turbines. Sound propagation over water at large distances (generally above 2,000-3,000 m) involves a completely reflective surface and is dependent on the distance between the receiver and the sound source. As this distance increases, the effect of water reflection also increases. The influence of the reflecting water on the received sound level may be just as strong as the direct contribution from the sound source. In addition, downwind refractive effects result in a cylindrical wave spreading to form a reflecting layer in the atmosphere at a specified height. Strong reflection may occur during certain periods of the year with higher gradients in wind speed and direction at relatively low heights. Due to this reflecting layer, the sound from a source may be enclosed and form spherical waves that appear at certain distances as a cylindrical wave. This cylindrical spreading of sound energy due to multiple reflections from the sea surface generates a reduced sound at large distances with a slower rate of reduction than sound propagating over land, similar to the effect created by atmospheric temperature and wind gradients. Therefore, sound propagation over water is variable and dependent on a number of factors including:

- The distance over water from the sound source to the receiver,
- The height of the sound source above the completely reflective water surface,
- The height of the atmospheric inversion layer trapping the sound waves below the height of the source, thus creating the cylindrical wave,
- The atmospheric absorption coefficient due to the shoreline effect, and

- The attenuation due to the ground damping and the damping of sound.

As a result, the transmission loss between the received sound pressure at the receiver point and at the sound source may vary considerably due to these noted factors that are unique to offshore sound sources such as offshore wind turbines.

For the Revolution Wind Offshore Wind Farm project an airborne sound assessment was conducted for noise impacts to onshore receptors. This assessment assumed a maximum sound power level of 120 dBA per fixed-bottom wind turbine (VHB 2020). Using this sound power level noise propagation was calculated at various distances from the wind turbine (Table 5.9.5).

As shown in Table 5.9.5 the noise level from the operation of a fixed-bottom wind turbine is 33 dBA at 20,000 ft (3.3 nautical miles). The Revolution Wind Offshore Wind Farm project is located approximately 17.4 nautical miles from shore. The Revolution Wind in-air noise assessment of the wind turbine operations showed noise levels of 27 dBA or less at on-shore receptors.

Furthermore, after the Block Island Wind Farm was constructed continuous in-air noise monitoring was conducted at an onshore location for a three-month time to document the operational noise levels of the wind turbine operations. The monitor was placed approximately 3.5 nautical miles from the five offshore wind turbines at the top of the Southeast Lighthouse. The results of the study showed no airborne noise was identified from the operations of the wind turbines at any time during the monitoring period (BOEM 2019b).

Table 5.9.5. In-Air Sound Propagation Levels from Fixed-bottom Wind Turbines.

Distance (ft)	Sound Pressure Level (dBA)
50	85
100	79
250	71
500	65
1,000	59
2,500	51
5,000	45
7,500	41
10,000	39
20,000	33

5.10 Use of Rare Earth Minerals

5.10.1 Rare Earth Element Permanent Magnet Generators, Recycling and Efficiency, and Alternatives

Rare earth elements (REEs) are so-called because of their geological dispersal rather than their lack of abundance (CSE 2017). REEs comprise a group of chemical elements with similar properties that are used in a range of high-tech applications. Among this group, the key elements for clean energy technologies are neodymium, praseodymium, dysprosium and terbium, which are used to manufacture neodymium–iron–boron (NdFeB) permanent magnets. NdFeB permanent magnets are used as components in generators for wind turbines (Alves et al. 2020). The challenge is that REEs typically do not occur in concentrated deposits, are often found mixed together and are difficult, and therefore expensive, to separate (Wind Power Monthly 2018). REEs are crucial to accomplishing renewable energy targets throughout the world, including wind energy.

Permanent magnet generators have been utilized in offshore turbines, as they allow for high power density and small size with the highest efficiency at all speeds, offering a high annual production of energy with a low lifetime cost (Alves et al. 2020). Permanent magnets make small, light, space-saving designs for the gearboxes of wind turbines possible. They also enhance low-voltage ride-through capability, thus improving a turbine's capacity to remain connected to the grid (Gielen and Lyons 2022).

Most direct-drive turbines are equipped with permanent magnet generators that typically contain neodymium and smaller quantities of dysprosium. The same, although on a different scale, is true for several gearbox designs. In 2018 generators containing permanent magnets were used in nearly all offshore wind turbines in Europe and in approximately 76% of offshore wind turbines worldwide. The generators in direct-drive turbines, by contrast, can be based either on permanent magnets (the Goldwind, Siemens and General Electric models are examples) or an electric generator (e.g., Enercon direct-drive models). A key advantage of the direct-drive configuration is that it makes smaller and lighter turbines possible (by eliminating the gearbox), making it more competitive in offshore applications (Gielen and Lyons 2022).

High-performance sintered NdFeB magnets dominate the market today. They are used in wind turbines because of their high magnetic properties and productivity. The amount of dysprosium they contain can be greatly reduced by employing "grain boundary diffusion processing". Using current production technology and applications, the amount of added dysprosium can on average be halved. In the best scenario, it can be brought down to about 2% without reducing coercivity (Gielen and Lyons 2022).

There are several alternatives to current designs that use permanent magnets, a proven one being the use of 'hybrid drive' generators, which employs a single-stage gearbox with a smaller permanent magnet. This type of design evolution can result in less maintenance needed due to the lower number of gears involved when compared to a conventional turbine gearbox (CSE 2017). Using a hybrid drive generator could lead to a reduction in use of neodymium, praseodymium and dysprosium by up to two thirds per turbine (CSE 2017). However, most replacements for permanent magnets are less efficient and less performant and are thus not viable alternatives (Rabe et al. 2017).

Progress is also being made to reduce or eliminate the content of rare earths in permanent magnet generators for wind turbines. In July 2022, GreenSpur Wind in collaboration with Niron Magnetics, developed an axial-flux generator design that makes the use of rare-earth free magnets possible (Niron Magnetics 2022). This concept can also minimize risks with supply chain constraints and volatile pricing (Drives and Controls 2022).

5.10.2 Supply Chain Constraints and Production Diversification Outlook

Despite the extensive requirements of REEs, current supply chains are mainly fulfilled by the Chinese rare earth industry. In 2021, China possessed 36% of the global REE reserves or 44 million tons with a mine production share of 60% (U.S. Geological Survey 2022). Rare earth concentrates produced in the U.S. and Myanmar are currently exported to China to carry out the final separation and purification processes (Ilkankoon et al. 2022). This has resulted in price volatility, supply chain uncertainties, and REE trade disputes (Ilkankoon et al. 2022). Availability of REEs and supply diversification have an impact on technological development, international trade and delocalization of manufacturing, and may constitute a bottleneck to the deployment of wind turbines.

In June 2021, the Biden-Harris Administration released a first-of-its-kind supply chain assessment that found the U.S. is over-reliance on foreign sources and adversarial nations for critical minerals and materials posed national and economic security threats (WHBR 2022). In addition to working with partners and allies to diversify sustainable sources, the report recommended expanding domestic mining, production, processing, and recycling of critical minerals and materials (WHBR 2022).

5.11 Visual Impacts and Visibility Thresholds for Other Activities and Operations in the Gulf of Maine

The purpose of this section is to describe the existing visual character of the coastal New Hampshire landscape, and preliminarily identify sensitive scenic resources that could be affected by future offshore wind development in the GOM. The potential for and magnitude of effects to scenic resources from offshore wind projects depends on many factors. Distance, scale, prominence, patterns of atmospheric conditions, viewer expectations and values, experiential duration, and visual contrast of the change all influence the effects of visual change.

The BOEM released its guidelines for the evaluation of visual effects from offshore wind projects: *Assessment of Seascape, Landscape, and Visual Impacts of Offshore Wind Energy Developments on the Outer Continental Shelf of the United States in 2021.*

5.11.1 Existing Visual Character

The study area for this section has been defined as the area of New Hampshire within five miles of the Atlantic Ocean. This distance was selected as the most likely to be directly affected by potential offshore wind developments. This study area falls entirely within the GOM Coastal Lowland ecoregion, which extends about 15 miles into the state. It is bordered to the south and west by the Southern New England Coastal Plains and Hills ecoregion of Massachusetts and to the north by the rockier Midcoast ecoregion of Maine (Griffith et al. 2009). New Hampshire includes approximately 18 miles (29 km) of coastline, offering several publicly accessible beaches, rocky shorelines, historic sites, salt marshes, and coastal communities, all of which are connected by State Route NH-1A. The topography is primarily flat with irregular plains inland, and coastal areas feature light-colored sand beaches, rocky shorelines, bays defined by low, rocky heads, and tidal flats. Major shoreline communities include Portsmouth, Rye, Hampton, and Seabrook; each with various levels of residential and commercial development.

Visibility toward the GOM from shorefront areas varies widely through the seasons and would directly influence whether and how offshore wind developments could be seen from a given location. Clear, sunny skies would offer greatest visibility across the sea, which would influence the magnitude of potential adverse effects from offshore wind projects. Conversely, fog, haze and cloud cover would obscure offshore developments, even within the nearshore visibility thresholds. Based on annual weather pattern data for Hampton, New Hampshire, the skies are mostly cloud-covered to overcast from November to May (Weather Spark 2022). As with many coastal areas, the appearance of the Atlantic Ocean from shorefront locations is highly variable depending on the season and weather conditions. During bright summer and fall days, it can appear deep, dark blue; cloudy or hazy skies can reflect a silvery grey sea.

5.11.2 Viewer Groups

The population potentially affected by offshore wind projects are referred to as viewer groups. This study identifies three broad categories of viewers that are likely to experience changes to the visual environment and bring varying sensitivities and expectations for views. For offshore wind projects, viewer groups are typically categorized as:

- **Residents:** viewers who live, work, and recreate within the coastal landscape or seascape. Residents may have similar or dissimilar reactions to changes to views they are most familiar with, particularly those from their home. Residents' threshold for visual quality can be variable and is tempered by the visual character and setting of their neighborhood, as well as their personal beliefs about specific project technologies. It is assumed that residents are generally familiar with the local landscape and may not be tolerant of changes, particularly regarding views that are important to them.
- **Commuters and Through Travelers:** Motorists passing through an area typically view the landscape from vehicles on their way to and from work or other routine destinations. Unlike residents, who would view a project from a static position, motorists view a project briefly as they pass by at vehicle speeds. Travelers include daily commuters and people engaged in various types of business or personal travel. Commuters traveling within the Visual Study Area view the landscape from motor vehicles on their way to work or other business destinations. Commuters do not tend to stop along their travel routes, have a relatively narrow field of view because they are focused on road and traffic conditions, and are destination-oriented. Commuters may be more likely to notice changes compared with visitors because they view the environment regularly. Passengers in commuter vehicles would have greater opportunities for longer views toward landscape features and, accordingly, may have greater perception of changes in the visual environment.
- **Tourists and Visitors:** Out-of-town vacationers and seasonal/weekend residents visit the area for the purpose of experiencing its scenic and recreational resources. These viewers include sightseers, families on vacation, and weekend/seasonal homeowners. They may view the landscape on their way to a destination (i.e., on a roadway or from a boat) or from the destination itself. Some, such as weekend and seasonal homeowners, may spend extended time in the area. Visitation to the New Hampshire coast is very seasonal; June through August offer the warmest temperatures and draw the most tourists and seasonal residents.

5.11.3 Scenic Resource Inventory

Federal, State, and local public databases and planning documents were reviewed to identify and locate important scenic resources within the 5-mile study area, which are summarized in Table 5.11.1.

Table 5.11.1. Important Scenic Resources within the 5-mile Study Area

Type of Resource	Data Source	Occurrences of Resources within Visual Study Area
National Historic Landmarks	https://irma.nps.gov/DataStore/Reference/Profile/2210280//	0
Properties Listed on the National Registers of Historic Places	https://irma.nps.gov/DataStore/Reference/Profile/2210280//	53
National Natural Landmarks	National Natural Landmarks Directory - National Natural Landmarks (U.S. National Park Service) (nps.gov)	0
State Designated Scenic Overlooks	NH State Parks : Welcome	0
National Wildlife Refuges	Our Facilities | U.S. Fish & Wildlife Service (fws.gov)	0
State Wildlife Management Areas	DNCR State Lands Viewer (arcgis.com)	2
National Parks	New Hampshire (U.S. National Park Service) (nps.gov)	0
State Parks	NH State Parks : Welcome	11
National Forests	Interactive Visitor Map (usda.gov)	0
State Forests	DNCR State Lands Viewer (arcgis.com)	0
National Recreation Areas and/or National Seashores	New Hampshire (U.S. National Park Service) (nps.gov)	0
State Beaches	NH State Parks : Welcome	2
National or State Designated Wild, Scenic, or Recreational Rivers	New Hampshire (rivers.gov)	0
National or State Designated Scenic Highways	NH-Official-One-Pager_2022.pdf (scenic.org)	2
National Historic/Recreation/Heritage Trails	New Hampshire (U.S. National Park Service) (nps.gov)	0
Public Beaches	NH State Parks : Welcome	13
Ferry Routes	https://hifld-geoplatform.opendata.arcgis.com/datasets/ferryroutes/explore?location=40.762325%2C-114.136299%2C4.05	0
	Isles of Shoals Steamship Company	1[a/]
Seaports (Commercial Maritime Facilities)	Port of New Hampshire, Portsmouth, NH - Downtown - PortsmouthNH.com	1

Note:
a/ A private vendor operates a seasonal ferry service to access the public sites on Isles of Shoals

Of those resources identified, locations with open views oriented toward the GOM would have the highest likelihood to be affected by offshore wind developments. These include public beaches, shoreline state parks, historic sites and districts, NH-1A (a state-designated scenic byway), and oceanfront commercial and residential communities. Future detailed studies would be required to determine how specific offshore wind projects located within viewable distance from New Hampshire coastal areas could affect views from individual scenic resources.

5.11.4 Distance Zones and Visibility

Because this study is concerned with the potential visual effects of wind energy developments in the GOM, the locations of which are not yet known, distance zones are applied here relative to the Atlantic Ocean shoreline of New Hampshire. Based on the Bureau of Land Management (BLM) Best Management Practices for Reducing Visual Impacts of Renewable Energy Facilities on BLM-Administered Lands (BLM 2013) these zones include the Foreground-Middle Ground (0-5 miles), Background (5-15 miles), and Seldom Seen (>15 miles). However, based on prior experience with offshore wind project visual analyses and feedback from BOEM, 'seldom seen' does not accurately represent the visibility across the open ocean, where wind turbines may be visible at 25 miles, under rare circumstances. For this reason, the distance zone greater than 15 miles is referred to as 'Distant Background'. A study completed in Europe, *Offshore Wind Turbine Visibility and Visual Impact Threshold Distances* (Sullivan, et al. 2013) concluded that offshore wind facilities were judged to be a major focus of visual attention at distances up to 10 miles (16 km); were noticeable to casual observers at distances of almost 18 miles (29 km); and were visible with extended or concentrated viewing at distances beyond 25 miles (40 km; Sullivan et al. 2013).

Offshore wind turbines are required by the FAA to include nighttime lighting on the nacelle for aircraft avoidance. Appearing as red pulsing lights, previously unobstructed nighttime ocean views can be adversely affected by the presence of such dominant lighting. These effects can be mitigated by the employment of aircraft detection lighting systems, which use sensors to activate FAA lighting on the wind turbines when aircraft come within a predetermined distance, reducing the total time the lighting is present.

5.11.5 Conclusions

The level of change perceived by viewers is dependent upon distance between the viewer and the structure, the height of the structure, the elevation of the viewer, earth curvature, atmospheric conditions, and individual viewer activities and expectations. Potential wind development projects within the GOM could be observed by viewers from a variety of locations along the New Hampshire shoreline. However, given the small proportion of area within the GOM developable for wind energy and that falls within 40 miles (64.4 km) of the New Hampshire shoreline, it is anticipated that most potential wind developments would be located beyond the distance from which visible offshore wind components could cause adverse visual effects. Future offshore wind project(s) located within 40 miles of the New Hampshire coast, including the historic sites on the Isles of Shoals, have the potential to adversely affect or impact scenic resources and would be studied in detail as part of the project permitting process.

Based on the visual resource inventory conducted for this study, public shoreline areas with open views toward the GOM could have views of future offshore wind developments, particularly during the summer months when atmospheric conditions would favor higher visibility toward the ocean horizon, and in combination with higher numbers of total viewers enjoying the shoreline as seasonal residents or tourists. These resources include national and state historic sites, public beaches, state parks, oceanfront walkways, elevated public locations such as lighthouses, and beachfront communities.

5.12 References

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6 Permitting and Regulatory Issues

BOEM oversees the leasing for offshore wind energy on the U.S. OCS and permitting of wind projects on developed leases under the Outer Continental Shelf Lands Act (OCSLA; 43 U.S.C. § 1337) as amended by the Energy Policy Act of 2005 (EPAct). The EPAct authorized BOEM to issue leases, easements, and rights of way for renewable energy development on the OCS (BOEM 2022a). BOEM is required to coordinate with relevant federal agencies and affected state and local governments, obtain fair returns for leases and grants issued, and ensure that renewable energy development takes place in a safe and environmentally responsible manner (BOEM 2022a). BOEM has statutory obligations to ensure that any activities it authorizes will consider the protection of the environment and the conservation of natural resources. BOEM also has statutory obligations under the National Environmental Policy Act (NEPA; 42 U.S.C. § 4321) as the lead federal agency for offshore renewable energy projects. BOEM is obligated to evaluate impacts to biological, physical, socioeconomic, and human resources; sufficient baseline information on the area to be impacted as well as the proposed activity must be provided. BOEM's Informational Guidelines for a Renewable Energy Construction and Operations Plan (COP Guidelines; BOEM 2020) are intended to "clarify and provide a general understanding of the information which BOEM requires to adequately address" these issues. The other federal agencies that are included in the permitting process for an offshore wind project are outlined below by agency and major permitting requirement:

- Bureau of Ocean Energy Management (Construction and Operations Plan, Environmental Impact Statement [NEPA], Section 106 Review)

- U.S. Army Corps of Engineers (Rivers and Harbors Act, 404 Clean Water Act, Joint Permit Authorization)

- National Oceanic and Atmospheric Administration (Marine Mammal Protection Act Incidental Take Authorization, Magnuson-Stevens Fishery Conservation and Management Act, Essential Fish Habitat Consultation, Endangered Species Act Section-7 Consultation)

- U.S. Fish and Wildlife Service (Endangered Species Act Section-7 Consultation)

- Environmental Protection Agency (OCS Air Permit, National Pollutant Discharge Elimination System Permit)

- Other federal agency consultations, as appropriate (e.g., U.S. Coast Guard, Federal Aviation Administration, others)

The federal and state permits that are required for the siting, construction, operation, and decommissioning of an offshore wind project and associated infrastructure are summarized in Table 6.0.1.

Table 6.0.1 Federal and State Permitting Considerations for an Offshore Wind Project.

Permitting Agency	Applicable Permit or Approval	Statutory Basis	Regulations
Federal Permits			
US Department of the Interior (USDOI), Bureau of Ocean Energy Management (BOEM) Other Federal Agencies will typically leverage the Environmental Impact Statement prepared by the Lead Federal Agency when issuing their decision documents (permit approvals).	Outer Continental Shelf (OCS) Lands Commercial Lease, Survey Plan Acceptance, Site Assessment Plan (SAP) Approval, Construction and Operations Plan (COP) Acceptance	Outer Continental Shelf Lands Act 43 U.S.C. 1337 Energy Policy Act of 2005	BOEM Final Rule on Renewable Energy Development on the OCS 30 CFR Part 585
	National Environmental Policy Act (NEPA)	National Environmental Policy Act	Council on Environmental Quality
		42 U.S.C. 4320 et seq.	NEPA Regulations 40 CFR 1500
		Energy Policy Act of 2005 (EPAct)	et seq.
		Outer Continental Shelf Lands Act 43 U.S.C.1337	
U.S. Army Corps of Engineers (USACE)	Section 10 Construction Permit	Rivers and Harbors Act – Section 10	33 CFR 320
	Section 404 Dredge Discharge Permit	Clean Water Act Section 404, 33 U.S.C. 1344	33 CFR 320
	Section 408 Civil Works Projects	Section 14 of the Rivers and Harbors Act of 189	33 U.S.C. 408
NOAA National Marine Fisheries Service (NMFS)	Endangered Species Act (ESA) Incidental Take Permits	Endangered Species Act 16 U.S.C. 66016 U.S.C. 1531 et seq.	50 CFR 402
	Marine Mammal Protection Act (MMPA) Letter of Authorization (LOA) or Incidental Harassment Authorization (IHA)	Marine Mammal Protection Act 16 U.S.C. 1361et seq.	50 CFR 216
	Magnuson-Stevens Conservation and Management Act	Magnuson-Stevens Conservation and Management Act 16 U.S.C. 1801	50 CFR Part 600

Table 6.0. 1. Continued.

Permitting Agency	Applicable Permit or Approval	Statutory Basis	Regulations
Federal Permits			
Environmental Protection Agency (EPA)	Outer Continental Shelf (OCS) Air Permit	Clean Air Act – Section 328	40 CFR Part 55
	National Pollutant Discharge Elimination System Permit (only applicable if cooling water intake/discharge is part of offshore substation design)	Clean Water Act – Section 316(a) and 316(b)	40 CFR Parts 122 and 125
U.S. Department of Defense (DOD)	Consultation	Title 32: National Defense	32 CFR Part 211
Federal Aviation Administration (FAA)	Determination of No Hazard	Title 14: Aeronautics and Space	14 CFR § 77.9.
National Parks Service (NPS)	Commercial Filming and Still Photography Permit	NPS Organic Act (Public Law No. 235)	N/A
Applicable Federal Land Management Agencies	Archaeological Resources Protection Act (ARPA) Permit	16 U.S.C. 470aa-mm	36 CFR Part 79
U.S. Fish and Wildlife Service (USFWS)	Endangered Species Act Incidental Take Permits	Federal Endangered Species Act	50 CFR Part 13,
		16 U.S.C. 1531	Part 17, Part 402
		Migratory Bird Treaty Act	50 CFR Part10
		16 U.S.C. 703 et seq.	
		Bald and Golden Eagle Protection Act	
		16 U.S.C. 668	50 CFR Part 22
	Migratory Bird Treaty Act and Bald and Golden Eagle Protection Act permits	Migratory Bird Treaty Act	50 CFR Part10
		16 U.S.C. 703 et seq.	
		Bald and Golden Eagle Protection Act	50 CFR Part 22
		16 U.S.C. 668	

Table 6.0. 1. Continued.

Permitting Agency	Applicable Permit or Approval	Statutory Basis	Regulations
Federal Permits			
Advisory Council on Historic Preservation (ACHP)	National Historic Preservation Act Section 106 Consultation	National Historic Preservation Act 16 U.S.C. 470	36 CFR Part 60, Part 800
	Abandoned Shipwreck Act/Consultation and Determination	Abandoned Shipwreck Act 43 U.S.C. 2101 et seq.	
United States Coast Guard (USCG)	Local Notice to Mariners	49 U.S.C. 44718	33 CFR Part 66
	Approval for Private Aids to Navigation	14 U.S.C. 81	33 CFR Part 66
State of New Hampshire Permits			
New Hampshire Energy Facility Site Evaluation Committee (NHSEC)	Certificate of Site and Facility	Energy Facility Evaluation, Siting, Construction and Operation RSA 162-H	Draft Administrative Rules Chapter Site 100-400
New Hampshire Department of Environmental Services (NHDES)	Dredge and Fill Permit	RSA 482-A	Env-WT 100-800
	Coastal Zone Management Consistency Determination	Coastal Zone Management Act, Section 307	Consistency Review with the NH CZM Program Policies (15 CFR 923, 15 CFR 930
	Shoreland Protection Approval	RSA 483-B Comprehensive Shoreland Protection Act	Env-WQ 1400
	Clean Water Act Certification	U.S. Clean Water Act, Section 401	Env-WS 451-455
		16 U.S.C. 1451	
New Hampshire Department of Fish & Game	Consultation under Endangered Species Act	Endangered Species Conservation Act, RSA § 212-A:1-15.	
New Hampshire Division of Historic Resources	Consultation on state and federal historic and cultural resources	RSA 227-C:9	
New Hampshire Public Utilities Commission	Consultation	RSA 362	Part PUC 309 filing requirements for long range plans for bulk power supply facilities

Table 6.0. 1. Continued.

Permitting Agency	Applicable Permit or Approval	Statutory Basis	Regulations
State of New Hampshire Permits			
New Hampshire Department of Transportation	State Roadway Excavation Permit	RSA 231, 184-186; RSA 236, 9-11	

6.1 Regulatory Roadmap

The offshore wind development process comprises four phases and three rounds of NEPA reviews and consultations. Permitting for the potential wind developer is limited to Phase 3 and Phase 4. The four phases include:

Phase 1) Planning and Analysis (approximately 2 years; USDOE 2022):

- Identify tracts of OCS with potential for offshore wind (OSW) development
- Round 1 NEPA Review and Consultation: BOEM prepares an Environmental Assessment (EA) to analyze the environmental impacts of the lease issuance, site characterization (underwater surveys) and site assessment (installing equipment to measure meteorological conditions) activities.

Phase 2) Leasing (1 – 2 years):

- BOEM initiates a competitive leasing process by publishing a public notice of Request for Interest in the Federal Register. The responses inform BOEM whether competitive interest exists for the OSW parcels, and if so, it proceeds with auctioning off the lease areas.

