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Marine Mammal Risk Assessment for New England Offshore Windfarm Construction and Operational Scenarios

US Department of the Interior
Bureau of Ocean Energy Management
Headquarters

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DISCLAIMER

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CITATION

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List of Abbreviations and Acronyms

AI	Activity Index
ANNR	ambient noise-noise ratio
BOEM	Bureau of Ocean Energy Management
dB re 1 μPa	decibels relative to 1 micropascal
EI	exposure index
HF	high-frequency
IUCN	International Union for the Conservation of Nature
LF	low-frequency
MF	mid-frequency
PW	pinnipeds in water
PBR	potential biological removal
Rms	root-mean-square
SL	source level
SI	spectral index
SAR	stock assessment report
TL	transmission loss
US	United States
VHF	very high frequency

1 Overview

An expert working group of acousticians and research biologists with backgrounds in interpretation and policy applications of science initially began conceptualizing and developing risk assessment methods for evaluating the effects of underwater noise on marine mammals in 2012. The initial approach was to derive methods for evaluating discrete (“acute”) noise exposure events (e.g., a defined interval and area for a single industrial activity) that applied elements of and were explicitly compared with results from and assessment using the common U.S. regulatory evaluations at the time (Wood et al., 2012). The objective was to develop a common sense, transparent, biologically based, quantitative risk assessment framework that evaluated relative risk in a more holistic and realistic manner than using single received level step function ‘thresholds.’

The analytical framework was substantially enhanced and expanded, with additional expertise and perspectives, within a project jointly supported by several energy companies (British Petroleum and Shell) that were interested in seeing earlier risk assessment concepts developed further within the context of seismic surveys. Aspects of the resulting acute noise risk assessment methodology were presented in scientific fora by Ellison et al. (2015) and Southall et al. (2018). The acute noise risk assessment framework was the basis for further development and improvements within the context of an earlier project jointly supported by the Bureau of Ocean Energy Management (BOEM) and National Oceanic and Atmospheric Administration (Southall et al., 2019). Enhancements to the acute risk assessment framework were made, along with a novel approach for evaluating multiple (“aggregate”) activities on broader time and space scales, specifically multiple seismic survey operations overlapping in time in the Gulf of Mexico for selected marine mammals. Subsequently, BOEM supported the current project, the objectives of which were to expand on the earlier analysis and consider all Gulf species and to adapt and apply the analytical framework to conduct a risk assessment for different noise sources (construction and operation of offshore wind energy facilities) in a different location (off the U.S. east coast). The former objective was achieved and presented previously (Southall et al., 2021). This report considers the subsequent enhancement of the risk assessment methods and their adaptation and application to the realistic installation and operation of two offshore wind farms off the U.S. east coast using multiple scenarios related to patterns of installation, mitigation, and other factors.

The evaluation of noise impacts within the acute risk assessment framework explicitly considered the potential for physical injury (hearing loss) and behavioral responses. This was done deliberately in order to provide some continuity and to provide conclusions that could be evaluated with regard to current U.S. regulatory evaluation methods of considering Level A and B harassment under the U.S. Marine Mammal Protection Act. Modifications made to the initial Ellison et al. (2015) methods for improving the acute framework included relatively minor changes to approaches for evaluating potential hearing loss and more substantive changes to the behavioral response analyses and evaluation of potential vulnerability in terms of a species’ life history, population status, and other known stressors in the area, accounting for a host of contextual factors (see: Ellison et al., 2012; 2018).

Several key modifications were identified to evaluate the potential effects of multiple (aggregate) activities more effectively and realistically, and to account for progress in evaluating the contextual aspects of noise exposure and response characteristics (Ellison et al., 2012; 2018). Ellison et al. (2015) built upon and conceptually integrated general principles and aspects of the acute exposure framework in developing new approaches for application to broader scales (larger than any single activity) and multiple overlapping sources. A fundamentally spatial-temporal-spectral quantitative intersection of potential disturbance and marine species was developed and applied using a non-dimensional risk index through this process and was presented by Southall et al. (2019; 2021). Both the original acute and derived aggregate approaches have, as their core, risk assessment methods using a combination of quantitative and, where needed and appropriate, structured expert-assessment analytical approaches framed within a population level and biologically based perspective. Importantly, both are also inherently dependent on the spatial, temporal, and spectral dynamics of noise-generating activities as they relate to population and biological characteristics of exposed animals. The intent throughout the entire conceptual progression of this process was to provide systematic and increasingly quantitative methods that enable the evaluation of potential aggregate effects over defined, and/or tunable spatial and temporal scales. That is, the risk assessment was designed to be inherently scalable to allow a relativistic risk assessment-based means of assessing potential scenarios of disturbance and distribution that could be tuned to key questions, areas, or degrees of spatial resolution. This scalability was intended to provide means of evaluating relative risk over defined periods and ultimately provide a means of evaluating chronic impacts within the scope of a defined known or hypothetical activity scenario. Given this objective and the fundamental recognition that essentially all potential effects of noise depend critically on the temporal, spatial, and spectral interactions of noise-generating activities and the species in question, we developed objective means by which to consider these key factors using novel risk assessment metrics several of which have expanded substantively from earlier efforts described above, including the draft version of this report.

Several key elements of this relativistic framework that should be noted are the relative ease of implementation and the modular and scalable nature of how it is constructed. Unlike some quantitative impact assessments, this spatial-temporal-spectral model that intersects potential disturbance and protected species distribution does not require complex noise propagation or individual or group tracking assumptions or complex and often difficult to reproduce energetic model assumptions about populations. While those may be useful and are certainly needed in some contexts, this framework provides a standardized, transparent, understandable means of evaluating and deriving means of minimizing risk through testing multiple scenarios. Further, the assumptions underlying calculations to evaluate variable scenarios, as well as the spatial and temporal framework in which they are assessed, are sufficiently modular to be fully adaptable as new scientific findings or different characteristics of potential disturbance, including non-acoustic disturbance, are considered.

The overall risk assessment approach for evaluating a range of potential effects (hearing loss, disturbance, auditory masking) of aggregate anthropogenic activity within longer timescales and larger areas is similar in some regards to the acute risk assessment method for evaluating behavioral responses. The initial approach for behavioral impact analysis for discrete exposures is described briefly below, as it fundamentally formed the basis of the overall risk assessment framework for aggregate noise assessments (see Southall et al., 2019; 2021). The structural framework for the acute exposure risk assessment was based on: (1) a systematic evaluation of species-typical life history, population, and other stressors as the basis for rating the species-specific “vulnerability” and (2) an algorithm based on the relative magnitude and duration of exposure (Southall et al., 2019; 2021). This population-based evaluation yields a relative metric based on the combined disturbance magnitude and total duration to conduct the rating overall risk magnitude. For the acute risk assessment, the relative magnitude and duration of exposure was described as the exposure “severity.”

For the aggregate assessment described in this report, the analogous quantification of the magnitude of exposure is quantified as a relative spatial-temporal-spectral “exposure index” metric with associated levels of relative assessed risk. The derivation and underlying assumptions of this index are described in detail in Section 2. The underlying analytical concepts for the aggregate noise risk assessment process retain the context-dependent aspects of exposure in terms of species-typical biological, behavioral, and population level factors within the vulnerability assessment (with several additional quantitative aspects) while quantifying the relative magnitude of exposure in terms of how animals and potential disturbance intersect in space, time, and frequency spectrum. The objective, relativistic “exposure index” was developed to quantify overall exposure magnitude given the temporal, spatial, and spectral information about defined categories of human activities in aggregate relative to species-specific biological factors (e.g., seasonal distribution patterns, hearing filter types). Notably, the exposure index provides a consistent, objective means of evaluating the relative magnitude of predicted exposure from many exposure events. Unlike the acute risk assessment where specific “takes” are estimated for injury and behavioral disturbance and then put into an analytical framework, in this aggregate risk assessment framework, no effort is made to explicitly distinguish among potential auditory injury (hearing loss) or behavioral or auditory effects (masking) in terms of exposure magnitude. Rather, because the probability of each of these effects are to some degree correlated with one another spatially, temporally, and spectrally, this species-specific exposure index is intended to serve as a relative proxy across species and contexts for all forms of potential disturbance. It’s function therefore is to identify aggregate temporal and spatial conditions under which any potential auditory or behavioral effects are deemed more or less likely based on the relative overlap between the temporal, spatial, and spectral features of the noise fields generated by the aggregate activities and the species-specific attributes of exposed animals. The scalability of the exposure index enables the user to evaluate species of interest for defined intervals (e.g., one month, one year, five years) for defined geographical areas (e.g., 10x10 km cells within defined broader ‘zones’ (as in Southall et al., 2019; 2021), over larger ‘regions’ (e.g., 100s to 10,000s of square km) than generally occurring for discrete activities (Southall et al., 2021). A notable progression of the exposure index from earlier phases of this effort, including the draft version of this report, is the final form of the exposure index metric, which is here quantified as the relative magnitude of exposure and presumed impact as a proportion of the local population within both the defined geographic ‘zone’ (primary focus of the risk assessment) as well as the entire defined ‘region’ (see Section 2).

The species-specific vulnerability assessment remains relatively consistent with earlier efforts and includes a host of species-specific relevant population, life history, perceptual, and other stressors assessments using structured and increasingly quantitative metrics (see Section 3). A notable development for the wind farm scenarios considered off the U.S. East coast in this report is the quantification of scores in some of the factors related to distribution, masking, reproduction, and migration patterns that have strong seasonal patterns for many of the species considered. While there is relatively little seasonality and thus temporal variance in some of these parameters for the Gulf of Mexico species considered for seismic survey operations (Southall et al., 2019; 2021), for these scenarios there are often strong seasonal patterns. Thus, many of the vulnerability scores differ, sometimes strongly, from month to month across the year, reflecting the divergent potential susceptibility to disturbance based on their natural history and other factors. Seasonal patterns in distribution can have strong influences on both the exposure index and vulnerability ratings and ultimately drive the relative risk assessed and thus the logical assessments about how they could and should be interpreted in terms of potential impacts for the wind farm installation and operational scenarios evaluated here.

The final stage of this structured, transparent, relativistic, risk assessment is to integrate the exposure index and vulnerability ratings within specified scenarios (crossing the index and vulnerability scores described in sections 2 and 3 below) using a tailored 5x5 matrix with resultant risk evaluated on a five-step relative scale from lowest (blue) to highest (red) (Fig. 1). This matrix, which is slightly skewed to weight the exposure index score slightly more than the vulnerability score, yields a species-specific assessment of relative risk across species considered within defined scenarios of defined industrial operational conditions (defined below).

Exposure Index					
5	M	H	H	H +	H +
4	M	M	H	H	H +
3	L	M	M	H	H
2	L -	L	L	M	M
1	L -	L -	L	L	M
Rating	1	2	3	4	5
	Vulnerability				

Key	Color	Risk Assessment Rating
	Red	Highest (H+)
	Orange	Higher (H)
	Yellow	Moderate (M)
	Green	Lower (L)
	Blue	Lowest (L-)

Figure 1. Integrated risk assessment rating matrix applied in integrating species and scenario-specific exposure index and vulnerability rating scores.

Offshore Wind Farm Installation and Operational Scenarios

Our team worked closely together with BOEM representatives during and following the post award meeting to converge on an agreed approach for specific aspects and objectives of this novel analysis as applied to a region of interest on the U.S. East Coast. The aggregate risk assessment framework developed and applied to the Gulf of Mexico seismic scenario (Southall et al., 2021) was adapted (in some regards substantially) for the east coast theater and strategically selected focal species here. Assessed risk levels are determined for each focal species within specified operational ‘zones’ (as defined below), using the approach described briefly above, and in more detail below, regarding exposure index (see Section 2) and vulnerability (see Section 3).

It is recognized that there are fundamental noise-source-specific and operational differences in the installation and operational scenarios considered here for stationary offshore wind facilities and highly mobile seismic surveys in the Gulf of Mexico (Southall et al., 2021). There are also many contextual differences, including different species and species groups (e.g., pinnipeds) than previously considered, strong migration periods and routes for key species, extremely different aspects of sound sources (e.g., stationary vs. mobile, different spectra and source levels), fundamental differences in sound sources and operational phases, different biotic and abiotic aspects of soundscapes, among others. These differences necessitated many discussions about assumptions, how to handle data limitations, and how best to prioritize the analysis within the context of the available resources for this analysis. Some of these key differences necessitated both evolutions of and substantial ‘tuning’ of the previous approaches to a new context. Some of these lessons in adapting the approach to a new context provide insight into the relative generalizability to applying the assessment framework in other context and the relevance and caveats required in comparing results in an absolute sense across different context with different species. These lessons and perspectives regarding subsequent applications of the framework are being addressed in a publication on the derivation and overall construct of the framework in a paper that will be submitted for peer-reviewed publication as a product of this contract.

Through collaborative discussions with our team and BOEM to share information and concur on the most important aspects that could realistically be assessed with the time and resources available for this initial study, we developed a common understanding for the areas, species, and installation and operational scenarios to be investigated. Details regarding species and scenarios selected to investigate are provided below.

Focal marine mammal species

A full application of the risk assessment would include all known or possible species within the entire region. However, each species considered often requires the integration of multiple data sources to estimate density for all defined spatial grid cells across the entire east coast region, as well as species-specific calculations of exposure index and vulnerability scores in a variety of contexts. Within the scope of the current effort, we strategically selected focal species using several criteria. This included the consideration of the relative population size/conservation status of the species, the respective hearing group in terms of auditory noise exposure criteria[1], and other factors such as local habitat utilization (e.g., resident, migrating). Overall, it was clear

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[1] See: Southall, B. L., Finneran, J. J., Reichmuth, C., Nachtigall, P. E., Ketten, D. R., Bowles, A. E., Ellison, W. T., Nowacek, D. P., and Tyack, P. L. (2019). Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects. *Aquatic Mammals 45*, 125-232. doi: 10.1578/AM.45.2.2019.125

(and specified in the proposal and contract) that North Atlantic right whales (*Eubalaena glacialis*) would be considered, as well as selected other species.

Other species were selected in consideration of population, habitat usage, and hearing group factors (as defined in Southall et al., 2007; this group nomenclature is retained here as M-weighting is applied in the spectral index – see below) and with the goal of comparatively considering different kinds representative' species from different taxa. Those identified as focal species to be considered are:

1. North Atlantic right whale (ESA- and MMPA-listed, baleen whale, LF hearing group)
2. Humpback whale (*Megaptera novaeangliae*; MMPA-listed, relatively common, baleen whale, LF group)
3. Common dolphin (*Delphinus sp*.; MMPA-listed, odontocete, very common, MF group)
4. Harbor porpoise (*Phocoena phocoena*; MMPA-listed, odontocete, less common pelagically, HF group, particularly sensitive species)
5. Gray seal (*Halichoerus grypus*; MMPA-listed, phocid pinniped, increasingly common but less so pelagically, PW group)

Offshore Wind Farm Specifications

Following extensive discussions about what would be both important considerations/contrasts while remaining feasible within the scope of the current project, it was decided to evaluate risk associated with the installation and operation of two different wind farms within non-overlapping Southern New England Offshore Lease Areas relatively. The intention was to consider two developments that were within the larger and smaller ends of current realistic proposed scenarios. The intention is also to select wind farm areas that are similar, but not identical to any specific current lease and planned installation areas and to position the two different wind farms sufficiently close to one another that they might have interacting effects (which will be evaluated), while not being immediately adjacent to one another.

Wind farm #1[2]

- 25x25 sq km (~150k acres) with central location at 40 deg 47' N, 70 deg 32'W
- 180 monopiles (10 m diameter); 120 installed in installation year 1 and 60 installed in installation year 2 (see below)

[2] *note*: this represents a scenario slightly smaller than the largest existing/proposed offshore facilities currently being considered on the east coast

Wind farm #2[3]

- 10x20 sq km (~50k acres) with central location at 41 deg 9' N, 71 deg 7'W
- 60 monopiles (10 m diameter) all of which would be installed in year 2 (see below)

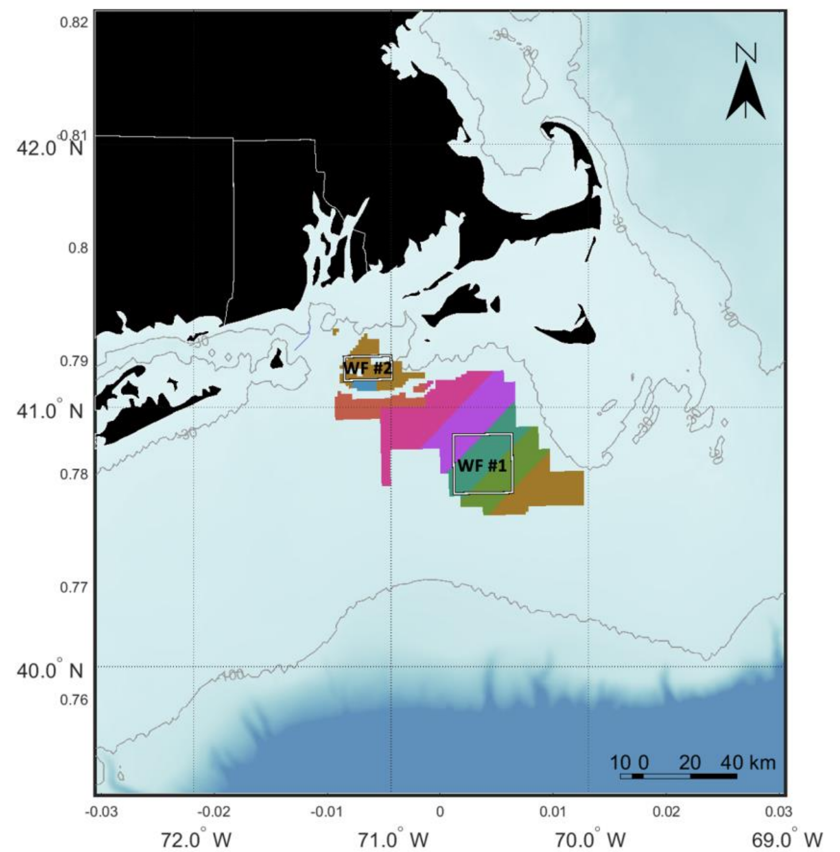

Figure 2. Southern New England offshore lease areas
Offshore leased areas shown in colored polygons, with two rectangles (white boxes) representing the corresponding locations for the Windfarm #1 (top left) and Windfarm #2 areas (bottom right).

Spatial Resolution and Regional "Zones"

For the G&G operations in the Gulf of Mexico (Southall et al., 2021), there were nine specified 'zones' which had both artificial (state boundaries) and biologically based (e.g., relation to shelf break) delineations. The east coast is segregated into different 'planning areas' for offshore

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[3] *note*: this represents a scenario slightly larger than the smallest existing/proposed offshore facilities currently being considered on the east coast

wind leases; scenarios here occurred in the northeast planning area. However, this region was not explicitly spatially segregated ahead of this assessment as was the case in the Gulf of Mexico.

The calculation of exposure index and multiple aspects of the vulnerability rating require a sub-division of this planning area for a more realistic and finer scale assessment. For elements of both the exposure index and vulnerability ratings, calculations require the distinctions of discrete spatial 'zones' within a larger 'region.' Given that these zones were not distinguished a priori for the defined east coast region, we derived a means of doing so prior to conducting the risk assessment.

A relatively recent ecosystem assessment of discretized northeast US coastal and offshore areas has been conducted that provides some guidance. The Northwest Atlantic Marine Ecoregional Assessment[4] was led by Dr. Peter Auster (University of Connecticut), Dr. Les Kaufman (Boston University) and Dr. Heather Leslie (Brown University). This assessment considered a variety of oceanographic, biological productivity, ecological, and spatial distribution and density data for a range of species to delineate three different ecosystem areas. We apply these (approximately north-south) delineations to identify three broad sub-regions spanning the large east coast region defined here as extending from Cape Hatteras, NC to the US-Canada border at the extent of Maine (effectively mid-Atlantic, NY Bight/southern NE, and Gulf of Maine).

We distinguish "coastal" depths (defined as <100 m water depth as a demarcation of the Atlantic shelf-break) to identify multiple "on-shelf" zones and "pelagic" depths (defined as 100-2500 m water depths) to identify multiple an "off-shelf" zones. This results in relatively discrete coastal and pelagic zones for the mid-Atlantic and NY Bight/southern New England areas. For the northernmost sub-region, in which some <100 m water depths occur much further from the coast than in the two southern sub-regions, coastal (nearshore MA north of Cape Cod, NH, ME) and pelagic zones are delineated, while the shallow <100 m area of George's Bank is considered a discrete zone.

This results in a bounded distinction of the entire defined region (again, coastal and pelagic waters from NC to ME) into seven (7) discrete zones shown in the overview map below (Fig. 3)

4 https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/edc/reportsdata/marine/namera/namera/Pages/default.aspx

with the offshore wind lease areas for the entire east coast.[5] It should be noted that the scenarios identified here and shown above (Fig. 2) appear in what is identified as Zone 2.

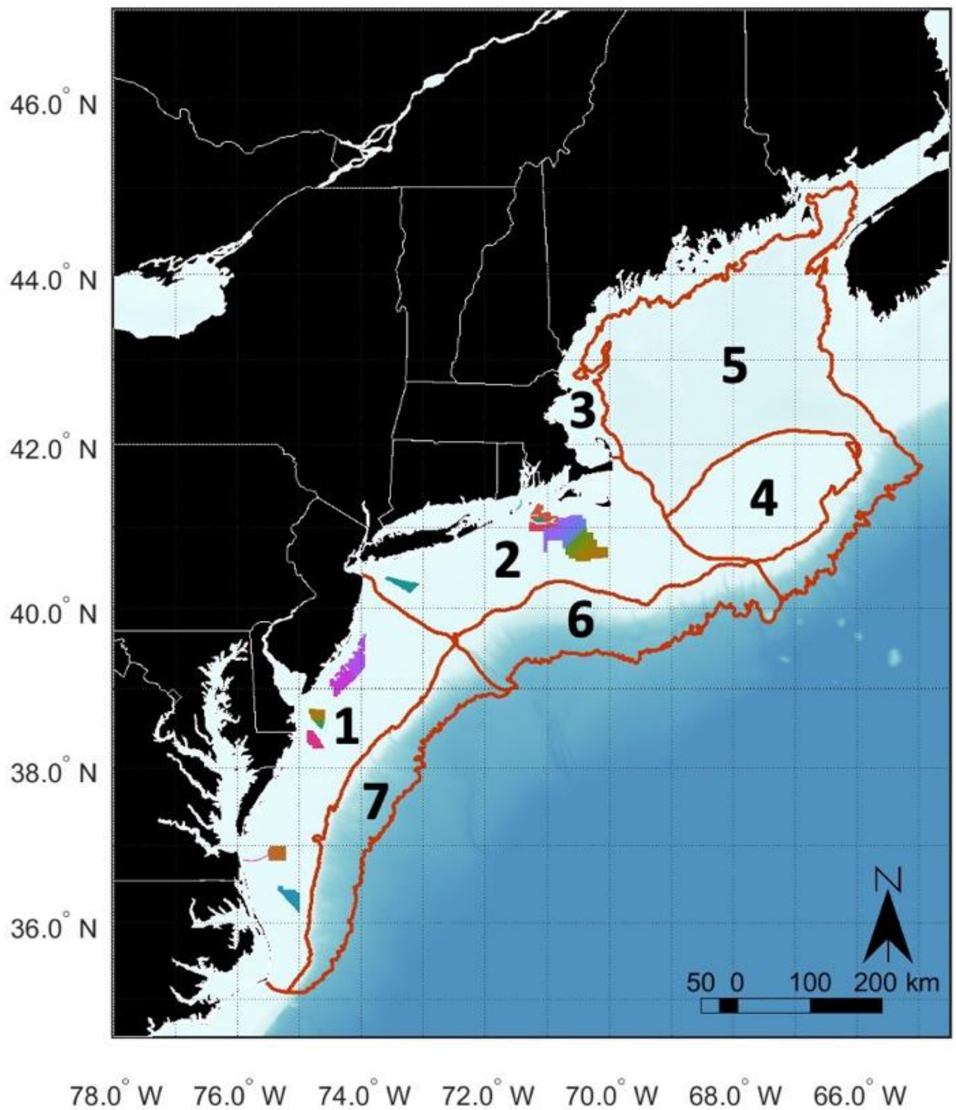

Figure 3. Seven (7) defined geographical "zones" within a broad "region" of the U.S. east coast extending from North Carolina to Maine.

[5] Note: polygon .kml, .mat, and .png files of maps derived from the EBM report and lease sales provided by BOEM are archived at: https://drive.google.com/drive/folders/1UkI8Q_PY9dpXXGpQmzmyX4mtKFA19KVT. These are generated using NOAA's ETOPO1 for the bathymetry (https://www.ngdc.noaa.gov/mgg/global/) and Natural Earth for the land/country borders (https://www.naturalearthdata.com/). Wind farm lease areas and coastline in the final polygons were obtained from https://www.boem.gov/renewable-energy/mapping-and-data/renewable-energy-gis-data.

Analysis Scenarios

We conducted full aggregate risk assessment for each of the five focal species on a monthly basis over a three-year (36 months) period using a variety of defined windfarm installation and operational scenarios. These scenarios were not intended to directly represent any specific ongoing or planned industrial operation. Rather, they were constructed in direct collaboration with BOEM with cognizance of and an intent to realistically represent nominal activities given the current state of play with the industry off the U.S. east coast. These scenarios include installation of multiple large piles at either one or both sites in the first two years, and the presumed operation of both sites with associated operational and service vessel noise in a third year. Details of each operation are given below.

Year #1 - Farm #1: installation only.

This scenario includes species-specific risk assessment for the installation phases of solely the “large” farm during construction with evaluating the noise associated with pile driving for turbine foundations. As noted, 120 of the presumed 180 total piles were assumed to be driven in year 1 with the remaining 60 in year 2 (below) in several different timing scenarios.

For comparative purposes to demonstrate the scenario-testing power of the risk assessment framework, we conducted separate complete risk assessments for all species in three distinct scenarios in which piling could begin at one of three presumed possible start dates (1 March, 1 May, or 1 July). Within each of these three discrete start dates, we further evaluated two different temporal scenarios that influence how long piling will occur. The first assumes daytime-only piling, meaning that one monopile will be driven per day, and driving the 120 specified monopiles will take approximately four months. The second assumes both daytime and nighttime piling could occur, enabling two monopiles to be driven per day and the 120 specified monopiles would be driven and installation completed in two months. Finally, we presume in this scenario a nominal ‘unmitigated’ disturbance range for exposure index calculations of either 10 km (most focal species) or 20 km (harbor porpoise), as well as a ‘mitigated’ disturbance range presuming noise dampening mitigation measures of either 5 km (most focal species) or 15 km (harbor porpoise). These are described in terms of their derivation and application in greater detail in Section 2 below.

Vulnerability assessments were conducted for all months of the year, whereas exposure index values are calculated for months in which installation would occur for the (12) resultant scenarios described above. This results in a species-specific, comparative assessment of resulting two or four-month installation periods at different intervals without necessarily considering operational or regulatory practicality or cost of installation (a separate, but important consideration). The intent of this assessment of risk for a single wind farm for construction possible during most of the year (March-November) is to provide a normalized, species-specific comparative evaluation of a range of scenarios related to timing and seasonally derived mitigation measures (e.g. seasonal exclusion periods), presumptions about disturbance ranges and associated mitigation measures, and the relative impact on risk assessed of condensing activity through measures such as nighttime operations.

Year #2 - Farm #1 and Farm #2: installation only.

The objective in the second year is to compare the relative interacting and/or cumulative effects if multiple installation activities were to occur within the same region either sequentially or partially or fully overlapping one another. For this scenario, we presume one pile/day would be driven at each location (i.e., no nighttime piling), and that the unmitigated (worst-case) disturbance scenario occurred. This was done to reduce the degrees of freedom in contrasting patterns of temporal overlap between installation at each site, presuming that the roles of condensing operations and quieting mitigation could be evaluated from the year 1 scenario.

Based on both the results from the year 1 scenario and assumptions about regulatory and operational conditions for installation of foundations supporting offshore wind turbines off the east coast, we focused the year 2 scenarios around the late summer to early fall months. The assumption was that 60 monopiles would be driven at each of the two wind farms, within three discrete temporal scenarios considered:

1. Sequential Installation: windfarm #1 during July and August and windfarm #2 during September and October.
2. Partial overlap of installation at both sites – windfarm #1 during July, both during August, and windfarm #2 only during September
3. Total overlap of installation activity at both sites – Both windfarms during August and September

Year #3 - Farm #1 and Farm #2: operation only.

For this scenario, the assumption was that both windfarms were in simultaneous and continuous operation. The primary noise footprint for operations was assumed to be vessel noise and to a lesser extent operational noise from active turbines. While the servicing patterns associated with large scale windfarm operations off the U.S. east coast are not well known since none are yet in operation, simplifying assumptions based on available information about servicing scope and patterns were made based on information about type, number, and speed of activities provided by BOEM. These patterns as well as the noise spectra of all signal types used in modeling calculations are described in section 2 below.

2 Aggregate Risk Assessment: Evaluating Species-Specific Exposure Magnitude ("Exposure Index")

We developed a robust and modular method for seismic surveys in the Gulf of Mexico (Southall et al., 2021) that is adapted and applied here to calculate a spatially and temporally explicit "exposure index" related to the potential magnitude of disturbance from offshore wind farm installation and operation in defined zones off the U.S. east coast. This metric quantifies the magnitude of activity in each zone and is based on the location, date, and duration of operations within the scenarios defined above and how it relates to the abundance and distribution of focal marine mammal species. The exposure index is a relativistic metric that quantifies potential acoustic exposure and risk to the species based on their spatial and temporal distribution. It is critical to note that the implementation of the risk assessment provides a relative assessment within the context of the scenarios and species evaluated rather than an absolute presumed level of impact readily extrapolated across scenarios. It is intended to provide a means of quantitatively determining spatial-temporal-spectral intersection of activities and animals within the contexts and scenarios considered for use in relative assessment, evaluation and scenario testing (forecasting). It is not presumed nor intended to provide an alternative or replicate assessments of population level calculations of consequences of disturbance. Rather, the goal is to provide a straightforward, common-sense means of systematically and quantitatively determining spatial, temporal, and spectral intersection of animals and disturbance as one of two means of determining relative risk in prescribed scenarios of operation.

The overall objective here is to adapt and improve earlier methods to assess the sounds generated during offshore wind farm construction and operation and potential acoustic risk to marine mammals on a monthly basis within a geographical area of interest (specifically Zone 2 in Fig. 3). The exposure index is designed to explicitly assess activities associated with construction phases (impact pile driving sounds) and operational phases (turbine operation and vessel traffic). It has the following key characteristics:

- Consideration of the spatial, temporal, and spectral components of sounds generated during the installation during construction (impact pile driving) and operational phase (turbine operation and vessel traffic) activities in relation to the marine mammals present in the area.
- Spatial resolution for calculation is on 10 x 10 km grid cells for all species other than North Atlantic right whales, for which 5 x 5 km grid cells are used given the higher resolution density information provided in Roberts et al. (2020).
- The method is comprised of an *activity index*, a *spectral index*, and a resulting *exposure index*. These indices are a measure of the temporal and spatial extent of the sound generated during an activity and the potential impact to marine mammals while

considering their hearing abilities and abundance (see further definitions and calculations below).

- The exposure index is calculated for individual wind farms and summed to determine the aggregate risk in a certain area.

- Exposure index values for this assessment are calculated at a monthly resolution; as noted this is a modular parameter.

- Final exposure index calculations for each scenario for use in the aggregate risk assessment matrix (Fig. 1) are presented and rated in a relativistic sense in terms of the percentage of the total population predicted to be affected within the geographic zone (of seven for the scenario here – see Fig. 3 above) of operations. The percentage of the total regional population (i.e., within all seven zones) affected is also calculated for reference.

The design of the method requires specific information about activities that will be conducted. We evaluate the scenarios identified above using the methods and assumptions regarding source characteristics described here.

2.1. Activity Index

This component quantifies the spatial and temporal extent of wind farm activity into a single metric. The activity index (AI) is calculated by using species-specific limits that are associated with the presumed onset of behavioral responses to sound at specified geographic ranges. The AI is calculated for each month during which installations and/or operations are assumed to occur at either wind farm. The AI term has two discrete terms, spatial and temporal activity.

$$AI = AI_{spatial} * AI_{temporal}$$

2.1.1. Spatial Activity Index

This component represents the acoustic footprint that contains received levels that are thought to elicit a behavioral response in marine mammals during each month from the wind farm activity. It is calculated for each wind farm individually for each month. Different means of determining the spatial activity term were developed for the different contexts of turbine installation and operation and vessel operations, but in both cases the units of $AI_{spatial}$ are square km.

Turbines: The spatial area potentially impacted is acoustically based for turbine construction and operation based on the species-specific received sound level deemed 50% likely to elicit a behavioral response. These areas differ based on the species being considered since some species react to lower received levels (see Southall et al., 2021).

- Harbor Porpoise = area that encompasses received levels (RL) exceeding 120 dB re 1µPa RMS (hereafter referred to as dB)
- All other species = area that encompasses RLs exceeding 160 dB

Values are calculated for each wind farm individually for each month by:

$$AI_{spatial} = \pi r^2 * N_t$$

where r = range (in km) to received level isopleth, which is determined separately for impact pile driving and operational conditions:

- Ranges for impact pile driving of an 8 m monopile were determined as conservative estimates based on measurements made during the installation of a 7.8 m monopile at the Coastal Virginia Offshore Wind Farm (Ørsted, 2020). Measurements were made at various ranges during the pile driving activities and the measured received levels were compared to current acoustic thresholds. The measured range to a 160 dB received level was 3.9 km with a bubble curtain and 7.7 km without a bubble curtain. As a precautionary approach given the uncertainty in terms of response ranges in realistic scenarios for any species, these ranges were rounded up to assume 5 km and 10 km for the mitigated and unmitigated case for most marine mammal species; harbor porpoises ranges were estimated as 15 km and 20 km for mitigated and unmitigated scenarios.
    - Harbor porpoise (120 dB RL)
        - 15 km for mitigated case
        - 20 km for unmitigated case
    - All other species (160 dB RL)
        - 5 km for mitigated case
        - 10 km for unmitigated case
- The average range used for turbine operation was 100 m, which is the estimated distance to a received level of 120 dB based on measurements presented in Tougaard et al. (2020). The radiated noise level of an operating turbine, while it may vary over time given different wind speeds and other factors is clearly much lower than that during impact pile driving and the levels at closer range did not exceed 160 dB. Therefore, due to these reduced radiated noise levels expected, the range to 120 dB was used for all species.

and where N_t = daily turbine activity defined for installation and operation as follows:

- Installation: 1 or 2 turbines a day (depending on scenario)
- Operation: number of turbines operating each day, which is typically the total number of turbines in each windfarm each month.

Acoustic impact area assumption: When 2 turbines a day are installed, the $\mathrm{AI}_{\mathrm{spatial}}$ calculation conservatively assumes no overlap in the acoustic impact area on that day (i.e. the maximum area of impact). An alternative 'minimum area of impact' scenario was explored whereby the two turbine installation areas are overlapped, separated by a distance of 1 nautical mile (the current understanding of likely turbine separation). A ratio of maximum to minimum area of impact was calculated for the specified disturbance impact radii of 5, 10, 15 and 20 km to illustrate the scale of differences across these two assumptions. This sensitivity assessment was included to identify the potential advantage of installing 2 turbines a day rather than 1, due to the reduction in assumed impact area. Any reduction in $\mathrm{AI}_{\mathrm{spatial}}$ will have a corresponding reduction in the final exposure index. The premise of this sensitivity exercise is to explore consequences of how animals respond to noise on short timescales of a few hours.

Vessels: The spatial index term in this context represents the area around a vessel within which a behavioral response from marine mammals is presumed to be elicited (at identical RLs as specified above; specified as 120 dB for harbor porpoise and 160 dB for other species). This area is contextual for vessel operations (i.e. the presence of the vessels within a certain range from the animals will elicit a behavioral response as opposed to the sound level). It is calculated for the vessel activity within each wind farm individually for each month using the following equation

$$AI_{spatial} = 2r * S_v * T_v$$

where: r is the max range (in km) to estimated behavioral response; Sv is the average speed of a vessel within the wind farm area (km/hr); and Tv is the average length of time of a vessel trip in hours.

Estimates of vessel activity provided by BOEM indicate that crew transfer type vessels will be the most prevalent vessels in the wind farm area during the operational phase. The average duration (Tv) of each vessel trip was estimated to be 4 hours, and the average speed (Sv) of the crew transfer vessels was estimated to be 31 km/hr. The range to an estimated behavioral response (r) was taken as 0.5 km, which is supported by observations described in Holt et al (2021) demonstrating whales adjusting their behavior when vessels were closer to them.

2.1.2. Temporal Activity Index

The temporal activity index captures the percentage of days within a month that activity will occur. It is calculated for each windfarm individually for each month in which installation or operation occurs. Similar equations are used for turbine and vessel activity

- Turbine installation and operation

$$AI_{temporal} = \frac{N_{td}}{N_d}$$

- Vessel operations

$$AI_{temporal} = \frac{N_v}{N_d}$$

where N_{td} = the total number of turbines days in a month and for:

- Construction: N_{td}= N_{tm}/N_t
  - N_{tm} = number of turbines being installed in the month
- Operation: number of days in the month when turbines are operational

N_v = the total number of vessel trips operating in an individual windfarm in a month; and

N_d = the total number of days in a month

2.2. Exposure Index Calculation

The exposure index is calculated by combining the activity index with an integrated metric of the buffered wind farm area abundance and hearing capabilities of marine mammals of interest, defined as the *Spectral Index.*

2.2.1. Spectral Index

This index:

- Takes into consideration the species distribution within the windfarm area and the functional hearing range of different species groups.
- Quantifies the spectral difference between the LF, MF, HF and PW functional hearing groups (from Southall et al. (2007) using M-weighting (and functional groups designated here) as a deliberately wider frequency range than the subsequent Southall et al. (2019) criteria given the context here being more focused on behavioral response) and combines this with the marine mammal abundance distribution to yield the spectral abundance index

- Is calculated for each wind farm using the total abundance of animals within a buffered individual wind farm footprint ($N_{animals\ buffered\ WF}$), according to the following specifications and assumptions:

    - *Turbine construction and operation*: Windfarm area is buffered by the range to the received level threshold of interest for individual species

    - *Vessel operation*: Windfarm area is buffered by the range that encompasses contextual behavioral reactions from animals

- Is calculated for each individual species using the representative species abundance

- Determines abundance by month based on source data provided in Roberts et al. (2020)

- Applies the following equation to calculate the spectral index (SI):

$$SI = \frac{E_{weighted\ spectrum}}{E_{unweighted\ spectrum}} * \ N_{animals\ buffered\ WF}$$

where E = the amount of acoustic energy in the unweighted spectrum or in a spectrum weighted by the M-weighting functions.

A representative source spectrum is used to assess the impact pile driving (Fig. 4), operating turbine (Fig. 5), and vessel operations (Fig. 6). The representative spectrums were identified as:

- For impact pile driving, a spectrum measured during the installation of an 8 m monopile at a distance of approximately 3 km was used (HDR, 2020).

- For an operating turbine, a spectrum measured from an operating monopile at a distance of approximately 83 m during wind speeds of 14 m/s was used (Ingemansson Technology AB, 2003).