Phase 3) Site Assessment (up to 5 years; USDOE 2022):

- Once an OCS lease is obtained, the offshore developer must submit a Site Assessment Plan (SAP[19]) to BOEM. The SAP includes:
    - means and methods intended to assess meteorological and oceanographic (“metocean”) conditions,
    - data from physical site characterization surveys (geological and hazards), and
    - baseline environmental (biological and archaeological) surveys in the specified lease area.
- Once the SAP is submitted, BOEM will either conduct a categorical exclusion review for meteorological (met) buoys and/or towers, prepare a determination of NEPA adequacy for the met buoys/towers, or conduct site-specific NEPA analyses if the proposed activities are outside the scope of previously analyzed activities.
- Once the SAP has been approved by BOEM, meteorological buoys and/or towers may be deployed.

Phase 4) Lessee develops and submits a Construction and Operations Plan (COP; approximately 2 years).

[19] The specific requirements for the information required in the SAP and COP can be found in 30 CFR 585.610 and 585.626, respectively.

- The COP details the offshore wind developer's construction, operations, and decommissioning plans including all onshore and support facilities and anticipated easements.
  - BOEM prepares a project-specific NEPA analysis (i.e., Environmental Impact Statement [EIS]).
    - BOEM publishes a Notice of Intent (NOI) to prepare an EIS in the Federal Register with a comment period of 30 days.
    - Once the Draft EIS is complete, BOEM publishes a Notice of Availability (NOA) in the Federal Register for public comments. The comment period is 45 days.
    - BOEM publishes the Final EIS and Record of Decision (ROD) in which BOEM approves, approves with modification, or disapproves of the COP (Rowe 2017, Burke 2018, Comay and Clark 2021).

If the COP is approved or approved with modification, the lessee must submit a Fabrication and Installation Report (FIR) and Facility Design Report (FDR) for BOEM's review and then proceed through the regulatory process (30 CFR 585.700-702) prior to fabricating and installing the proposed project elements (Rowe 2017).

In addition, simultaneous with BOEM's review process, the lessee needs to comply with environmental consultations under the following regulations:

- National Historic Preservation Act (NHPA): requires Federal agencies to consider the effects of their proposed action on historic properties;
- Migratory Bird Treaty Act (MBTA): BOEM coordinates with the U.S. FWS to confirm that all aspects of this act pertaining to migratory birds are being monitored;
- Endangered Species Act (ESA): BOEM coordinates with the NMFS and U.S. FWS; consultation is required if BOEM believes a proposed action may affect ESA-listed species or adversely modify designated critical habitat;
- Magnuson-Stevens Fishery Conservation and Management Act (Essential Fish Habitat [EFH]): BOEM is required to consult with NMFS if they fund, permit, or undertake activities that may adversely affect EFH;
- Marine Mammal Protection Act (MMPA): This Act prohibits, with certain exceptions, the "take" of marine mammals in U.S. waters. The lessee is required to consult with the NMFS regarding any marine mammal concerns, and
- Coastal Zone Management Act (CZMA): This Act requires that Federal actions that are reasonably likely to affect coastal use or coastal resources be "consistent to the maximum extent practicable" with relevant enforceable policies of the State's federally approved coastal management program. For this consultation, BOEM coordinates appropriately with the affected State (Rowe 2017).

The recommended data and information for the COP for the first phase of development are summarized below. For some of these resources, such as fisheries, BOEM requires a full biological survey for the initial COP for the first phase of development followed by a desktop analysis for proposed development in subsequent phases. However, the site characteristic requirements for each resource differ and details of the required survey work should be discussed further with BOEM in pre-survey meetings before submission of the initial COP (Rowe 2017). Details on specific COP requirements can be found in USDOI's *Information Guidelines for a Renewable Energy Construction and Operations Plan (COP)*[20] (USDOI 2020) and 30 CFR § 585.627 "*What information and certifications must I submit with my COP to assist the BOEM in complying with NEPA and other relevant laws?*"

The COP must include information on the following resources, conditions, and activities that may be affected by the proposed activity (BOEM 2016):

- Hazard information: Meteorology, oceanography, sediment transport, geology, and shallow geological or manmade hazards
- Water Quality: Turbidity and total suspended solids from construction
- Biological Resources: Benthic communities, marine mammals, sea turtles, coastal and marine birds, [bats], fish and shellfish, plankton, seagrasses, and plant life
- Threatened or Endangered Species: As defined by the ESA
- Sensitive Biological Resources or Haibtats: Essential Fish Habitat, refuges, preserves, special management areas identified in coastal management programs, sanctuaries, rookeries, hard bottom habitat, chemosynthetic communities, corals, kelp forests, calving grounds, barrier islands, beaches, dunes, and wetlands
- Archaeological resources: As required by the NHPA (National Historic Preservation Act)
- Social and Economic Resources: Employment, existing offshore and coastal infrastructure (including major sources of supplies, services, energy, and water), land use, subsistence resources and harvest practices, recreation, recreational and commercial fishing (including typical fishing seasons, location, and type) minority and lower income groups, coastal zone management programs, and viewshed
- Coastal and Marine Uses: Military activities, vessel traffic, and energy and nonenergy mineral exploration or development
- Consistency Certification: As required by the CZMA regulations.
- Other Resources, Conditions, and Activities: As identified by BOEM (30 CFR § 585.627).

The COP must also include an Oil Spill Response Plan as required by 30 CFR part 254 and a Safety Management System as required by 30 CFR § 585.810.

[20] Available at: https://www.boem.gov/sites/default/files/documents/about-boem/COP%20Guidelines.pdf

Historically BOEM published guidance for applicants in preparing the COP. However, delays in the NEPA analysis after the NOI caused disruption for applicants, cooperating agencies, and BOEM's decision making. It became apparent to BOEM that it was not always possible or practicable for applicants to meet all data and information requirements for the initial COP submission. In response to this issue, BOEM has proposed that it may begin processing partial COP submissions that meet the minimum requirements as defined in the recently published *Draft Information Needed for Issuance of a Notice of Intent (NOI) Under the National Environmental Policy Act (NEPA) for a Construction and Operations Plan (*USDOI 2022). The revised process for partial COP submission, referred to as the "NOI Checklist", is in the draft phase as of October 24, 2022, and will be finalized in the first quarter of 2023. The NOI Checklist provides the minimum information and deadlines BOEM requires to adequately continue or complete the COP review (USDOI 2022). The NOI Checklist for the minimum information needed clarifies but does not supersede BOEM's regulations governing COPs or its previous guidance for COPS (USDOI 2022):

The following is a summary of the NOI Checklist minimum requirements:

- The NOI Checklist and FAST-41: Applicants are increasingly submitting FAST-41 initiation notices (FINs) to the Federal Permitting Improvement Steering Council (FPISC) to get their project designated as a "covered project" and posted to the Permitting dashboard. In the past, BOEM coordinated with FPISC to accept FINs for COPS that were not complete or sufficient under BOEM's regulations. Thus, BOEM will now strictly adhere to its existing COP requirement regulations as described in the NOI Checklist and will not make a "covered project" determination unless the COP meets these requirements (USDOI 2022).
- Project Description: Should include a complete, well-defined, and illustrated description of the project including the Project Design Envelope (PDE),[21] Action Area, description of the project goals, minimum amount of energy the project must generate to be economically practicable or feasible, scheduling constraints, points of interconnection, and electricity tariffs among others.
- Detailed Description of Potential Impacts: Identify all impact producing factors (IPFs) for each biological, physical, and socioeconomic resource and any environmental protection measures and monitoring activities.
- Identification of Layout and Design Options Considered for the Proposed Action: Identify options considered for resources that may be significantly impacted by the proposed action and of known concern to stakeholders (e.g., North Atlantic Right Whales; visual impacts to tourism, Essential Fish Habitats, co-located fisheries, etc.)

[21] The PDE is an approach in which developers specify a range of design parameters, rather than a final, fixed design. For offshore wind, this could include elements such as turbine type, number, foundation type, locations for export cable routes, onshore substation and/or grid connection, construction methods, and timing. Once the COP is approved (with or without modifications), developers must also submit supporting evidence regarding the selection and justification for the final design elements (Rowe 2017).

- Description and Confirmation of Meaningful Coordination with Agencies: Provide a list of agencies the applicant has consulted with prior to submission of the COP. For example, the Department of Defense's Military Aviation and Installation Assurance Siting Clearinghouse, National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service, U.S. Coast Guard, U.S. Army Corps of Engineers, National Park Service, affected State government agencies and officials, etc.
- Viewshed Modeling and Visual resource Assessment: Include a complete report presenting an inventory and assessment of visual impacts, and a visual impact assessment (VIA) for all proposed offshore and onshore components.
- Benthic Habitat Assessment: COP submittals should include a benthic habitat assessment that provides the information described in BOEM's *Guidelines for Providing Benthic Habitat Survey Information for Renewable Energy Development on the Atlantic Outer Continental Shelf Pursuant to 30 CFR Part 585 and Guidelines for Providing Geophysical, Geotechnical, and Geohazard Information Pursuant to 30 CFR Part 585*. Benthic habitat data should be characterized according to the Coastal and Marine Ecological Classification Standard (CMECS) to identify and describe the physical and biological components of benthic habitats and features, enumerating and delineating sensitive habitats, soft sediment habitats, complex habitats, and benthic features, consistent with CMECS. Identify all Essential Fish Habitat and habitat areas of particular concern (HAPC) (e.g., habitats for inshore juvenile Atlantic Cod, Sand Tiger Shark, etc.) in the project area.
- Marine Site Investigation Report (MSIR): Information on project-specific geologic conditions, shallow hazards, and a site investigation report based on site-specific data including the geological ground model (including for cable routings), geohazard analysis, sediment mobility estimates, and man-made risks. Supporting data is described in BOEM's guidance document *Guidelines for Providing Geophysical, Geotechnical, and Geohazard Information*. The MSIR should also meet the "Part 1: Evaluation Criteria" listed and defined in the BOEM-sponsored report *Data Gathering Process - Geotech Departures for Offshore Wind Energy*.
- Information on Subsea Cables: Includes an analysis of the risks that project subsea cables may present to other maritime users in the vicinity (e.g., shipping, fishing, dredging, and sand borrow activities).
- Navigation Safety Risk Assessment (NSRA): Information required under the U.S. Coast Guard's Navigation and Vessel Inspection Circular (NVIC) 01-19 for developing a navigation safety risk assessment of an offshore wind energy project.
- Radar Assessment: Includes all land-based radar systems potentially impacted by the project and identifies the owners and users of those systems.
- List of Solid and Chemical Waste to be Generated and Chemical Products to be Used (if Stored Volume Will Exceed EPA Reportable Quantities)
- National Historic Preservation Act Information and Reports
- The Preliminary Area of Potential Effect (PAPE)
- Identification of Historic Properties Within the PAPE

- Offshore Wind Project Pile Driving Sound Exposure Modeling and Sound Field Measurement: Marine acoustic modeling submission in support of BOEM's completion of an Endangered Species Act effects analysis. Evaluate the effects of the project's underwater noise generating activities (e.g., vibratory pile driving, socket drilling, screw piling, horizontal direction drilling, trenching, unexploded ordinance disposal, etc.) with detail and sophistication appropriate for the level of effect possible.
- Endangered Species Act (ESA) and NEPA Information: Including seasonal abundance and distribution of ESA-listed species and description of critical habitat in the action area.
    - Identify IPFs and conduct an effects analysis that includes a description of baseline conditions in the action area that impact endangered and threatened species including past, present, and reasonably anticipated to occur future human and natural factors impacting the status of the species, habitat, and ecosystem within the action area.
    - For each IPF, a description of each stressor and how it may affect protected species, including a description of any differences in exposure to different life history stages.
    - A qualitative assessment of the duration and intensity of exposure to each species or species group and to each life history stage likely to be exposed.
    - An analysis and description of the expected response to the exposure for species and life history stages.
    - An assessment of the IPF stressors to potentially affect the physical and biological features of any designated critical habitat in the action area.
    - A description of the effect to the physical and biological features, including duration and extent, and whether adverse modification and destruction of critical habitat may occur.
- Marine Mammal Protection Act and NEPA Information:
    - Abundance and distribution of marine mammals in the action area.
    - Description of important habitat, such as biologically important areas, for all marine mammals.
    - A description of the marine mammals that may be exposed to the effects and stressors of the proposed action, including a description of the life history stages.
    - A qualitative assessment of marine mammal life history stages likely to be exposed and the duration and intensity of that exposure.
    - A description of whether the stressor may result in any impacts to marine mammal habitat.
- Supplemental Filing Schedule: Written supplemental filing schedule with the first COP submission. Data and information submitted through supplemental filings should be submitted *and determined sufficient by BOEM* to allow BOEM adequate environmental and technical review time before an upcoming review milestone, such as: the issuance of an NOI and the publication of a DEIS or FEIS.

In addition to the NOI Checklist above, the following documents provide guidance for other aspects that are included in the permitting process:

- Guidelines for a Renewable Energy Construction and Operations Plan (COP) Version 4.0 May 27, 2020 (USDOI 2020). https://www.boem.gov/sites/default/files/documents/about-boem/COP%20Guidelines.pdf
- FAST-41: Title 41 of the Fixing America's Surface Transportation Act. The proponent of a large or complex infrastructure project may seek to initiate the FAST-41 process to improve government-wide coordination, transparency, and accountability by submitting a FAST-41 initiation notice to the Permitting Council's executive director and the applicable facilitating Federal agency. For more information, see OMB and CEQ memo M-17-14 entitled *Guidance to Federal Agencies Regarding the Environmental Review and Authorization Process for Infrastructure Projects,* available at https://www.permits.performance.gov/sites/permits.dot.gov/files/2019-10/Official%20Signed%20FAST-41%20Guidance%20M-17-14%202017-01-13.pdf
- 30 CFR § 585.628(a) and (e). For more discussion of the term "sufficient" *see e.g.*, page 7 of BOEM's COP guidelines *available at* https://www.boem.gov/sites/default/files/renewable-energy-program/COP-Guidelines.pdf
- A CPP: A "concise plan for coordinating public and agency participation in, and completion of, any required Federal environmental review and authorization for the project." 42 U.S.C. § 4370m-2(c)(1)(A).
- For more information on the project design envelope (PDE) see BOEM's "Guidance Regarding the Use of a Project Design Envelope in a Construction and Operations Plan" available at https://www.boem.gov/sites/default/files/renewable-energy-program/Draft-Design-Envelope-Guidance.pdf

6.2 Jones Act Compliance

The Merchant Marine Act of 1920, better known as the Jones Act (JA), requires that any cargo travelling by sea between two U.S. ports must:

- Sail on a ship both built and registered in the U.S.
- Be owned by a U.S. citizen or permanent resident, or owned by a U.S.-based company with over 75% of the ownership stake held by U.S. citizens; and
- Have a crew consisting of a majority of U.S. citizens.

The JA was initially endorsed as a way to ensure adequate domestic shipbuilding capacity and sufficient supply of merchant mariners to be available during times of war, while further encouraging developments within the U.S. maritime industry (Grabow 2018, Rawson and Huang 2022, Shoemate and Franklin 2019). However, the law has proved divisive, with opponents asserting that the JA has cost the U.S. economy overall in time, resources, and money, with few of the original intended benefits (Grabow 2018, Grabow 2021). Indeed, the number of major active shipyards in the U.S. remains in the single digits, compared to over 60 in Europe, 1,000 in Japan, and 2,000 in China (OECD 2011, 2016). Furthermore, the number of ocean-going ships of at least 1,000 gross tons which are JA compliant have dwindled from thousands when the act was written, to 193 in 2000, to only 99 by 2018 (Grabow 2018). This has caused the industry to suffer rather than prosper in several key ways: the price of shipping has been driven up, shipbuilding itself is slow and costly, merchant mariners are scarce, and JA compliant procedures involve far more steps, further increasing both cost and risk.

It seems that the domestically-built requirement is the largest hurdle for the maritime industry, due simply to the cost. Instead of domestic port infrastructure growing in size and efficiency with demand for cargo, military, and specialized research or construction vessels, these agencies are commissioning foreign fleets and shipyards for cheaper vessels but with JA compliant workarounds often involving several extra vessels. Despite a multiple-vessel strategy causing added time, risk, and logistical difficulties, it remains cost-effective. That a compounded effort in this way proves the most economical is a testament to the exorbitant assembly costs in the U.S. For example, container vessels for shipping goods by sea cost between $190 and $250 million each to produce in the U.S., whereas the cost to build a similar ship overseas is about $30 million (Fritelli 2017).

These same financial and logistical difficulties extend to the renewable energy sector, and especially to offshore wind. Effects of the JA percolate into almost every step involved in the design, installation, maintenance, and decommissioning of each type of offshore turbine, including both fixed-bottom foundations and floating foundations. According to the most recent NREL offshore resource assessment completed in August 2022, the GOM RFI Area represents an area which could incorporate both fixed and floating substructure types (Lopez et al. 2022). However, the majority of the area would be most suitable for floating offshore wind turbines (FOWTs) due to the sharp depth increase with distance from shore. The FOWT industry is extremely young with procedures evolving in real-time, so the optimal roadmap for compliance has not been laid out. Therefore, this section will first detail the problems and workarounds regarding the JA that have been or are in the process of being employed with fixed-bottom foundation turbines, followed by how the FOWT projects may be able to adapt under various design scenarios.

6.2.1 Fixed-bottom Foundations

As is the case with commercial shipping vessels, the particular vessels necessary for the installation and upkeep of offshore wind turbines are often non-JA compliant, and in the case of critical installation vessels, exclusively foreign-made. Installation is widely recognized as a choke point for U.S. offshore wind, with these costs alone accounting for approximately 30% of the overall project cost, and of that installation cost, 20% goes exclusively toward vessel day rates (Siljan and Hansen 2017).

There are several reasons for this bottleneck at the installation stage of offshore projects. Wind turbine installation vessels (WTIVs) are highly specialized and can both transport and install foundations and turbines safely offshore in depths of up to 70 m (Shoemate and Franklin 2019). They cannot easily be replaced by any combination of JA-compliant vessels, because these WTIVs are the only vessels with the ability to both jack themselves above the waves to allow for stability, and lift and maneuver the components of the turbines safely and effectively (Figure 6.2.1; Shoemate and Franklin 2019, Huang et al. 2022). The weight of turbines being installed is also increasing. With a weight of approximately 50 tons per MW and recent offshore projects proposing at least 12-15MW designs, components of a single turbine will conservatively weigh in excess of 600 tons, a load which no current JA-compliant vessels can easily bear (Shoemate and Franklin 2019). In 2021, the global fleet of WTIVs was just 19 vessels, with a utilization rate of 90% as global offshore wind projects have rapidly increased (Robinson and Furtado 2022). Moreover, multiple offshore projects are likely to need these vessels in a relatively similar time frame over the next few years with the recent government-backed push in offshore wind advancement and subsequent influx of proposals, further exacerbating the bottlenecking issue and increasing cost (Shoemate and Franklin 2019). It has become clear that to meet the government's stated goal of constructing 30GW of offshore wind energy capacity by 2030 (WHBR 2021), the industry in the U.S. needs to produce innovative designs and procedures to ease the logistical strain induced by the Jones Act restrictions. This issue is being tackled in real-time from multiple angles.

Figure 6.2.1. Mockup of the Charybdis, the first domestically built JA compliant WTIV due to be completed in late 2023 (Dominion Energy).

To increase the JA compliant fleet, the Biden Administration in 2021 announced a development program totaling $230 million for upgrading current port infrastructure to allow for building and accommodating larger installation vessels (WHBR2021). In addition, Dominion Energy has already commissioned the first U.S. WTIV to be built domestically at a cost of approximately $500 million, which is scheduled to be completed in 2023 (Figure 6.2.1). It goes without saying that building a fleet of U.S. WTIVs would solve the Jones Act issues regarding bottlenecking, however this may not be the best option overall due to time and money constraints. With a current average cost of $250 to $500 million to build domestically, JA-compliant WTIVs run at least 1.5 to 2 times the cost of a vessel built overseas, and considering the influx of offshore projects in the coming years, the overall vessel investment alone would be in excess of $6-7 billion (Huang et al. 2022, Westwood 2013). The current completion times for WTIV vessels averages 3-4 years (Robinson and Furtado 2022), so even if every capable shipyard in the U.S. began construction today the fleet would not be service-ready until close to 2027, which would make the 30GW by 2030 goal all but unreachable. Finally, there are currently very few Atlantic coast ports that can be upgraded relatively easily to accommodate the needs of loading and marshalling a WTIV, as many do not have the beam or draft clearances to even allow entry, let alone loading (Huang et al. 2022). For these reasons, it has generally been found that in the shorter term, more feasible solutions involve a combination of JA compliant supporting vessels with noncompliant WTIVs; and in the longer term, completely bypassing the need for WTIVs altogether with workarounds.

The most common existing workaround involves ‘feeder’ vessels, or vessels which are JA compliant that ferry cargo, personnel, or equipment to/from U.S. ports and the noncompliant vessels waiting offshore (Shoemate and Franklin 2019). There are advantages and disadvantages to this strategy. It can be utilized immediately with existing vessels, however in the upcoming years with the predicted increase in projects needing installation vessels at a similar time, even the global fleet may not be enough to cover projected busy times. Also, the use of feeder vessels creates extra steps (Figure 6.2.2) and increases operational downtime, which puts more ships, crew, and equipment at risk due to the often harsh conditions in the Atlantic and the hazards posed by lifting heavy components from one vessel to another (Grabow 2021, Huang et al. 2022). According to the JA, a wind turbine foundation is considered a U.S. port, which has adverse implications for the installation procedures (ABS 2021, GustoMSC 2017). For example, if a feeder vessel were to bring two turbine assemblies to a WTIV from a nearby onshore staging area, that WTIV could not assemble one turbine at site A and then move on to site B, as that would be a violation of the JA, so they are forced to install a single turbine at a time with a separate equipment transfer at each location. However, despite the use of additional vessels increasing the overall installation cost by about 28%, it actually takes about 29% less time in total, allowing for more rapid energy (and revenue) generation, meaning that the overall cost differential may be relatively minor (COWI 2018, Shoemate and Franklin 2019).

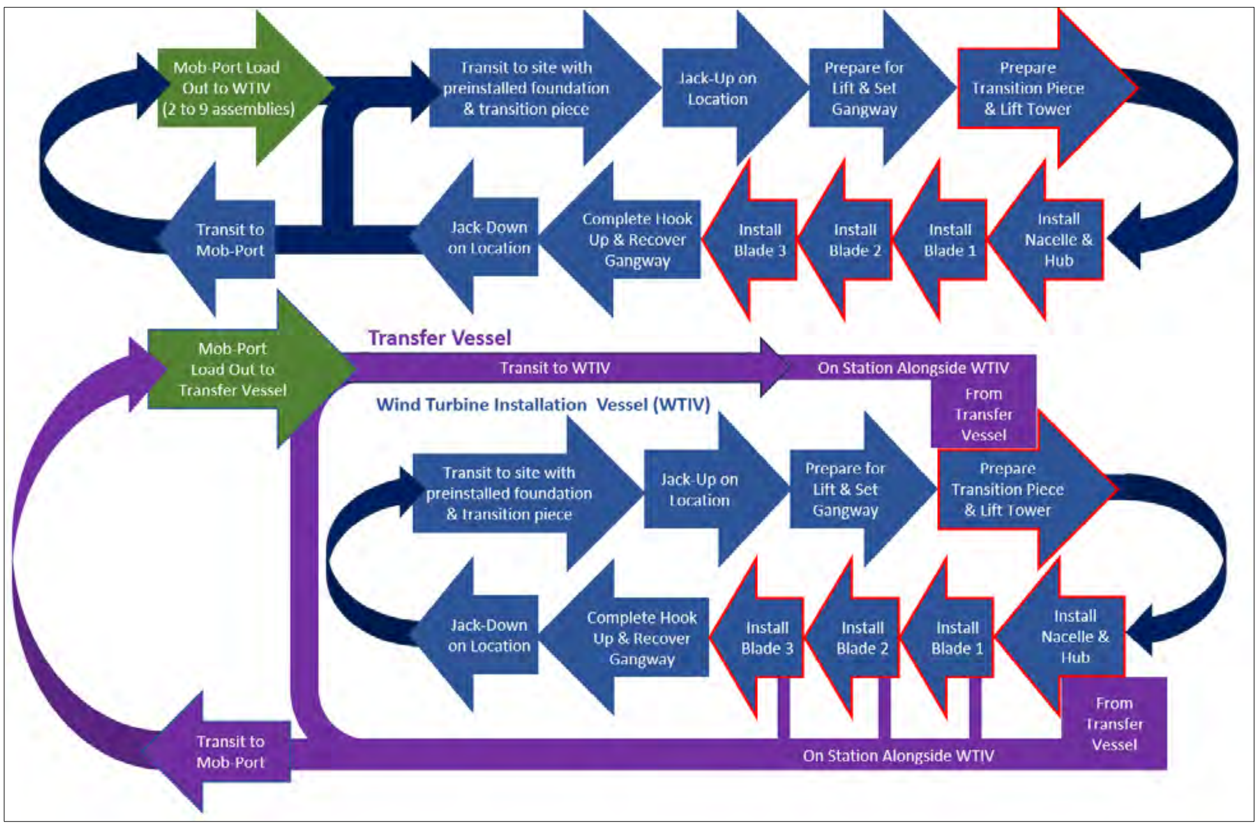

Figure 6.2.2. Typical WTIV installation sequence in non-U.S. waters (top) versus the sequence necessary in the U.S. using a non-Jones Act compliant vessel (bottom; modified from Robinson and Furtado 2022).

Further solutions to the WTIV problem include innovative turbine designs which do not require heavy lifts, and which could potentially be installed with lighter vessels, or even robotically, though most of these proposals are still in the preliminary modelling stage (Robinson and Furtado 2022). Offshore wind currently violates the 'golden rule' established by the offshore oil and gas industry: what costs $1 onshore will cost $2 in port, and $10 offshore (Ramachandran et al. 2022, Robinson and Furtado 2022). Therefore, it makes sense to challenge the current method of assembling turbines at offshore locations. Accordingly, several models around the world have been designed, with some prototypes being deployed for preliminary viability testing. One of the most attractive alternatives for development at present is the design of platforms that allow in-port assembly of the turbine structure, which would then be towed out to the site location as opposed to assembled there. For example, the ELISA Gravity Base Structure prototype of fixed-bottom turbines developed in Spain in 2018 uses a telescoping tower which stays low during portside assembly and tow-out with a reusable collar, then extends during installation at the site location (Robinson and Furtado 2022, Urbano 2019).

6.2.2 Floating Foundations

FOWTs may represent an ideal solution to reach the goal of reducing overall cost and eliminating the necessity for WTIV use., Particularly since the Biden Administration announced an additional goal to reach 15 MW of floating offshore wind capacity by 2035 backed by over $50 million in additional funding for the advancement of FOWT technologies (WHBR 2022). While WTIVs can be configured to support floating platform installation in deeper waters (Rawson and Huang 2022), FOWTs thus far are largely assembled in port and installed by smaller maneuver support vessels, of which there are already some that are JA-compliant (Powers et al. 2022, Robinson and Furtado 2022). However, marine operations and vessel requirements vary depending on the type of FOWT design, so it is important to consider the requirements of the entire life cycle of the turbine when considering whether JA-compliant vessels are available or suitable. As the industry remains so small and young at the time of this report, there are no universally accepted optimal designs or procedures for manufacturing, installation, operation, maintenance, or dismantling FOWTs. The practices thus far have largely been adapted from the offshore oil and gas industry but incorporate unique challenges which have required bespoke design solutions (Barter et al. 2020). There are three broad categories of FOWTs based on how they attain their stability: ballast, buoyancy, or moorings (Chitteth Ramachandran et al. 2022). Examples of each of these categories of FOWTs are in operation currently around the world, and each have advantages and disadvantages for all stages of the turbine's life cycle (Table 1.4.1).

- Ballast-stabilized platforms include the SPAR-buoy type and suspended counter-weight type design and have already been used on large-scale projects such as the world's first floating offshore wind farm, the Hywind energy farm installed in 2017 off the coast of Scotland (Equinor 2022). These designs are generally considered to be the most economical for depths of 200 m and beyond (RWE 2022). The SPAR-buoy design used by Hywind relies on a large floater structure with high draughts to be towed and assembled offshore, so it has the disadvantage of requiring some type of heavy-lift vessel to upend and ballast the floater, then mate the tower/rotor assembly to the base (Chitteth Ramachandran et al. 2022). Similarly, the maintenance and dismantling will likely rely on the same type of heavy vessels unless innovative processes are proposed as viable alternatives by the time the Hywind FOWTs need decommissioning. This will have implications for U.S. projects that wish to utilize the SPAR-buoy design, as there may not be a sufficient supply of JA-compliant heavy-lift vessels readily available. The newer suspended counter-weight design may eliminate the need for offshore assembly based on the smaller size and draught limits of the components, however it faces additional logistical difficulties as the inherent design of the assembly before the addition of the counterweight can be unstable and may require custom barges similar to those required for the tension-leg platform design.

- Buoyancy-stabilizing designs include the semi-submersible and barge platforms, such as those utilized for the WindFloat project deployed off the coast of Portugal in 2019 (Principle Power 2022). These designs have the advantage of being fully constructed onshore and towed to the site location, making them one of the most cost-effective from an installation standpoint. Installation requires the use of smaller tugs and supply or support ships, of which JA-compliant vessels are already available, though they are highly specialized and often repurposed from the oil and gas industry (Chitteth Ramachandran et al. 2022). These projects do not require heavy-lift vessels at any stage of their life cycle; however, they do need to be constructed and assembled at a port close enough to the site location from which they can be successfully towed. If the port is not clsoe enough, additional logistical issues would arise with the need to transport heavy components which cannot be transported by land to or from a suitable port. If that is the case, heavy-lift vessels may be required which would then need to be JA- compliant (Chitteth Ramachandran et al. 2022).
- The moorings-stabilized concept that has been most explored is the tension-leg platform (TLP) design, as it has been widely used in the oil and gas industry and is estimated to be well-suited for intermediate depth just beyond what is possible for fixed-foundation turbines (between 70-200 m; Chitteth Ramachandran et al. 2022). In 2008, a TLP design prototype was successfully deployed off the coast of Italy by Blue H Technologies (Adam et al. 2014), however commercial-scale projects have not yet been realized. The main challenge involved is the instability of the TLP assembly as it is towed to the site location before it is connected to the mooring lines. While the installation procedures do not call for heavy-lift or WTIV type vessels, the safe transportation and positioning of the system will likely need bespoke barges (Chitteth Ramachandran et al. 2022), adding cost and time to the overall project with the need for each custom vessel to be JA-compliant. Maintenance and decommissioning can also be challenging. For example, if it is easier to disassemble the components to provide stability before disconnecting from the moorings, a heavy-lift vessel may be required. However, recent designs have

proposed novel ways to address these challenges which could be employed by the time any TLP assemblies need decommissioning.

The FOWT domain is extremely young, with research and development of innovative turbine design – and therefore vessel requirements – occurring in real-time. Similarly, many questions surrounding how the JA applies to each part of the offshore wind industry are yet to be clarified. For example, U.S. Customs and Border Protection only just released a guidance document in April 2022 which clarifies that while noncompliant WTIVs or supporting vessels cannot bring turbine components from one offshore site to another, they would be allowed to bring materials and crew, as these are not considered 'merchandise' or 'passengers' according to the JA (Papavizas 2022). These and many other ambiguities will need to be clarified as the industry progresses, along with corresponding updates to JA-compliant protocols.

6.3 Stakeholder Concerns and Recommendations

A variety of stakeholders have raised concerns and made recommendations associated with offshore wind development in the GOM. These stakeholders include, but are not limited to, federal and state government agencies, non-governmental organizations (NGOs), and representatives from development and manufacturing groups, indigenous nations, and fisheries associations as well as individuals. Stakeholder concerns have been presented in a variety of formats and settings including in written public comments submitted to BOEM on the GOM RFI Area, verbal comments provided during BOEM GOM Draft Call Area Engagement meetings and Gulf of Maine Intergovernmental Renewable Energy Task Force meetings, presentations and discussion at the New Hampshire Offshore Wind Summit and other conferences on offshore wind development, and public outreach and individual stakeholder group meetings organized by the State of New Hampshire. This section summarizes the concerns and recommendations stakeholders have raised, first focusing on the topics of concern and then presenting the recommendation suggested to help address these concerns.

6.3.1 Stakeholder Concerns

Stakeholder concerns covered several subjects that were grouped into three main topics: environmental concerns, lease process concerns, and ocean user conflicts and food security concerns.

Environmental Concerns

Stakeholders of all backgrounds mentioned the need to minimize the impact on sensitive environments, ecological and commercial important areas, and individual species (CLF 2022, NOAA NMFS 2022, NWF et al. 2022, TNC 2022, BOEM 2023a, b, Fisheries Stakeholders 2023, Pennacook-Abenaki Representatives 2023). Stakeholders have expressed a general sense that the impacts from FOWT on habitats and species, including fish stocks and protected species, are not fully understood and that data gaps exist in understanding the impacts of floating offshore wind technologies (BOEM 2022b, BOEM 2023a, Fisheries Stakeholders 2023). They expressed specific concerns and priorities for site selection of offshore wind.

One of the most common concerns raised is that of interfering with the natural foraging, mating, and migration behaviors of species which use the GOM, particularly federally protected species such as the critically endangered North Atlantic right whale (CLF 2022, GEO 2022, GSWW 2022, NFS11 2022, NOAA NMFS 2022, NWF et al. 2022, TNC 2022, Fisheries Stakeholders 2023, Pennacook-Abenaki Representatives 2023). Stakeholders pointed out that there is a lack of sufficient information about environmental characteristics in some areas of the GOM to develop lease areas that balance multiple tradeoffs. There are also concerns that the impact on critical species, protected areas, and ecosystems by floating arrays is not well understood (e.g., vibrations, acoustic impacts), and that more baseline studies are needed to assess the degree to which the variety of floating platform designs may alter natural environmental processes and impact species. (AOLA 2022, NEFMC 2022, NFS11 2022, NHFG 2022, Fisheries Stakeholders 2023, Pennacook-Abenaki Representatives 2023). Stakeholders would like the environmental baseline studies to be completed before floating arrays are placed in the GOM, similar to the baseline studies that were done for Seabrook Station. There are concerns that once offshore wind is built in the GOM that some impacts may not be immediately known and operation will be allowed to continue for decades or centuries similar to the impacts dams have had and still have on fish passage of anadromous and diadromous species. Once these companies build these arrays, there will be no going back (Fisheries Stakeholders 2023).

Among a general unease that adverse effects floating arrays may have on ecological processes, specific concerns were also raised about the uncertain effects that electromagnetic fields (EMF) from transmission cables may have on the ecosystem. Particularly these concerns focus on the need for cables to be routed through sensitive coastal waters to reach onshore infrastructure, impacts to larval and juvenile fish (e.g., Haddock), lobster, and crab behaviors, and impacts to fish migration patterns (MFWG 2022, NEYFA 2022, NFS11 2022, NHCFA 2022, BOEM 2023a, Fisheries Stakeholders 2023). Stakeholders have expressed the desire to eliminate the risks associated with EMF from the transmission cables, not just limit the amount of EMF around the cables. Stakeholders also expressed concern that the hard bottom in the GOM will prevent burying the cables which will result in using concrete blankets to cover the cables, preventing the mitigation or elimination of EMF (Fisheries Stakeholders 2023).

Another concern raised was the potential impacts on species from additional light sources and light disruption due to the floating structures and rotating turbine blades (i.e., shading and strobe effects) that would occur with FOWT deployment. These concerns included the current lack of understanding of these effects and the potential extent of effects that could occur for both marine and avian species. Each turbine will have a light on it for airplane navigation safety, potentially disrupting one-third of the Atlantic Flyway (Fisheries Stakeholders 2023).

Lastly, concerns were raised about the impacts of how climate change would change wind resources and the potential effects of changes to or loss of wind and offshore currents. There are concerns that the impacts of climate change are already occurring in the GOM (including on the fishing industry) and there is a need to address climate change impacts (BOEM 2022b).

To address these potential issues, many of the stakeholders that expressed environmental concern provided a variety of recommendations. These recommendations are listed in detail in Section 6.3.2.

Leasing Process Concerns

Stakeholders expressed several types of concerns on the siting and leasing process including the process timeframe, community involvement, transparency, and economic feasibility (AOLA 2022, MFWG 2022, NEFMC 2022, NHCFA 2022, BOEM 2023a, Fisheries Stakeholder 2023, Pennacook-Abenaki Representatives 2023). The specific siting and leasing process concerns are discussed below.

A common concern raised by stakeholders from all backgrounds is the speed with which BOEM seems to be carrying out the commercial leasing and site selection process in the GOM. Multiple stakeholders expressed concern that the GOM RFI Area and the GOM Research Array leasing sites were open for comment simultaneously, and as a result that the Research Array will not be able to generate or provide data that can be used to better understand potential impacts from floating arrays and inform potential leasing sites for the RFI Area (AOLA 2022, BOEM 2022b, MFWG 2022, MSC 2022, NEFMC 2022, NEYFA 2022, NHCFA 2022, NSC 2022, BOEM 2023a, b). Additionally, concerns exist over the pace and number of offshore wind projects that are being developed along the Atlantic coast and the difficulties in conducting thorough analysis of potential individual and cumulative impacts on resources and individuals or communities that depend on them (NEFMC 2022). Stakeholders want planning and development conducted in a responsible manner with the benefit of scientific information to better inform decision makers and the public of how to avoid and minimize adverse impacts on marine resources and reduce conflicts with ocean users (NOAA NMFS 2022, NHFG 2022). There are concerns that the BOEM process for offshore wind development is still fluid and being developed, and that it does not yet have the consistency observed in oil and gas leases including the use of preliminary EIS before lease sales (NHDOE 2022).

Concern was also expressed by several stakeholders that disadvantaged or underrepresented communities would not be given consideration throughout the life of the project; including those of lower socioeconomic status; rural coastal communities with little legal or union representation; Native American tribal communities; and/or members of smaller localized fisheries, among others (BOEM 2022b, GEO 2022, NWF et al. 2022, ROSA 2022, BOEM 2023a, b). Stakeholders would like a process that meets the needs of the local communities so that they have a solid foundation from which their voices and concerns are actually brought into the process and heard (NH SeaGrant 2022). Stakeholders indicated a lack of clear federal framework requiring agencies to engage specific stakeholders in offshore wind development and leasing in general, so community engagement in the newly evolving industry may be inconsistent or lacking entirely (MCFA 2022, NEFMC 2022, NSC 2022). Furthermore, a concern raised the issue that there is no concrete evidence available to the public that specific recommendations put forth through community engagement efforts have been implemented in the development process (MCFA 2022).

Stakeholders voiced concerns about the archaeological impact that offshore wind development will have on the GOM. During the last glacial period, the coastline extended 75 miles out beyond the Isles of Shoals and Star Island. Concerns were raised on how the 106 process (Section 106 of the National Historic Preservation Act of 1966) would be applied during the leasing and development process. Stakeholders would like assurance the submerged paleo-cultural heritage will be properly identified and avoided (BOEM 2023b, Pennacook-Abenaki Representatives 2023).

Concerns were also raised that the current wind turbines being considered for deployment in the GOM would not be the best technology or designs available and that newer and more aesthetically pleasing designs (e.g., vertical-axis wind turbine, wind trees) would not be considered by the industry due to costs. The stakeholders want the best available designs used during development and feel that aesthetics is important consideration for wind development in New Hampshire and the GOM due the tourism and offshore recreational boating and fishing that are important parts of the region's economy. The stakeholders also suggested that the design criteria should include minimizing impacts to marine mammals and other species as well as considering extreme weather events such as 100-or 1,000-year storms that are occurring more frequently due to climate change (Pennacook-Abenaki Representatives 2023).

Stakeholders raised concerns about the types of transmission cables that will be used in the GOM offshore wind development and where future transmission cables might be placed. They want to understand the amount of transmission cables and the structure of these cables (BOEM 2022b, BOEM 2023a, Fisheries Stakeholder 2023).

Several stakeholders have raised concerns over the economic viability of offshore wind projects in the GOM (Fisheries Stakeholder 2023, Pennacook-Abenaki Representatives 2023). There are concerns that government subsidies may not be sufficient for these projects given the unique environmental issues that are expected to arise. Additional concerns included questions of who would be paying for any land-based infrastructure updates; the ratepayers or taxpayers of the state of the landing site, regionally through ISO-NE, or by wind developers (Fisheries Stakeholder 2023).

Additional concerns were raised on fisheries mitigation and the process BOEM plans to use for this type of mitigation especially for the New Hampshire industry. BOEM has no regulatory authority with regards to mitigation and can only provide recommendations. Currently there are nine states pushing for clarity on BOEM's approach and whether congressional legislation will be necessary to allow a regional, coastal, or national comprehensive approach (Fisheries Stakeholder 2023).

The last leasing process concern raised was blade replacement and decommissioning of the turbines and farms. The stakeholders want to understand what would happen to these components at the end of use. There needs to be a forward-looking approach with a life cycle analysis conducted at the beginning of the process and not after the leases are implemented (Fisheries Stakeholders 2023, NHDOE 2022, Pennacook-Abenaki Representatives 2023).

Ocean User Conflicts and Food Security

Several stakeholders expressed concern on the lack of reliable data on fisheries activities in GOM waters. More specifically, there are concerns that the data being used to evaluate fisheries and fishing areas by BOEM are outdated and may not reflect the shifts that have occurred in catch volumes or fishing areas since 2015, are incomplete due to lack of required reporting or use of the Vessel Monitoring Systems (VMS) or Vessel Trip Reports (VTR), and/or are not comprehensive for all species especially the HMS and gear types (BOEM 2022, GEO 2022, GFWA 2022, MLA 2022, NEFMC 2022, Fisheries Stakeholder 2023). This seems to be particularly relevant to the bluefin, spearfishing, and lobster fisheries, as they tend to be smaller operations without VMS/VTR or comprehensive reporting requirements (GEO 2022, MLA 2022, Fisheries Stakeholder 2023).

There is also a concern that development of offshore wind in the Gulf of Maine will negatively affect fishery landings. This concern is compounded by related economic factors and considerations including shoreside infrastructure being diminished over time that would result in vessels, permits, and fishing communities being displaced and/or consolidated. There are already challenges to maintaining working waterfronts and the fishing industry access. Once lost, shoreside infrastructure is very difficult to reestablish. Additionally, this loss may not be adequately represented in economic impact studies looking at near-term project effects (NHDOE 2022, NHFG 2022), and fishermen are concerned that they will lose dock assess. These concerns include the economic loss of the investments fishermen have made into their vessels and permits. If the industry collapses there will be no interest in the purchase of these assets and as result the value, which is often used as a retirement fund, will be lost (NHDOE 2022).

Displacement of fisheries may not just be due to shoreside infrastructure loss. Several stakeholders expressed concern that offshore wind sites may exclude fishing vessels entirely due to safety, operational, and insurance concerns due to the cabling and anchoring presenting hazards or obstacles for fishing vessels. There is a general concern with continued access to historic and current fishing grounds (AOLA 2022, FSF 2022, MFWG 2022, NFS11 2022, BOEM 2023a). This could adversely affect the fishing industry and local economy depending on the type and extent of exclusion (MFP 2022, NEFMC 2022, NFS11 2022). Furthermore, exclusion from sites in this way may not necessarily have as much impact in the immediate future if the site presents very little conflict with current fisheries-heavy areas, however there is concern that leasing sites may become more important as time passes due to climate change shifts to the presence of key species (MFWG 2022, NEFMC 2022, NFS11 2022).

Some of the other concerns raised focus on navigational corridors and navigational equipment. As it has been shown that turbines can negatively affect navigational equipment performance, several stakeholders expressed fears on safety implications this may have if lease sites were located within or in close proximity to areas of heavy vessel traffic and use (FSF 2022, NHCFA 2022, Fisheries Stakeholder 2023). These concerns included whether the full environmental and climate impact of offshore wind, once construction and maintenance activities are factored in, has been considered, as well if vessel trips will be longer in order to avoid the arrays (BOEM 2023a).

Stakeholders mentioned concerns that New Hampshire is a vulnerable state in both energy and food production as it is very dependent on other regional resources (Pennacook-Abenaki Representatives 2023). Stakeholders are concerned about energy sources and costs in New Hampshire and wonder if there is a way to address these concerns similar to the efforts used to address the pandemic (BOEM 2023a).

6.3.2 Stakeholder Recommendations

Several stakeholders provided suggestions and recommendations to help address their concerns. These recommendations are presented below in the same main topics as the comments along with other general recommendations.

Recommendations on Environmental Concerns

It was recommended by several stakeholders that a programmatic environmental impact statement (PEIS – see glossary for definition) under the National Environmental Policy Act be conducted and made publicly available for any wind energy areas (WEAs) identified for the leasing of the offshore wind array (AOLA 2022, BOEM 2022b, CLF 2022, EOW 2022, MCFA 2022, MFWG 2022, NEFMC 2022, NHFG 2022, NOAA NMFS 2022, NSC 2022, NWF et al. 2022, RODA 2022). This would support a more collaborative, transparent, and inclusive planning effort, help to overcome data limitations, and identify important complex habitats.

A number of stakeholders highlighted the need to close critical data gaps prior to the selection of a lease area, which would require baseline studies to characterize the ecology, benthos, and seafloor in any potential WEA. It is recommended that BOEM address closing the data gaps such as those laid out in the Offshore Wind Roadmap created by the State of Maine and the Environment and Wildlife Working Group, as well as the recommendations of the Maine Fisheries Working Group convened to inform offshore wind development (MCFA 2022, MFP 2022, MFWG 2022, NEFMC 2022, NWF et al. 2022). It was recommended that BOEM and other federal agencies provide clear and unified guidance on priorities for data collection needed for sustainable OSW development, develop cost-sharing and public-private partnerships on data collection, and to require that new data collected in response to OSW development be archived in centralized repositories. Data collection needs to be planned and executed at large scales, specifically the entire WEAs and adjacent waters (NERACOOS 2022).

Some of the specific baseline studies recommended include:

- Characterization of the plankton and settlement throughout the water column, as well as the benthos (EOW 2022, MFWG 2022, NEFMC 2022)
- Further understanding of the temperature stratification of the water column (EOW 2022)
- Bird and bat tracking studies, including migration, foraging, and nesting behaviors (EOW 2022, NWF et al. 2022)
- Tracking studies on ESA-listed species specifically, including both marine and non-marine birds and bats, marine mammals, sea turtles, and fish (MFWG 2022, NWF et al. 2022)
- Detailed substrate mapping throughout the GOM ideally, but particularly in any considered WEAs (EOW 2022, MFWG 2022, MLA 2022, NE4OSW 2022, NEFMC 2022, NWF et al. 2022)
- Advancement of current pelagic fish studies, including all life stages (CLF 2022, EOW 2022, MFWG 2022)
- Sound pollution studies (both from construction/maintenance operations, and from the operating turbines), with particular focus on potential adverse effects on critical and protected species (EOW 2022, NHCFA 2022)
- Effects of electromagnetic fields (EMF) that are produced by FOWT cables and infrastructure (EOW 2022, MFWG 2022, NEYFA 2022, NHCFA 2022, NWF et al. 2022)

The current RFI excludes the following areas: areas within 3 nm from shore and those beyond 200nm from shore, national parks, national wildlife refuges, national marine sanctuaries, national monuments, existing traffic separation scheme (TSS) fairways or other internationally recognized navigation measures, existing BOEM lease areas, and unsolicited lease request areas that are the subject of a separate request for competitive interest (i.e., State of Maine requested research lease).

Many of the recommendations put forth by the stakeholders propose additional exclusion areas for the selection of the lease area due to their environmental importance. These proposed additional exclusion areas include:

- Habitat Management Areas (HMAs) as designated by NOAA (CLF 2022, GEO 2022, MA EEA 2022, NHFG 2022, NOAA NMFS 2022, NWF et al. 2022)
- Habitat areas of particular concern (HAPCs) within essential fish habitats (NEFMC 2022, NOAA NMFS 2022, Ørsted 2022)
- Coral protection areas or areas of coral research (CLF 2022, GEO 2022, NEFMC 2022, NOAA NMFS 2022, TNC 2022)
- Foraging areas of nesting and roosting seabirds (NHCFA 2022, NWF et al. 2022)
- Nearshore waters (i.e., the 'western GOM' or any area of the GOM west of 69° 50′ 0′′ W longitude) heavily used by commercial and recreational fisheries with a variety of gear types as well as coastal communities, whale watching operations, etc. (GEO 2022, GSWW 2022, MA EEA 2022, NEFMC 2022, NFS11 2022, NHCFA 2022, NHFG 2022, NOAA NMFS 2022, TNC 2022)
- Year-round groundfish and cod spawning closure areas, as well as highly productive and fisheries-heavy groundfish harvest areas including Platt's Bank (CLF 2022, FSF 2022, NEFMC 2022, NFS11 2022, NOAA NMFS 2022, NWF et al. 2022, TNC 2022, BOEM 2023a)
- Atlantic Large Whale Take Reduction Plan restricted areas including the LMA1 restricted area (CLF 2022, NWF et al. 2022, BOEM 2023a)
- Known sensitive habitat features of high complexity and therefore high productivity and biodiversity (such as hard-bottom habitat, slopes, ledges, basins, etc.; MA EEA 2022, NEFMC 2022, NHFG 2022, NOAA NMFS 2022, NWF et al. 2022, TNC 2022)
- Areas of high frequency or density of protected species, such as areas of frequent occurrence of the NARW (GEO 2022, NHCFA 2022, NOAA NMFS 2022, Ørsted 2022, TNC 2022)
- Areas of long-term surveying or monitoring (NEFMC 2022, NHFG 2022)

In addition to baseline studies, many stakeholders highlighted the need for BOEM to establish a robust long-term monitoring plan which would last the lifetime of any offshore wind projects, with room for adaptability as more data informs ongoing processes (NWF et al. 2022). It was also recommended that BOEM use the best available modelling technology and methodology available to address the potential influence of climate change on ecological systems in the GOM, and incorporate these predictions into long-term monitoring efforts. The Northeast Regional Habitat Assessment (NRHA) habitat model or ecosystem-based model results should be incorporated once they are finalized and updated regularly in BOEM's data inventories (NEFMC 2022, NHFG 2022).