For vessel operations, a spectrum measured at a distance of 100 m from a vessel traveling at 30 km/hr was used. Vessels in the windfarm area are estimated to travel at 30 km/hr (17 kts). The ratio of total acoustic energy available to the hearing groups for the different source types is the ratio of the integrated M-weighted (LF, MF, HF, PW) and unweighted spectra. The ratio for each of the source types according to the representative spectra are provided in Table 1.

Table 1. Spectral index values for marine mammal hearing groups for impact pile driving, operational turbines, and vessel operations

Marine Mammal Hearing Group	Impact Pile Driving	Operating Turbine	Vessel Operations
LF	0.99	0.95	0.99
MF	0.18	0.33	0.14
HF	0.11	0.19	0.08
PW	0.46	0.68	0.41

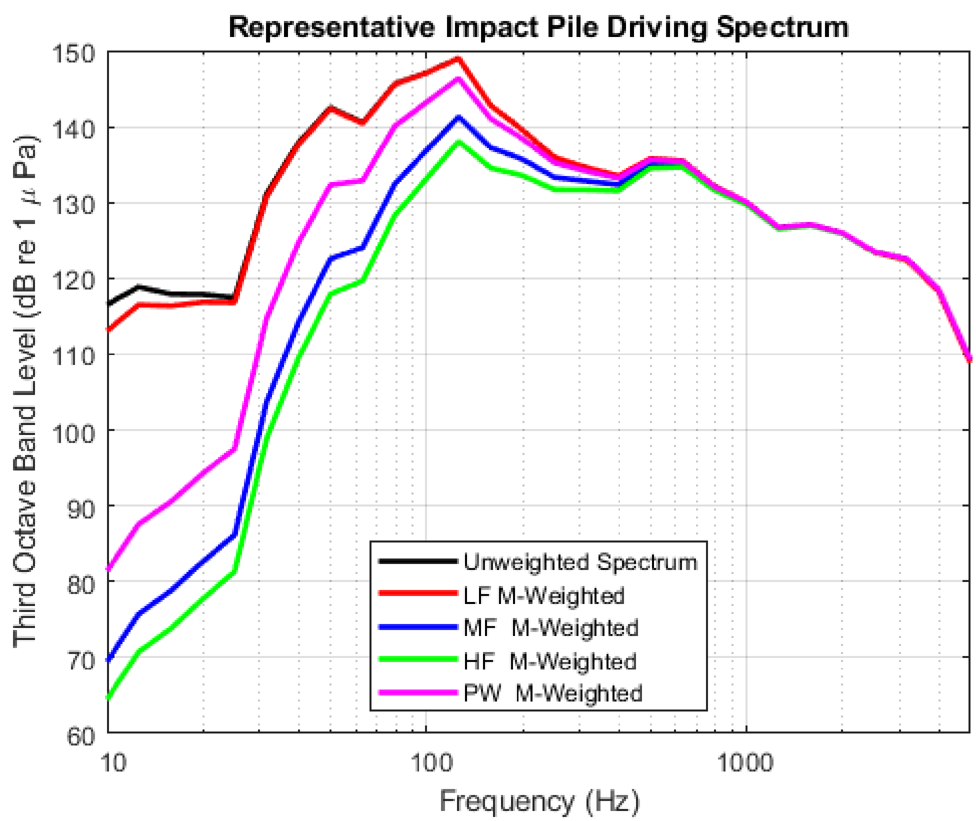

Figure 4. Representative spectrum measured from impact pile driving of a 7.8 m monopile

Values are presented in third octave band levels as described in Ørsted (2020). Unweighted pile driving spectrum (black line) compared to the spectrum weighted for LF, MF, HF, and PW species using M-weighting (as in Southall et al., 2007).

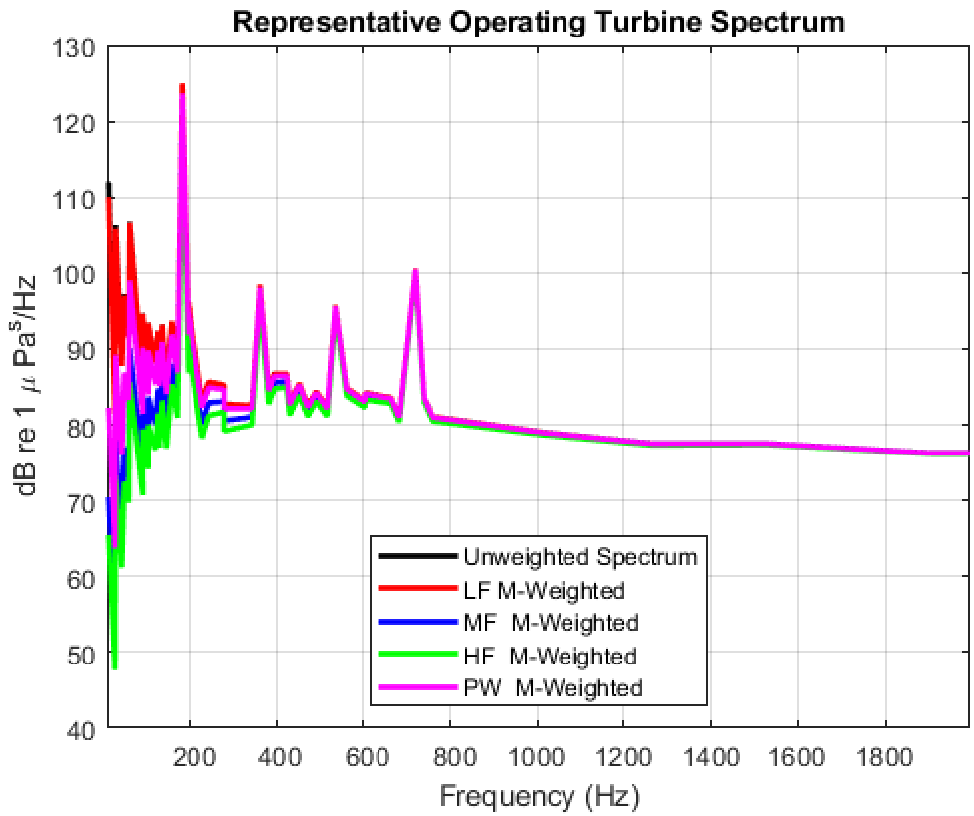

Figure 5. Representative spectrum measured from an operating monopile turbine (from Ingemansson Technology AB, 2003).

Unweighted wind turbine operational spectrum (black line) compared to the spectrum weighted for LF, MF, HF, and PW species using M-weighting.

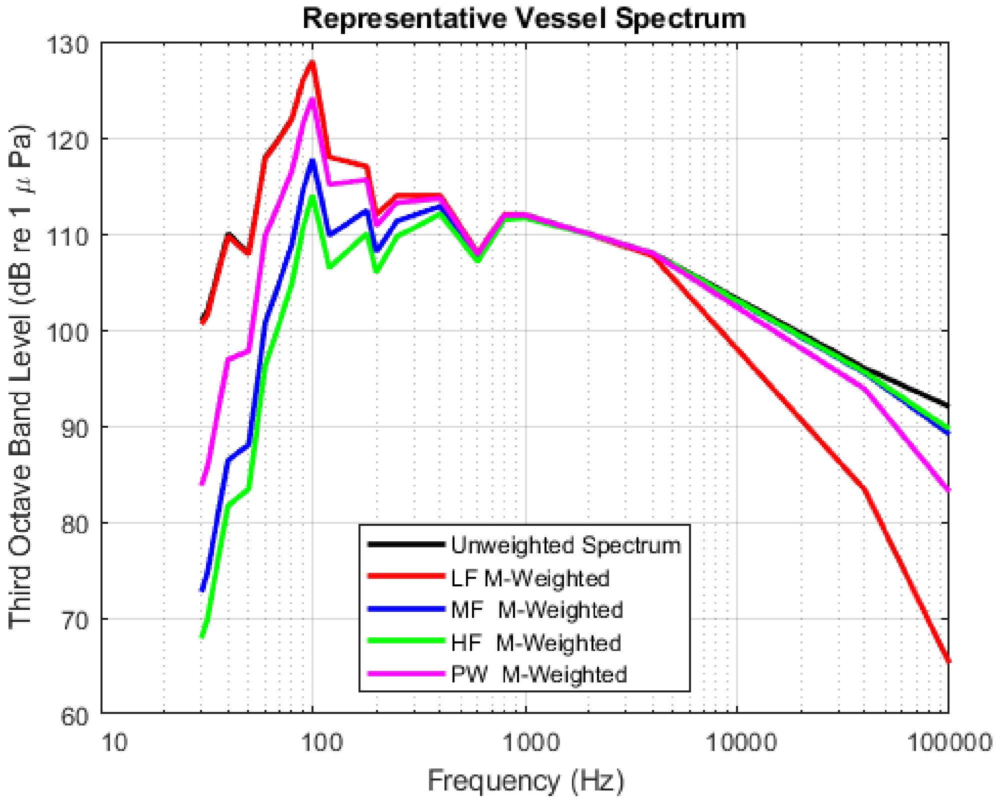

Figure 6. Representative spectrum of a vessel traveling at approximately 30 km/hr.

Levels are given in third octave band levels as measured (Hermannsen (2014). Unweighted vessel operational spectrum (black line) compared to the spectrum weighted for LF, MF, HF, and PW species using M-weighting.

2.2.2. Exposure Index

The exposure index is calculated for each wind farm, month, and species individually by:

- Calculating for each wind farm separately allows for the wind farms to be in separate phases (i.e. one could be in construction and the other could be in operation) because the spectrum changes based on activity. If we didn't calculate for each individually, all windfarms in the scenario would have to effectively be in the same activity. This is calculated using the equation:

$$EI = AI * SI$$

- Summing the exposure index from all the wind farms (WF) to get an aggregate index for each month, using the equation:

$$EI_{aggregate} = \sum_{WF} EI$$

- Normalizing by the total number of animals within a zone or region, whichever the user is interested in ($N_{total\ animals}$) using:

$$EI_{aggregate,normalized} = \frac{EI_{aggregate}}{N_{total\ animals}}$$

- $EI_{aggregate,normalized}$ is related as the percentage of the species within a zone or region that will be presumed to be disturbed during the month.
- The EI is normalized such that it can be compared across species provided the same region was used to determine the $N_{total\ animals}$ term. It is calculated for each wind farm independently so the index of each wind farm will inform the user which wind farm is of higher impact to the species.
- When calculating the exposure index for wind farm operational years, use whichever activity yields the highest exposure index as the representative EI (turbine operation or vessel operation).

2.3. Optional Zone Delineation

The Activity and Exposure indices evaluate the potential risk to different species by ocean zone. If the geographical area being assessed is delineated into multiple zones, which was not the case for scenarios here, then the activity and exposure index can be calculated in each zone. To calculate by zone for each wind farm, the AI should be multiplied by the following factor prior to calculating the EI.

$$Zone\ Ratio = \frac{A_{activity\ in\ each\ zone}}{A_{activity}}$$

$A_{activity\ in\ each\ zone}$ = area of the wind farm in each zone

$A_{activity}$ = total area of the wind farm

2.4. Exposure Index Risk Assessment Rating Methods

Following calculation of exposure index values for each grid for the defined period (here = month) within the specified zone (here = zone 2; see Fig. 3), several processes are required in order to determine a zone-specific and species-specific exposure index severity rating by which (in combination with the vulnerability rating) to provide an overall risk assessment.

Following the above process, a zone-wide representation of the effective exposure index results was determined from the most representative scenarios to serve as reference for comparing relative exposure risk across species within scenarios and across scenarios within species. Specifically, we calculated all of the resulting exposure index scores as a percentage of the zone-specific population for the installation of the larger windfarm (#1) during one pile/day conditions and unmitigated disturbance ranges (10 km for most species, 20 km for harbor porpoise). We then determined the 20th, 40th, 60th, and 80th percentile points of this distribution, yielding five equally distributed proportions. These points served as a means of quantitatively assessing relative risk based on the distribution of a representative scenario. It should be clearly stated and noted that this process is thus entirely dependent upon the selection of species to be included (herein five focal species of several dozen present in the overall area), the geographic area considered (herein one zone of seven in the region), and the context of the base distribution used to determine these percentile breakpoints (herein the scenario described above). Again, this process is emphasized to be a transparent, consistent tool used to evaluate relative risk in defined scenarios for assessing species and scenario differences and/or in contingency and scenario planning rather than an absolute quantification of risk.

Then, within each scenario and month in which exposure index scores are calculated, the relative associated risk rating is determined. The species-specific, exposure index scores (representing the percentage of the zone-specific population predicted to be affected) were evaluated using the below scale to determine an exposure index relative risk rating for use in the overall risk assessment (Table 2).

Table 2. Exposure index value percentile breakpoints and corresponding risk ratings

Exposure Index Value (% of zone population)	Exposure Index Relative Risk Rating
> 0.4218%	Highest (5)
> 0.2574%	Higher (4)
> 0.1853%	Moderate (3)
> 0.0595%	Lower (2)
< 0.0595%	Lowest (1)

3 Aggregate Risk Assessment: Species-Specific "Vulnerability"

The species-specific vulnerability rating comprises the second axis of the overall risk assessment (see: Fig. 1). This rating is determined discretely for each species, area, and temporal period being considered using a structured evaluation of key species and context-specific factors. They include the following factors, each of which is used to determine an overall potential vulnerability rating and is described below:

Species population factor

Species habitat use and compensatory abilities

Potential masking factor

Environmental risk factors

Methods used to determine vulnerability scores in each area are based upon and are largely similar to the vulnerability ratings derived for discrete exposures (see Southall et al., 2019), but with a number of subsequent and increasingly quantitative metrics. Many of these improvements and refinements are reflected and described in our recent final report for risk assessment for cetaceans in the Gulf of Mexico for potential disturbance from seismic surveys (Southall et al., 2021). However, several additional measures and distinctions have been made subsequent to that report and are identified and specifically defined here.

Here we describe the assessment methods and criteria used in each of these four biologically meaningful factors, which are collectively used to determine the species-specific vulnerability rating. We also provide results for the vulnerability assessment for each of the five focal species for the two construction years for offshore wind farm scenarios considered here. Results are based on calculations specified from the assessed scenarios, as described and defined, as well as information provided for each species within the three most recent SARs for the relevant development area.[6]

3.1 Species Population Factor

Population parameters are a critical consideration in evaluating the potential vulnerability of a species to disturbance from aggregate noise exposure. Although the exposure index relates the population distribution relative to noise sources as the inherent basis for evaluating exposure magnitude, other parameters that are not explicitly considered include the conservation status,

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[6] 2017 SAR: https://repository.library.noaa.gov/view/noaa/22730

2018 SAR: https://repository.library.noaa.gov/view/noaa/20611

2019 SAR: https://media.fisheries.noaa.gov/dam-migration/2019_sars_atlantic_508.pdf population trend, and overall population size (Table 3). Higher relative vulnerability is assigned for species that are endangered or depleted, have a clearly negative population trajectory, or have a low overall population size. This factor includes a maximum possible score of seven (7) out of a total possible score of 30 for the overall vulnerability rating.

This factor has the benefit of relatively well-defined quantitative criteria, although it should be noted that a limitation in this component of assessment can be the lack of current or sufficiently precise stock assessment reports. Specific wording has been added to the second bullet in the population trend element to identify conditions for which a trend is unknown (and the corresponding score). On a related note, an additional score is now identified within the population size element for scenarios in which no population size is identified within the last three SARs, where the regional population may be below 2,500 (in relation to the IUCN designation of small population size). It is noted that that use of multiple SARs for population estimates requires that methods and regions evaluated are comparable and sufficiently robust. Where this does not clearly exist, an unknown rating is assigned.

Table 3. Species population factor assessment criteria (defined for regional population or stock)

Population Factor Elements	**Score (max 7)**
Population status: • *Endangered* (ESA) or *depleted* (MMPA) = **3** • *Threatened* = **1**	**max = 3**
Population trend: • *Decreasing* (last three stock assessment reports [SARs] for which new population estimates were updated) = **2** • *Unknown* (last three SARs) - no population trend analysis performed or data deficient = **1** • *Stable* (last three SARs) for which new population estimates were updated within 5%) = **0** • *Increasing* (last three SARs) = **-1**	**max = 2**

Population size: • Small (n < 2,500, as specified by International Union for the Conservation of Nature [IUCN] designation) = **2** • Unknown (last three SARs) but possibly below 2,500 = **1** • > 2,500 = **0**	**max = 2**

3.2 Species Habitat Use and Compensatory Abilities

The relative biological importance of a specified zone[7] where a noise-generating activity will occur is evaluated as an element of potential species-specific vulnerability. Ideally, relatively fine-scale spatial (km to tens of km) and temporal (days) overlap between activities and species-typical habitat usage would be evaluated, given the importance of this overlap in determining exposure and the likely magnitude of potential response. Given that information at such fine-scale resolution is typically limited or not available because of data limitations, particularly in terms of species-typical habitat usage, a relatively coarser assessment of vulnerability is applied here based on the relative prevalence of a species within broader defined areas and time periods.

Relatively higher potential vulnerability is assessed for areas where a species is known to occur in relatively higher concentrations (e.g., Forney et al., 2017), or where there is a relatively higher degree of spatial overlap between a noise-generating activity and a biologically important activity, including mating, rearing of offspring, foraging in a concentrated area, and/or migrating. For the habitat use term, the percentage of the total species-specific population occurring within the operational zone where activities are occurring is calculated (based on Roberts et al., 2020). Specifically, this is the proportion of the species in Zone 2 (Fig. 1) out of the entire population occurring in all seven zones). Slightly greater weight is given to the habitat term here relative to earlier iterations of the risk assessment framework, along with and in part due to an increased resolution on the proportion of the species present within the zone. In previous assessments in the Gulf of Mexico where many species lack strong seasonal patterns this was calculated annually. For this assessment off the U.S. east coast where most species have quite distinct seasonal patterns, this and the temporal overlap elements were calculated monthly. Information on seasonal trends in activity patterns (e.g., calving or pupping seasons) were evaluated from the SARs and knowledge of the natural history of each species. This factor includes a maximum

[7] This zone is the area over which a specified activity is evaluated. A zone-specific population is determined out of the entire evaluated region (here the U.S. east coast from North Carolina to Maine from the coast to 2,500 m depth contour); herein, this was defined as each of seven zones delineated in section 1.

possible score of seven (7) out of a total possible score of 30 for the overall vulnerability rating (Table 4).

Table 4. Species habitat and temporal factor scoring criteria

Species habitat and temporal factor elements	**Score (max 7)**
Habitat use: • Specified area contains ≥ 30% of total regionwide or estimated population (during defined the temporal window considered) = **5** • < 30% and ≥ 20% = **4** • < 20% and ≥ 10% = **3** • < 10% and ≥ 5% = **2** • < 5% and ≥ 1% = **1** • < 1% = **0**	**max = 5**
Temporal overlap: • High probability that activity will overlap with concentrated breeding/maternal care periods and/or key feeding or migration periods within specified area = **2** • Low probability that activity will overlap with concentrated breeding/maternal care periods and/or key feeding or migration periods within specified area = **1** (also assigned when insufficient data on species biology exists by which to assess potential overlap). • No probability that activity will overlap with concentrated breeding/maternal care periods and/or key feeding or migration periods within specified area = **0** (only when <0.1% of total regionwide or estimated population occurs within zone).	**max = 2**

3.3 Potential Masking Risk Factor

The potential masking considers the potential for disturbance and disruption of bioacoustically mediated behaviors such as communication (primarily) and spatial orientation and navigation through passive listening. Masking potential depends critically on the location and nature of each anthropogenic noise source in question; the noise field generated by each source; the aggregate noise field generated by multiple sources; and the degree of spectral overlap between the aggregate noise field and the hearing, signal functions, ongoing activity, and acoustic ecology of the species of interest. A rating of masking potential, specifically for the proposed activity though put into the context of the existing estimated or known ambient noise, is assessed relative to baseline ambient noise conditions, ideally based on empirical results from measurements within the area being considered over multiple seasons. This is considered on the vulnerability side of the framework as a separate kind of stressor rather than presumed to be subsumed in the exposure index calculation which is more tuned to potential behavioral response and may be seen as a proxy for higher-order auditory effects (e.g., hearing threshold shifts).