Recommendations on Leasing Process Concerns

Stakeholders overwhelmingly support a more collaborative, inclusive, and transparent planning effort from the outset. A majority expressed the need for robust inclusion of communities most affected by offshore wind projects in all aspects of the leasing, construction, and ongoing maintenance and monitoring processes. Specific recommendations include:

- BOEM should fund and carry out a PEIS or equivalent *prior to* the selection of WEAs for leasing, as opposed to after WEA selection, to ensure that the most comprehensive scientific data collection informs the leasing process (AOLA 2022, CLF 2022, NHFG 2022, NSC 2022, NWF et al. 2022, RODA 2022)
- BOEM should establish clear guidance for developers to engage with fisheries, and should be held accountable for doing so as well as for implementing fisheries recommendations (MCFA 2022, MFP 2022, NSC 2022)
- BOEM should support and fund a convening of fishermen's ecological knowledge (FEK) researchers and practitioners to meaningfully involve local fishermen in baseline studies informing site selection (AOLA 2022, GFWA 2022, MFP 2022, ROSA 2022)
- BOEM should make a particular effort to include historically disadvantaged or underrepresented communities by funding outreach and involvement programs as well as bringing infrastructure, professional training programs, and job opportunities to them (BGA 2022, GEO 2022, NE4OSW 2022, NWF et al. 2022)
- BOEM should make a concerted effort to engage in transparent communication with Native American tribes (both Federally and Non-federally recognized) prior to site selection, and include tribal representative knowledge in all aspects of project siting and operations where applicable (NWF et al. 2022)
- BOEM should use local or regional businesses wherever possible in fabrication, manufacturing, and transport of foundation components to bring as many economic benefits to the region as possible (Triton Anchor 2022).
- BOEM should make public exactly what criteria are used in the framework or modelling to determine lease areas when they are selected, and the weight that each category of data is given within the framework or model (MSC 2022, NEFMC 2022)

Additionally, several stakeholders recommended the establishment of Project Labor Agreements (PLAs), which will ensure a protected, skilled regional workforce capable of safely handling this and other offshore wind projects. It was also suggested that BOEM ensure that the workforce is unionized to maintain necessary employee protections (IWLocal7 2022, MLCC 2022).

Recommendations on Ocean User Conflicts and Food Security Concerns

Several stakeholders recommend that BOEM fund and conduct fisheries stock assessments prior to selection of a lease area, so that the most up-to-date data can be used to inform areas of highest conflict with important New England fisheries (FSF 2022, NHFG 2022). Of particular concern is the American Lobster fishery, as there seems to be a lack of reliable data. Therefore, outreach and inclusion efforts particularly targeted to characterization of this fishery has been strongly recommended from multiple stakeholders as well as individuals involved in the fishery directly (AOLA 2022, GEO 2022, MLA 2022). Stakeholders have requested that the time series data includes the most recent data available and include consultation with NMFS on additional fisheries and gear types that may be underrepresented (GFWA 2022, NEFMC 2022).

Other General Recommendations

Some of the other general recommendations addressed specific concerns with the leasing, development, and maintenance processes:

- To avoid visual impacts from shore, several stakeholders recommend a visual buffer of 20 nm from shore based on the height of current turbine designs (NHFG 2022,), or exclusion of particular areas of the GOM which are adjacent to national parks, to protect the natural scenic ocean views from park grounds (FOA 2022).
- Recommend making the lease areas as large as possible (within reasonable bounds of avoiding conflict with stakeholders/fisheries/protected species, etc.) to ensure meeting the country's and individual states' clean energy goals, as well as facilitate competition and innovation in developers wishing to bid on a variety of lease areas inside any identified WEAs (BNOW 2022, GOMSA 2022, NE4OSW 2022, NEFMC 2022, Ørsted 2022, UMaine 2022)
- Stakeholder input meetings have indicated that the area between the NH coast and the Western Gulf of Maine Closure Area is extremely busy with overlapping transportation, commercial, and recreation fishing. It has been suggested that this area in particular is too conflicted for placement of offshore wind facilities (NHFG 2022).
- BOEM should create a framework for mitigation in advance of construction, which outlines accountability and compensatory measures for any predicted unavoidable impacts, long-term monitoring plans, and conservation plans on a species and/or taxa basis with funding over the lifetime of the project (NOAA NMFS 2022, NWF et al. 2022) In addition, there should be consequences on developers for negative environmental impacts – i.e., they should be required to fund mitigation or clean-up efforts as well as subsequent monitoring of long-term effects (EOW 2022, NEYFA 2022)
- Recommend excluding areas in close proximity to liquid natural gas ports, traffic lanes, safe shipping routes, etc. and implement a 2 nm buffer zone around the outer boundary of any large shipping lanes with 5 nm around entry or exits or the TSS (USCG 2022, WSC 2022).
- Recommend identifying submarine cables as critical infrastructure and follow established spatial separation recommendations to outline exclusion zones around

existing submarine cable and leasing areas (NASCA 2022). Also recommend that BOEM consider transmission early in leasing to ensure the best transmission system be implemented from the outset with any future projects in mind (ACP 2022), and that BOEM consider a 'backbone' style transmission system as the ideal transmission option for the GOM (Anbaric 2022).

6.4 Pros and Cons of the Various Areas of the Gulf of Maine Under Consideration for the Potential Locating of Offshore Wind Deployment

Currently, no WEAs or leases have been designated for the GOM, and while the RFI Area has been reduced from its original 13,713,825 acres to approximately 9,845,092 acres in the Call Area (Figure 1.2.3), this is still a substantial portion of the region (Section 1.2). BOEM has released a preliminary map presenting the portions of the Call Area that developers have expressed an interest in (Figure 1.2.4). This map represents the best available predictor of where future lease areas may be designated. Therefore, to discuss the pros and cons for various areas in the GOM, these areas of interest were used to compare portions of the Call Area to each other, with the caveats that the available map does not define specific plots, just the level of interest present at each given point on the map, and all possible ways to define boundaries within the Call Area are preliminary and temporary until the final WEAs are established by BOEM. For ease of discussion, the areas of interest have been grouped into eight sections based on a combination of location and overall interest level and assigned letters (A-H) in Figure 6.4.1. The letters are used to define the locations in Table 6.4.1.

The pros and cons in Table 6.4.1 are based on available knowledge at the time of this report and are intended as a higher-level general review. Offshore wind in the U.S. is a rapidly developing industry and the information needs for each step in the process has undergone significant updates over the past several years. There is very little information available in the GOM for several important resources and new surveys will be required to fill in data gaps. Even available data are typically incomplete and/or do not encompass the entire RFI Area, and the lack of established WEAs further confounds the ability to do a more quantitative comparison.

The comparison presented in Table 6.4.1 attempts to consider these limitations in available data and incorporate them in the assessment. For example, most sites in the GOM have not yet been surveyed for deep-sea corals and sponges and the NOAA National Database for Deep-Sea Corals and Sponges is a "presence-only" data set (i.e., it confirms where corals have been found but does not confirm a lack of corals). A location with no known corals can be thought of as having the *potential* to be a coral-free site (a pro), which is preferable to sites already known to have corals (a con), but ultimately, site-specific surveys must be conducted to confirm the actual presence or absence.

The entirety of the RFI Area is NARW critical foraging habitat (Figure 5.3.20). All measures possible should be taken to reduce impacts to NARW and having critical habitat in a potential wind development area is a significant con. However, based on current data presented in Section 5.3.1, there are three subregions within the 8 delineated areas (A-H) that suggest relatively low use by NARW. It is important to note that this information is based on NARWs' historical and current use in the GOM, which is predicted to continue to shift over the next several decades. The eastern quarter of Area G, eastern half of Area D, and the eastern half of Area F could currently be considered a pro for NARW and are included in Table 6.4.1 as "pros". In addition, when compared to the overall interest level (number of nominations) among these three Areas, Area G (east quarter) has the relatively highest level of interest with a range of 1-5 nominations. Area D (east half) has the second highest number of nominations (1 – 3), and Area F (east half) has 1 to 2 nominations (Figure 6.4.1).

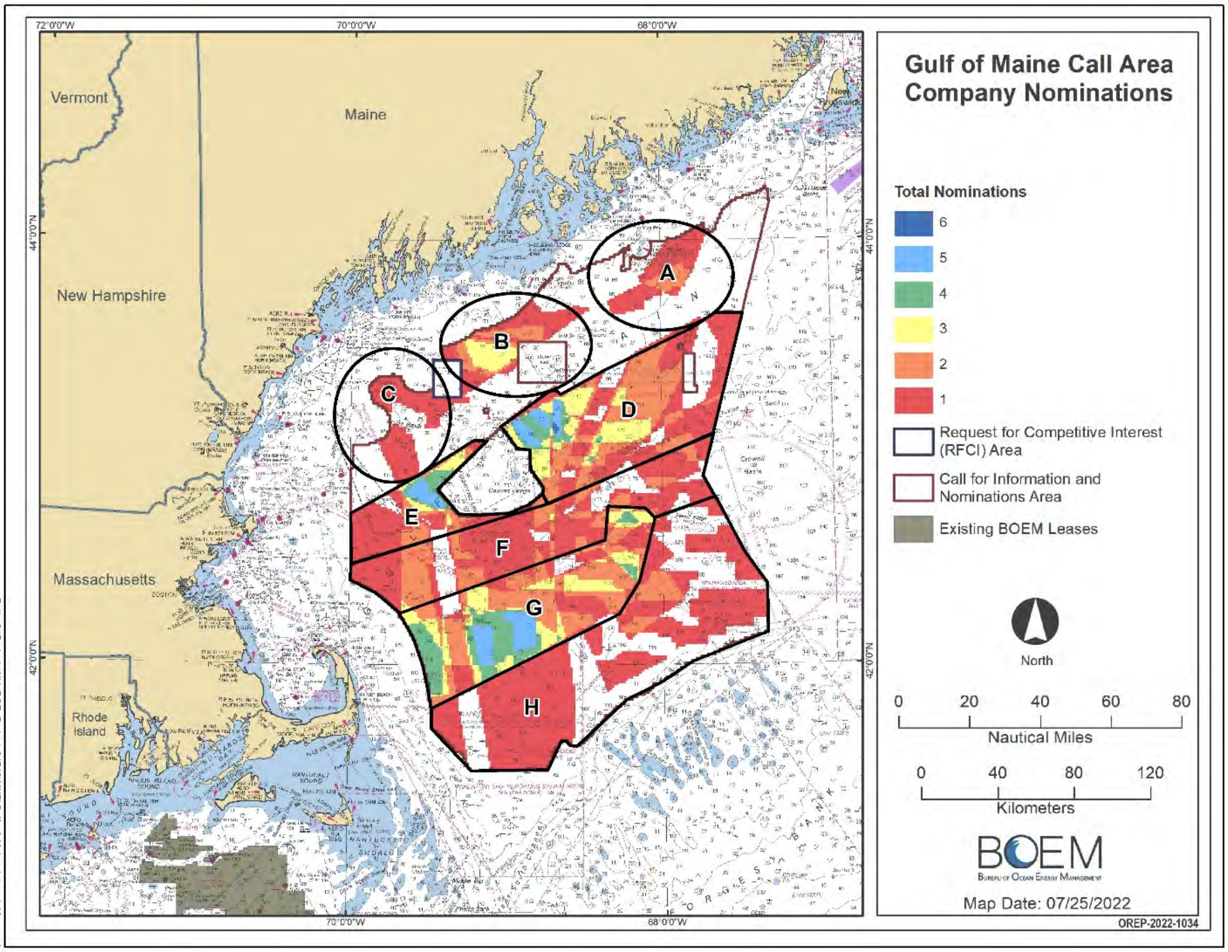

Figure 6.4.1. General locations for comparison in the GOM RFI based on current developer interest.

The following characteristics are not included in Table 6.4.1 because they apply to the entire RFI Area, making them un-useful for comparison between potential development sites:

- The RFI excludes all deep-sea coral protection and research areas (a pro; Figure 5.1.1).
- None of the locations overlap with HMAs, groundfish closure areas, or HAPC (a pro; Figure 5.1.2 and Figure 5.1.3).

Additionally, discussion of birds and bats is omitted from Table 6.4.1 because the species that occur in the GOM and times of year they are present are well-documented but specific locations and areas of occurrence within the RFI Area are not identified (Section 5.4). Coastal areas in the GOM are part of the Atlantic Flyway, an important migration pattern along the Eastern Seaboard used by hundreds of species. More surveys to map bird and bat usage of the RFI Area are necessary to compare different locations within it for these species.

Table 6.4.1. Pros and Cons by General Location.

Location[a] & Interest Level[b]	Category	Pros	Cons	Additional Considerations
A Low (1-2)	Environmentally Sensitive Areas	• No overlap with cod protection closures (Figure 5.1.2)	• Includes a known coral location; is near the Mount Desert Rock Protection Area and Outer Schoodic Ridge Coral Protection Area (Figure 5.1.1). • Overlap with Jeffrey's Bank (Figure 5.1.4)	• Stakeholders recommend excluding coral protection areas (Section 6.3.2); minimum safe distance to prevent impacts is unclear. • Complex habitat features (e.g., banks) have high productivity and biodiversity.
	Fisheries	• Overall Low to Medium-Low levels of commercial fishing vessel activity[c] (NMFS VMS data; Figure 5.2.5) • No NH commercial fishing activity (Figure 5.2.6) • No NH recreational fishing activity (Figure 5.2.7)	• Contains some (relatively small) areas of Medium-High fishing vessel activity (Figure 5.2.5)	
	Marine Mammals and Sea Turtles	• No or minimal overlap with cetacean feeding BIA, cetacean migratory corridor BIA, cetacean reproduction BIA, and minke whale and sei whale BIAs (Figure 5.3.4) • No sea turtle sightings reported by STSH from 2002-2022 (Figure 5.3.34)	• Minor overlap with harbor porpoise BIA (Figure 5.3.4) • Significant overlap with humpback whale BIA (Figure 5.3.4) • Overlap with fin whale BIA (Figure 5.3.4) • Overlap with NARW BIA (Figure 5.3.4) • Adjacent to LMA1 restricted area (Atlantic Large Whale Take Reduction Plan)	• Stakeholders recommend exclusion of LMA1 restricted area (Section 6.3.2); the RFI excludes it, but it is unclear if development activity near LMA1 may affect NARW.
	Sand and Gravel Resources	• Area is dominated by majority mud (Figure 5.5.2)	• Mud with some sand and/or gravel present in northeastern portion (Figure 5.5.2)	
	Other		• Northern side is at the 20nm minimum visual buffer from parts of the Maine coast.	• Stakeholders recommend a visual buffer of 20nm based on current turbine heights. Any design changes may require more distance (Section 6.3.2).

Table 6.4.1. Continued.

Location[a] & Interest Level[b]	Category	Pros	Cons	Additional Considerations
B Low to Moderate (1-3)	Environmentally Sensitive Areas	• No overlap with Cod protection closures (Figure 5.1.2)	• Includes known coral locations (Figure 5.1.1) • Adjacent to Jefferys Bank Habitat Management Area (Figure 5.1.2) • Overlap with Jeffrey's Bank (Figure 5.1.4)	• Complex habitat features (e.g., banks) have high productivity and biodiversity.
	Fisheries	• Overall Low to Medium-Low levels of commercial fishing vessel activity[c] (NMFS VMS data; Figure 5.2.5) • No NH commercial fishing activity (Figure 5.2.6) • No NH recreational fishing activity (Figure 5.2.7)	• Contains some areas of Medium-High fishing vessel activity (Figure 5.2.5)	
	Marine Mammals and Sea Turtles	• No or minimal overlap with cetacean migratory corridor BIA and minke whale, fin whale, and NARW BIAs (Figure 5.3.4) • No sea turtle sightings reported by STSH from 2002-2022 (Figure 5.3.34)	• Overlap with cetacean feeding BIA (Figure 5.3.4) • Overlap with cetacean reproduction BIA (Figure 5.3.4) • Overlap with harbor porpoise BIA (Figure 5.3.4) • Entirely overlaps with humpback whale BIA (Figure 5.3.4) • Entirely overlaps with sei whale BIA (Figure 5.3.4) • Overlap with NARW BIA (Figure 5.3.4) • Adjacent to LMA1 restricted area (Atlantic Large Whale Take Reduction Plan)	• Any potential impacts to NARW are of high concern to stakeholders (Section 6.3.2). • Stakeholders recommend exclusion of LMA1 restricted area (Section 6.3.2); the RFI excludes it, but it is unclear if development activity near LMA1 may affect NARW.
	Sand and Gravel Resources	• Area is dominated by majority mud (Figure 5.5.2)	• Mud with some sand and/or gravel present in eastern portion (Figure 5.5.2)	
	Other		• Northern side is at the 20nm minimum visual buffer from parts of the Maine coast.	• Stakeholders recommend a visual buffer of 20nm based on current turbine heights. Any design changes may require more distance (Section 6.3.2).

Table 6.4.1. Continued.

Location[a] & Interest Level[b]	Category	Pros	Cons	Additional Considerations
C Low (1)	Environmentally Sensitive Areas	• No known coral locations (Figure 5.1.1)	• Overlap with GOM Cod Protection Closure I (Figure 5.1.2) • Overlap with Platt's Bank; near Jeffrey's Ledge (Figure 5.1.4)	• GOM Cod Protection Closure I is closed in May (Stakeholders recommend exclusion of year-round closure areas; Section 6.3.2) • Complex habitat features (e.g., banks & ledges) have high productivity and biodiversity. • Stakeholders recommend excluding Platt's Bank due to its productive groundfish harvest (Section 6.3.2)
	Fisheries		• Overall Medium-High to High levels of NMFS VMS commercial fishing vessel activity; includes small area of Very High activity (Figure 5.2.5) • Low to High levels of NH commercial fishing activity (Figure 5.2.6) • Areas with Low levels of NH recreational fishing activity (Figure 5.2.7) • Significant commercial & recreational fishing activity occurs west of Area C, between the RFI and the NH coastline.	• Stakeholders have expressed concerns that the area between the NH coast and Western GOM Closure Area (situated between Area C and the NH coast) is too congested with boat traffic for wind development (Section 6.3.2)
	Marine Mammals and Sea Turtles	• No or minimal overlap with cetacean migratory corridor BIA, cetacean reproduction BIA, and harbor porpoise, minke whale, fin whale, and NARW BIAs (Figure 5.3.4)	• Overlap with cetacean feeding BIA (Figure 5.3.4) • Entirely overlaps with humpback whale BIA (Figure 5.3.4) • Entirely overlaps with sei whale BIA (Figure 5.3.4) • Adjacent to LMA1 restricted area (Atlantic Large Whale Take Reduction Plan) • Low number of sea turtle sightings by STSH between 2002-2022 (Figure 5.3.34)	• Stakeholders recommend exclusion of LMA1 restricted area (Section 6.3.2); the RFI excludes it, but it is unclear if development activity near LMA1 may affect NARW.

Table 6.4.1. Continued.

Location[a] & Interest Level[b]	Category	Pros	Cons	Additional Considerations
	Sand and Gravel Resources	• Area is dominated by majority mud (Figure 5.5.2)	• Mud with some sand and/or gravel present in some portions (Figure 5.5.2)	
	Other		• Northern side is at the 20nm minimum visual buffer from parts of the Maine coast.	• Stakeholders recommend a visual buffer of 20nm based on current turbine heights. Any design changes may require more distance (Section 6.3.2).
D Low to Highest (1-6)	Environmentally Sensitive Areas	• No overlap with Cod protection closures (Figure 5.1.2)	• Includes multiple known coral locations (though not in the areas of highest interest); adjacent to the Jordan Basin Dedicated Habitat Research Area (Figure 5.1.1). • Adjacent to Cashes Ledge Closure Area and Cashes Ledge Habitat Management Area (Figure 5.1.2) • Adjacent to Cashes Ledge HAPC (Figure 5.1.3) • Overlap with Jordan Basin; adjacent to Cashes Ledge (Figure 5.1.4)	• Stakeholders recommend excluding coral protection areas, year-round groundfish closures (e.g., Cashes Ledge), HMAs and HAPCs (Section 6.3.2); minimum safe distance to prevent impacts is unclear. • Complex habitat features (e.g., basins & ledges) have high productivity and biodiversity.
	Fisheries	• Half of this area has Low to Medium-Low NMFS VMS commercial fishing vessel activity (Figure 5.2.5) • No NH recreational fishing activity (Figure 5.2.7)	• Half of this area has Medium-High to High fishing vessel activity; includes a small area of Very High activity (Figure 5.2.5) • Small, patchy areas of Low to High levels of NH commercial fishing activity (Figure 5.2.6)	

Table 6.4.1. Continued.

Location[a] & Interest Level[b]	Category	Pros	Cons	Additional Considerations
	North Atlantic Right Whales	• Relatively low historic and current use in eastern half of this area (Figures 5.3.22 – 5.3.25)	• Relatively high historic and current use in western half of this area (Figures 5.3.22 – 5.3.25) • Overlap with NARW BIA (Figure 5.3.4)	• Any potential impacts to NARW are of high concern to stakeholders (Section 6.3.2). • Stakeholders recommend exclusion of LMA1 restricted area (Section 6.3.2); the RFI excludes it, but it is unclear if development activity near LMA1 may affect NARW.
	All Other Marine Mammals and Sea Turtles	• No or minimal overlap with cetacean feeding BIA, cetacean migratory corridor BIA, and minke whale and fin whale BIAs (Figure 5.3.4) • No sea turtle sightings reported by STSH from 2002-2022 (Figure 5.3.34)	• Overlap with cetacean reproduction BIA (Figure 5.3.4) • Minor overlap with harbor porpoise BIA (Figure 5.3.4) • Minor overlap with humpback whale BIA (Figure 5.3.4) • Minor overlap with sei whale BIA (Figure 5.3.4) • Adjacent to LMA1 restricted area (Atlantic Large Whale Take Reduction Plan)	
	Sand and Gravel Resources	• Half the area is composed of majority mud (Figure 5.5.2)	• Half the area is composed of mud with some sand, with smaller patches of mud with sand and/or gravel (Figure 5.5.2)	
	Other	• Entire area is greater than 40 nm from shore		• Stakeholders recommend a visual buffer of 20 nm from shore to avoid visual impacts (Section 6.3.2)

Table 6.4.1. Continued.

Location[a] & Interest Level[b]	Category	Pros	Cons	Additional Considerations
E Low to High (1-5)	Environmentally Sensitive Areas	• No overlap with Cod protection closures (Figure 5.1.2)	• Includes a known coral location (Figure 5.1.1). • Adjacent to Cashes Ledge Closure Area and the Western Gulf of Maine Habitat Management Area (Figure 5.1.2) • Adjacent to Jeffreys & Stellwagen HAPC (Figure 5.1.3) • Overlap with Wilkinson Basin; adjacent to Cashes Ledge; near Stellwagen Bank (Figure 5.1.4)	• Stakeholders recommend excluding year-round groundfish closures (e.g., Cashes Ledge), HMAs and HAPCs (Section 6.3.2); minimum safe distance to prevent impacts is unclear. • Complex habitat features (e.g., basins, ledges & banks) have high productivity and biodiversity.
	Fisheries		• Overall Medium-High to High levels of NMFS VMS commercial fishing vessel activity; includes small area of Very High activity (Figure 5.2.5) • Some areas of Low to High levels of NH commercial fishing activity, primarily near Cashes Ledge (Figure 5.2.6) • Areas with Low levels of NH recreational fishing activity, primarily near Cashes Ledge (Figure 5.2.7) • Significant commercial & recreational fishing activity occurs west of Area E, between the RFI and the NH coastline.	• Stakeholders have expressed concerns that the area between the NH coast and Western GOM Closure Area (situated between Area E and the NH coast) is too congested with boat traffic for wind development (Section 6.3.2)

Table 6.4.1. Continued.

Location[a] & Interest Level[b]	Category	Pros	Cons	Additional Considerations
	Marine Mammals and Sea Turtles	• No or minimal overlap with cetacean migratory corridor BIA, cetacean reproduction BIA, and harbor porpoise and NARW BIAs (Figure 5.3.4)	• Overlap with cetacean feeding BIA (Figure 5.3.4) • Entirely overlaps with humpback whale BIA (Figure 5.3.4) • Overlap with minke whale BIA (Figure 5.3.4) • Entirely overlaps with sei whale BIA (Figure 5.3.4) • Minor overlap with fin whale BIA (Figure 5.3.4) • Low number of sea turtle sightings by STSH between 2002-2022 (Figure 5.3.34) • Adjacent to LMA1 restricted area (Atlantic Large Whale Take Reduction Plan)	
	Sand and Gravel Resources	• Area is dominated by majority mud (Figure 5.5.2)		
	Other	• Entire area is greater than the minimum 20nm buffer from shore		• Stakeholders recommend a visual buffer of 20 nm from shore to avoid visual impacts (Section 6.3.2)
F Low (1-2)	Environmentally Sensitive Areas		• Includes multiple known coral locations (Figure 5.1.1). • Overlap with GOM Cod Protection Closure V; directly adjacent to Western Gulf of Maine HMA (Figure 5.1.2) • Adjacent to Jeffreys & Stellwagen HAPC (Figure 5.1.3) • Overlap with Wilkinson Basin and Rodgers Basin; near Stellwagen Bank (Figure 5.1.4)	• GOM Cod Protection Closure V is closed in March. Stakeholders recommend exclusion of year-round closure areas, HMAs and HAPCs (Section 6.3.2); minimum distance to prevent impacts is unclear. • Complex habitat features (e.g., basins & banks) have high productivity and biodiversity.

Table 6.4.1. Continued.

Location[a] & Interest Level[b]	Category	Pros	Cons	Additional Considerations
	Fisheries	• No NH recreational fishing activity (Figure 5.2.7)	• Majority is Medium-High to High (primarily High) levels of NMFS VMS commercial fishing vessel activity (Figure 5.2.5). • Some areas of Low to High levels of NH commercial fishing activity, especially near Cashes Ledge (Figure 5.2.6)	
	North Atlantic Right Whales	• Relatively low historic and current use in eastern half of this area (Figures 5.3.22 – 5.3.25)	• Relatively high historic and current use in western half of this area (Figures 5.3.22 – 5.3.25)	• Any potential impacts to NARW are of high concern to stakeholders (Section 6.3.2). • Stakeholders recommend exclusion of LMA1 restricted area (Section 6.3.2); the RFI excludes it, but it is unclear if development activity near LMA1 may affect NARW.
	All Other Marine Mammals and Sea Turtles	• No or minimal overlap with cetacean migratory corridor BIA, cetacean reproduction BIA, and harbor porpoise and fin whale BIAs (Figure 5.3.4) • No sea turtle sightings reported by STSH from 2002-2022 (Figure 5.3.34)	• Overlap with cetacean feeding BIA (Figure 5.3.4) • Overlap with humpback whale BIA (western side only) (Figure 5.3.4) • Minor overlap with minke whale BIA (Figure 5.3.4) • Overlap with sei whale BIA (western side only) (Figure 5.3.4) • Minor overlap with NARW BIA (Figure 5.3.4)	• Any potential impacts to NARW are of high concern to stakeholders (Section 6.3.2). • Sea turtle density is high near Cape Cod; it is possible this Area has higher turtle density than reports indicate due to proximity to the Cape (Figure 5.3.34)
	Sand and Gravel Resources	• Large patches of majority mud (Figure 5.5.2)	• Large patches of mud with some sand (Figure 5.5.2)	
	Other	• Eastern side is well outside of visual range of coastline	• Western side is at the 20 nm minimum visual buffer from Cape Cod	• Stakeholders recommend a visual buffer of 20nm based on current turbine heights. Any design changes may require more distance (Section 6.3.2).

Table 6.4.1. Continued.

Location[a] & Interest Level[b]	Category	Pros	Cons	Additional Considerations
G Low to High (1-5)	Environmentally Sensitive Areas		• Includes multiple known coral locations (Figure 5.1.1). • Significant overlap with GOM Cod Protection Closure V (Figure 5.1.2)	• GOM Cod Protection Closure V is closed in March (Stakeholders recommend exclusion of year-round closure areas; Section 6.3.2)
	Fisheries	• Majority is Low to Medium-Low levels of NMFS VMS commercial fishing vessel activity (Figure 5.2.5). • Very little NH commercial fishing activity (Figure 5.2.6) • No NH recreational fishing activity (Figure 5.2.7)	• Contains some areas of Medium-High to High NMFS VMS commercial fishing vessel activity (Figure 5.2.5) • Overlap with Wilkinson Basin and Rodgers Basin; near Stellwagen Bank (Figure 5.1.4)	• Complex habitat features (e.g., basins & banks) have high productivity and biodiversity.
	North Atlantic Right Whales	• Relatively low historic and current use in eastern quarter of this area (Figures 5.3.22 – 5.3.25)	• Relatively high historic and current use in western ¾ of this area (Figures 5.3.22 – 5.3.25) • Minor overlap with NARW BIA (Figure 5.3.4)	• Any potential impacts to NARW are of high concern to stakeholders (Section 6.3.2).
	All Other Marine Mammals and Sea Turtles	• No or minimal overlap with cetacean reproduction BIA and harbor porpoise, minke whale, and fin whale BIAs (Figure 5.3.4) • No sea turtle sightings reported by STSH from 2002-2022 (Figure 5.3.34)	• Overlap with cetacean feeding BIA (Figure 5.3.4) • Overlap with cetacean migratory corridor BIA (Figure 5.3.4) • Overlap with humpback whale BIA (Figure 5.3.4) • Minor overlap with sei whale BIA (Figure 5.3.4)	• Any potential impacts to NARW are of high concern to stakeholders (Section 6.3.2). • Sea turtle density is high near Cape Cod; it is possible this Area has higher turtle density than reports indicate due to proximity to the Cape (Figure 5.3.34)
	Sand and Gravel Resources	• Large patches of majority mud (Figure 5.5.2)	• Primarily mud with some sand, with patches containing higher quantities of sand and/or gravel (Figure 5.5.2)	
	Other	• Eastern side is well outside of visual range of coastline.	• Western side is at the 20nm minimum visual buffer from Cape Cod	Stakeholders recommend a visual buffer of 20 nm based on current turbine heights. Any design changes may require more distance (Section 6.3.2).

Table 6.4.1. Continued.

Location[a] & Interest Level[b]	Category	Pros	Cons	Additional Considerations
H Low (1-2)	Environmentally Sensitive Areas		• Includes multiple known coral locations; adjacent to the Jordan Basin Dedicated Habitat Research Area (Figure 5.1.1). • Some overlap with GOM Cod Protection Closure V (Figure 5.1.2) • Near Great South Channel Juvenile Cod HAPC (Figure 5.1.3) • Overlap with Georges Basin & Rodgers Basin (Figure 5.1.4)	• GOM Cod Protection Closure V is closed in March. Stakeholders recommend exclusion of year-round closure areas, HMAs and HAPCs (Section 6.3.2); minimum distance to prevent impacts is unclear. • Complex habitat features (e.g., basins) have high productivity and biodiversity.
	Fisheries	• No NH recreational fishing activity (Figure 5.2.7)	• Majority is Medium-High to High (primarily High) levels of NMFS VMS commercial fishing vessel activity (Figure 5.2.5). • Eastern portion has Low to High levels of NH commercial fishing activity (Figure 5.2.6)	
	Marine Mammals and Sea Turtles	• No or minimal overlap with cetacean reproduction BIA and harbor porpoise BIA (Figure 3.4.4) • No sea turtle sightings reported by STSH from 2002-2022 (Figure 5.3.34)	• Overlap with cetacean feeding BIA (Figure 5.3.4) • Overlap with cetacean migratory corridor BIA (Figure 5.3.4) • Overlap with humpback whale BIA (Figure 5.3.4) • Overlap with minke whale BIA (Figure 5.3.4) • Overlap with sei whale BIA (Figure 5.3.4) • Overlap with fin whale BIA (Figure 5.3.4) • Overlap with NARW BIA (Figure 5.3.4)	• Any potential impacts to NARW are of high concern to stakeholders (Section 6.3.2). Sea turtle sightings occur just outside this location on the southwestern side of RFI. Sea turtle density is high near Cape Cod; it is possible this Area has higher turtle density than reports indicate due to proximity to the Cape (Figure 5.3.34)
	Sand and Gravel Resources	• Some small patches of majority mud (Figure 5.5.2)	• Primarily mud with some sand, with patches containing higher quantities of sand and/or gravel (Figure 5.5.2)	

Table 6.4.1. Continued.

Location[a] & Interest Level[b]	Category	Pros	Cons	Additional Considerations
	Other	• Eastern • side is well outside of visual range of coastline	• Western side is at the 20nm minimum visual buffer from Cape Cod	• Stakeholders recommend a visual buffer of 20nm based on current turbine heights. Any design changes may require more distance (Section 6.3.2).

[a] General locations are defined in Figure 6.4.1. Table descriptions focus on areas of interest within the delineated locations and exclude areas that are not of interest or not part of the RFI.

[b] Interest levels are defined by the number of nominations by developers and are as follows: Low (1-2), Moderate (3-4), High (5), and Highest (6).

[c] Commercial fishing vessel traffic from NMFS vessel monitoring system (VMS) represents the majority of vessel operations in most of the fisheries managed in federal waters, except the lobster fishery. Preliminary assessment indicated 95% of groundfish, herring, monkfish, and scallop landings from 2014 through 2019 were from vessels equipped with VMS.

6.5 References

30 CFR § 585.627. Code of Federal Regulations, Title 30 - Mineral Resources, Chapter V - Bureau of Ocean Energy Management, Department of the Interior Subchapter B - Offshore Part 585 - Renewable Energy and Alternate Uses of Existing Facilities on the Outer Continental Shelf, Subpart F Contents of the Construction and Operations Plan § 585.627 What information and certifications must I submit with my COP to assist the BOEM in complying with NEPA and other relevant laws?

42 U.S.C. § 4321. United States Code, Title 42 - The Public Health and Welfare, Chapter 55 - National Environmental Policy, Section 4321 - Congressional declaration of purpose.

43 U.S.C. § 1337. Title 43 - Public Lands, Chapter 29 - Submerged Lands, Subchapter III - Outer Continental Shelf Lands, Section 1337 - Leases, easements, and rights-of-way on the Outer Continental Shelf.

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Appendix A: Glossary

Alternating Current (AC): A flow of electrical current that increases to a maximum in one direction decreases to zero, and then reverses direction and reaches maximum in the other direction. The cycle is repeated continuously. The number of such cycles per second is equal to the frequency, measured in Hertz (Hz). U.S. commercial power is 60Hz.

Array cable: Electrical cable that connects the turbines to each other and the offshore substation.

Atmospheric ducting: A phenomenon that alters how electromagnetic waves propagate, usually in the lower layers of Earth's atmosphere, where the waves are bent by atmospheric refraction. Ducting events are driven by steep vertical changes in air density due to differing temperatures and moisture content with height.

Bathymetry: Topography of the ocean floor indicated by depth contours drawn at regular intervals.

Benthic: Of, relating to, or occurring at the bottom of a body of water.

Biota: The combined flora and fauna of a region.

Candidate species: Plants and animals for which the U.S. Fish and Wildlife Service has sufficient information on their biological status and threats to propose them as endangered or threatened under the Endangered Species Act, but for which development of a listing regulation is precluded by other higher-priority listing activities.

Capacity: The rated continuous load-carrying ability of generation, transmission, or other electrical equipment, expressed in megawatts (MW) for active power or megavolt-amperes (MVA) for apparent power.

Capacity factor: Ratio of annual energy production to maximum energy production if the turbine or wind farm ran at rated power all year.

Carbon monoxide (CO): A colorless, odorless gas formed when carbon in fuel is not burned completely. Motor vehicle exhaust is a major contributor to nationwide CO emissions, followed by nonroad engines and vehicles. CO interferes with the blood's ability to carry oxygen to the body's tissues and results in numerous adverse health effects. CO is listed as a criteria air pollutant under Title I of the Clean Air Act.

Catch rate: The estimated number of fish caught per angler trip. Marine Recreational Information Program (MRIP) catch rate is determined using data collected through the Access Point Angler Intercept Survey (APAIS).

Catenary spread mooring system: A multi-point mooring system were the mooring lines between the floating unit and the seabed through gravity form the U-shaped curve of a free hanging line. The mooring lines hang horizontally at the seabed. As a result, the lengths of the lines must be greater than the water depth.

Cetacean: Any of various aquatic, chiefly marine mammals of the order Cetacea, including the whales, dolphins, and porpoises, which are characterized by a nearly hairless body, anterior limbs modified into broad flippers, vestigial posterior limbs, and a flat notched tail.

Charter boat: A charter boat is a vessel that take a group of anglers—usually six or fewer—on a fishing trip with a licensed captain and crew. The anglers hire, or "charter," the vessel, and pay a fee for the captain's services. Charter boats engage in a full range of fishing techniques, including drift fishing, trolling, and bottom fishing. Charter boat catch is sampled at public fishing access sites through the Access Point Angler Intercept Survey (APAIS) and Large Pelagics Intercept Survey.

Circular economy: Economic markets that give incentives to reusing products rather than disposing of them and then extracting new resources.

Coastal: An imprecise area of land and water located at the interface between the shore and the ocean, where physical, chemical, and biological processes occur as interactions between these two ecosystems or because of their proximity to each other.

Coastal State: A State bordering the Atlantic or Pacific Oceans, or the Gulf of Mexico.

Coastal Zone Management Act (CZMA): 16 U.S.C. 1451 et seq. The CZMA regulates development in coastal areas to protect their unique resources.

Commercial fishing: Catching and marketing fish and shellfish for profit.

Compensation: The action or process of awarding an individual or individuals money or other items of economic value as a recompense for economic loss, injury, or suffering.

Consumption: The use of goods and services by the consumer.

Continental shelf: The shallow, gradually sloping seabed around a continental margin, usually no deeper than 200 m (660 ft) and formed by the submergence of part of a continent.

Cost: The monetary value of goods and services purchased by producers and consumers.

Co-processing: A residual product from mechanical recycling is used as a substitute for new raw materials for the production of a new material.

Counterfactual modeling: A construction of fictitious scenarios about worlds that do not exist. The models allow the study of what might happen under a set of conditions.

Crew Transfer Vessel (CTV): A vessel used to transport wind farm technicians and other personnel to the offshore wind farm turbines either from port or from a fixed or floating base. Vessels operating today are typically specially designed catamarans that accommodate around 12 passengers.

Critical habitat: The specific area within the geographical area occupied by a species at the time it is listed as an endangered or threatened species. The area in which physical or biological features essential to the conservation of the species is found. These areas may require special management or protection.

Cumulative impacts: Are impacts that result from the successive, incremental, and/or combined effects of an action, project, or activity (developments) when added to other existing, planned, and/or reasonably anticipated future developments.

Days at sea: Any continuous 24-hour period recorded in a vessel logbook beginning when the vessel leaves a port.

Decibel (dB): A standard unit for the measurement of the relative loudness or intensity of sound. The relative intensity is the ratio of the intensity of a sound wave to a reference intensity. In general, a sound doubles in loudness with every increase of 10 dB. By convention, the intensity level of sound at the threshold of hearing for a young healthy individual is 0 dB.

Decommissioning: The activities necessary to take out of service and dispose of a facility after its useful life.

Demand: A consumer's desire and willingness to purchase a product or service at a time or over time.

Demersal fishes: Those fishes that spend at least the adult portion of their life cycle in association with the ocean bottom.

Direct current (DC): Electric current that flows in one direction only.

Dispatchable generation: A source of electricity that can be provided on demand at the request of power grid operators, according to market needs. Examples include nuclear, natural gas, and coal power plants.

Distinct Population Segment (DPS): A term under the Endangered Species Act used for listing, delisting, and reclassification purposes to describe a vertebrate population or group of populations that is discrete from other populations of the species and significant in relation to the entire species.

Duck bank: A group of electrical conduits that provide pathways and protection for buried electrical or data cables.

Dynamic cables: Power cables that are located in the water column and are characterized by excellent mechanical strength, high fatigue endurance, and designed to withstand a lifetime of constant movement.

Ecosystem: A group of organisms and their physical environment interacting as an ecological system.

Efficiency: For a turbine, it describes the amount of active electrical power generated as a percentage of the wind power incident on the rotor area.

Elasmobranchs: Cartilaginous fishes of a group that comprises sharks, rays, and skates.

Electricity: A form of energy resulting from the existence of charged particles (e.g., electrons), either statically as an accumulation of charge or dynamically as a current.

Electricity demand: The total electricity consumption in GWh consumed by a nation annually.

Electromagnetic field (EMF): The field of energy resulting from the movement of alternating electric current (AC) along the path of a conductor, composed of both electrical and magnetic components and existing in the immediate vicinity of, and surrounding, the electric conductor. Electromagnetic fields exist in both high-voltage electric transmission power lines and in low-voltage electric conductors in homes and appliances.

Endangered species: Any species, plant or animal, that is in danger of extinction throughout all or a significant part of its range. Requirements for declaring a species endangered are found in the Endangered Species Act.

Energy: The power derived from the utilization of physical or chemical resources, especially to provide light and heat or to work machines.

Ensnarement: The inadvertent catch of marine debris including lost or abandoned fishing gear in the mooring lines, cables, or other infrastructure components of a floating offshore wind farm.

Environmental Impact Statement (EIS): A document required of Federal agencies by the National Environmental Policy Act for major proposals or legislation that would or could significantly affect the environment.

Environmental Justice: The fair treatment of people of all races, cultures, incomes, and educational levels with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.

Environmentally Sensitive Area: An area that contains plant or animal life, their habitats, or a natural feature, that are either rare or especially valuable due to their special nature or role in an ecosystem and which would be easily disturbed or degraded by human activities and developments. Under NEPA and other relevant laws for offshore wind development these areas include essential fish habitat, refuges, preserves, special management areas identified in coastal management programs, sanctuaries, rookeries, hard bottom habitat, chemosynthetic communities, and calving grounds, barrier islands, beaches, dunes, and wetlands.

Essential Fish Habitat (EFH): Waters and substrates necessary to fish for spawning, breeding, feeding, or growth to maturity. The term is specifically associated with the Magnuson-Stevens Fishery Conservation and Management Act.

Export cable: Electrical cable that connects the onshore and offshore substations, or between an AC offshore substation and a DC converter substation.

Fault Ride-through (FRT): A requirement of many network operators, such that the wind turbine remains connected during sever disturbances on the electricity system and returns to normal operation very quickly after the disturbance ends.

Federal Exclusive Economic Zone (EEZ): An area contiguous to all state territorial seas, extending seaward 200 nautical miles from the baseline from which the state territorial sea is measured.

Fish: a) Fish or finfish is a limbless aquatic vertebrate animal with gills; b) Fish defined under the Magnuson-Stevens Act as finfish, mollusks, crustaceans, and all other forms of marine animal and plant life other than marine mammals and birds.

Fishery: As defined under the Magnuson-Stevens Act as (a) one or more stocks of fish which can be treated as a unit for purposes of conservation and management and which are identified on the basis of geographical, scientific, technical, recreational, and economic characteristics; and (b) any fishing for such stocks.

Fishing: Fishing is defined under the Magnuson-Stevens Act as (a) the catching, taking, or harvesting of fish; (b) the attempted catching, taking, or harvesting of fish; (c) any other activity which can reasonably be expected to result in the catching, taking, or harvesting of fish; or (d) any operations at sea in support of, or in preparation for, any activity described in subparagraphs (a) through (c). The term does not include any scientific research activity which is conducted by a scientific research vessel.

Fishing community: Fishing community is defined under the Magnuson-Stevens Act as a community which is substantially dependent on or substantially engaged in the harvest or processing of fishery resources to meet social and economic needs, and includes fishing vessel owners, operators, and crew and United States fish processors that are based in such community.

Fixed-bottom foundation: A foundation for a wind turbine that has a rigid connection between the turbine and the seafloor. For example, a monopile foundation. These foundation are used in water less than 60 meters deep.

Floating foundation: A buoyant foundation structure anchored to the seafloor via mooring lines. The term includes several foundation types including spar buoys, tension leg platforms and semi-submersibles.

Frequency (pitch): For sound waves, frequency is the rate at which the sound-producing sound wave is vibrating or the rate at which the sound-producing body completes one vibration cycle. Frequency is expressed in units of Herts (Hz), where one Hz is equal to one vibration cycle per second.

Ghost gear: Any discarded, lost, or abandoned fishing gear in the marine environment.

Gigawatt (GW) and Gigawatt hour (GWh): Unit of power and unit of energy.

Grid-connected: A wind turbine is grid-connected when its output is channeled directly into a national grid (see also stand-alone system).

Groundfish: In the Greater Atlantic region, from Cape Hatteras, North Carolina to the U.S./Canada border, a complex of 13 of bottom-dwelling fish including Atlantic Cod, Haddock, Yellowtail Flounder, Pollock, American Plaice, Witch Flounder, White Hake, Windowpane, Winter Flounder, Acadian Redfish Atlantic Halibut Atlantic Wolffish, and Ocean Pout.

Habitat: The place where a plant or animal lives.

Hazardous Waste: A waste with properties that make it dangerous or capable of having a harmful effect on human health or the environment.

Headboat: A headboat or a party boat is defined as a vessel that take multiple individual and/or small groups of anglers on a fishing trip with a licensed captain and crew. Headboats are generally larger than charter boats, and almost always take more than six anglers on a given trip. Headboat catch is sampled at sea through the Access Point Angler Intercept Survey (APAIS).

Heave: The up and down motion floating platform or vessel due to a wave swells.

High voltage (HV): typically 100 to 150 kV.

High Voltage Alternating Current (HVAC): An electrical power transmission system that uses direct current for the bulk transmission of electrical power. Alternating current is the form in which electric power is generated by wind turbines and delivered to an end user.

High voltage direct current (HVDC): An electric power transmission system that uses direct current for the bulk transmission of electric power. They are currently only used for point-to-point connections.

Highly Migratory Species (HMS): Fish species that travel long distances and often cross domestic and international boundaries including tuna species, marlin (*Tetrapturus* spp. and *Makaira* spp.), oceanic sharks, sailfishes (*Istiophorus* spp.), and swordfish (*Xiphias gladius*).

Horizontal directional drilling (HDD): Horizontal directional drilling is a low impact (trenchless) method of installing underground cables using a surface-launched drilling rig.

Hub height: The height of the rotor axis above the ground.

Impact: Any change to a population, habitat, or the ecosystem, whether adverse or beneficial, resulting from an activity.

Installed capacity: The total MW of operational generation plant of a given technology.

Interannual variability (IAV): The magnitude of the year to year change in a data set.

Interconnection: A transmission link (such as a tieline or transformer), which connects two control areas.

Invertebrate: An organism lacking a backbone or spinal column. Any animal other than a fish, amphibian, reptile, bird, or mammal.

ISO New England: An independent, non-profit regional transmission organization headquartered in Holyoke, Massachusetts, serving Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, and Vermont. In the U.S., regional transmission organizations are an electric power transmission system operator that coordinates, controls, and monitors a multi-state electric grid regulated by the Federal Energy Regulatory Commission (FERC).

Landfall: The point at which cables carrying power from an offshore wind farm reach the shore.

Levelized cost of energy (LCOE): The average minimum price at which the electricity generated by a power plant is required to be sold to offset the total costs of production over its lifetime.

Load: An end-use device or customer that receives power from the electricity system. Load should not be confused with demand, which is the measure of power that a load receives or requires.

Lobster trawl: Multiple set of traps attached in series by a single line.

Low voltage (LV): below 1000 V.

Low-voltage ride through (LVRT): see fault ride-through.

Marine protected area (MPA): A defined region designated and managed for the long-term conservation of marine resources, ecosystems services, or cultural heritage.

Megawatt: A unit of power equal to 1,000 watts.

Mitigation: The act of avoiding an impact, minimizing the impact, rectifying the impact, reducing or eliminating the impact over time, or replacing or providing substitute resources or environments.

Mobile fishing gear: Any dredge, trawl, net, or similar device that is actively towed or pushed to take any fisheries resources on the seafloor.

National Marine Fisheries Service (NMFS): A federal agency that is a part of the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) that is responsible for the stewardship of U.S. national marine resources and their habitat. NMFS is responsible for the management, conservation, and protection of living marine resources within the United States Exclusive Economic Zone. NMFS is commonly referred to as NOAA fisheries.

National Oceanic and Atmospheric Administration (NOAA): A federal agency within the United States Department of Commerce that forecasts changes in climate, weather, oceans, and coasts to supports severe weather preparedness, international shipping, and conservation and management of coastal and marine ecosystems and resources.

Nitrogen dioxide (NO_2): A reddish-brown gas that is a strong oxidizing agent produced by combustion (such as fossil fuels). The reactive oxides of nitrogen in the atmosphere are largely NO and NO_2, known together as NOx. During the day, there exists a rapid interconversion of NO and NO_2 (see Nitrogen oxides (NOx)). NO_2 is one of the six criteria air pollutants specified under Title I of the Clean Air Act.

Noise: A sound, especially one that is loud, unpleasant, or that causes disturbance.

Offshore substation (OSS): The structure used to transform and transfer energy collected by the wind turbines to land in the most efficient manner. It may involve increasing the voltage, providing reactive compensation, and converting the current from AC to DC. Some wind farms may have more than once offshore substation and equipment may be located on several smaller structures and potentially on one or more turbine transition pieces.

Offshore wind turbines: Turbines which are fixed or anchored in bodies of water – usually at sea, but can include lakes, fjords, and sheltered coastal areas – which generate electricity through the force of offshore winds and transmit it via subsea (or undersea) cable systems into onshore electricity networks.

Output: The quantity of goods or services produced in a specific time span.

Outer Continental Shelf (OCS): All submerged land, its subsoil and seabed that are lying seaward and outside the states' jurisdiction to the extent of Federal jurisdiction (200 nautical miles).

Particle: The smallest element of the medium that represents the medium's mean density.

Particle motion: The back-and-forth motion of the medium as specified in terms of particle displacement, particle velocity, or particle acceleration. Particle motions differs from sound pressure in that it is inherently directional, usually taking place along the axis of transmission.

Pelagic: Living or growing near the surface and in the upper layers of the ocean.

Pinnipeds: An order of carnivorous marine mammals, including harbor seals, sea lions, walruses, and elephant seals.

Pitch: The up and down motion of a floating platform or vessel.

Point of interconnection: The point at which responsibility for ownership and operation of the electrical system passes from the wind farm to the electricity network operator; also known as delivery point or point of connection.

Population: A group of individuals of the same species occupying a defined locality during a given time that exhibit reproductive continuity from generation to generation.

Power: To supply a device with mechanical or electrical energy.

Primary entanglement: The inadvertent restraint of a marine animal by anthropogenic materials.

Producer surplus: The difference between the price a company is willing to sell a good or service for and the actual price a consumer pays for a good or service.

Production: The act or process of making or manufacturing goods and products from raw materials or components.

Profit: The money generated from the selling of a good or service after the expenses to manufacture or produce the good or service.

Programmatic Environmental Impact Statement (PEIS): An evaluation of the effects of broad proposals or planning-level decisions that may include a wide range of individual projects; implementation over a long timeframe; and/or implementation across a large geographic area. A PEIS differs from a project-level impact statement in that it includes broad mitigation strategies amongst multiple planning-level alternatives (while project-level impact statements focus only on precise project-specific details and designs), as well as interaction among multiple proposed projects or plan elements to evaluate cumulative effects.