For earlier assessments (Ellison et al., 2015), the potential masking factor was evaluated using largely subjective considerations of relative spectral overlap between the predominant energy from a single noise source and species-typical sounds of interest. As we developed the aggregate noise risk assessment (Southall et al., 2019; 2021), a more quantitative, objective approach for deriving the potential masking factor was derived. The potential masking factor is calculated in a species-specific manner using frequency-weighted values (see Southall et al., 2021 for a more detailed discussion, including the logic of retaining M-weighting curves for this specific application). It includes consideration of multiple frequency bands associated with species-specific communication as well as low frequency (LF; 0.01-1 kHz) and mid-frequency (MF; 1-10 kHz) bands where passive listening may facilitate spatial orientation and navigation. It includes a maximum possible score of nine (9) out of a total possible score of 30 for the overall vulnerability rating.

This process has a series of iterative, quantitative steps to characterize noise sources and associated aggregate noise fields and relate them to quantitative metrics of ambient noise from various sources weighted for each marine mammal taxa. These signal-to-noise ratios (herein defined as ambient noise-to-noise (ANNR) values) are calculated for LF, MF, and high frequency (HF; > 10 kHz) within defined zones during specified periods of time (herein months) for biologically appropriate frequency bands. We define these three biological, contextual frequency bands as those in which basic bioacoustic functions that are potentially liable to masking occur, where the masking contexts considered susceptible to disturbance and disruption are communication (primarily) and spatial orientation for foraging and navigation. The communication bands for the LF band is primarily with respect to baleen whale and pinniped communication. Communication in MF bands include communication signals for many odontocetes (e.g., common dolphins considered here), although harbor porpoise communication signals occur within the HF bands.

The four basic steps in the process for deriving a species-specific, potential masking factor score are as follows:

1. For the noise source, generate M-weighted, aggregate (full bandwidth) noise spectra throughout a region at 10 km x 10 km spatial resolution and one-month time resolution for each of the four M-weighted conditions for species considered here (M_{LF}, M_{PW}[8], $M_{MF,}$ and M_{HF}).

2. For the non-noise source condition (no pile driving in this scenario), generate M-weighted, aggregate noise spectrum throughout a region at 10 km x 10 km spatial resolution and one-month time resolution for each of the four M-weighted conditions (M_{lf}, M_{pw}, $M_{mf,}$ and M_{hf}), based on existing data. This is a baseline ambient noise condition that is based on available empirical or estimated measurements of month-specific ambient noise within the zone[9]

3. Estimate relative spectrum level differences between these two M-weighted, aggregate noise spectrum levels (from above items 1 and 2) between aggregate noise spectra and background noise. Convert these ambient noise-to-noise spectrum differences into ANNR values for each of three LF, MF and HF bands, specific to each of the four taxa (LF cetaceans (baleen whales = NARW, humpback whale), MF cetaceans (odontocetes = common dolphin), HF cetaceans (odontocetes = harbor porpoise), and pinnipeds in water (gray seal)). This is done for each potentially relevant band scenario for respective hearing group (e.g., LF and MF bands for LF and MF cetaceans; LF, MF, and HF bands for HF cetaceans)

4. For each species of interest, determine the masking factor score for each of the M-weighted, activity-specific contexts based on quantitative criteria given below (Table 4). Note: the upper range of the communication masking factor score for the current offshore wind assessment herein was modified from > 30 dB to > 20 dB in part because of the relatively high current low-frequency noise levels in the zone evaluated here resulting from an existing (pre-wind farm installation) shipping lane. Similar tuning up or down may be required for other scenarios, which will be directly enabled where consistent and calibrated ambient noise data are available.

We differentiate among sounds that may be primarily utilized for communication (conspecific or auto-communication, i.e., echolocation) and those used in passive listening for spatial orientation, foraging, or other contexts. We assign greater weight in the potential masking factor score to signals most likely associated with communication, defined as signals within the primary species-specific communication band (e.g., LF for LF cetaceans; HF for HF cetaceans). However, for all species a consideration of potential masking within the LF and MF bands, which is most likely to convey information relevant to navigation and spatial orientation, is made

[8] M_{PW} = M weighting for pinnipeds in water (from Southall et al., 2007)
[9] Direct empirical measurements for multiple recorders within Zone 2 near hypothetical wind farm #1 were available through collaborators at Cornell University's Bioacoustics Research Program

based on the M-weighted ANNR values. This factor includes a maximum possible score of nine (9) out of a total possible score of 30 for the overall vulnerability rating (Table 5).

Table 5. Potential masking factor scoring criteria

Masking Factor Elements	**Score (max 9)**
Communication masking factor: • Median ANNR (for all cells within zone in which species is predicted to occur) within primary species-specific communication (conspecific and auto-communication) band ≥ 20 dB = **6** • 10–19 dB = **4** • 1–9 dB = **1** • < 1 dB = **0**	**max = 6**
Spatial orientation and navigation masking factor: • Median ANNR within LF band ≥ 20 dB = **2** • 10–19 dB = **1** • < 10 dB = **0**	**max = 2**
Spatial orientation and navigation masking factor: • Median ANNR within MF band is ≥ 20 dB = **1** • < 20 dB = **0**	**max = 1**

3.4 Environmental Risk Factors

Other (chronic) noise and non-noise stressors: The final set of biologically relevant factors in the species-specific vulnerability assessment considers other environmental factors beyond those associated with the noise-generating activity being considered (i.e., wind farm construction and operation in this assessment). The logic here is that the increased prevalence of other stressors may increase species-specific vulnerability to the potential disturbance being considered. This has been a key element of the framework from the earlier development (Ellison et al., 2016), although there has been substantial revision during and subsequent to the recent assessment for seismic surveys in the Gulf of Mexico (Southall et al., 2021). These modifications include additional quantitative distinctions and reference points (specifically to potential biological removal (PBR) based on SAR results) to criteria for assessing the magnitude of other potential sources of disturbance or other stressors that may influence a species' response to noise from a defined/proposed activity.

Specific factors considered were both the relative levels of ongoing human activity in an area, as well as the existence and severity of other biological risk factors such as disease or nutritional stress, as identified within the SARs or other sources. This factor is evaluated on an annual basis given the nature of the associated stressors and typical resolution of data for each. Conditions under which chronic anthropogenic disturbance from other activities or biological stressors are relatively higher are evaluated as having a higher potential impact. This risk factor includes a maximum possible score of seven (7) out of a total possible score of 30 for the vulnerability rating (Table 6).

Table 6. Environmental risk factors scoring criteria

Other Stressors Factor Elements	**Score (max 7)**
Chronic anthropogenic noise: Species subject to variable levels of current or known future chronic anthropogenic noise (i.e., dense or overlapping concentrations of industrial activity such as shipping lanes, sonar testing ranges, areas of regular seismic surveys)	**Up to 2**

Chronic anthropogenic risk factors (non-noise direct anthropogenic impacts): Species subject to variable degrees of current or known future risk from other chronic, non-noise anthropogenic activities (e.g., regular documented cases of fisheries interactions, whale-watching, research activities, ship-strike). Total annual known or estimated direct anthropogenic mortality from all sources, as documented in last SARs, evaluated relative to species-specific potential biological removal (PBR). • Annual mortality ≥ PBR: **3** • Annual mortality ≥ 50% PBR or mortality unknown/unreliable: **2** • Annual mortality ≥ 25% PBR: **1** • Annual mortality < 25% PBR: **0**	**Up to 3**
Chronic biological risk factors (non-noise environmental impacts): Variable presence of disease, parasites, prey limitation (including indirect climate change related), or high predation pressure (recent SARs as reference). • Documented instances of multiple such stressors in last three SARs: **2** • Documented instance of one such stressor in last three SARs: **1** (also assigned when insufficient data for the species is present). • No documented instances of such stressors where species are sufficiently monitored: **0**	**Up to 2**

3.5 Total Vulnerability Score Rating Methods

The total vulnerability score is based on the total (aggregate) score from factors 1-4, determined monthly for each scenario. Based on the total risk score (as a percentage of the possible total score), an associated vulnerability rating is then assigned, as identified (Table 7). As with the final exposure index scores, we emphasize that for more generalizable applications, subsequent testing sensitivity assessments would be important to further evaluate the break points identified.

Table 7. Normalized zone- and species-specific exposure index values and corresponding severity ratings

Total Vulnerability Score (from factors 1-4)	Total Risk Probability (% of total possible)	Relative Vulnerability Rating
24–30	80-100%	Highest
18–23	60–79%	High
12–17	40–59%	Moderate
6–11	20–39%	Low
0–5	< 20%	Lowest

3.6 Total Vulnerability Score Risk Assessment Results

We applied the criteria described above to assess relative vulnerability for each of the five focal species for each of the four vulnerability factors. This was done first for the year 1 installation scenario and then evaluated for differences in each of the other installation and operational year scenarios. Monthly values are reported for several of the factors, while others were determined as described, on an annual basis. As only the masking factor scores changed between years in terms of vulnerability assessments for different scenarios, the resulting vulnerability scores are given here for the year 1 scenario and those differences are described and alternate results for species where they differ are presented with results for each of the three scenarios. Results are given below for species population factor (Table 8), species habitat and temporal factor (Table 9), potential masking factor (Table 10), and other stressors (Table 11).

Table 8. Species population factor assessment results

Focal Species	***Population Status***	***Population Trend*** *(from last 3 SARs)*	***Population Size*** *(from 2019 SAR)*	**TOTAL SCORE**
North Atlantic Right Whale	ESA listed: **3**	Decreasing: **2** 2019: 428 2018: 451 2017: 458	< 2500: **2**	**7**
Humpback Whale (Gulf of Maine stock)	Not listed or threatened**:** **0**	Increasing: **-1** 2019: 1396[10] 2018: not given 2017: 335[11]	< 2500: **2**	**1**
Common Dolphin (western NA stock)	Not listed or threatened**:** **0**	Unknown (no trend analysis conducted)**:** **1** 2019: 172,825 2018: 70,184 2015: 173,486	**0 (> 2500)**	**1**
Harbor Porpoise (Gulf of Maine/BOF stock)	Not listed or threatened**:** **0**	Unknown (no trend analysis conducted)**:** **1** 2019: 95,543 2018: 79,883 2017: 79,883	**0 (> 2500)**	**1**
Gray Seal	Not listed or threatened**:** **0**	Unknown (no trend analysis conducted)**:** **1** 2019: 27,131 (min) 2018: 27,131 (min) 2017: 27,131 (min)	**0 (> 2500)[12]**	**1**

[10] From Pace (2017), referenced in 2019 SAR
[11] From Palka (2012), referenced in 2017 SAR
[12] While no firm number on population in U.S. waters this is deemed a reasonable assumption based on minimum pup estimates in SARs

Table 9. Species habitat and temporal factor scoring results

Species	***Month***	***Habitat Use (monthly)***	***Temporal Overlap (monthly)***	**TOTAL SCORE**
North Atlantic Right Whale	**January**	(39.2%) **5**	**1**	**6**
	February	(46.0%) **5**	**1**	**6**
	March	(42.6%) **5**	**2** (migration; females w/ young calves)	**7**
	April	(40.7%) **5**	**2** (migration; females w/ young calves)	**7**
	May	(23.8%) **4**	**1** (migration; females w/ young calves)	**5**
	June	(5.1%) **2**	**1** (migration; females w/ young calves)	**3**
	July	(1.5%) **1**	**1**	**2**
	August	(2.3%) **1**	**1**	**2**
	September	(2.4%) **1**	**1**	**2**
	October	(7.0%) **2**	**1**	**3**
	November	(19.7%) **3**	**1**	**4**
	December	(35.4%) **5**	**1**	**6**
Humpback Whale (Gulf of Maine stock)	**January**	(12.6%) **3**	**2** (migration)	**5**
	February	(9.7%) **2**	**2** (migration)	**2**
	March	(10.3%) **3**	**2** (migration; females w/ young calves)	**5**
	April	(12.8%) **3**	**2** (migration; females w/ young calves)	**5**
	May	(8.5%) **2**	**1** (feeding)	**3**

	June	(9.5%) **2**	**1** (feeding)	**3**
	July	(6.7%) **2**	**1** (feeding)	**3**
	August	(5.0%) **2**	**1** (feeding)	**3**
	September	(6.9%) **2**	**1** (feeding)	**3**
	October	(8.2%) **2**	**1** (feeding)	**3**
	November	(8.5%) **2**	**1** (migration)	**3**
	December	(9.9%) **2**	**1** (migration)	**3**
Common Dolphin (western NA stock)	**January**	(16.0%) **3**	**1** (foraging)	**4**
	February	(8.5%) **2**	**1** (foraging)	**3**
	March	(4.1%) **1**	**1** (foraging)	**2**
	April	(4.4%) **1**	**1** (foraging)	**2**
	May	(4.3%) **1**	**1** (foraging)	**2**
	June	(5.1%) **2**	**1** (foraging)	**3**
	July	(5.7%) **2**	**1** (foraging)	**3**
	August	(8.1%) **2**	**1** (foraging)	**3**
	September	(8.0%) **2**	**1** (foraging)	**3**
	October	(8.9%) **2**	**1** (foraging)	**3**
	November	(6.9%) **2**	**1** (foraging)	**3**
	December	(11.1%) **3**	**1** (foraging)	**4**
Harbor Porpoise (Gulf of Maine/BOF stock)	**January**	(23.3%) **4**	**1** (foraging)	**5**
	February	(22.5%) **4**	**1** (foraging)	**5**
	March	(23.3%) **4**	**1** (foraging)	**5**
	April	(18.9%) **3**	**1** (foraging)	**4**

	May	(13.6%) **3**	**1** (foraging)	**4**
	June	(2.3%) **1**	**2** (foraging; calving)	**3**
	July	(0.8%) **0**	**2** (foraging; calving)	**2**
	August	(0.6%) **0**	**2** (foraging; calving)	**2**
	September	(0.9%) **0**	**1** (foraging)	**1**
	October	(4.0%) **1**	**1** (foraging)	**2**
	November	(16.7%) **3**	**1** (foraging)	**4**
	December	(22.5%) **4**	**1** (foraging)	**5**
Gray Seal	**January**	(43.1%) **5**	**1** (foraging)[13]	**6**
	February	(39.8%) **5**	**1** (foraging)	**6**
	March	(38.5%) **5**	**1** (foraging)	**6**
	April	(53.9%) **5**	**1** (foraging)	**6**
	May	(58.8%) **5**	**1** (foraging)	**6**
	June	(16.8%) **3**	**1** (foraging)	**4**
	July	(5.5%) **2**	**1** (foraging)	**3**
	August	(4.5%) **1**	**1** (foraging)	**2**
	September	(4.8%) **1**	**1** (foraging)	**2**
	October	(9.3%) **2**	**1** (foraging)	**3**
	November	(57.6%) **5**	**1** (foraging)	**6**
	December	(54.2%) **4**	**1** (foraging)	**6**

[13] Note – gray seals generally have pups and breed in winter, but this is not scored as an additional risk factor here as these biologically important activities occur generally near or on land and not in the vicinity of either of the nominal wind farms being constructed in the scenarios here.

Table 10. Potential masking factor scoring results (shown only for months where installation occurs)

Focal Species	*Communication Masking Factor*	*Spatial Orientation and Navigation Factor (LF band)*	*Spatial Orientation and Navigation Factor (MF band)*	TOTAL SCORE
North Atlantic Right Whale **Humpback Whale (Gulf of Maine stock)** (as LF species both share identical scores)	Mar (16 dB): 4	Mar (16 dB): 1	Mar (-10 dB): 0	5
	Apr (18 dB): 4	Apr (18 dB): 1	Apr (-9 dB): 0	5
	May (19 dB): 4	May (19 dB): 1	May (-9 dB): 0	5
	Jun (19 dB): 4	Jun (19 dB): 1	Jun (-8 dB): 0	5
	Jul (20 dB): 6	Jul (20 dB): 2	Jul (-8 dB): 0	8
	Aug (19 dB): 4	Aug (19 dB): 1	Aug (-8 dB): 0	5
	Sept (20 dB): 6	Sept (20 dB): 2	Sept (-8 dB): 0	8
	Oct (19 dB): 4	Oct (19 dB): 1	Oct (-9 dB): 0	5
Common Dolphin (western NA stock)	Mar (-23 dB): 0	Mar (-10 dB): 0	Mar (-23 dB): 0	0
	Apr (-21 dB): 0	Apr (-10 dB): 0	Apr (-21 dB): 0	0
	May (-21 dB): 0	May (-6 dB): 0	May (-21 dB): 0	0
	Jun (-20 dB): 0	Jun (-6 dB): 0	Jun (-20 dB): 0	0
	Jul (-20 dB): 0	Jul (-6 dB): 0	Jul (-20 dB): 0	0
	Aug (-20 dB): 0	Aug (-6 dB): 0	Aug (-20 dB): 0	0
	Sept (-20 dB): 0	Sept (-5 dB): 0	Sept (-20 dB): 0	0
	Oct (-21 dB): 0	Oct (-8 dB): 0	Oct (-21 dB): 0	0
Harbor Porpoise (Gulf of Maine/BOF stock)	Mar (-30 dB): 0	Mar (-24 dB): 0	Mar (-30 dB): 0	0
	Apr (-28 dB): 0	Apr (-23 dB): 0	Apr (-28 dB): 0	0
	May (-27 dB): 0	May (-23 dB): 0	May (-27 dB): 0	0
	Jun (-26 dB): 0	Jun (-22 dB): 0	Jun (-26 dB): 0	0
	Jul (-25 dB): 0	Jul (-23 dB): 0	Jul (-25 dB): 0	0

	Aug (-25 dB): 0	**Aug (-23 dB): 0**	**Aug (-25 dB): 0**	**0**
	Sept (-25 dB): 0	**Sept (-22 dB): 0**	**Sept (-25 dB): 0**	**0**
	Oct (-27 dB): 0	**Oct (-22 dB): 0**	**Oct (-27 dB): 0**	**0**
Gray Seal	**Mar (-3 dB): 0**	**Mar (-3 dB): 0**	**Mar (-15 dB): 0**	**0**
	Apr (-3 dB): 0	**Apr (-3 dB): 0**	**Apr (-14 dB): 0**	**0**
	May (-2 dB): 0	**May (-2 dB): 0**	**May (-13 dB): 0**	**0**
	Jun (-1 dB): 0	**Jun (-1 dB): 0**	**Jun (-14 dB): 0**	**0**
	Jul (-1 dB): 0	**Jul (-1 dB): 0**	**Jul (-14 dB): 0**	**0**
	Aug (-1 dB): 0	**Aug (-1 dB): 0**	**Aug (-14 dB): 0**	**0**
	Sept (0 dB): 0	**Sept (0 dB): 0**	**Sept (-13 dB): 0**	**0**
	Oct (0 dB): 0	**Oct (0 dB): 0**	**Oct (-13 dB): 0**	**0**

Table 11. Environmental risk factors scoring results

Species	***Chronic anthropogenic noise***	***Chronic anthropogenic risk factors (non-noise)***	***Chronic biological risk factors (non-noise)***	**TOTAL SCORE**
North Atlantic Right Whale	**2** Vessel traffic; Future OSW	**3** Vessel strike; Entanglement Annual mortality (6.85)/PBR (0.8) = 8.56x PBR	**2** 2017 UME; Climate-change related prey redistribution	**7**

Humpback Whale	**2** Vessel traffic; Future OSW	**2** Entanglement; vessel strike Annual mortality (12.15)/PBR (22) = 0.55x PBR	**1** 2018 UME	**5**
Common Dolphin	**1** Wide-ranging species so less subject to localized activities	**2** Fisheries bycatch; mortality estimate uncertainty Annual mortality (419)/PBR (1452) = 0.29x PBR	**1** Climate change related prey redistribution	**4**
Harbor Porpoise	**2** Coastal distribution so less subject to offshore activity, but particularly sensitive (documented strong responses)	**2** Fisheries bycatch; mortality estimate uncertainty Annual mortality (217)/PBR (851) = 0.25x PBR	**1** Predation pressure	**5**
Gray Seal	**1** Wide-ranging species so less subject to localized activities	**2** Fisheries bycatch and direct take/removal in Canada Annual mortality (946)/PBR (1389) = 0.68x PBR	**1** Insufficient monitoring data	**4**

From this process, the resulting vulnerability scores and integrated relative risk ratings (using criteria specified above) are given below for each focal species for each of the temporal scenarios depicted in year 1 and for species in which they differ for the second installation year and/or the operational year.