Public waters: Any river, lake, stream, sea, ocean, gulf, bay or other public body of water.

Pyrolysis: Heating a composite material to be separated without the absence of oxygen under controlled conditions. The process aims to break down organic materials into lower weight molecules (gases and oil fractions) that can be used for energy recovery for the pyrolysis process and other processes. The inorganic material (fibers and filler materials) is left intact for recovery.

Raptor: Bird of prey, such as eagle, owl, or hawk.

Recreational fishing: Fishing for sport or pleasure.

Reserve margin: The amount of unused available capability of an electric power system (at peak load for a utility system) as a percentage of total capability. For example, a reserve margin of 15% means that an electric system has excess capacity in the amount of 15% of expected peak demand.

Roll: The sideward or rotational motion of a floating platform or vessel.

Secondary entanglement: When anthropogenic materials such as fishing gear become entangled in the lines or cables of a floating offshore wind farm and this material entangles a marine animal.

Shellfish: Marine mollusks (e.g., oyster, sea scallop, or squid) or crustaceans (e.g., a crab, shrimp, or lobster). This term is frequently used for marine invertebrates that are harvested for human consumption.

Siting process: The process by which potential sites are identified, evaluated, narrowed, and final recommendations are made.

Sound: Sound can refer to any type of mechanical wave motion, in a solid or fluid medium, that propagates via the action of elastic stresses and that involves local compression and expansion of the medium.

Sound pressure: The difference between the instantaneous total pressure and the static pressure that would exist in the absence of sound, expressed in units of pascals (Pa). Sound pressure acts in all directions.

Sound pressure level: The relative magnitude of a sound wave's pressure compared to a reference pressure value. The pressure of the sound wave is proportional to the square of the sound's intensity and is measured in decibels.

Species of (Special) Concern: A species that may have a declining population, limited occurrence, or low numbers for any variety of reasons.

Stakeholder: Any person or group with a vested interest in an enterprise, project, or organization. Stakeholders may be internal or external, and typically consist of investors, employees, customers, suppliers, governments, trade associations, unions, or specific members of the public.

State territorial sea: An area extending three nautical miles from shore in all states and territories except for Puerto Rico and the Gulf coast of Florida, where the seaward state-federal boundary measures three leagues (about 10 miles). Does not include inland areas (e.g., bays, estuaries, or sounds).

Static fishing gear or fixed fishing gear: Any pots, traps, and longlines which passively take fisheries resources from the seafloor. These gears tend to be highly selective and relatively stationary.

Substation: A part of an electrical generation, transmission, and distribution system. Substations transform voltage from high to low, or the opposite, or perform several other important functions.

Suction caisson: A type of fixed platform anchor with an open bottomed tube embedded in the sediment and sealed at the top while in use so that lifting forces generate a pressure differential that holds the caisson down.

Supply: The total amount of a specific good or service that is available to consumers.

Template foundation: A foundation made by using a form, mold, or pattern so that each foundation has the dimensions and meets the same necessary specification.

Temporary: Lasting for a limited time (not permanent).

Tertiary entanglement: When a marine animal already entangled in gear swims through a floating offshore wind farm and the gear becomes entangled with a facility component.

Total allowable catch (as used in the models see footnote 2 in Section 2.2.2): The maximum number of or weight of fish that can be caught by a vessel is a certain timeframe for each species.

Transmission constraints: The lack of transmission line capacity to deliver electricity without exceeding thermal, voltage and stability limits designed to ensure reliability.

US Environmental Protection Agency (EPA): The independent Federal agency, established in 1970, that regulates Federal environmental matters and oversees the implementation of Federal environmental laws.

Utility: The incumbent electricity supplier to end users (usually state-owned at some period), which may own and operate other electricity supply assets, including transmission networks and usually generation plant.

Vessel collision or vessel strike: Any impact between any part of a vessel and a live animal.

Vessel Monitoring Systems (VMS): A satellite surveillance system primarily used to monitor the location and movement of commercial fishing vessels in the United States.

Visual impact: The creation of an intrusion or perceptible contrast that affects the scenic quality of a landscape.

Wake loss: The energy lost due to long wakes at wind farms. Long wakes are formed when wind turbines are placed close together in a wind farm allowing the interaction of individual turbine wakes with each other.

Water quality: The condition of water with respect to the amount of impurities in it.

Watt: An International System unit of power equal to one joule per second.

Wet-tow: When a component, unit, or rig is floating on its own deck or hull and towed by a tug or barge.

Wind Energy Area (WEA): An offshore area that is deemed most suitable for wind energy development because of a lack (or containing the fewest) obvious conflicts with existing uses. They are broad areas where cursory screenings have been completed with coordination among local, state, and federal partners, and represent an area within which further review may be conducted to identify suitable lease block areas for wind energy development.

Zooplanktivorous: consumes zooplankton.

Appendix B: Offshore Wind Resource Area by State with Potential by Wind Speed Interval, Water Depth, and Distance from Shore (Schwartz et al. 2010)

		Distance from Shoreline									
		0 - 3 nm			3 - 12 nm			12 - 50 nm			
		Depth Category (m)			Depth Category (m)			Depth Category (m)			
	Wind Speed	0 - 30	30 - 60	> 60	0 - 30	30 - 60	> 60	0 - 30	30 - 60	> 60	Total
State	**at 90m (m/s)**	**km^2 *(GW)***	**km^2 *(GW)***	**km^2 *(GW)***	**km^2 *(GW)***	**km^2 *(GW)***	**km^2 *(GW)***	**km^2 *(GW)***	**km^2 *(GW)***	**km^2 *(GW)***	**km^2 *(GW)***
Maine	**7.0-7.5**	787.0 *(3.9)*	91.2 *(0.5)*	11.9 *(0.1)*	7.8 *(0.0)*	4.8 *(0.0)*	3.5 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	906.2 *(4.5)*
	7.5-8.0	797.2 *(4.0)*	285.4 *(1.4)*	19.4 *(0.1)*	6.7 *(0.0)*	19.6 *(0.1)*	14.1 *(0.1)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	1,142.3 *(5.7)*
	8.0-8.5	777.0 *(3.9)*	440.8 *(2.2)*	74.2 *(0.4)*	63.4 *(0.3)*	385.6 *(1.9)*	234.5 *(1.2)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	1,975.6 *(9.9)*
	8.5-9.0	513.4 *(2.6)*	614.0 *(3.1)*	157.6 *(0.8)*	18.2 *(0.1)*	219.1 *(1.1)*	1,401.9 *(7.0)*	0.0 *(0.0)*	0.0 *(0.0)*	406.8 *(2.0)*	3,331.1 *(16.7)*
	9.0-9.5	142.2 *(0.7)*	390.0 *(2.0)*	309.2 *(1.5)*	25.9 *(0.1)*	469.0 *(2.3)*	3,504.1 *(17.5)*	0.0 *(0.0)*	57.8 *(0.3)*	3,530.9 *(17.7)*	8,429.2 *(42.1)*
	9.5-10.0	5.5 *(0.0)*	24.9 *(0.1)*	42.3 *(0.2)*	1.0 *(0.0)*	38.3 *(0.2)*	1,459.8 *(7.3)*	0.0 *(0.0)*	7.4 *(0.0)*	13,905.6 *(69.5)*	15,484.7 *(77.4)*
	>10.0	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	41.6 *(0.2)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	41.6 *(0.2)*
New Hampshire	**7.0-7.5**	18.6 *(0.1)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	18.6 *(0.1)*
	7.5-8.0	45.8 *(0.2)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	45.8 *(0.2)*
	8.0-8.5	44.6 *(0.2)*	29.7 *(0.1)*	0.0 *(0.0)*	6.9 *(0.0)*	75.5 *(0.4)*	14.0 *(0.1)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	170.6 *(0.9)*
	8.5-9.0	0.0 *(0.0)*	8.0 *(0.0)*	7.2 *(0.0)*	0.0 *(0.0)*	12.4 *(0.1)*	255.7 *(1.3)*	0.0 *(0.0)*	10.1 *(0.1)*	42.2 *(0.2)*	335.7 *(1.7)*
	9.0-9.5	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	35.2 *(0.2)*	66.4 *(0.3)*	101.6 *(0.5)*
Massachusetts	**7.0-7.5**	201.6 *(1.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	201.6 *(1.0)*
	7.5-8.0	521.4 *(2.6)*	4.7 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	526.1 *(2.6)*
	8.0-8.5	927.4 *(4.6)*	327.3 *(1.6)*	28.6 *(0.1)*	78.2 *(0.4)*	152.0 *(0.8)*	125.5 *(0.6)*	0.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	1,639.1 *(8.2)*
	8.5-9.0	1,508.2 *(7.5)*	378.1 *(1.9)*	12.6 *(0.1)*	315.0 *(1.6)*	354.5 *(1.8)*	812.2 *(4.1)*	11.4 *(0.1)*	23.5 *(0.1)*	190.4 *(1.0)*	3,606.0 *(18.0)*
	9.0-9.5	1,137.0 *(5.7)*	322.6 *(1.6)*	20.0 *(0.1)*	2,696.9 *(13.5)*	1,418.6 *(7.1)*	1,006.5 *(5.0)*	1,689.9 *(8.4)*	5,051.8 *(25.3)*	7,007.4 *(35.0)*	20,350.7 *(101.8)*
	9.5-10.0	2.0 *(0.0)*	0.0 *(0.0)*	0.0 *(0.0)*	8.6 *(0.0)*	119.2 *(0.6)*	0.0 *(0.0)*	472.1 *(2.4)*	3,459.5 *(17.3)*	9,612.5 *(48.1)*	13,674.0 *(68.4)*

Appendix C: Partial List of Finfish Species Found in the Gulf of Maine

A partial list of finfish species (N = 204 species) found the Gulf of Maine with habitat designation (Collette and Klein-MacPhee 2002, Froese and Pauly 2022).

Family	Common Name	Scientific Name	Habitat
Achiridae	Hogchoker	*Trinectes maculatus*	demersal
Acipenseridae	Atlantic Sturgeon	*Acipenser oxyrinchus*	demersal
	Shortnose Sturgeon	*Acipenser brevirostrum*	demersal
Agonidae	Alligatorfish	*Aspidophoroides monopterygius*	demersal
Alopiidae	Thresher	*Alopias vulpinus*	pelagic-oceanic
Ammodytidae	American Sand Lance	*Ammodytes americanus*	demersal
	Northern Sand Lance	*Ammodytes dubius*	demersal
Anarhichadidae	Atlantic Wolffish	*Anarhichas lupus*	demersal
Anguillidae	American Eel	*Anguilla rostrata*	demersal
Antennariidae	Sargassumfish	*Histrio histrio*	reef-associated
Antigoniidae	Deepbody Boarfish	*Antigonia capros*	demersal
Argentinidae	Greater Argentine	*Argentina silus*	bathypelagic
Ariommatidae	Silver-rag Driftfish	*Ariomma bondi*	demersal
Atherinopsidae	Atlantic Silverside	*Menidia menidia*	pelagic-neritic
	Inland Silverside	*Menidia beryllina*	pelagic-neritic
Balistidae	Grey Triggerfish	*Balistes capriscus*	reef-associated
Batrachoididae	Oyster Toadfish	*Opsanus tau*	reef-associated
Belonidae	Atlantic Needlefish	*Strongylura marina*	reef-associated
	Flat Needlefish	*Ablennes hians*	reef-associated
Berycidae	Alfonsino	*Beryx decadactylus*	bathydemersal
	Splendid Alfonsino	*Beryx splendens*	benthopelagic
Bothidae	Eyed Flounder	*Bothus ocellatus*	reef-associated
Bramidae	Big-scale Pomfret	*Taractichthys longipinnis*	pelagic-oceanic
Carangidae	African Pompano	*Alectis ciliaris*	reef-associated
	Atlantic Moonfish	*Selene setapinnis*	benthopelagic
	Banded Rudderfish	*Seriola zonata*	benthopelagic
	Bigeye Scad	*Selar crumenophthalmus*	reef-associated
	Blue Runner	*Caranx crysos*	reef-associated
	Crevalle Jack	*Caranx hippos*	reef-associated
	Leatherjacket	*Oligoplites saurus*	reef-associated
	Lookdown	*Selene vomer*	demersal
	Pilotfish	*Naucrates ductor*	reef-associated

Family	Common Name	Scientific Name	Habitat
	Rough Scad	*Trachurus lathami*	reef-associated
Carcharhinidae	Atlantic Sharpnose Shark	*Rhizoprionodon terraenovae*	demersal
	Blue Shark	*Prionace glauca*	pelagic-oceanic
	Dusky Shark	*Carcharhinus obscurus*	reef-associated
	Sandbar Shark	*Carcharhinus plumbeus*	benthopelagic
Carchariidae	Sand Tiger Shark	*Carcharias taurus*	reef-associated
Centriscidae	Longspine Snipefish	*Macroramphosus scolopax*	demersal
Centrolophidae	Barrelfish	*Hyperoglyphe perciformis*	pelagic-oceanic
	Rudderfish	*Centrolophus niger*	bathypelagic
Ceratiidae	Northern Giant Seadevil	*Ceratias holboelli*	bathypelagic
Cetorhinidae	Basking Shark	*Cetorhinus maximus*	pelagic-oceanic
Chaunacidae	Redeye Gaper	*Chaunax stigmaeus*	bathydemersal
Chlorophthalmidae	Shortnose Greeneye	*Chlorophthalmus agassizi*	bathydemersal
Clupeidae	Alewife	*Alosa pseudoharengus*	pelagic-neritic
	American Shad	*Alosa sapidissima*	pelagic-neritic
	Atlantic Herring	*Clupea harengus*	benthopelagic
	Atlantic Menhaden	*Brevoortia tyrannus*	pelagic-neritic
	Atlantic Thread Herring	*Opisthonema oglinum*	reef-associated
	Blueback Herring	*Alosa aestivalis*	pelagic-neritic
Congridae	American Conger	*Conger oceanicus*	demersal
Coryphaenidae	Common Dolphinfish	*Coryphaena hippurus*	pelagic-neritic
Cottidae	Arctic Staghorn Sculpin	*Gymnocanthus tricuspis*	demersal
	Atlantic Hookear Sculpin	*Artediellus atlanticus*	demersal
	Grubby	*Myoxocephalus aenaeus*	demersal
	Longhorn Sculpin	*Myoxocephalus octodecemspinosus*	demersal
	Shorthorn Sculpin	*Myoxocephalus scorpius*	demersal
	Moustache Sculpin	*Triglops murrayi*	demersal
Cryptacanthodidae	Wrymouth	*Cryptacanthodes maculatus*	demersal
Cyclopsettidae	Gulf Stream Flounder	*Citharichthys arctifrons*	demersal
	Smallmouth Flounder	*Etropus microstomus*	demersal
Cyclopteridae	Atlantic spiny Lumpsucker	*Eumicrotremus spinosus*	demersal
	Lumpfish	*Cyclopterus lumpus*	benthopelagic
Dactylopteridae	Flying Gurnard	*Dactylopterus volitans*	reef-associated
Dasyatidae	Roughtail Stingray	*Bathytoshia centroura*	demersal
Diodontidae	Striped Burrfish	*Chilomycterus schoepfii*	reef-associated
Echeneidae	Live Sharksucker	*Echeneis naucrates*	reef-associated
	Shark Sucker	*Remora remora*	reef-associated
	Spearfish Remora	*Remora brachyptera*	pelagic-oceanic

Family	Common Name	Scientific Name	Habitat
Elopidae	Ladyfish	*Elops saurus*	reef-associated
Engraulidae	Bay Anchovy	*Anchoa mitchilli*	pelagic-neritic
	Striped Anchovy	*Anchoa hepsetus*	pelagic-neritic
Etmopteridae	Black Dogfish	*Centroscyllium fabricii*	bathydemersal
Exocoetidae	Atlantic Flyingfish	*Cheilopogon melanurus*	pelagic-neritic
Fistulariidae	Cornetfish	*Fistularia tabacaria*	reef-associated
Fundulidae	Mummichog	*Fundulus heteroclitus*	benthopelagic
Fundulidae	Striped Killifish	*Fundulus majalis*	benthopelagic
Gadidae	Atlantic Cod	*Gadus morhua*	benthopelagic
	Atlantic Tomcod	*Microgadus tomcod*	demersal
	Haddock	*Melanogrammus aeglefinus*	demersal
	Pollock	*Pollachius virens*	demersal
Gaidropsaridae	Fourbeard Rockling	*Enchelyopus cimbrius*	demersal
Galeocerdonidae	Tiger Shark	*Galeocerdo cuvier*	benthopelagic
Gasterosteidae	Blackspotted Stickleback	*Gasterosteus wheatlandi*	benthopelagic
	Fourspine Stickleback	*Apeltes quadracus*	benthopelagic
	Three-spined Stickleback	*Gasterosteus aculeatus*	benthopelagic
Gempylidae	Oilfish	*Ruvettus pretiosus*	benthopelagic
Grammicolepididae	Spotted Tinselfish	*Xenolepidichthys dalgleishi*	benthopelagic
	Thorny Tinselfish	*Grammicolepis brachiusculus*	bathypelagic
Hemiramphidae	American Halfbeak	*Hyporhamphus meeki*	pelagic-neritic
Holocentridae	Bigeye Soldierfish	*Ostichthys trachypoma*	demersal
Istiophoridae	Blue Marlin	*Makaira nigricans*	pelagic-oceanic
Labridae	Cunner	*Tautogolabrus adspersus*	reef-associated
	Tautog	*Tautoga onitis*	reef-associated
Lamnidae	White Shark	*Carcharodon carcharias*	pelagic-oceanic
	Shortfin Mako	*Isurus oxyrinchus*	pelagic-oceanic
Lampridae	Opah	*Lampris guttatus*	bathypelagic
Latilidae	Tilefish	*Lopholatilus chamaeleonticeps*	demersal
Liparidae	Atlantic Seasnail	*Liparis atlanticus*	demersal
	Gulf Snailfish	*Liparis coheni*	demersal
	Inquiline Snailfish	*Liparis inquilinus*	demersal
	Scotian Snailfish	*Careproctus ranula*	demersal
Lophiidae	American Angler	*Lophius americanus*	demersal
Lotidae	Cusk	*Brosme brosme*	demersal
Macrouridae	Marlin-spike	*Nezumia bairdii*	benthopelagic
Megalopidae	Tarpon	*Megalops atlanticus*	reef-associated
Merlucciidae	Offshore Hake	*Merluccius albidus*	bathydemersal
	Silver Hake	*Merluccius bilinearis*	demersal

Family	Common Name	Scientific Name	Habitat
Mobulidae	Giant Manta Ray	*Manta birostris*	pelagic-oceanic
Molidae	Ocean Sunfish	*Mola mola*	pelagic-oceanic
	Sharptail Mola	*Masturus lanceolatus*	bathypelagic
Monacanthidae	Fringed Filefish	*Monacanthus ciliatus*	reef-associated
	Orange Filefish	*Aluterus schoepfii*	reef-associated
	Planehead Filefish	*Stephanolepis hispida*	reef-associated
	Scrawled Filefish	*Aluterus scriptus*	reef-associated
Moridae	Hakeling	*Physiculus fulvus*	benthopelagic
Moronidae	Striped Bass	*Morone saxatilis*	demersal
	White Perch	*Morone americana*	benthopelagic
Mugilidae	Striped Mullet	*Mugil cephalus*	benthopelagic
	White Mullet	*Mugil curema*	reef-associated
Myctophidae	Glacier Lanternfish	*Benthosema glaciale*	bathypelagic
	Dumeril's Lanternfish	*Diaphus dumerilii*	bathypelagic
	Dofleini's Lantern Fish	*Lobianchia dofleini*	bathypelagic
	Jewel Lanternfish	*Lampanyctus crocodilus*	bathypelagic
	Horned Lanternfish	*Ceratoscopelus maderensis*	bathypelagic
	Spotted Lanternfish	*Myctophum punctatum*	bathypelagic
Myxinidae	Atlantic Hagfish	*Myxine glutinosa*	benthopelagic
Nemichthyidae	Slender Snipe Eel	*Nemichthys scolopaceus*	bathypelagic
Ophichthidae	Margined Snake Eel	*Ophichthus cruentifer*	demersal
Ophidiidae	Blackrim Cusk-eel	*Lepophidium profundorum*	demersal
Osmeridae	Capelin	*Mallotus villosus*	pelagic-oceanic
	Rainbow smelt	*Osmerus mordax*	pelagic-oceanic
Paralepididae	Spotted Barracudina	*Arctozenus risso*	bathypelagic
Paralichthyidae	Summer Flounder	*Paralichthys dentatus*	demersal
Peristediidae	Armored Searobin	*Peristedion miniatum*	bathydemersal
Pholidae	Rock Gunnel	*Pholis gunnellus*	demersal
Phycidae	Longfin Hake	*Phycis chesteri*	benthopelagic
	Red Hake	*Urophycis chuss*	demersal
	Spotted Hake	*Urophycis regia*	demersal
	White Hake	*Urophycis tenuis*	demersal
Pleuronectidae	American Plaice	*Hippoglossoides platessoides*	demersal
	Smooth Flounder	*Liopsetta putnami*	demersal
	Atlantic Halibut	*Hippoglossus hippoglossus*	demersal
	Greenland Halibut	*Reinhardtius hippoglossoides*	benthopelagic
	Winter Flounder	*Pseudopleuronectes americanus*	demersal
	Witch Flounder	*Glyptocephalus cynoglossus*	demersal

Family	Common Name	Scientific Name	Habitat
Polymixiidae	Beardfish	*Polymixia lowei*	bathydemersal
Polyprionidae	Wreckfish	*Polyprion americanus*	demersal
Pomatomidae	Bluefish	*Pomatomus saltatrix*	pelagic-oceanic
Priacanthidae	Short Bigeye	*Pristigenys alta*	reef-associated
Psychrolutidea	Polar Sculpin	*Cottunculus microps*	demersal
	Pallid Sculpin	*Cottunculus thomsoni*	demersal
Rajidae	Barndoor Skate	*Dipturus laevis*	demersal
	Clearnose Skate	*Rostroraja eglanteria*	demersal
	Round Ray	*Rajella fyllae*	bathydemersal
	Smooth Skate	*Malacoraja senta*	bathydemersal
	Starry Ray	*Amblyraja radiata*	demersal
	Winter Skate	*Leucoraja ocellata*	demersal
Rhincodontidae	Whale Shark	*Rhincodon typus*	pelagic-oceanic
Rhinopteridae	Cownose Ray	*Rhinoptera bonasus*	benthopelagic
Salmonidae	Atlantic Salmon	*Salmo salar*	benthopelagic
	Brook Trout	*Salvelinus fontinalis*	benthopelagic
Sciaenidae	Black Drum	*Pogonias cromis*	demersal
	Northern Kingfish	*Menticirrhus saxatilis*	demersal
	Spot Croaker	*Leiostomus xanthurus*	demersal
	Weakfish	*Cynoscion regalis*	demersal
Scomberesocidae	Atlantic Saury	*Scomberesox saurus*	pelagic-oceanic
Scombridae	Bluefin Tuna	*Thunnus thynnus*	pelagic-oceanic
	Atlantic Bonito	*Sarda sarda*	pelagic-neritic
	Atlantic Chub Mackerel	*Scomber colias*	pelagic-neritic
	Atlantic Mackerel	*Scomber scombrus*	pelagic-neritic
	Spanish Mackerel	*Scomberomorus maculatus*	pelagic-neritic
	Bullet Mackerel	*Auxis rochei*	pelagic-neritic
	Cero	*Scomberomorus regalis*	reef-associated
	King Mackerel	*Scomberomorus cavalla*	pelagic-neritic
	Little Tunny	*Euthynnus alletteratus*	pelagic-oceanic
	Skipjack Tuna	*Katsuwonus pelamis*	pelagic-oceanic
Scyliorhinidae	Chain Catshark	*Scyliorhinus retifer*	demersal
Sebastidae	Acadian Redfish	*Sebastes fasciatus*	demersal
	Blackbelly Rosefish	*Helicolenus dactylopterus*	bathydemersal
Serranidae	Black Sea Bass	*Centropristis striata*	reef-associated
	Yellowfin Bass	*Anthias nicholsi*	benthopelagic
Serrivomeridae	Stout Sawpalate	*Serrivomer beanii*	bathypelagic
Somniosidae	Greenland Shark	*Somniosus microcephalus*	benthopelagic
Sparidae	Scup	*Stenotomus chrysops*	demersal

Family	Common Name	Scientific Name	Habitat
	Sheepshead	*Archosargus probatocephalus*	reef-associated
Sphyraenidae	Northern Sennet	*Sphyraena borealis*	reef-associated
Sphyrnidae	Smooth Hammerhead	*Sphyrna zygaena*	pelagic-oceanic
Squalidae	Spiny dogfish	*Squalus acanthias*	benthopelagic
Stichaeidae	Arctic Shanny	*Stichaeus punctatus*	demersal
	Radiated Shanny	*Ulvaria subbifurcata*	benthopelagic
Stomiidae	Threelight Dragonfish	*Trigonolampa miriceps*	bathypelagic
Stromateidae	Butterfish	*Peprilus triacanthus*	benthopelagic
Synaphobranchidae	Kaup's Arrowtooth Eel	*Synaphobranchus kaupii*	bathydemersal
Syngnathidae	Lined Seahorse	*Hippocampus erectus*	reef-associated
	Northern Pipefish	*Syngnathus fuscus*	demersal
Tetraodontidae	Northern Puffer	*Sphoeroides maculatus*	demersal
Torpedinidae	Electric Ray	*Tetronarce nobiliana*	benthopelagic
Trachichthyidae	Darwin's Slimehead	*Gephyroberyx darwinii*	benthopelagic
	Mediterranean Slimehead	*Hoplostethus mediterraneus*	benthopelagic
Triakidae	Dusky Smooth-hound	*Mustelus canis*	demersal
Trichiuridae	Largehead Hairtail	*Trichiurus lepturus*	benthopelagic
Triglidae	Northern Searobin	*Prionotus carolinus*	demersal
	Striped Searobin	*Prionotus evolans*	reef-associated
Xiphiidae	Swordfish	*Xiphias gladius*	pelagic-oceanic
Zeidae	Silvery John Dory	*Zenopsis conchifer*	benthopelagic
Zoarcidae	Atlantic Soft Pout	*Melanostigma atlanticum*	bathypelagic
	Ocean Pout	*Zoarces americanus*	demersal
	Wolf Eelpout	*Lycenchelys verrillii*	bathydemersal

Appendix D: Annual New Hampshire Commercial Landings for All Species from 2015 - 2021 (NOAA NMFS 2023a).