Vulnerability scores for North Atlantic right whales for the year 1 scenario are provided in Table 12. Masking factor scores presume operations in all four months. Right whale vulnerability scores for the year 2 installation scenarios are given in Table 13, the differences in masking factor scores (increasing from five to eight) occurring only in August in scenarios where both windfarms were being installed. Operational year (3) vulnerability scores for right whales are given in Table 14. Masking factor scores here are the only difference and correspond to the lowest non-zero rating for ANNR values in the low-frequency band resulting from associated vessel operations in an environment with measured high levels of existing shipping noise at comparable frequencies.

Table 12. North Atlantic right whale vulnerability score summary (year 1 installation scenarios)

1 MARCH START												
VULNERABILITY FACTOR	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Species Population	7	7	7	7	7	7	7	7	7	7	7	7
Habitat Use and Compensatory Abilities	6	6	7	7	5	3	2	2	2	3	4	6
Potential Masking	0	0	5	5	5	5	0	0	0	0	0	0
Other Environmental Stressors	7	7	7	7	7	7	7	7	7	7	7	7
TOTAL	20	20	26	26	24	22	16	16	16	17	18	20
VULNERABILITY RISK SCORE	HIGHER	HIGHER	HIGHEST	HIGHEST	HIGHEST	HIGHER	MODERATE	MODERATE	MODERATE	MODERATE	HIGHER	HIGHER

1 MAY START												
VULNERABILITY FACTOR	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Species Population	7	7	7	7	7	7	7	7	7	7	7	7
Habitat Use and Compensatory Abilities	6	6	7	7	5	3	2	2	2	3	4	6
Potential Masking	0	0	0	0	5	5	8	5	0	0	0	0
Other Environmental Stressors	7	7	7	7	7	7	7	7	7	7	7	7
TOTAL	20	20	21	21	24	22	23	21	16	17	18	20
VULNERABILITY RISK SCORE	HIGHER	HIGHER	HIGHER	HIGHER	HIGHEST	HIGHER	HIGHER	HIGHER	MODERATE	MODERATE	HIGHER	HIGHER

1 JULY START												
VULNERABILITY FACTOR	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Species Population	7	7	7	7	7	7	7	7	7	7	7	7
Habitat Use and Compensatory Abilities	6	6	7	7	5	3	2	2	2	3	4	6
Potential Masking	0	0	0	0	0	0	8	5	8	5	0	0
Other Environmental Stressors	7	7	7	7	7	7	7	7	7	7	7	7
TOTAL	20	20	21	21	19	17	23	21	23	22	18	20
VULNERABILITY RISK SCORE	HIGHER	HIGHER	HIGHER	HIGHER	HIGHER	MODERATE	HIGHER	HIGHER	HIGHER	HIGHER	MODERATE	HIGHER

Table 13. North Atlantic right whale vulnerability score summary (year 2 installation scenarios)

SEQUENTIAL INSTALLATION												
WF 1 July-Aug; WF 2 Sept-Oct												
VULNERABILITY FACTOR	**JAN**	**FEB**	**MARCH**	**APRIL**	**MAY**	**JUNE**	**JULY**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**
Species Population	7	7	7	7	7	7	7	7	7	7	7	7
Habitat Use and Compensatory Abilities	6	6	7	7	5	3	2	2	2	3	4	6
Potential Masking	0	0	0	0	0	0	8	5	5	5	0	0
Other Environmental Stressors	7	7	7	7	7	7	7	7	7	7	7	7
TOTAL	20	20	21	21	19	17	23	21	21	22	18	20
VULNERABILITY RISK SCORE	HIGHER	HIGHER	HIGHER	HIGHER	HIGHER	MODERATE	HIGHER	HIGHER	HIGHER	HIGHER	MODERATE	HIGHER
PARTIAL OVERLAP												
WF 1 July-Aug; WF 2 Aug-Sept												
VULNERABILITY FACTOR	**JAN**	**FEB**	**MARCH**	**APRIL**	**MAY**	**JUNE**	**JULY**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**
Species Population	7	7	7	7	7	7	7	7	7	7	7	7
Habitat Use and Compensatory Abilities	6	6	7	7	5	3	2	2	2	3	4	6
Potential Masking	0	0	0	0	0	0	8	8	8	0	0	0
Other Environmental Stressors	7	7	7	7	7	7	7	7	7	7	7	7
TOTAL	20	20	21	21	19	17	24	24	24	17	18	20
VULNERABILITY RISK SCORE	HIGHER	HIGHER	HIGHER	HIGHER	HIGHER	MODERATE	HIGHEST	HIGHEST	HIGHEST	MODERATE	MODERATE	HIGHER
TOTAL OVERLAP												
WF 1 Aug-Sept; WF 2 Aug-Sept												
VULNERABILITY FACTOR	**JAN**	**FEB**	**MARCH**	**APRIL**	**MAY**	**JUNE**	**JULY**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**
Species Population	7	7	7	7	7	7	7	7	7	7	7	7
Habitat Use and Compensatory Abilities	6	6	7	7	5	3	2	2	2	3	4	6
Potential Masking	0	0	0	0	0	0	0	8	8	0	0	0
Other Environmental Stressors	7	7	7	7	7	7	7	7	7	7	7	7
TOTAL	20	20	21	21	19	17	16	24	24	17	18	20
VULNERABILITY RISK SCORE	HIGHER	HIGHER	HIGHER	HIGHER	HIGHER	MODERATE	MODERATE	HIGHEST	HIGHEST	MODERATE	MODERATE	HIGHER

Table 14. North Atlantic right whale vulnerability score summary (year 3 operational scenarios)

Operational Year Scenario												
VULNERABILITY FACTOR	**JAN**	**FEB**	**MARCH**	**APRIL**	**MAY**	**JUNE**	**JULY**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**
Species Population	7	7	7	7	7	7	7	7	7	7	7	7
Habitat Use and Compensatory Abilities	6	6	7	7	5	3	2	2	2	3	4	6
Potential Masking	1	1	1	1	1	1	1	1	1	1	1	1
Other Environmental Stressors	7	7	7	7	7	7	7	7	7	7	7	7
TOTAL	21	21	22	22	20	18	17	17	17	18	19	21
VULNERABILITY RISK SCORE	HIGHER	HIGHER	HIGHER	HIGHER	HIGHER	HIGHER	MODERATE	MODERATE	MODERATE	HIGHER	HIGHER	HIGHER

Vulnerability scores for humpback whales, which include the same respective masking factor scores as described above for North Atlantic right whales are given in Table 15 (year 1), Table 16 (year 2), and Table 17 (year 3).

Table 15. Humpback whale vulnerability score summary (year 1 installation scenarios)

1 March Start												
VULNERABILITY FACTOR	**JAN**	**FEB**	**MARCH**	**APRIL**	**MAY**	**JUNE**	**JULY**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**
Species Population	1	1	1	1	1	1	1	1	1	1	1	1
Habitat Use and Compensatory Abilities	5	2	5	5	3	3	3	3	3	3	3	3
Potential Masking	0	0	5	5	5	5	0	0	0	0	0	0
Other Environmental Stressors	5	5	5	5	5	5	5	5	5	5	5	5
TOTAL	11	8	16	16	14	14	9	9	9	9	9	9
VULNERABILITY RISK SCORE	LOW	LOW	MODERATE	MODERATE	MODERATE	MODERATE	LOW	LOW	LOW	LOW	LOW	LOW
1 May Start												
VULNERABILITY FACTOR	**JAN**	**FEB**	**MARCH**	**APRIL**	**MAY**	**JUNE**	**JULY**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**
Species Population	1	1	1	1	1	1	1	1	1	1	1	1
Habitat Use and Compensatory Abilities	5	2	5	5	3	3	3	3	3	3	3	3
Potential Masking	0	0	0	0	5	5	8	5	0	0	0	0
Other Environmental Stressors	5	5	5	5	5	5	5	5	5	5	5	5
TOTAL	11	8	11	11	14	14	17	14	9	9	9	9
VULNERABILITY RISK SCORE	LOW	LOW	LOW	LOW	MODERATE	MODERATE	MODERATE	MODERATE	LOW	LOW	LOW	LOW
1 July Start												
VULNERABILITY FACTOR	**JAN**	**FEB**	**MARCH**	**APRIL**	**MAY**	**JUNE**	**JULY**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**
Species Population	1	1	1	1	1	1	1	1	1	1	1	1
Habitat Use and Compensatory Abilities	5	2	5	5	3	3	3	3	3	3	3	3
Potential Masking	0	0	0	0	0	0	8	5	8	5	0	0
Other Environmental Stressors	5	5	5	5	5	5	5	5	5	5	5	5
TOTAL	11	8	11	11	9	9	17	14	17	14	9	9
VULNERABILITY RISK SCORE	LOW	LOW	LOW	LOW	LOW	LOW	MODERATE	MODERATE	MODERATE	MODERATE	LOW	LOW

Table 16. Humpback whale vulnerability score summary (year 2 installation scenarios)

SEQUENTIAL INSTALLATION												
WF 1 July-Aug; WF 2 Sept-Oct												
VULNERABILITY FACTOR	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Species Population	1	1	1	1	1	1	1	1	1	1	1	1
Habitat Use and Compensatory Abilities	5	2	5	5	3	3	3	3	3	3	3	3
Potential Masking	0	0	0	0	0	0	8	5	5	5	0	0
Other Environmental Stressors	5	5	5	5	5	5	5	5	5	5	5	5
TOTAL	11	8	11	11	9	9	17	14	14	14	9	9
VULNERABILITY RISK SCORE	LOW	LOW	LOW	LOW	LOW	LOW	MODERATE	MODERATE	MODERATE	MODERATE	LOW	LOW
PARTIAL OVERLAP												
WF 1 July-Aug; WF 2 Aug-Sept												
VULNERABILITY FACTOR	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Species Population	1	1	1	1	1	1	1	1	1	1	1	1
Habitat Use and Compensatory Abilities	5	2	5	5	3	3	3	3	3	3	3	3
Potential Masking	0	0	0	0	0	0	8	8	8	0	0	0
Other Environmental Stressors	5	5	5	5	5	5	5	5	5	5	5	5
TOTAL	11	8	11	11	9	9	17	17	17	9	9	9
VULNERABILITY RISK SCORE	LOW	LOW	LOW	LOW	LOW	LOW	MODERATE	MODERATE	MODERATE	LOW	LOW	LOW
TOTAL OVERLAP												
WF 1 Aug-Sept; WF 2 Aug-Sept												
VULNERABILITY FACTOR	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Species Population	1	1	1	1	1	1	1	1	1	1	1	1
Habitat Use and Compensatory Abilities	5	2	5	5	3	3	3	3	3	3	3	3
Potential Masking	0	0	0	0	0	0	0	8	8	0	0	0
Other Environmental Stressors	5	5	5	5	5	5	5	5	5	5	5	5
TOTAL	11	8	11	11	9	9	9	17	17	9	9	9
VULNERABILITY RISK SCORE	LOW	LOW	LOW	LOW	LOW	LOW	LOW	MODERATE	MODERATE	LOW	LOW	LOW

Table 17. Humpback whale vulnerability score summary (year 3 operational scenarios)

Operational Year Scenario												
VULNERABILITY FACTOR	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Species Population	1	1	1	1	1	1	1	1	1	1	1	1
Habitat Use and Compensatory Abilities	5	2	5	5	3	3	3	3	3	3	3	3
Potential Masking	1	1	1	1	1	1	1	1	1	1	1	1
Other Environmental Stressors	5	5	5	5	5	5	5	5	5	5	5	5
TOTAL	12	9	12	12	10	10	10	10	10	10	10	10
VULNERABILITY RISK SCORE	MODERATE	LOW	MODERATE	MODERATE	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW

Vulnerability scores for common dolphins applicable to all year scenarios (given consistent 0 scores for masking factors) are given in Table 18.

Table 18. Common dolphin vulnerability score summary (all year scenarios)

1 March Start												
VULNERABILITY FACTOR	**JAN**	**FEB**	**MARCH**	**APRIL**	**MAY**	**JUNE**	**JULY**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**
Species Population	1	1	1	1	1	1	1	1	1	1	1	1
Habitat Use and Compensatory Abilities	4	3	2	2	2	3	3	3	3	3	3	4
Potential Masking	0	0	0	0	0	0	0	0	0	0	0	0
Other Environmental Stressors	4	4	4	4	4	4	4	4	4	4	4	4
TOTAL	9	8	7	7	7	8	8	8	8	8	8	9
VULNERABILITY RISK SCORE	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
1 May Start												
VULNERABILITY FACTOR	**JAN**	**FEB**	**MARCH**	**APRIL**	**MAY**	**JUNE**	**JULY**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**
Species Population	1	1	1	1	1	1	1	1	1	1	1	1
Habitat Use and Compensatory Abilities	4	3	2	2	2	3	3	3	3	3	3	4
Potential Masking	0	0	0	0	0	0	0	0	0	0	0	0
Other Environmental Stressors	4	4	4	4	4	4	4	4	4	4	4	4
TOTAL	9	8	7	7	7	8	8	8	8	8	8	9
VULNERABILITY RISK SCORE	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
1 July Start												
VULNERABILITY FACTOR	**JAN**	**FEB**	**MARCH**	**APRIL**	**MAY**	**JUNE**	**JULY**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**
Species Population	1	1	1	1	1	1	1	1	1	1	1	1
Habitat Use and Compensatory Abilities	4	3	2	2	2	3	3	3	3	3	3	4
Potential Masking	0	0	0	0	0	0	0	0	0	0	0	0
Other Environmental Stressors	4	4	4	4	4	4	4	4	4	4	4	4
TOTAL	9	8	7	7	7	8	8	8	8	8	8	9
VULNERABILITY RISK SCORE	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW

Vulnerability scores for harbor porpoise applicable to all year scenarios (given consistent 0 scores for masking factors) are given in Table 19.

Table 19. Harbor porpoise vulnerability score summary (all year scenarios)

1 March Start												
VULNERABILITY FACTOR	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Species Population	1	1	1	1	1	1	1	1	1	1	1	1
Habitat Use and Compensatory Abilities	5	5	5	4	4	3	2	2	1	2	4	5
Potential Masking	0	0	0	0	0	0	0	0	0	0	0	0
Other Environmental Stressors	5	5	5	5	5	5	5	5	5	5	5	5
TOTAL	11	11	11	10	10	9	8	8	7	8	10	11
VULNERABILITY RISK SCORE	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
1 May Start												
VULNERABILITY FACTOR	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Species Population	1	1	1	1	1	1	1	1	1	1	1	1
Habitat Use and Compensatory Abilities	5	5	5	4	4	3	2	2	1	2	4	5
Potential Masking	0	0	0	0	0	0	0	0	0	0	0	0
Other Environmental Stressors	5	5	5	5	5	5	5	5	5	5	5	5
TOTAL	11	11	11	10	10	9	8	8	7	8	10	11
VULNERABILITY RISK SCORE	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
1 July Start												
VULNERABILITY FACTOR	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Species Population	1	1	1	1	1	1	1	1	1	1	1	1
Habitat Use and Compensatory Abilities	5	5	5	4	4	3	2	2	1	2	4	5
Potential Masking	0	0	0	0	0	0	0	0	0	0	0	0
Other Environmental Stressors	5	5	5	5	5	5	5	5	5	5	5	5
TOTAL	11	11	11	10	10	9	8	8	7	8	10	11
VULNERABILITY RISK SCORE	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW

Vulnerability scores for gray seals for years 1 and 2 scenarios are provided in Table 20. Operational year (3) vulnerability scores for gray seals are given in Table 21; masking factor scores here are the only difference and correspond to the lowest non-zero rating for ANNR values in the low-frequency band resulting from associated vessel operations in an environment with known measured high levels of existing shipping at comparable frequencies (for which pinnipeds in water M-weighting is more comparable to LF-cetacean hearing than for impact pile driving).

Table 20. Gray seal vulnerability score summary (years 1 & 2 installation scenarios)

1 March Start												
VULNERABILITY FACTOR	**JAN**	**FEB**	**MARCH**	**APRIL**	**MAY**	**JUNE**	**JULY**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**
Species Population	1	1	1	1	1	1	1	1	1	1	1	1
Habitat Use and Compensatory Abilities	6	6	6	6	6	4	3	2	2	3	6	6
Potential Masking	0	0	0	0	0	0	0	0	0	0	0	0
Other Environmental Stressors	4	4	4	4	4	4	4	4	4	4	4	4
TOTAL	11	11	11	11	11	9	8	7	7	8	11	11
VULNERABILITY RISK SCORE	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
1 May Start												
VULNERABILITY FACTOR	**JAN**	**FEB**	**MARCH**	**APRIL**	**MAY**	**JUNE**	**JULY**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**
Species Population	1	1	1	1	1	1	1	1	1	1	1	1
Habitat Use and Compensatory Abilities	6	6	6	6	6	4	3	2	2	3	6	6
Potential Masking	0	0	0	0	0	0	0	0	0	0	0	0
Other Environmental Stressors	4	4	4	4	4	4	4	4	4	4	4	4
TOTAL	11	11	11	11	11	9	8	7	7	8	11	11
VULNERABILITY RISK SCORE	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
1 July Start												
VULNERABILITY FACTOR	**JAN**	**FEB**	**MARCH**	**APRIL**	**MAY**	**JUNE**	**JULY**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**
Species Population	1	1	1	1	1	1	1	1	1	1	1	1
Habitat Use and Compensatory Abilities	6	6	6	6	6	4	3	2	2	3	6	6
Potential Masking	0	0	0	0	0	0	0	0	0	0	0	0
Other Environmental Stressors	4	4	4	4	4	4	4	4	4	4	4	4
TOTAL	11	11	11	11	11	9	8	7	7	8	11	11
VULNERABILITY RISK SCORE	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW

Table 21. Gray seal vulnerability score summary (year 3 operational scenarios)

Operational Year Scenario												
VULNERABILITY FACTOR	**JAN**	**FEB**	**MARCH**	**APRIL**	**MAY**	**JUNE**	**JULY**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**
Species Population	1	1	1	1	1	1	1	1	1	1	1	1
Habitat Use and Compensatory Abilities	6	6	6	6	6	4	3	2	2	3	6	6
Potential Masking	1	1	1	1	1	1	1	1	1	1	1	1
Other Environmental Stressors	4	4	4	4	4	4	4	4	4	4	4	4
TOTAL	12	12	12	12	12	10	9	8	8	9	12	12
VULNERABILITY RISK SCORE	MODERATE	MODERATE	MODERATE	MODERATE	MODERATE	LOW	LOW	LOW	LOW	LOW	MODERATE	MODERATE

4 Risk Assessment Results – Installation and Operational Scenarios

Exposure index calculations with associated assessed relative risk and vulnerability scores for each of the many scenarios tested in the two installation and one operational year are presented and integrated below. Raw exposure index scores are first presented graphically within months of operations along with an aggregate exposure index as a means of assessing the cumulative magnitude of exposure in each scenario. Then, integrated risk assessment ratings for each species are presented in each scenario, which include both raw exposure index and vulnerability quantitative results. Finally, an interpretation and discussion of results in each scenario is provided here. A broader consideration of the overall results across scenarios and species and an assessment of the adaptation of the overall framework to these new contexts for offshore windfarms is provided in section 5.

4.1. Installation Year 1 Scenarios: Windfarm #1 only

For this scenario, installation is presumed to occur only at the larger windfarm (#1). Results are presented for each species for the 1 March, 1 May, and 1 July presumed start dates with discrete scenarios for each start date presuming four-month installation duration (1 pile/day) as well as two-month installation duration (2 piles/day), each calculated for the unmitigated disturbance distance (10 or 20 km) and mitigated disturbance ranges (5 or 15 km). Exposure index results for each scenario are given for each operational month and aggregate totals across scenarios (Figs. 7-13), followed by integrated assessed risk in each scenario for each focal species (Tables 22-36).

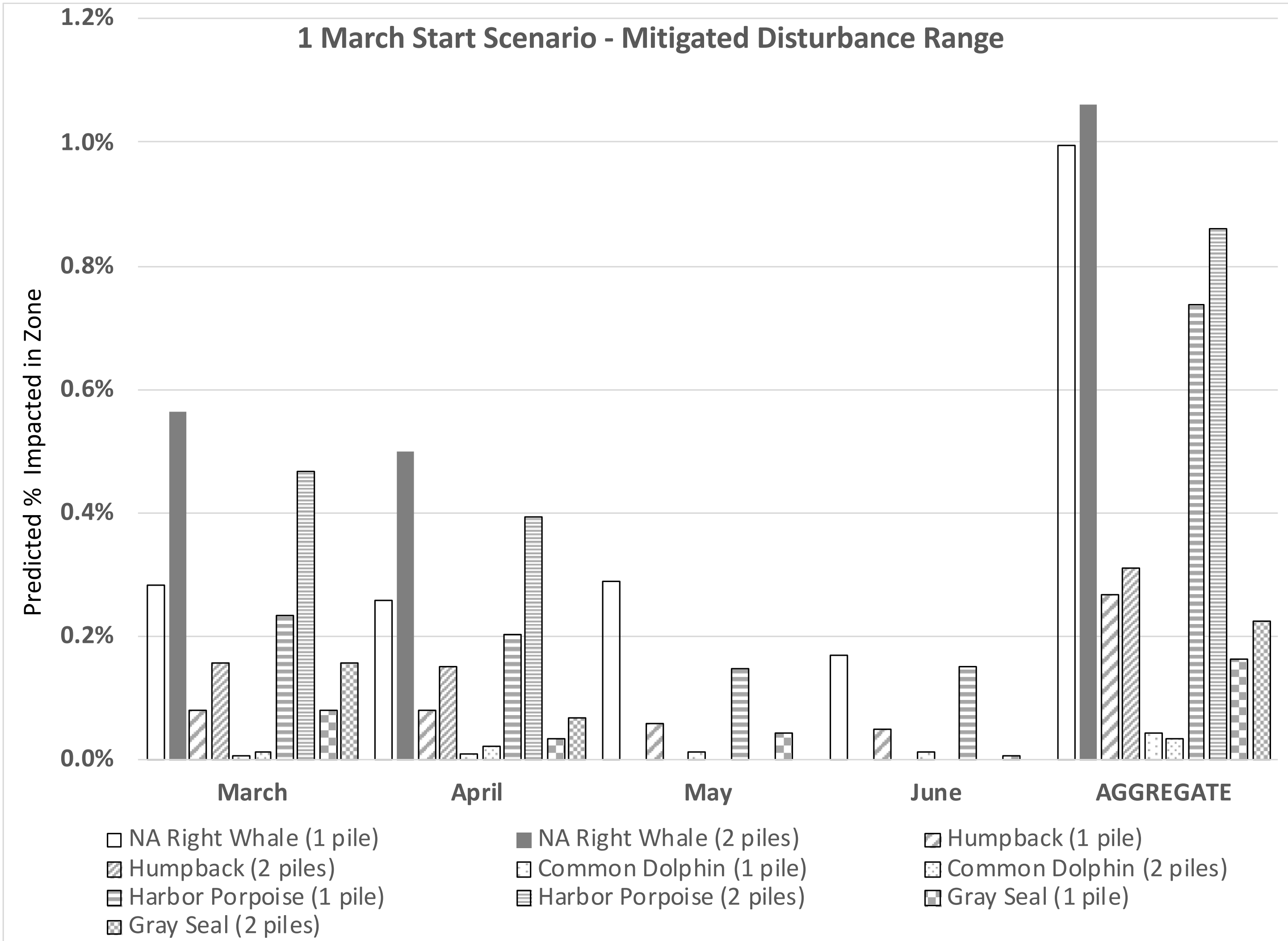


Figure 7. 1 March start scenario – 1 vs. 2 piles/day, mitigated disturbance ranges

(5 km for most species; 15 km for harbor porpoise)

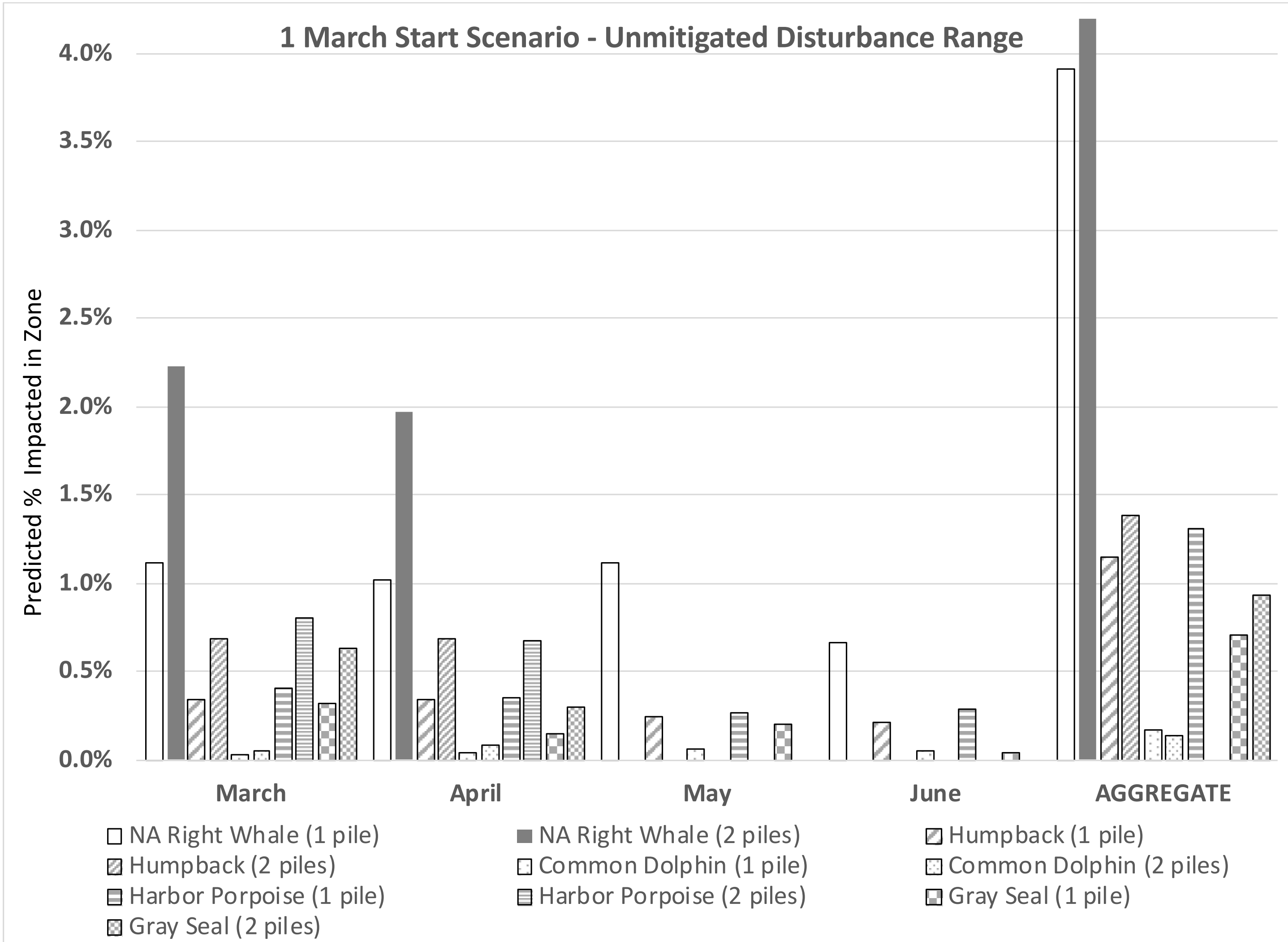


Figure 8. 1 March start scenario – 1 vs. 2 piles/day, unmitigated disturbance ranges

(10 km for most species; 20 km for harbor porpoise)

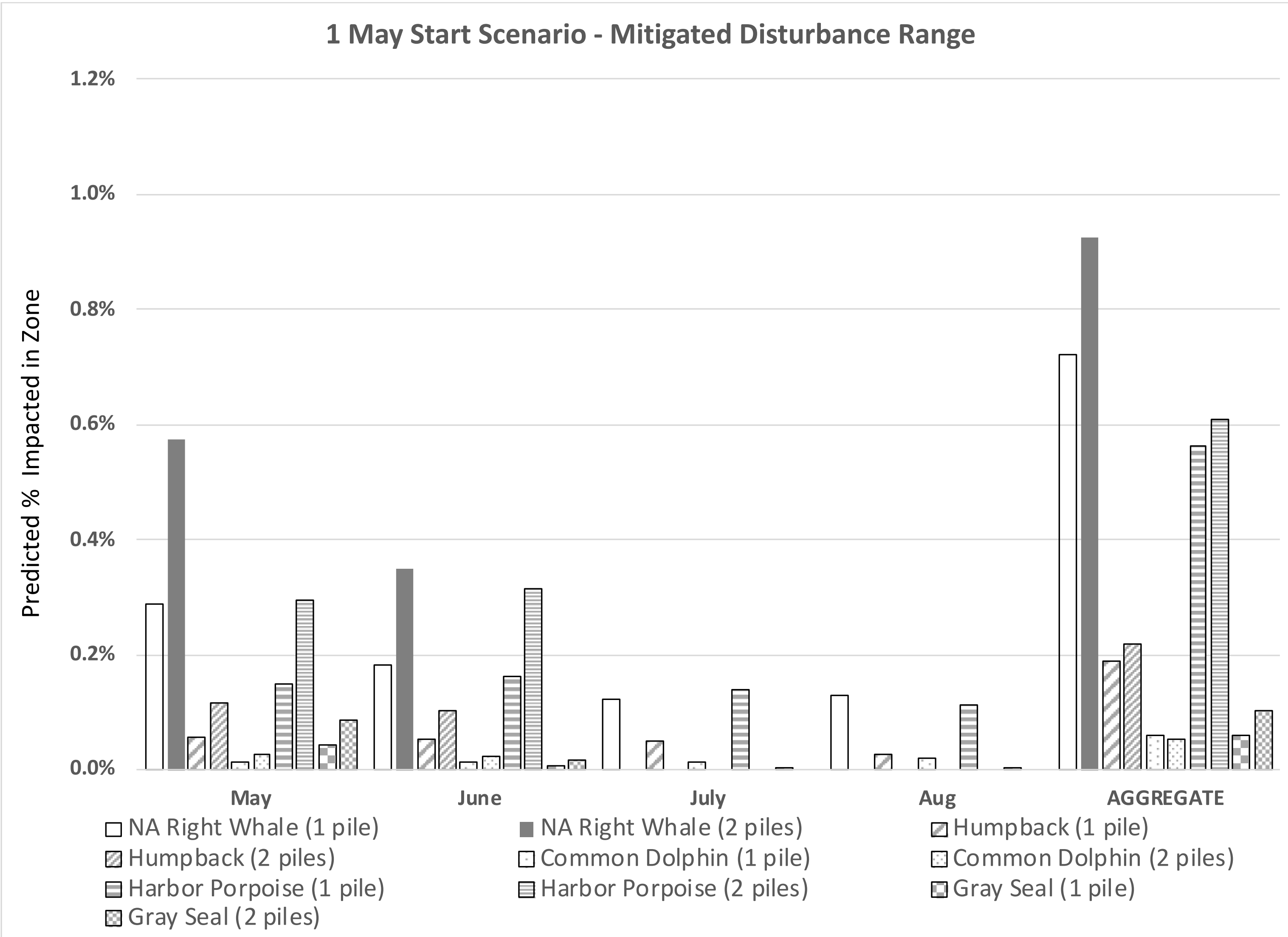


Figure 9. 1 May start scenario – 1 vs. 2 piles/day, mitigated disturbance ranges

(5 km for most species; 15 km for harbor porpoise)

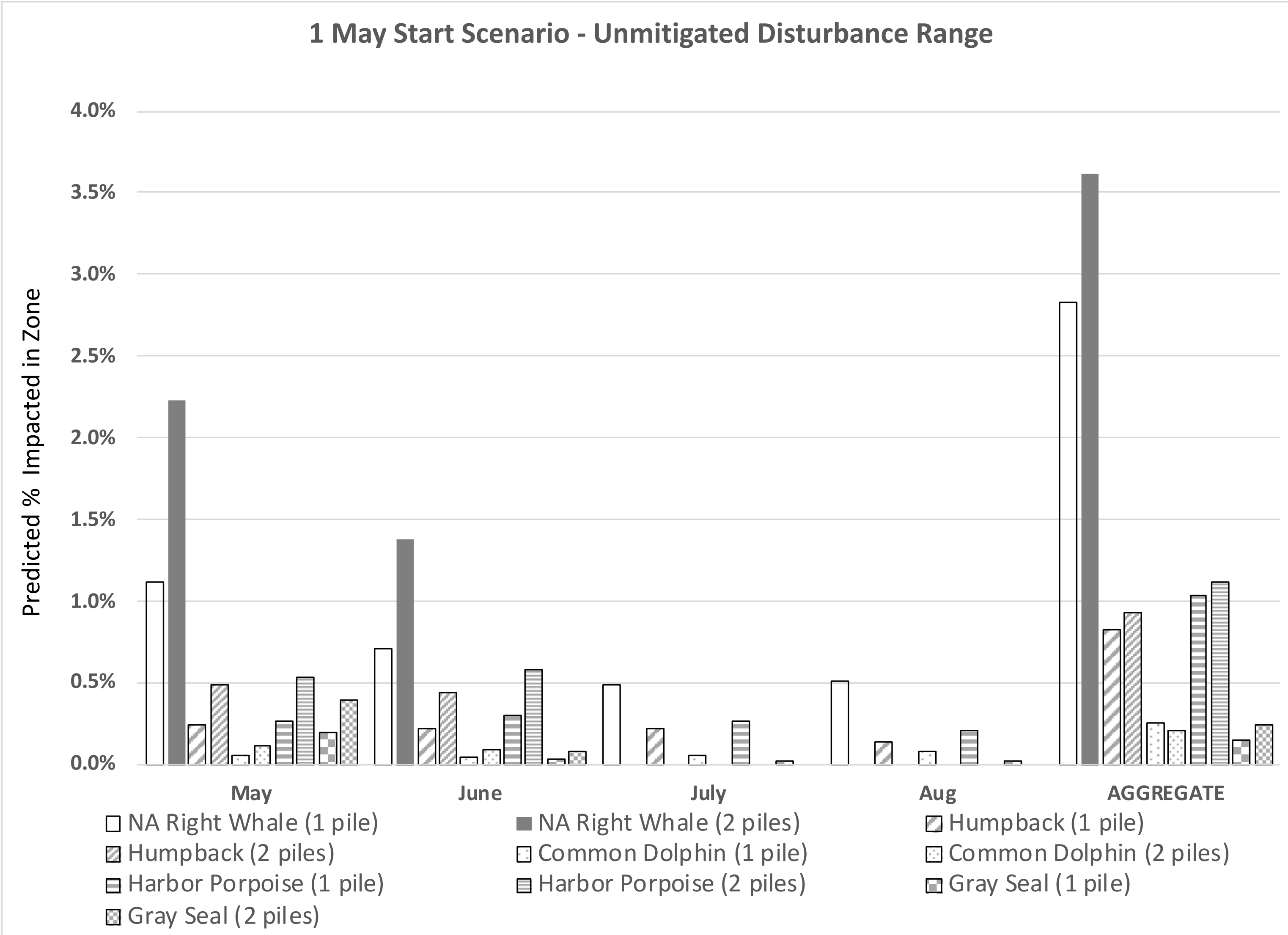


Figure 10. 1 May start scenario – 1 vs. 2 piles/day, unmitigated disturbance ranges

(10 km for most species; 20 km for harbor porpoise)

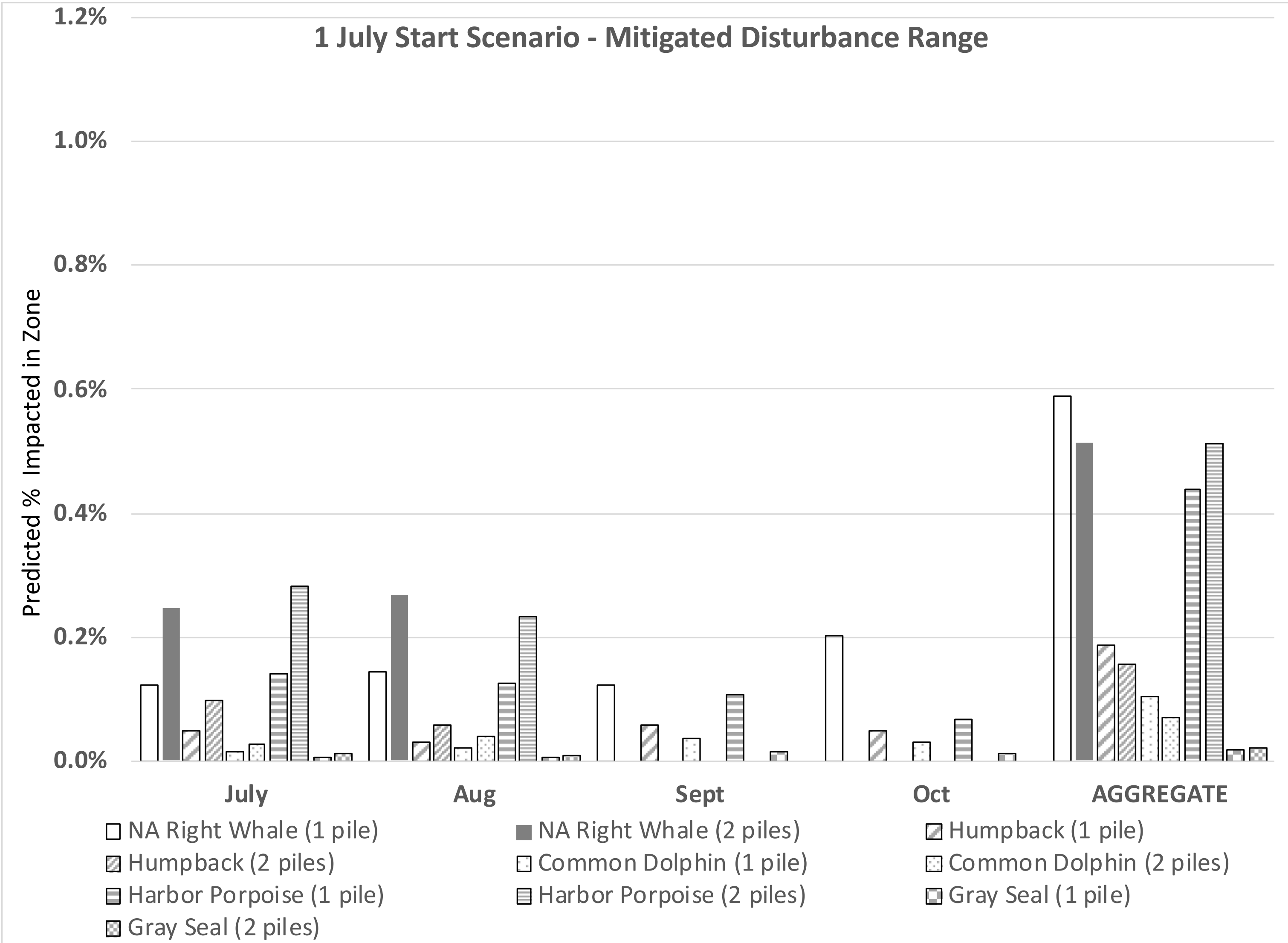


Figure 11. 1 July start scenario – 1 vs. 2 piles/day, mitigated disturbance ranges