Year	Common Name	Scientific Name	Pounds	Metric Tons	Value (US dollars)
2015	American Lobster	*Homarus americanus*	4,721,826	2,142	$24,543,716
2015	Bluefin Tuna	*Thunnus thynnus*	118,916	54	$685,087
2015	Atlantic Herring	*Clupea harengus*	3,998,860	1,814	$585,787
2015	Atlantic Sea Scallop	*Placopecten magellanicus*	30,999	14	$397,611
2015	Pollock	*Pollachius virens*	270,275	123	$356,059
2015	Monkfish	*Lophius americanus*	314,359	143	$351,282
2015	Other	Withheld for confidentiality	1,169,673	531	$336,159
2015	Silver Hake	*Merluccius bilinearis*	288,104	131	$229,975
2015	Atlantic Cod	*Gadus morhua*	44,701	20	$93,294
2015	Witch Flounder	*Glyptocephalus cynoglossus*	20,699	9	$55,584
2015	American Plaice	*Hippoglossoides platessoides*	34,445	16	$50,772
2015	Yellowtail Flounder	*Limanda ferruginea*	38,256	17	$43,197
2015	White Hake	*Urophycis tenuis*	20,696	9	$31,298
2015	Atlantic Halibut	*Hippoglossus hippoglossus*	1,573	1	$12,274
2015	Haddock	*Melanogrammus aeglefinus*	5,740	3	$8,111
2015	Winter Flounder	*Pseudopleuronectes americanus*	3,366	2	$6,218
2015	Atlantic Mackerel	*Scomber scombrus*	5,152	2	$3,609
2015	Acadian Redfish	*Sebastes fasciatus*	3,135	1	$2,235
2015	Cusk	*Brosme brosme*	2,575	1	$1,752
2015	Bluefish	*Pomatomus saltatrix*	Confidential		
2015	Butterfish	*Peprilus triacanthus*	Confidential		
2015	Atlantic Rock Crab	*Cancer irroratus*	Confidential		

Year	Common Name	Scientific Name	Pounds	Metric Tons	Value (US dollars)
2015	Jonah Crab	*Cancer borealis*	Confidential		
2015	Red Hake	*Urophycis chuss*	Confidential		
2015	Spiny Dogfish	*Squalus acanthias*	Confidential		
2015	Little Skate	*Leucoraja erinacea*	Confidential		
2015	Winter Skate	*Leucoraja ocellata*	Confidential		
2015	Longfin Squid	*Loligo pealeii*	Confidential		
2016	American Lobster	*Homarus americanus*	5,782,098	2,623	$30,372,614
2016	Bluefin Tuna	*Thunnus thynnus*	168,080	76	$1,340,157
2016	Monkfish	*Lophius americanus*	331,349	150	$337,777
2016	Atlantic Sea Scallop	*Placopecten magellanicus*	23,597	11	$283,742
2016	Silver Hake	*Merluccius bilinearis*	323,365	147	$258,262
2016	Other	Withheld for confidentiality	899,209	408	$233,110
2016	Pollock	*Pollachius virens*	97,838	44	$207,290
2016	Atlantic Cod	*Gadus morhua*	55,162	25	$108,696
2016	Jonah Crab	*Cancer borealis*	150,341	68	$105,075
2016	American Plaice	*Hippoglossoides platessoides*	38,218	17	$85,190
2016	Yellowtail Flounder	*Limanda ferruginea*	30,292	14	$50,672
2016	Witch Flounder	*Glyptocephalus cynoglossus*	11,661	5	$41,950
2016	Haddock	*Melanogrammus aeglefinus*	9,282	4	$14,420
2016	Atlantic Halibut	*Hippoglossus hippoglossus*	2,076	1	$14,342
2016	Winter Flounder	*Pseudopleuronectes americanus*	5,954	3	$12,948
2016	White Hake	*Urophycis tenuis*	6,191	3	$11,287
2016	Acadian Redfish	*Sebastes fasciatus*	1,088	0	$903
2016	Cusk	*Brosme brosme*	1,422	1	$824

Year	Common Name	Scientific Name	Pounds	Metric Tons	Value (US dollars)
2016	Bluefish	*Pomatomus saltatrix*	Confidential		
2016	Butterfish	*Peprilus triacanthus*	Confidential		
2016	Atlantic Rock Crab	*Cancer irroratus*	Confidential		
2016	Green Crab	*Carcinus maenas*	Confidential		
2016	Spider Crabs	Majidae	Confidential		
2016	Red Hake	*Urophycis chuss*	Confidential		
2016	Hakes (Red and White)	Urophycis	Confidential		
2016	Atlantic Herring	*Clupea harengus*	Confidential		
2016	Atlantic Mackerel	*Scomber scombrus*	Confidential		
2016	Scup	*Stenotomus chrysops*	Confidential		
2016	Spiny Dogfish	*Squalus acanthias*	Confidential		
2016	Northern Shrimp	*Pandalus borealis*	Confidential		
2016	Little Skate	*Leucoraja erinacea*	Confidential		
2016	Winter Skate	*Leucoraja ocellata*	Confidential		
2016	Longfin Squid	*Loligo pealeii*	Confidential		
2017	American Lobster	*Homarus americanus*	5,645,434	2,561	$32,364,527
2017	Bluefin Tuna	*Thunnus thynnus*	156,788	71	$852,848
2017	Atlantic Herring	*Clupea harengus*	2,829,007	1,283	$827,156
2017	Monkfish	*Lophius americanus*	549,562	249	$421,716
2017	Pollock	*Pollachius virens*	108,388	49	$188,523
2017	Spiny Dogfish	*Squalus acanthias*	858,120	389	$177,800
2017	Silver Hake	*Merluccius bilinearis*	214,535	97	$160,662
2017	Atlantic Cod	*Gadus morhua*	70,960	32	$149,768
2017	American Plaice	*Hippoglossoides platessoides*	51,129	23	$113,772
2017	Jonah Crab	*Cancer borealis*	114,155	52	$82,715

Year	Common Name	Scientific Name	Pounds	Metric Tons	Value (US dollars)
2017	Yellowtail Flounder	*Limanda ferruginea*	37,011	17	$76,509
2017	Atlantic Sea Scallop	*Placopecten magellanicus*	4,979	2	$65,654
2017	Other	Withheld for confidentiality	43,376	20	$51,646
2017	Witch Flounder	*Glyptocephalus cynoglossus*	18,234	8	$48,186
2017	Winter Flounder	*Pseudopleuronectes americanus*	12,321	6	$30,824
2017	Atlantic Halibut	*Hippoglossus hippoglossus*	3,687	2	$26,786
2017	Haddock	*Melanogrammus aeglefinus*	17,790	8	$22,489
2017	White Hake	*Urophycis tenuis*	11,992	5	$16,331
2017	Red Hake	*Urophycis chuss*	40,347	18	$8,863
2017	Winter Skate	*Leucoraja ocellata*	8,797	4	$2,320
2017	Cusk	*Brosme brosme*	2,378	1	$1,224
2017	Acadian Redfish	*Sebastes fasciatus*	369	0	$336
2017	Butterfish	*Peprilus triacanthus*	Confidential		
2017	Atlantic Rock Crab	*Cancer irroratus*	Confidential		
2017	Spider Crabs	Majidae	Confidential		
2017	Atlantic Mackerel	*Scomber scombrus*	Confidential		
2017	Menhadens	*Brevoortia* spp.	Confidential		
2017	Eastern Oyster	*Crassostrea virginica*	Confidential		
2017	Scup	*Stenotomus chrysops*	Confidential		
2017	Northern Shrimp	*Pandalus borealis*	Confidential		
2017	Little Skate	*Leucoraja erinacea*	Confidential		
2017	Skates	Rajidae	Confidential		
2017	Longfin Squid	*Loligo pealeii*	Confidential		
2017	Shortfin Squid	*Illex illecebrosus*	Confidential		

Year	Common Name	Scientific Name	Pounds	Metric Tons	Value (US dollars)
2018	American Lobster	*Homarus americanus*	6,199,365	2,812	$35,672,477
2018	Bluefin Tuna	*Thunnus thynnus*	196,758	89	$1,144,694
2018	Atlantic Herring	*Clupea harengus*	1,511,450	686	$436,184
2018	Monkfish	*Lophius americanus*	539,684	245	$352,837
2018	Pollock	*Pollachius virens*	185,685	84	$284,196
2018	Other	Withheld for confidentiality	871,228	395	$230,843
2018	Atlantic Cod	*Gadus morhua*	88,755	40	$209,414
2018	Atlantic Sea Scallop	*Placopecten magellanicus*	11,746	5	$154,936
2018	White Hake	*Urophycis tenuis*	124,388	56	$148,434
2018	Silver Hake	*Merluccius bilinearis*	163,968	74	$129,410
2018	Haddock	*Melanogrammus aeglefinus*	79,785	36	$107,048
2018	American Plaice	*Hippoglossoides platessoides*	40,000	18	$77,370
2018	Yellowtail Flounder	*Limanda ferruginea*	30,971	14	$59,278
2018	Witch Flounder	*Glyptocephalus cynoglossus*	17,457	8	$37,287
2018	Atlantic Halibut	*Hippoglossus hippoglossus*	3,212	1	$24,916
2018	Winter Flounder	*Pseudopleuronectes americanus*	9,966	5	$23,662
2018	Jonah Crab	*Cancer borealis*	22,434	10	$14,894
2018	Winter Skate	*Leucoraja ocellata*	18,001	8	$5,113
2018	Cusk	*Brosme brosme*	2,488	1	$2,388
2018	Acadian Redfish	*Sebastes fasciatus*	1,887	1	$1,836
2018	Atlantic Mackerel	*Scomber scombrus*	1,080	0	$1,028
2018	Butterfish	*Peprilus triacanthus*	Confidential		
2018	Atlantic Rock Crab	*Cancer irroratus*	Confidential		
2018	Green Crab	*Carcinus maenas*	Confidential		

Year	Common Name	Scientific Name	Pounds	Metric Tons	Value (US dollars)
2018	Spider Crabs	Majidae	Confidential		
2018	Cunner	Tautogolabrus adspersus	Confidential		
2018	Red Hake	*Urophycis chuss*	Confidential		
2018	Menhadens	*Brevoortia* spp.	Confidential		
2018	Eastern Oyster	*Crassostrea virginica*	Confidential		
2018	Scup	*Stenotomus chrysops*	Confidential		
2018	Spiny Dogfish	*Squalus acanthias*	Confidential		
2018	Northern Shrimp	*Pandalus borealis*	Confidential		
2018	Barndoor Skate	*Dipturus laevis*	Confidential		
2018	Little Skate	*Leucoraja erinacea*	Confidential		
2018	Longfin Squid	*Loligo pealeii*	Confidential		
2018	Swordfish	*Xiphias gladius*	Confidential		
2019	American Lobster	*Homarus americanus*	6,093,615	2,764	$36,020,851
2019	Menhadens	*Brevoortia* spp.	4,540,800	2,060	$791,716
2019	Bluefin Tuna	*Thunnus thynnus*	120,803	55	$619,891
2019	Atlantic Sea Scallop	*Placopecten magellanicus*	35,750	16	$385,083
2019	Monkfish	*Lophius americanus*	576,745	262	$311,742
2019	Other	Withheld for confidentiality	1,016,667	461	$278,840
2019	Pollock	*Pollachius virens*	175,030	79	$268,862
2019	Atlantic Cod	*Gadus morhua*	98,439	45	$243,959
2019	White Hake	*Urophycis tenuis*	113,236	51	$150,347
2019	Silver Hake	*Merluccius bilinearis*	193,925	88	$138,032
2019	Haddock	*Melanogrammus aeglefinus*	106,517	48	$132,603
2019	Jonah Crab	*Cancer borealis*	70,818	32	$42,589

Year	Common Name	Scientific Name	Pounds	Metric Tons	Value (US dollars)
2019	Winter Flounder	*Pseudopleuronectes americanus*	14,635	7	$35,856
2019	Yellowtail Flounder	*Limanda ferruginea*	19,415	9	$35,772
2019	Atlantic Halibut	*Hippoglossus hippoglossus*	3,984	2	$27,390
2019	American Plaice	*Hippoglossoides platessoides*	15,224	7	$27,112
2019	Witch Flounder	*Glyptocephalus cynoglossus*	11,402	5	$25,225
2019	Eastern Oyster	*Crassostrea virginica*			$5,422
2019	Winter Skate	*Leucoraja ocellata*	13,284	6	$3,608
2019	Cusk	*Brosme brosme*	2,686	1	$3,199
2019	Acadian Redfish	*Sebastes fasciatus*	2,013	1	$1,500
2019	Butterfish	*Peprilus triacanthus*	Confidential		
2019	Atlantic Rock Crab	*Cancer irroratus*	Confidential		
2019	Green Crab	*Carcinus maenas*	Confidential		
2019	Spider Crabs	Majidae	Confidential		
2019	Fourspot Flounder	*Paralichthys oblongus*	Confidential		
2019	Red Hake	*Urophycis chuss*	Confidential		
2019	Atlantic Herring	*Clupea harengus*	Confidential		
2019	Atlantic Mackerel	*Scomber scombrus*	Confidential		
2019	Spiny Dogfish	*Squalus acanthias*	Confidential		
2019	Barndoor Skate	*Dipturus laevis*	Confidential		
2019	Little Skate	*Leucoraja erinacea*	Confidential		
2019	Skates	Rajidae	Confidential		
2019	Red Snapper	*Lutjanus campechanus*	Confidential		
2019	Longfin Squid	*Loligo pealeii*	Confidential		
2019	Yellowfin Tuna	*Thunnus albacares*	Confidential		
2019	Channeled Whelk	*Busycotypus canaliculatus*	Confidential		

Year	Common Name	Scientific Name	Pounds	Metric Tons	Value (US dollars)
2020	American Lobster	*Homarus americanus*	5,014,143	2,274	$26,550,588
2020	Other	Withheld for confidentiality	5,116,541	2,321	$1,391,480
2020	Bluefin Tuna	*Thunnus thynnus*	124,544	56	$474,814
2020	Haddock	*Melanogrammus aeglefinus*	265,467	120	$292,739
2020	Pollock	*Pollachius virens*	225,656	102	$280,171
2020	Atlantic Cod	*Gadus morhua*	67,340	31	$182,664
2020	Monkfish	*Lophius americanus*	343,515	156	$175,172
2020	Atlantic Sea Scallop	*Placopecten magellanicus*	6,406	3	$72,886
2020	Witch Flounder	*Glyptocephalus cynoglossus*	28,159	13	$47,843
2020	Silver Hake	*Merluccius bilinearis*	72,035	33	$36,147
2020	Atlantic Halibut	*Hippoglossus hippoglossus*	3,662	2	$22,754
2020	Jonah Crab	*Cancer borealis*	31,658	14	$19,949
2020	Winter Flounder	*Pseudopleuronectes americanus*	6,098	3	$10,441
2020	American Plaice	*Hippoglossoides platessoides*	9,516	4	$9,824
2020	Yellowtail Flounder	*Limanda ferruginea*	14,389	7	$9,425
2020	Acadian Redfish	*Sebastes fasciatus*	5,508	2	$3,516
2020	Eastern Oyster	*Crassostrea virginica*			$2,880
2020	Cusk	*Brosme brosme*	2,039	1	$1,535
2020	Alewife	*Alosa pseudoharengus*	Confidential		
2020	Butterfish	*Peprilus triacanthus*	Confidential		
2020	Atlantic Rock Crab	*Cancer irroratus*	Confidential		
2020	Green Crab	*Carcinus maenas*	Confidential		
2020	Spider Crabs	Majidae	Confidential		
2020	Offshore Hake	*Merluccius albidus*	Confidential		

Year	Common Name	Scientific Name	Pounds	Metric Tons	Value (US dollars)
2020	Red Hake	*Urophycis chuss*	Confidential		
2020	White Hake	*Urophycis tenuis*	Confidential		
2020	Atlantic Herring	*Clupea harengus*	Confidential		
2020	Atlantic Mackerel	*Scomber scombrus*	Confidential		
2020	Atlantic Chub Mackerel	*Scomber colias*	Confidential		
2020	Menhadens	Brevoortia	Confidential		
2020	Scup	Stenotomus chrysops	Confidential		
2020	Spiny Dogfish	*Squalus acanthias*	Confidential		
2020	Barndoor Skate	*Dipturus laevis*	Confidential		
2020	Little Skate	*Leucoraja erinacea*	Confidential		
2020	Smooth Skate	*Malacoraja senta*	Confidential		
2020	Winter Skate	*Leucoraja ocellata*	Confidential		
2020	Longfin Squid	*Loligo pealeii*	Confidential		
2020	Shortfin Squid	*Illex illecebrosus*	Confidential		
2020	Yellowfin Tuna	*Thunnus albacares*	Confidential		
2020	Waved Whelk	*Buccinum undatum*	Confidential		
2021	American Lobster	*Homarus americanus*	5,708,942	2,590	$44,164,031
2021	Menhadens	*Brevoortia* spp.	4,807,900	2,181	$1,697,400
2021	Bluefin Tuna	*Thunnus thynnus*	162,492	74	$858,266
2021	Haddock	*Melanogrammus aeglefinus*	370,828	168	$504,803
2021	Other	Withheld for confidentiality	892,215	405	$298,119
2021	Monkfish	*Lophius americanus*	283,217	128	$224,918
2021	White Hake	*Urophycis tenuis*	141,585	64	$211,752
2021	Pollock	*Pollachius virens*	110,514	50	$198,744

Year	Common Name	Scientific Name	Pounds	Metric Tons	Value (US dollars)
2021	Atlantic Sea Scallop	*Placopecten magellanicus*	10,897	5	$184,416
2021	Atlantic Cod	*Gadus morhua*	45,836	21	$124,631
2021	Jonah Crab	*Cancer borealis*	123,729	56	$94,028
2021	Witch Flounder	*Glyptocephalus cynoglossus*	23,503	11	$38,012
2021	Silver Hake	*Merluccius bilinearis*	27,254	12	$20,185
2021	Atlantic Halibut	*Hippoglossus hippoglossus*	1,914	1	$14,266
2021	American Plaice	*Hippoglossoides platessoides*	13,893	6	$13,430
2021	Winter Flounder	*Pseudopleuronectes americanus*	6,002	3	$10,721
2021	Yellowtail Flounder	*Limanda ferruginea*	12,129	6	$8,604
2021	Acadian Redfish	*Sebastes fasciatus*	2,863	1	$1,565
2021	Cusk	*Brosme brosme*	1,628	1	$790
2021	Atlantic Mackerel	*Scomber scombrus*	410	0	$221
2021	Butterfish	*Peprilus triacanthus*	Confidential		
2021	Atlantic Rock Crab	*Cancer irroratus*	Confidential		
2021	Green Crab	*Carcinus maenas*	Confidential		
2021	Deepsea Red Crab	*Chaceon quinquedens*	Confidential		
2021	Spider Crabs	Majidae	Confidential		
2021	Summer Flounder	*Paralichthys dentatus*	Confidential		
2021	Red Hake	*Urophycis chuss*	Confidential		
2021	Hakes (Red and White)	*Urophycis* spp.	Confidential		
2021	Atlantic Herring	*Clupea harengus*	Confidential		
2021	Atlantic Thread Herring	*Opisthonema oglinum*	Confidential		
2021	Longhorn Sculpin	*Myoxocephalus octodecemspinosu*	Confidential		

Year	Common Name	Scientific Name	Pounds	Metric Tons	Value (US dollars)
2021	Scup	*Stenotomus chrysops*	Confidential		
2021	Spiny Dogfish	*Squalus acanthias*	Confidential		
2021	Barndoor Skate	*Dipturus laevis*	Confidential		
2021	Little Skate	*Leucoraja erinacea*	Confidential		
2021	Smooth Skate	*Malacoraja senta*	Confidential		
2021	Winter Skate	*Leucoraja ocellata*	Confidential		
2021	Longfin Squid	*Loligo pealeii*	Confidential		
2021	Swordfish	*Xiphias gladius*	Confidential		
2021	Yellowfin Tuna	*Thunnus albacares*	Confidential		
2021	Channeled Whelk	*Busycotypus canaliculatus*	Confidential		
2021	Knobbed Whelk	*Busycon carica*	Confidential		

Appendix E: New Hampshire Commercial Fishing Activity from 2004 - 2022 by Individual Gear Type.

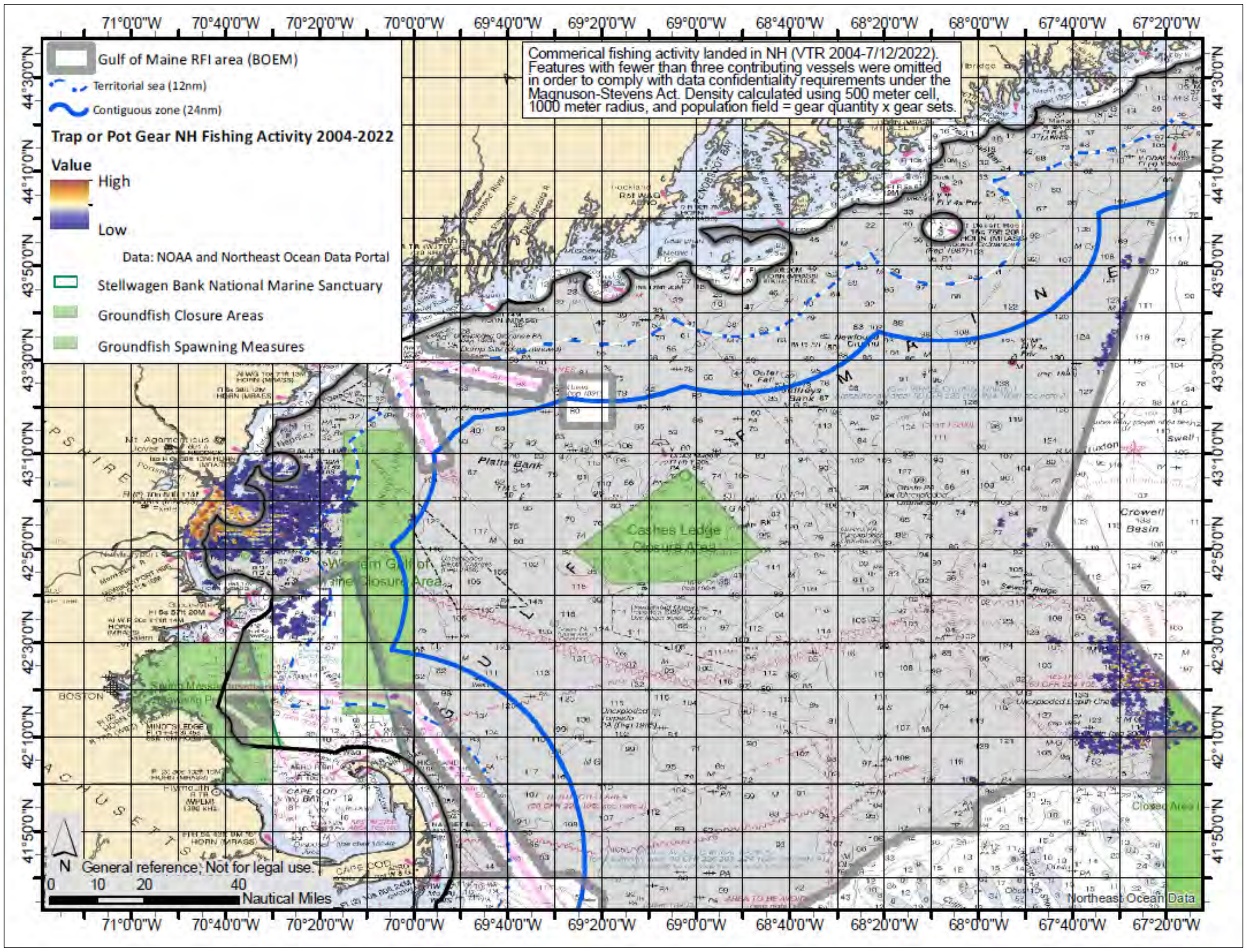

Figure E.1. New Hampshire commercial trap or pot activity from 2004 through 2022 based non-confidential vessel trip reports.