(5 km for most species; 15 km for harbor porpoise)

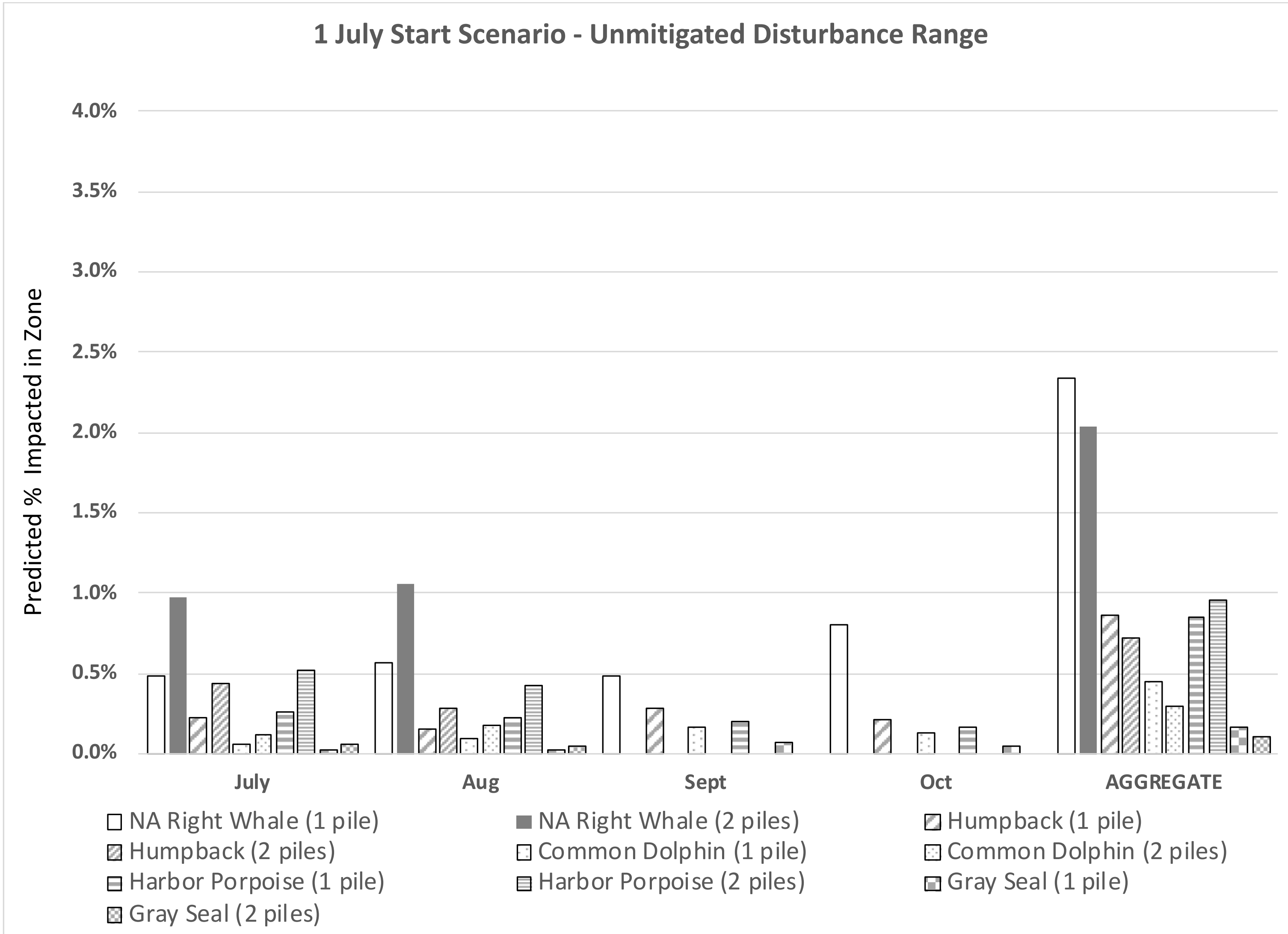
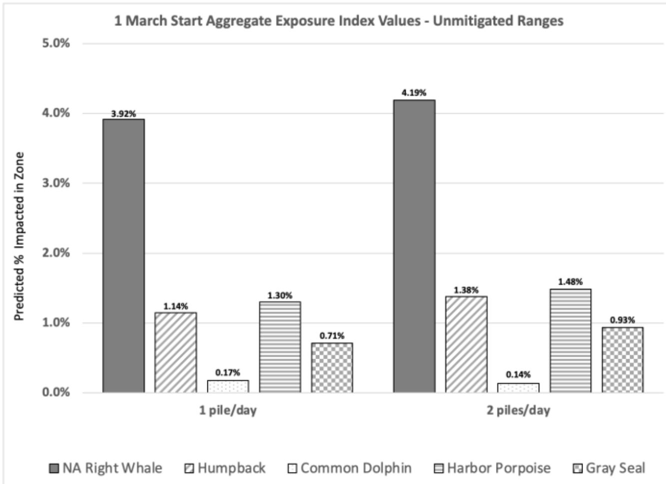
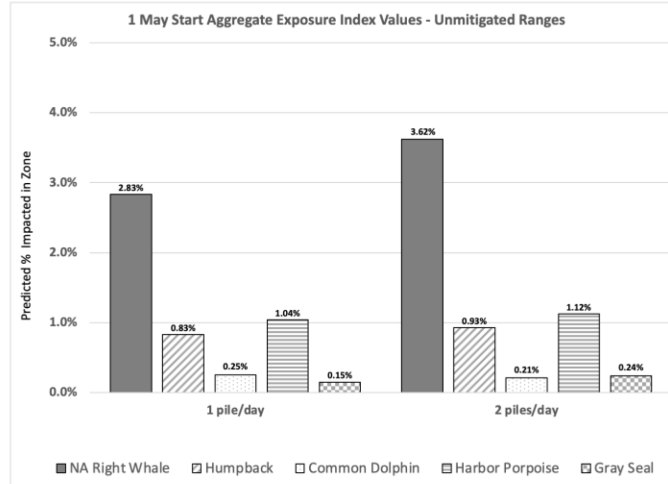


Figure 12. 1 July start scenario – 1 vs. 2 piles/day, unmitigated disturbance ranges

(10 km for most species; 20 km for harbor porpoise)





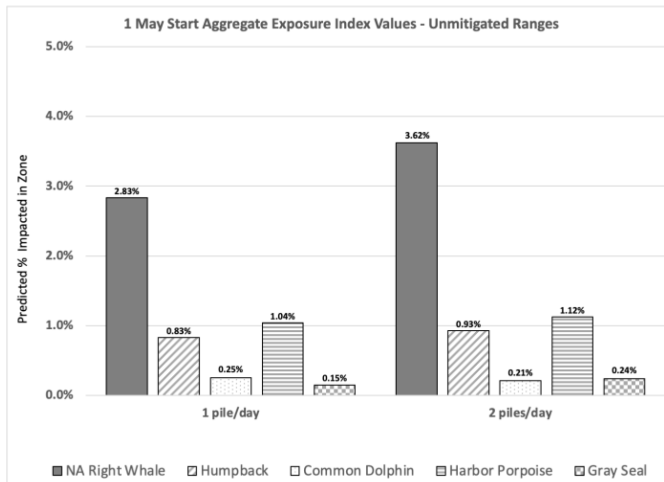


Figure 13. Aggregate exposure index values for 1 March (top), 1 May (middle), and 1 July scenarios for 1 pile/day and 2 piles/day with unmitigated disturbance ranges

(10 km for most species; 20 km for harbor porpoise)

Table 22. 1 March start scenario – North Atlantic right whale risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
1 March START (1 pile/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	0.1281%	0.1211%	0.0883%	0.0103%	n/a	n/a	n/a	n/a	n/a	n/a	0.3479%
	EXPOSURE INDEX (ZONE)	n/a	n/a	0.2814%	0.2582%	0.2874%	0.1693%	n/a	n/a	n/a	n/a	n/a	n/a	0.9962%
	VULNERABILITY RISK SCORE	20	20	26	26	24	22	16	16	16	17	18	20	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	HIGHEST	HIGHEST	HIGHEST	HIGHER	n/a	n/a	n/a	n/a	n/a	n/a	
1 March START (2 piles/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	0.2562%	0.2341%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.4903%
	EXPOSURE INDEX (ZONE)	n/a	n/a	0.5627%	0.4991%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.0619%
	VULNERABILITY RISK SCORE	20	20	26	26	24	22	16	16	16	17	18	20	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	HIGHEST	HIGHEST	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
1 March START (1 pile/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	0.5065%	0.4768%	0.3434%	0.0408%	n/a	n/a	n/a	n/a	n/a	n/a	1.3676%
	EXPOSURE INDEX (ZONE)	n/a	n/a	1.1125%	1.0167%	1.1173%	0.6686%	n/a	n/a	n/a	n/a	n/a	n/a	3.9151%
	VULNERABILITY RISK SCORE	20	20	26	26	24	22	16	16	16	17	18	20	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	HIGHEST	HIGHEST	HIGHEST	HIGHEST	n/a	n/a	n/a	n/a	n/a	n/a	
1 March START (2 piles/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	1.0131%	0.9218%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.9349%
	EXPOSURE INDEX (ZONE)	n/a	n/a	2.2251%	1.9655%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4.1906%
	VULNERABILITY RISK SCORE	20	20	26	26	24	22	16	16	16	17	18	20	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	HIGHEST	HIGHEST	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	

Table 23. 1 March start scenario – Humpback whale risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
1 March START (1 pile/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	0.0081%	0.0101%	0.0049%	0.0048%	n/a	n/a	n/a	n/a	n/a	n/a	0.0278%
	EXPOSURE INDEX (ZONE)	n/a	n/a	0.0792%	0.0787%	0.0581%	0.0501%	n/a	n/a	n/a	n/a	n/a	n/a	0.2661%
	VULNERABILITY RISK SCORE	11	8	16	16	14	14	9	9	9	9	9	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	LOWER	LOWER	LOWER	LOWER	n/a	n/a	n/a	n/a	n/a	n/a	
1 March START (2 piles/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	0.0162%	0.0194%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.0357%
	EXPOSURE INDEX (ZONE)	n/a	n/a	0.1583%	0.1522%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.3105%
	VULNERABILITY RISK SCORE	11	8	16	16	14	14	9	9	9	9	9	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	LOWER	LOWER	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
1 March START (1 pile/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	0.0354%	0.0438%	0.0207%	0.0201%	n/a	n/a	n/a	n/a	n/a	n/a	0.1200%
	EXPOSURE INDEX (ZONE)	n/a	n/a	0.3448%	0.3427%	0.2445%	0.2119%	n/a	n/a	n/a	n/a	n/a	n/a	1.1440%
	VULNERABILITY RISK SCORE	11	8	16	16	14	14	9	9	9	9	9	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	HIGHER	HIGHER	MODERATE	MODERATE	n/a	n/a	n/a	n/a	n/a	n/a	
1 March START (2 piles/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	0.0707%	0.0846%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.1553%
	EXPOSURE INDEX (ZONE)	n/a	n/a	0.6897%	0.6897%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.3793%
	VULNERABILITY RISK SCORE	11	8	16	16	14	14	9	9	9	9	9	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	HIGHEST	HIGHEST	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	

Table 24. 1 March start scenario – Common dolphin risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
1 March START (1 pile/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	0.0003%	0.0005%	0.0006%	0.0006%	n/a	n/a	n/a	n/a	n/a	n/a	0.0019%
	EXPOSURE INDEX (ZONE)	n/a	n/a	0.0062%	0.0107%	0.0140%	0.0114%	n/a	n/a	n/a	n/a	n/a	n/a	0.0423%
	VULNERABILITY RISK SCORE	9	8	7	7	7	8	8	8	8	8	8	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	LOWEST	LOWEST	LOWEST	LOWEST	n/a	n/a	n/a	n/a	n/a	n/a	
1 March START (2 piles/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	0.0005%	0.0009%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.0014%
	EXPOSURE INDEX (ZONE)	n/a	n/a	0.0124%	0.0207%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.0331%
	VULNERABILITY RISK SCORE	9	8	7	7	7	8	8	8	8	8	8	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	LOWEST	LOWEST	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
1 March START (1 pile/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	0.0010%	0.0019%	0.0025%	0.0024%	n/a	n/a	n/a	n/a	n/a	n/a	0.0079%
	EXPOSURE INDEX (ZONE)	n/a	n/a	0.0250%	0.0443%	0.0582%	0.0472%	n/a	n/a	n/a	n/a	n/a	n/a	0.1747%
	VULNERABILITY RISK SCORE	9	8	7	7	7	8	8	8	8	8	8	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	LOWEST	LOWEST	LOWEST	LOWEST	n/a	n/a	n/a	n/a	n/a	n/a	
1 March START (2 piles/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	0.0021%	0.0038%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.0058%
	EXPOSURE INDEX (ZONE)	n/a	n/a	0.0500%	0.0857%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.1357%
	VULNERABILITY RISK SCORE	9	8	7	7	7	8	8	8	8	8	8	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	LOWEST	LOWER	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	

Table 25. 1 March start scenario – Harbor porpoise risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
1 March START (1 pile/day; 15 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	0.0060%	0.1019%	0.0740%	0.0757%	n/a	n/a	n/a	n/a	n/a	n/a	0.0129%
	EXPOSURE INDEX (ZONE)	n/a	n/a	0.2334%	0.2038%	0.1481%	0.1515%	n/a	n/a	n/a	n/a	n/a	n/a	0.7368%
	VULNERABILITY RISK SCORE	11	11	11	10	10	9	8	8	7	8	10	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	MODERATE	MODERATE	LOWER	LOWER	n/a	n/a	n/a	n/a	n/a	n/a	
1 March START (2 piles/day; 15 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	0.0121%	0.0083%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.0204%
	EXPOSURE INDEX (ZONE)	n/a	n/a	0.4668%	0.3941%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.8609%
	VULNERABILITY RISK SCORE	11	11	11	10	10	9	8	8	7	8	10	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	HIGHER	MODERATE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
1 March START (1 pile/day; 20 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	0.0235%	0.0165%	0.0091%	0.0016%	n/a	n/a	n/a	n/a	n/a	n/a	0.0508%
	EXPOSURE INDEX (ZONE)	n/a	n/a	0.4034%	0.3495%	0.2689%	0.2827%	n/a	n/a	n/a	n/a	n/a	n/a	1.3046%
	VULNERABILITY RISK SCORE	11	11	11	10	10	9	8	8	7	8	10	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	MODERATE	MODERATE	MODERATE	MODERATE	n/a	n/a	n/a	n/a	n/a	n/a	
1 March START (2 piles/day; 20 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	0.0470%	0.0319%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.0790%
	EXPOSURE INDEX (ZONE)	n/a	n/a	0.8069%	0.6758%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.4826%
	VULNERABILITY RISK SCORE	11	11	11	10	10	9	8	8	7	8	10	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	HIGHER	HIGHER	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	

Table 26. 1 March start scenario – Gray seal risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
1 March START (1 pile/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	0.0303%	0.0187%	0.0254%	0.0013%	n/a	n/a	n/a	n/a	n/a	n/a	0.0756%
	EXPOSURE INDEX (ZONE)	n/a	n/a	0.0786%	0.0347%	0.0431%	0.0078%	n/a	n/a	n/a	n/a	n/a	n/a	0.1643%
	VULNERABILITY RISK SCORE	11	11	11	11	11	9	8	7	7	8	11	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	LOWER	LOWEST	LOWEST	LOWEST	n/a	n/a	n/a	n/a	n/a	n/a	
1 March START (2 piles/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	0.0605%	0.0361%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.0966%
	EXPOSURE INDEX (ZONE)	n/a	n/a	0.1573%	0.0670%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.2243%
	VULNERABILITY RISK SCORE	11	11	11	11	11	9	8	7	7	8	11	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	LOWER	LOWER	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
1 March START (1 pile/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	0.1225%	0.0823%	0.1181%	0.0063%	n/a	n/a	n/a	n/a	n/a	n/a	0.3293%
	EXPOSURE INDEX (ZONE)	n/a	n/a	0.3184%	0.1528%	0.2008%	0.0377%	n/a	n/a	n/a	n/a	n/a	n/a	0.7096%
	VULNERABILITY RISK SCORE	11	11	11	11	11	9	8	7	7	8	11	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	MODERATE	LOWER	MODERATE	LOWEST	n/a	n/a	n/a	n/a	n/a	n/a	
1 March START (2 piles/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	0.2451%	0.1592%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.4042%
	EXPOSURE INDEX (ZONE)	n/a	n/a	0.6369%	0.2953%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.9322%
	VULNERABILITY RISK SCORE	11	11	11	11	11	9	8	7	7	8	11	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	HIGHER	MODERATE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	

Table 27. 1 May start scenario – North Atlantic right whale risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
1 May START (1 pile/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	0.0883%	0.0111%	0.0025%	0.0042%	n/a	n/a	n/a	n/a	0.11%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	0.2874%	0.1814%	0.1226%	0.1294%	n/a	n/a	n/a	n/a	0.72%
	VULNERABILITY RISK SCORE	20	20	21	21	24	22	23	21	16	17	18	20	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	HIGHEST	MODERATE	MODERATE	MODERATE	n/a	n/a	n/a	n/a	
1 May START (2 piles/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	0.1766%	0.0214%	n/a	n/a	n/a	n/a	n/a	n/a	0.1981%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	0.5747%	0.3506%	n/a	n/a	n/a	n/a	n/a	n/a	0.9254%
	VULNERABILITY RISK SCORE	20	20	21	21	24	22	23	21	16	17	18	20	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	HIGHEST	HIGHER	n/a	n/a	n/a	n/a	n/a	n/a	
1 May START (1 pile/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	0.3434%	0.0438%	0.0101%	0.0165%	n/a	n/a	n/a	n/a	0.4138%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	1.1173%	0.7163%	0.4861%	0.5119%	n/a	n/a	n/a	n/a	2.8316%
	VULNERABILITY RISK SCORE	20	20	21	21	24	22	23	21	16	17	18	20	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	HIGHEST	HIGHEST	HIGHEST	HIGHEST	n/a	n/a	n/a	n/a	
1 May START (2 piles/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	0.6868%	0.0846%	n/a	n/a	n/a	n/a	n/a	n/a	0.7714%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	2.2347%	1.3849%	n/a	n/a	n/a	n/a	n/a	n/a	3.6195%
	VULNERABILITY RISK SCORE	20	20	21	21	24	22	23	21	16	17	18	20	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	HIGHEST	HIGHEST	n/a	n/a	n/a	n/a	n/a	n/a	