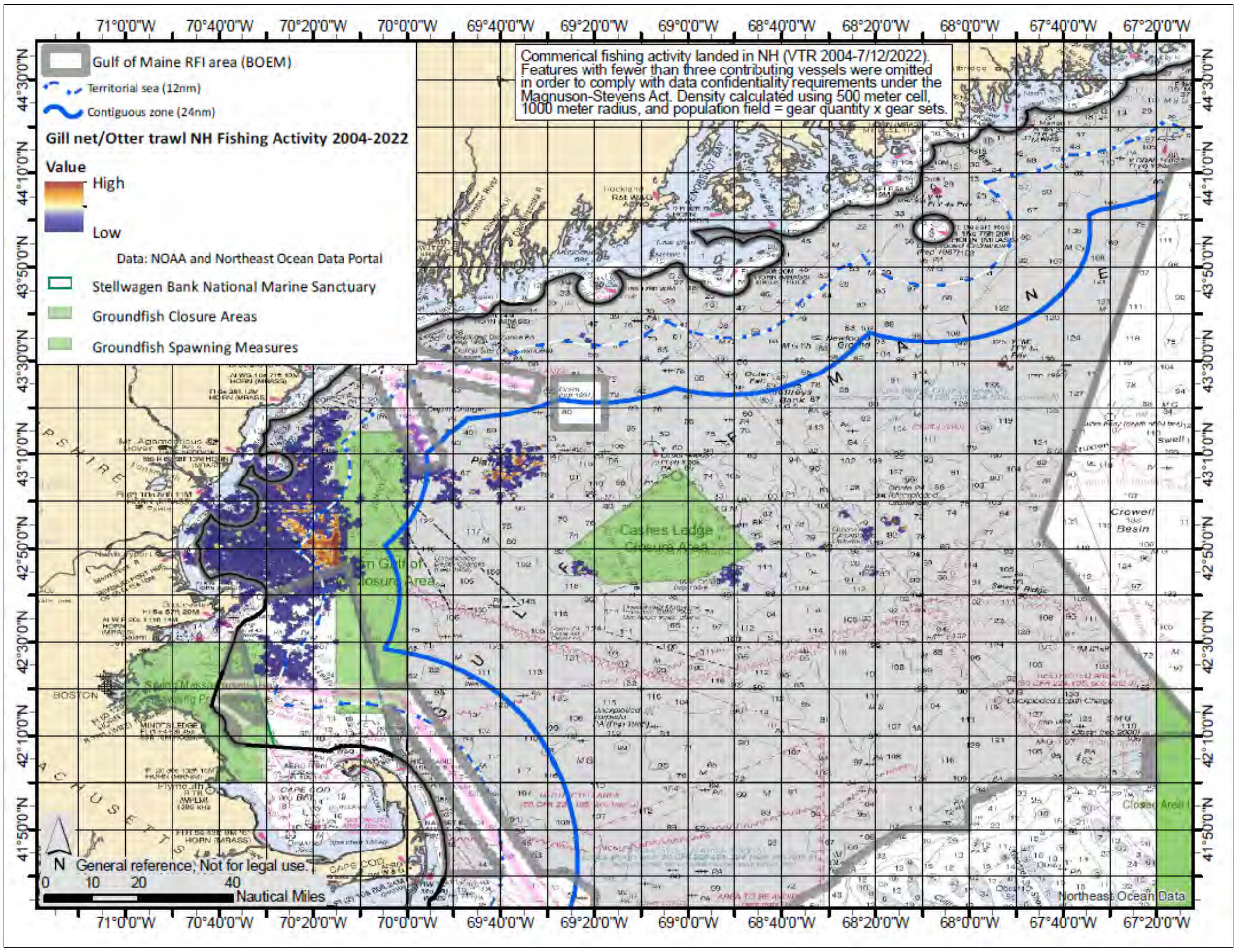

Figure E.2. New Hampshire commercial gill net or otter trawl activity from 2004 through 2022 based non-confidential vessel trip reports.

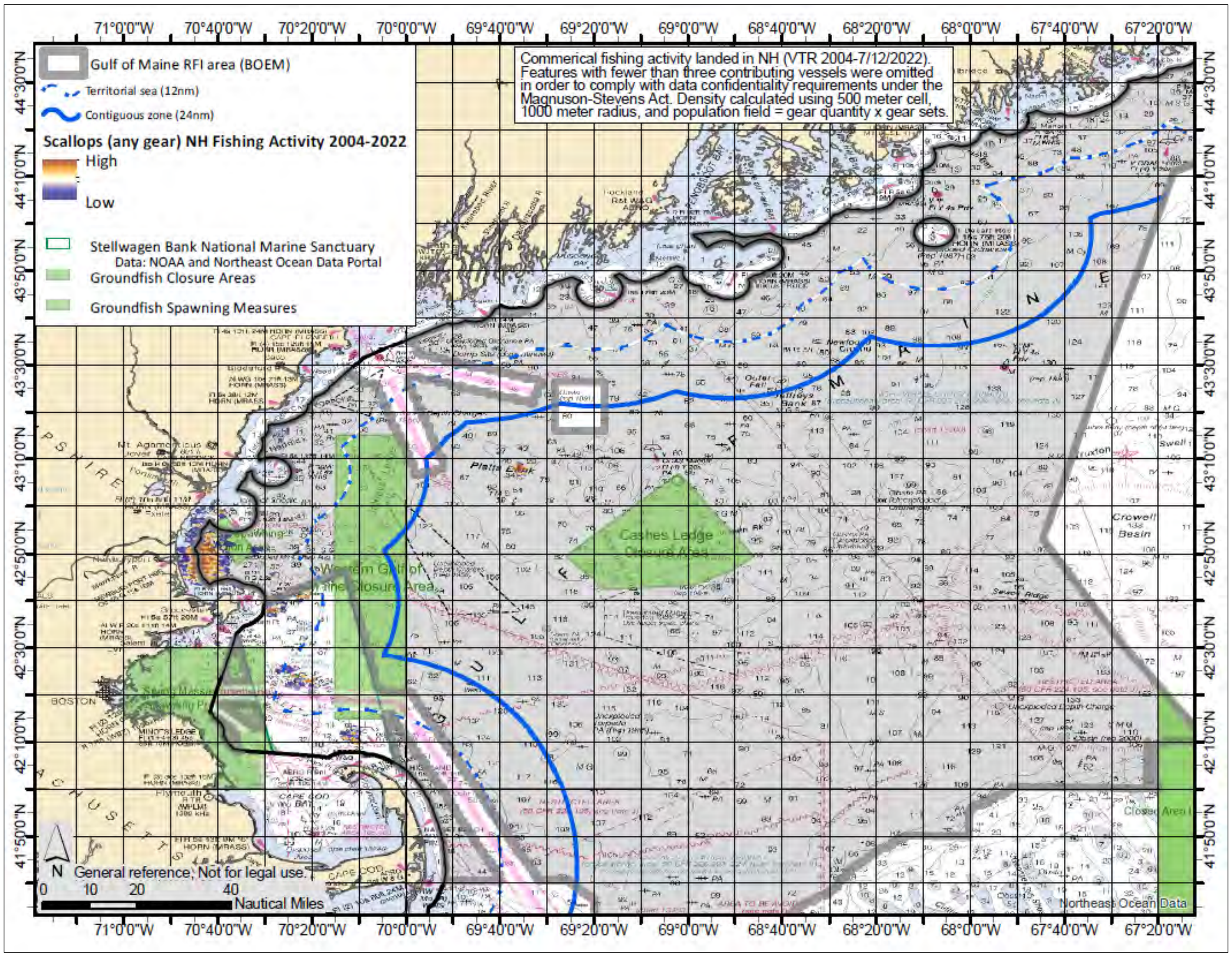

Figure E.3. New Hampshire commercial scallop (any gear) activity from 2004 through 2022 based non-confidential vessel trip reports.

Appendix F: Annual New Hampshire Recreational Landings for All Species from 2015 - 2021 (NOAA NMFS 2023b).

Year	Common Name	Scientific Name	Pounds	Metric Tons
2015	Striped Bass	*Morone saxatilis*	201,906	92
2015	Bluefish	*Pomatomus saltatrix*	88,465	40
2015	Atlantic Bonito	*Sarda sarda*	4	0
2015	Atlantic Cod	*Gadus morhua*	7,086	3
2015	Cunner	*Tautogolabrus adspersus*	2,396	1
2015	Cusk	*Brosme brosme*	60,250	27
2015	Winter Flounder	*Pseudopleuronectes americanus*	20,272	9
2015	Haddock	*Melanogrammus aeglefinus*	426,004	193
2015	Red Hake	*Urophycis chuss*	14,257	6
2015	Silver Hake	*Merluccius bilinearis*	23,686	11
2015	White Hake	*Urophycis tenuis*		
2015	Atlantic Halibut	*Hippoglossus hippoglossus*		
2015	Atlantic Mackerel	*Scomber scombrus*	405,490	184
2015	Pollock	*Pollachius virens*	347,863	158
2015	Acadian Redfish	*Sebastes fasciatus*	41,709	19
2015	Longhorn Sculpin	*Myoxocephalus octodecemspinosus*	282	0
2015	Spiny Dogfish	*Squalus acanthias*	1,799	1
2016	Striped Bass	*Morone saxatilis*	190,943	87
2016	Bluefish	*Pomatomus saltatrix*	22	0
2016	Atlantic Cod	*Gadus morhua*	102,116	46
2016	Codfishes	Gadidae		
2016	Cunner	*Tautogolabrus adspersus*	1,354	1
2016	Cusk	*Brosme brosme*	65,751	30
2016	Winter Flounder	*Pseudopleuronectes americanus*	10,955	5
2016	Haddock	*Melanogrammus aeglefinus*	536,350	243
2016	Red Hake	*Urophycis chuss*	209	0

Year	Common Name	Scientific Name	Pounds	Metric Tons
2016	Silver Hake	*Merluccius bilinearis*	567	0
2016	White Hake	*Urophycis tenuis*	1,488	1
2016	Atlantic Herring	*Clupea harengus*	22	0
2016	Atlantic Mackerel	*Scomber scombrus*	1,201,333	545
2016	White Perch	*Morone americana*	5,800	3
2016	Pollock	*Pollachius virens*	193,304	88
2016	Sea Raven	*Hemitripterus americanus*	723	0
2016	Acadian Redfish	*Sebastes fasciatus*	11,817	5
2016	Longhorn Sculpin	*Myoxocephalus octodecemspinosus*	150	0
2016	Spiny Dogfish	*Squalus acanthias*	776	0
2017	Alewife	*Alosa pseudoharengus*	214	0
2017	Striped Bass	*Morone saxatilis*	394,099	179
2017	Atlantic Cod	*Gadus morhua*	220,820	100
2017	Cunner	*Tautogolabrus adspersus*	15,053	7
2017	Cusk	*Brosme brosme*	87,777	40
2017	Winter Flounder	*Pseudopleuronectes americanus*	14,368	7
2017	Monkfish	*Lophius americanus*	968	0
2017	Haddock	*Melanogrammus aeglefinus*	361,413	164
2017	Red Hake	*Urophycis chuss*	32,847	15
2017	Silver Hake	*Merluccius bilinearis*	129,802	59
2017	Atlantic Herring	*Clupea harengus*	364	0
2017	Blueback Herring	*Alosa aestivalis*	26	0
2017	Herrings	Clupeidae		
2017	River Herrings	Alosinae		
2017	Atlantic Mackerel	*Scomber scombrus*	1,317,596	598
2017	Atlantic Menhaden	*Brevoortia tyrannus*	61,648	28
2017	White Perch	*Morone americana*	32,322	15
2017	Pollock	*Pollachius virens*	581,946	264
2017	Acadian Redfish	*Sebastes fasciatus*	21,290	10

Year	Common Name	Scientific Name	Pounds	Metric Tons
2017	Shorthorn Sculpin	*Myoxocephalus scorpius*	4	0
2017	Scup	*Stenotomus chrysops*	2,156	1
2017	American Shad	*Alosa sapidissima*	597	0
2017	Spiny Dogfish	*Squalus acanthias*	31,145	14
2018	Alewife	*Alosa pseudoharengus*		
2018	Striped Bass	*Morone saxatilis*	129,974	59
2018	Atlantic Bonito	*Sarda sarda*	2,932	1
2018	Butterfish	*Peprilus triacanthus*		
2018	Atlantic Cod	*Gadus morhua*	990	0
2018	Cunner	*Tautogolabrus adspersus*	3,655	2
2018	Cusk	*Brosme brosme*	62,704	28
2018	American Eel	*Anguilla rostrata*		
2018	Winter Flounder	*Pseudopleuronectes americanus*	20,276	9
2018	Haddock	*Melanogrammus aeglefinus*	568,667	258
2018	Red Hake	*Urophycis chuss*	5,853	3
2018	Silver Hake	*Merluccius bilinearis*	12,935	6
2018	White Hake	*Urophycis tenuis*	635	0
2018	Atlantic Herring	*Clupea harengus*	37	0
2018	Mackerel Family	Scombridae		
2018	Atlantic Mackerel	*Scomber scombrus*	568,238	258
2018	Atlantic Chub Mackerel	*Scomber colias*	2,059	1
2018	Atlantic Menhaden	*Brevoortia tyrannus*	114,843	52
2018	White Perch	*Morone americana*	15,959	7
2018	Pollock	*Pollachius virens*	140,743	64
2018	Acadian Redfish	*Sebastes fasciatus*	21,442	10
2018	Spiny Dogfish	*Squalus acanthias*	17,212	8
2018	Bluefin Tuna	*Thunnus thynnus*	972	0
2019	Alewife	*Alosa pseudoharengus*	1,005	0
2019	Striped Bass	*Morone saxatilis*	291,235	132

Year	Common Name	Scientific Name	Pounds	Metric Tons
2019	Atlantic Cod	*Gadus morhua*	24,317	11
2019	Cunner	*Tautogolabrus adspersus*	428	0
2019	Cusk	*Brosme brosme*	40,845	19
2019	Winter Flounder	*Pseudopleuronectes americanus*	7,610	3
2019	Haddock	*Melanogrammus aeglefinus*	418,594	190
2019	Red Hake	*Urophycis chuss*	23,005	10
2019	Silver Hake	*Merluccius bilinearis*	71,990	33
2019	White Hake	*Urophycis tenuis*	805	0
2019	Atlantic Herring	*Clupea harengus*	40	0
2019	Blueback Herring	*Alosa aestivalis*		
2019	Herrings	Clupeidae		
2019	Atlantic Mackerel	*Scomber scombrus*	560,305	254
2019	Atlantic Chub Mackerel	*Scomber colias*	82	0
2019	Atlantic Menhaden	*Brevoortia tyrannus*	142,097	64
2019	Pollock	*Pollachius virens*	172,900	78
2019	Acadian Redfish	*Sebastes fasciatus*	28,722	13
2019	Longhorn Sculpin	*Myoxocephalus octodecemspinosus*	79	0
2019	Searobins	*Prionotus* spp.		
2019	Bluefin Tuna	*Thunnus thynnus*	1,135,889	515
2020	Alewife	*Alosa pseudoharengus*	551	0
2020	Black Sea Bass	*Centropristis striata*	3,389	2
2020	Striped Bass	*Morone saxatilis*	28,689	13
2020	Bluefish	*Pomatomus saltatrix*	1,801	1
2020	Atlantic Bonito	*Sarda sarda*	677	0
2020	Butterfish	*Peprilus triacanthus*		
2020	Atlantic Cod	*Gadus morhua*	21,440	10
2020	Cunner	*Tautogolabrus adspersus*	4,151	2
2020	Cusk	*Brosme brosme*	81,408	37

Year	Common Name	Scientific Name	Pounds	Metric Tons
2020	American Eel	*Anguilla rostrata*		
2020	Winter Flounder	*Pseudopleuronectes americanus*	10,781	5
2020	Haddock	*Melanogrammus aeglefinus*	429,977	195
2020	Red Hake	*Urophycis chuss*	18,869	9
2020	Silver Hake	*Merluccius bilinearis*	34,630	16
2020	White Hake	*Urophycis tenuis*	1,168	1
2020	Hakes (Red and White)	Urophycis		
2020	Atlantic Halibut	*Hippoglossus hippoglossus*		
2020	Atlantic Herring	*Clupea harengus*	104	0
2020	Blueback Herring	*Alosa aestivalis*	35	0
2020	Mackerel Family	Scombridae		
2020	Atlantic Mackerel	*Scomber scombrus*	560,629	254
2020	Atlantic Chub Mackerel	*Scomber colias*	2,826	1
2020	Atlantic Menhaden	*Brevoortia tyrannus*	48,945	22
2020	White Perch	*Morone americana*	2,138	1
2020	Pollock	*Pollachius virens*	173,436	79
2020	Acadian Redfish	*Sebastes fasciatus*	12,101	5
2020	Longhorn Sculpin	*Myoxocephalus octodecemspinosus*	236	0
2020	Spiny Dogfish	*Squalus acanthias*	2,553	1
2020	Porbeagle Shark	*Lamna nasus*		
2020	Bluefin Tuna	*Thunnus thynnus*	43,411	20
2021	Black Sea Bass	*Centropristis striata*	4,101	2
2021	Striped Bass	*Morone saxatilis*	35,880	16
2021	Bluefish	*Pomatomus saltatrix*	3,796	2
2021	Atlantic Bonito	*Sarda sarda*	8,248	4
2021	Atlantic Cod	*Gadus morhua*	46,308	21
2021	Cunner	*Tautogolabrus adspersus*	3,104	1
2021	Cusk	*Brosme brosme*	69,796	32

Year	Common Name	Scientific Name	Pounds	Metric Tons
2021	Flatfishes	Pleuronectiformes		
2021	Winter Flounder	*Pseudopleuronectes americanus*	4,217	2
2021	Haddock	*Melanogrammus aeglefinus*	434,121	197
2021	Red Hake	*Urophycis chuss*	4,691	2
2021	Silver Hake	*Merluccius bilinearis*	29,324	13
2021	White Hake	*Urophycis tenuis*	1,241	1
2021	Hakes (Red and White)	Urophycis		
2021	Atlantic Herring	*Clupea harengus*	7,183	3
2021	Herrings	Clupeidae		
2021	River Herrings	Alosinae		
2021	Atlantic Mackerel	*Scomber scombrus*	324,338	147
2021	Atlantic Menhaden	*Brevoortia tyrannus*	3,743	2
2021	Pollock	*Pollachius virens*	183,941	83
2021	Acadian Redfish	*Sebastes fasciatus*	51,857	24
2021	Longhorn Sculpin	*Myoxocephalus octodecemspinosus*	64	0
2021	Searobins	*Prionotus* spp.		
2021	Spiny Dogfish	*Squalus acanthias*	66,758	30
2021	Bluefin Tuna	*Thunnus thynnus*	5,381	2

Appendix G: Non-listed Marine Mammal Density Maps

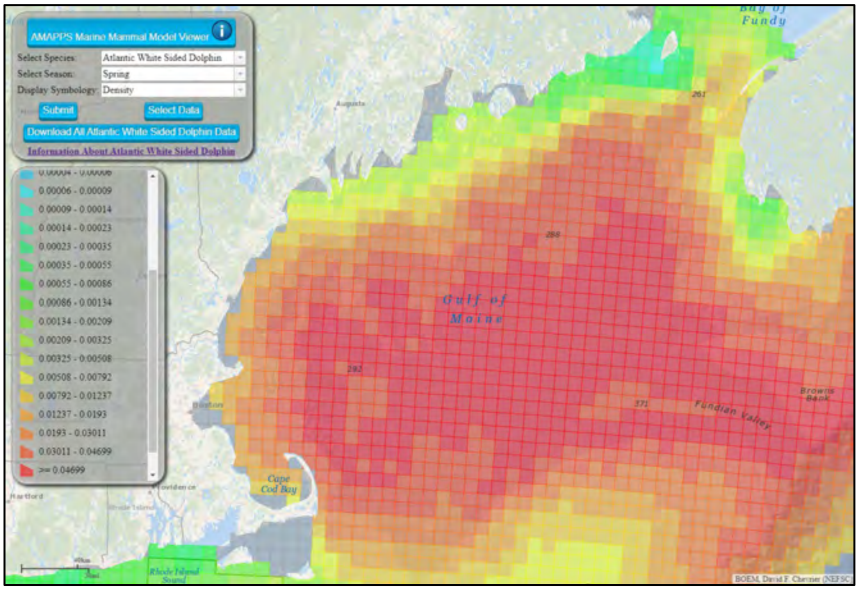

Figure G.1. Atlantic white-sided dolphin average spring density (red colored squares >0.04699 animals per sq km; Palka et al. 2021).

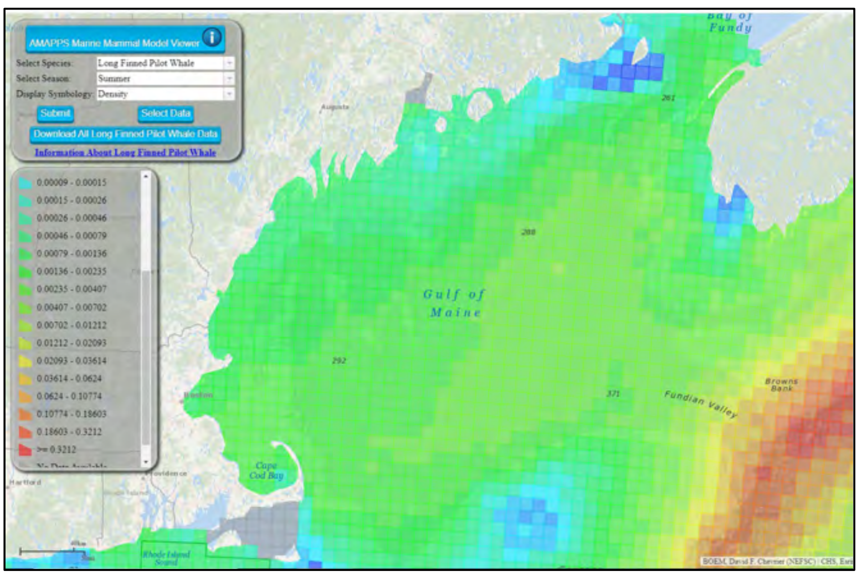

Figure G.2. Long-finned pilot whale average summer density (Palka et al. 2021).

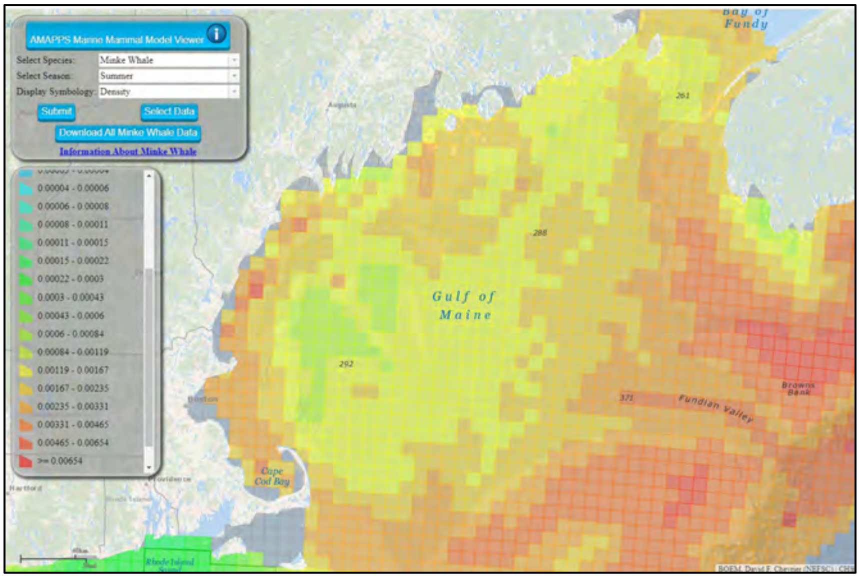

Figure G.3. **Minke whale average summer density (Palka et al. 2021).**

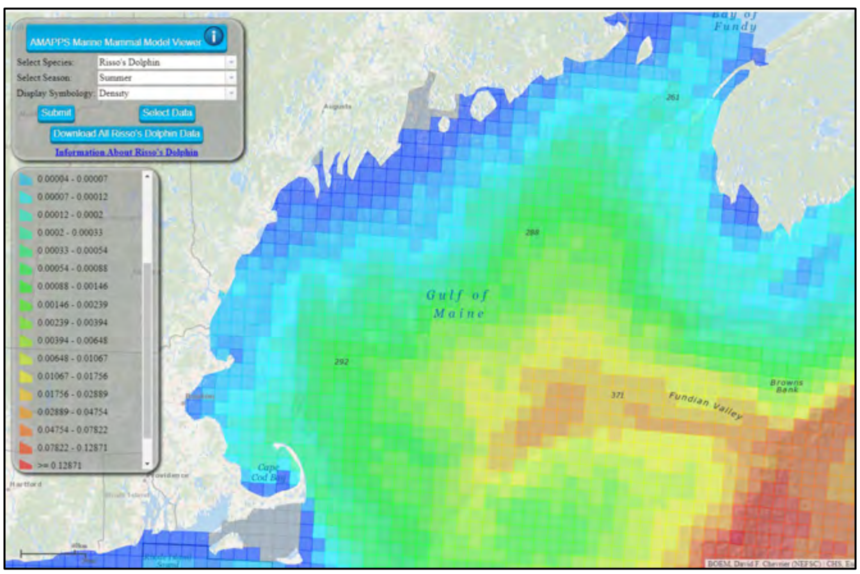

Figure G.4. **Risso's dolphin average summer density (Palka et al. 2021).**