Table 28. 1 May start scenario – Humpback whale risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
1 May START (1 pile/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	0.0049%	0.0051%	0.0033%	0.0014%	n/a	n/a	n/a	n/a	0.0148%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	0.0581%	0.0537%	0.0495%	0.0282%	n/a	n/a	n/a	n/a	0.1895%
	VULNERABILITY RISK SCORE	11	8	11	11	14	14	17	14	9	9	9	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	LOWER	LOWER	LOWER	LOWER	n/a	n/a	n/a	n/a	
1 May START (2 piles/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	0.0098%	0.0099%	n/a	n/a	n/a	n/a	n/a	n/a	0.0197%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	0.1161%	0.1039%	n/a	n/a	n/a	n/a	n/a	n/a	0.2200%
	VULNERABILITY RISK SCORE	11	8	11	11	14	14	17	14	9	9	9	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	LOWER	LOWER	n/a	n/a	n/a	n/a	n/a	n/a	
1 May START (1 pile/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	0.0207%	0.0216%	0.0148%	0.0068%	n/a	n/a	n/a	n/a	0.0639%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	0.2445%	0.2270%	0.2203%	0.1352%	n/a	n/a	n/a	n/a	0.8271%
	VULNERABILITY RISK SCORE	11	8	11	11	14	14	17	14	9	9	9	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	MODERATE	MODERATE	MODERATE	LOWER	n/a	n/a	n/a	n/a	
1 May START (2 piles/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	0.0414%	0.0417%	n/a	n/a	n/a	n/a	n/a	n/a	0.0831%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	0.4891%	0.4390%	n/a	n/a	n/a	n/a	n/a	n/a	0.9281%
	VULNERABILITY RISK SCORE	11	8	11	11	14	14	17	14	9	9	9	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	HIGHEST	HIGHEST	n/a	n/a	n/a	n/a	n/a	n/a	

Table 29. 1 May start scenario – Common dolphin risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
1 May START (1 pile/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	0.0006%	0.0006%	0.0008%	0.0016%	n/a	n/a	n/a	n/a	0.0036%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	0.0140%	0.0122%	0.0142%	0.0195%	n/a	n/a	n/a	n/a	**0.0599%**
	VULNERABILITY RISK SCORE	9	8	7	7	7	8	8	8	8	8	8	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	LOWEST	LOWEST	LOWEST	LOWEST	n/a	n/a	n/a	n/a	
1 May START (2 piles/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	0.0012%	0.0012%	n/a	n/a	n/a	n/a	n/a	n/a	0.0024%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	0.0280%	0.0236%	n/a	n/a	n/a	n/a	n/a	n/a	**0.0516%**
	VULNERABILITY RISK SCORE	9	8	7	7	7	8	8	8	8	8	8	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	LOWEST	LOWEST	n/a	n/a	n/a	n/a	n/a	n/a	
1 May START (1 pile/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	0.0025%	0.0026%	0.0035%	0.0068%	n/a	n/a	n/a	n/a	0.0154%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	0.0582%	0.0505%	0.0613%	0.0840%	n/a	n/a	n/a	n/a	**0.2540%**
	VULNERABILITY RISK SCORE	9	8	7	7	7	8	8	8	8	8	8	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	LOWEST	LOWEST	LOWER	LOWER	n/a	n/a	n/a	n/a	
1 May START (2 piles/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	0.0050%	0.0050%	n/a	n/a	n/a	n/a	n/a	n/a	0.0100%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	0.1164%	0.0977%	n/a	n/a	n/a	n/a	n/a	n/a	**0.2141%**
	VULNERABILITY RISK SCORE	9	8	7	7	7	8	8	8	8	8	8	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	LOWER	LOWER	n/a	n/a	n/a	n/a	n/a	n/a	

Table 30. 1 May start scenario – Harbor porpoise risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
1 May START (1 pile/day; 15 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	0.0022%	0.0004%	0.0001%	0.0001%	n/a	n/a	n/a	n/a	0.0029%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	0.1481%	0.1623%	0.1406%	0.1122%	n/a	n/a	n/a	n/a	0.5631%
	VULNERABILITY RISK SCORE	11	11	11	10	10	9	8	8	7	8	10	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	LOWER	LOWER	LOWER	LOWER	n/a	n/a	n/a	n/a	
1 May START (2 piles/day; 15 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	0.0045%	0.0008%	n/a	n/a	n/a	n/a	n/a	n/a	0.0053%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	0.2962%	0.3137%	n/a	n/a	n/a	n/a	n/a	n/a	0.6099%
	VULNERABILITY RISK SCORE	11	11	11	10	10	9	8	8	7	8	10	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	MODERATE	MODERATE	n/a	n/a	n/a	n/a	n/a	n/a	
1 May START (1 pile/day; 20 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	0.0091%	0.0017%	0.0005%	0.0003%	n/a	n/a	n/a	n/a	0.0117%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	0.2689%	0.3029%	0.2628%	0.2067%	n/a	n/a	n/a	n/a	1.0413%
	VULNERABILITY RISK SCORE	11	11	11	10	10	9	8	8	7	8	10	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	MODERATE	MODERATE	MODERATE	MODERATE	n/a	n/a	n/a	n/a	
1 May START (2 piles/day; 20 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	0.0183%	0.0033%	n/a	n/a	n/a	n/a	n/a	n/a	0.0216%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	0.5379%	0.5856%	n/a	n/a	n/a	n/a	n/a	n/a	1.1235%
	VULNERABILITY RISK SCORE	11	11	11	10	10	9	8	8	7	8	10	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	HIGHER	HIGHER	n/a	n/a	n/a	n/a	n/a	n/a	

Table 31. 1 May start scenario – Gray seal risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI FOR SCENARIO
1 May START (1 pile/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	0.0254%	0.0014%	0.0003%	0.0002%	n/a	n/a	n/a	n/a	0.0273%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	0.0431%	0.0084%	0.0051%	0.0046%	n/a	n/a	n/a	n/a	0.0612%
	VULNERABILITY RISK SCORE	11	11	11	11	11	9	8	7	7	8	11	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	LOWEST	LOWEST	LOWEST	LOWEST	n/a	n/a	n/a	n/a	
1 May START (2 piles/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	0.0507%	0.0027%	n/a	n/a	n/a	n/a	n/a	n/a	0.0535%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	0.0862%	0.0163%	n/a	n/a	n/a	n/a	n/a	n/a	0.1025%
	VULNERABILITY RISK SCORE	11	11	11	11	11	9	8	7	7	8	11	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	LOWER	LOWEST	n/a	n/a	n/a	n/a	n/a	n/a	
1 May START (1 pile/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	0.1181%	0.0068%	0.0015%	0.0011%	n/a	n/a	n/a	n/a	0.1276%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	0.2008%	0.0403%	0.0280%	0.0248%	n/a	n/a	n/a	n/a	0.1470%
	VULNERABILITY RISK SCORE	11	11	11	11	11	9	8	7	7	8	11	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	MODERATE	LOWEST	LOWEST	LOWEST	n/a	n/a	n/a	n/a	
1 May START (2 piles/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	0.2363%	0.0131%	n/a	n/a	n/a	n/a	n/a	n/a	0.2494%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	0.4016%	0.0780%	n/a	n/a	n/a	n/a	n/a	n/a	0.2398%
	VULNERABILITY RISK SCORE	11	11	11	11	11	9	8	7	7	8	11	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	MODERATE	LOWER	n/a	n/a	n/a	n/a	n/a	n/a	

Table 32. 1 July start scenario – North Atlantic right whale risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
1 July START (1 pile/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0025%	0.0046%	0.0038%	0.0173%	n/a	n/a	0.0283%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.1226%	0.1432%	0.1210%	0.2022%	n/a	n/a	0.5890%
	VULNERABILITY RISK SCORE	20	20	21	21	19	17	23	21	23	22	18	20	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	MODERATE	MODERATE	MODERATE	MODERATE	n/a	n/a	
1 July START (2 piles/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0051%	0.0087%	n/a	n/a	n/a	n/a	0.0137%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.2452%	0.2680%	n/a	n/a	n/a	n/a	0.5132%
	VULNERABILITY RISK SCORE	20	20	21	21	19	17	23	21	23	22	18	20	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	MODERATE	MODERATE	n/a	n/a	n/a	n/a	
1 July START (1 pile/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0101%	0.0183%	0.0150%	0.0691%	n/a	n/a	0.1125%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.4861%	0.5667%	0.4814%	0.8056%	n/a	n/a	2.3398%
	VULNERABILITY RISK SCORE	20	20	21	21	19	17	23	21	23	22	18	20	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	HIGHEST	HIGHEST	HIGHEST	HIGHEST	n/a	n/a	
1 July START (2 piles/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0202%	0.0343%	n/a	n/a	n/a	n/a	0.0544%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.9722%	1.0603%	n/a	n/a	n/a	n/a	2.0325%
	VULNERABILITY RISK SCORE	20	20	21	21	19	17	23	21	23	22	18	20	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	HIGHEST	HIGHEST	n/a	n/a	n/a	n/a	

Table 33. 1 July start scenario – Humpback whale risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
1 July START (1 pile/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0033%	0.0016%	0.0040%	0.0039%	n/a	n/a	0.0128%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.0495%	0.0312%	0.0582%	0.0473%	n/a	n/a	0.1862%
	VULNERABILITY RISK SCORE	11	8	11	11	9	9	17	14	17	14	9	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	LOWER	LOWER	LOWER	LOWER	n/a	n/a	
1 July START (2 piles/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0066%	0.0029%	n/a	n/a	n/a	n/a	0.0096%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.0990%	0.0584%	n/a	n/a	n/a	n/a	0.1574%
	VULNERABILITY RISK SCORE	11	8	11	11	9	9	17	14	17	14	9	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	LOWER	LOWER	n/a	n/a	n/a	n/a	
1 July START (1 pile/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0148%	0.0075%	0.0193%	0.0176%	n/a	n/a	0.0593%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.2203%	0.1496%	0.2809%	0.2141%			0.8649%
	VULNERABILITY RISK SCORE	11	8	11	11	9	9	17	14	17	14	9	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	MODERATE	LOWER	HIGHER	MODERATE	n/a	n/a	
1 July START (2 piles/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0296%	0.0141%	n/a	n/a	n/a	n/a	0.0437%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.4407%	0.2800%	n/a	n/a	n/a	n/a	0.7206%
	VULNERABILITY RISK SCORE	11	8	11	11	9	9	17	14	17	14	9	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	HIGHER	HIGHER	n/a	n/a	n/a	n/a	

Table 34. 1 July start scenario – Common dolphin risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
1 July START (1 pile/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0008%	0.0018%	0.0029%	0.0027%	n/a	n/a	0.0082%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.0142%	0.0216%	0.0370%	0.0303%	n/a	n/a	0.1031%
	VULNERABILITY RISK SCORE	9	8	7	7	7	8	8	8	8	8	8	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	LOWEST	LOWEST	LOWEST	LOWEST	n/a	n/a	
1 July START (2 piles/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0016%	0.0033%	n/a	n/a	n/a	n/a	0.0049%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.0284%	0.0404%	n/a	n/a	n/a	n/a	0.0688%
	VULNERABILITY RISK SCORE	9	8	7	7	7	8	8	8	8	8	8	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	LOWEST	LOWEST	n/a	n/a	n/a	n/a	
1 July START (1 pile/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0035%	0.0076%	0.0128%	0.0115%	n/a	n/a	0.0353%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.0613%	0.0930%	0.1610%	0.1286%	n/a	n/a	0.4438%
	VULNERABILITY RISK SCORE	9	8	7	7	7	8	8	8	8	8	8	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	LOWER	LOWER	LOWER	LOWER	n/a	n/a	
1 July START (2 piles/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0070%	0.0141%	n/a	n/a	n/a	n/a	0.0211%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.1225%	0.1739%	n/a	n/a	n/a	n/a	0.2965%
	VULNERABILITY RISK SCORE	9	8	7	7	7	8	8	8	8	8	8	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	LOWER	LOWER	n/a	n/a	n/a	n/a	

Table 35. 1 July start scenario – Harbor porpoise risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
1 July START (1 pile/day; 15 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0001%	0.0001%	0.0001%	0.0003%	n/a	n/a	0.0006%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.1406%	0.1242%	0.1056%	0.0666%	n/a	n/a	0.4370%
	VULNERABILITY RISK SCORE	11	11	11	10	10	9	8	8	7	8	10	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	LOWER	LOWER	LOWER	LOWER	n/a	n/a	
1 July START (2 piles/day; 15 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0003%	0.0002%	n/a	n/a	n/a	n/a	0.0004%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.2812%	0.2323%	n/a	n/a	n/a	n/a	0.5135%
	VULNERABILITY RISK SCORE	11	11	11	10	10	9	8	8	7	8	10	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	MODERATE	MODERATE	n/a	n/a	n/a	n/a	
1 Juky START (1 pile/day; 20 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0005%	0.0004%	0.0005%	0.0016%	n/a	n/a	0.0030%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.2628%	0.2288%	0.1985%	0.1621%	n/a	n/a	0.8522%
	VULNERABILITY RISK SCORE	11	11	11	10	10	9	8	8	7	8	10	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	MODERATE	MODERATE	MODERATE	LOWER	n/a	n/a	
1 July START (2 piles/day; 20 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0011%	0.0007%	n/a	n/a	n/a	n/a	0.0017%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.5256%	0.4281%	n/a	n/a	n/a	n/a	0.9537%
	VULNERABILITY RISK SCORE	11	11	11	10	10	9	8	8	7	8	10	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	HIGHER	HIGHER	n/a	n/a	n/a	n/a	

Table 36. 1 July start scenario – Gray seal risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI FOR SCENARIO
1 July START (1 pile/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0003%	0.0002%	0.0007%	0.0010%	n/a	n/a	0.0022%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.0051%	0.0051%	0.0143%	0.0104%	n/a	n/a	0.0349%
	VULNERABILITY RISK SCORE	11	11	11	11	11	9	8	7	7	8	11	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	LOWEST	LOWEST	LOWEST	LOWEST	n/a	n/a	
1 July START (2 piles/day; 5 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0006%	0.0004%	n/a	n/a	n/a	n/a	0.0010%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.0102%	0.0096%	n/a	n/a	n/a	n/a	0.0198%
	VULNERABILITY RISK SCORE	11	11	11	11	11	9	8	7	7	8	11	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	LOWEST	LOWEST	n/a	n/a	n/a	n/a	
1 July START (1 pile/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0015%	0.0012%	0.0032%	0.0043%	n/a	n/a	0.0102%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.0280%	0.0275%	0.0658%	0.0458%	n/a	n/a	0.1671%
	VULNERABILITY RISK SCORE	11	11	11	11	11	9	8	7	7	8	11	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	LOWEST	LOWEST	LOWER	LOWEST	n/a	n/a	
1 July START (2 piles/day; 10 km disturbance)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0031%	0.0023%	n/a	n/a	n/a	n/a	0.0054%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.0559%	0.0515%	n/a	n/a	n/a	n/a	0.1074%
	VULNERABILITY RISK SCORE	11	11	11	11	11	9	8	7	7	8	11	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	LOWEST	LOWEST	n/a	n/a	n/a	n/a	

Installation Year 1 Scenario Discussion

We evaluated a considerable number of different scenarios for this year for the installation of 120 piles for a single windfarm (#1) off the MA coast within the existing lease areas. Scenario comparisons were across three potential start dates through the year, for unmitigated and mitigated turbine installation and for 1 versus 2 piles/day. As the risk assessments conducted are intended to provide a relativistic assessment of different conditions of disturbance both across species in the same scenarios and within species across multiple scenarios, it is useful to consider the results in this manner.

Looking across scenarios, several patterns and observations emerge:

- Across scenarios and species, considerable temporal variance exists in both exposure index scores and vulnerability. An important component of these differences are attributable to variability in the relative occurrence of animals within the specified zone overall (e.g., as a result of migration patterns) as well as finer scale differences of habitat use for animals within the zone (e.g., local concentrations in density related to patterns of foraging and attendance to young for amphibious species such as gray seals). For example, February through April >40% of the regional population of NARW are found in zone 2, whereas this drops to 1.5% in July. Gray seals in zone 2 represent 54-58% of the regional population in April and May, reducing to <6% in July through September (see Table 8). In general, integrated risk is assessed higher for NARW (noting their higher vulnerability), lower for common dolphins and in some periods, gray seals (noting both species have low assessed vulnerability). While harbor porpoise also have low vulnerability, large acoustic impact zones can result in higher integrated risk in summer months when a larger relative fraction of the zone population are exposed. It is noted that finer scale and more direct data on habitat use patterns and factors that may favor aggregation (e.g., prey patchiness) probably strongly influence these patterns on smaller temporal and spatial scales and room for improvement in modeling these important sources of variance remain.
- Not surprisingly, assessed risk in the 'mitigated' (5 or 15 km disturbance) scenarios is universally lower than risk in the 'unmitigated' (10 or 20 km disturbance) scenarios, given the sometimes large differences in exposure index scores. Aggregate regional exposure index percent decrease by around 4-fold when disturbance is reduced from 10 to 5 km and by a little under 2-fold when disturbance is reduced from 20 to 15 km (harbor porpoise only). This can result in as little as a single lower step in the integrated risk rating but can be as much as three (of five) steps difference in some instances (e.g., humpback whales in the 1 March start scenarios). It should be noted that the differences in the basic assumption of 120 and/or 160 dB RL values as median disturbance points and their occurring at the presumed ranges based on mitigation measures such as bubble curtains have not been fully scientifically demonstrated and additional research in this regard is needed. This is particularly important in seeing the magnitude of presumed differences in risk for some instances here.
- During months where two piles/day were driven, exposure index values are approximately double and consequently associated risk assessment scores are

generally equal to or one step higher than for the same month for one pile/day scenarios. However, when one considers the zone aggregates, aggregate exposure index values are lower overall in many contexts, sometimes substantially so, for some scenarios in which two piles/day were driven as opposed to the four months in which one pile/day were driven for the same species and disturbance range. This phenomenon is particularly evident in the summer and early fall months (e.g., the 1 July start scenario) for four of the five species, including the critically endangered North Atlantic right whale. This phenomenon was also observed for common dolphins for a 1 May start. For common dolphins and gray seals, the 1 July start aggregate exposure index percent reductions in the 2 piles/day scenarios are 33-36%, while for baleen whales the reduction is around 15%. This observation is amplified by several observations in the year 2 scenarios. In contrast, for a 1 March start, 2 piles/day increase the aggregate percent by 10-30% over a 1 pile/day schedule. The beneficial effect or not of piling over two months (at 2 piles/day) rather than four months (at 1 pile/day) thus depends largely on how animal density varies over those four months, pointing to strategic possible tactics to reduce risk. The results of this scenario importantly highlight the logical fact that if you can target two consecutive low-density months and pile at 2 piles/day, considerable exposure reduction benefits can be accrued compared to a longer period of 1 pile/day.

Evaluating results within species across scenarios, we offer the following observations:

- Not surprisingly, assessed risk was highest for North Atlantic right whales in essentially all scenarios considered. Given their critically endangered status, current population trend, seasonal use of this habitat, and other known and well-documented stressors, both the exposure indices and vulnerability scores are relatively higher across the board than for most other species. However, within that context, there are clearly periods of the year in which scenarios were run, notably late summer and early fall, for which exposure indices and vulnerability scores are relatively much lower than other periods (e.g., spring), including some scenarios in which lower to moderate impact were predicted.
- Humpback whales had lower risk overall than right whales but higher risk than other species in most scenarios, in part due to higher masking factor scores due to their presumed low frequency hearing and the low-frequency nature of the pile driving spectra. While not as clear of a pattern as evident with right whales, for some scenarios relative risk is also lower in the late summer and fall months. Both NARW and humpback whales have a high spectral index factor compared with the remaining species. This weighting results in relatively higher exposures index values, all other things being equal.
- Common dolphins generally had low assessed risk overall, resulting from generally low exposure index values and consistently low vulnerability scores. The only period of the year in which moderate or higher integrated risk scores were observed were in the spring months for the 1 March start scenario for common dolphins.

- Assessed risk for harbor porpoise was moderate overall in comparison with the other four species assessed. It should be noted that assumptions regarding their sensitivity are extrapolated from other scenarios mostly in European waters and laboratory studies. Further, limited at-sea observations support the distribution of this species in the offshore areas being considered here. Given these caveats, with the assumptions made here, the lowest risk overall for harbor porpoise was actually in the early and mid-summer, with higher assessed risk in the spring and into the fall.
- The same limitations regarding limited direct information on distribution in the areas considered for installations here certainly exist for gray seals and remain an area of needed better direct measurements. But with the available information, overall risk across scenarios is generally lower for gray seals than most other species. Further, the lowest risk periods for these areas and scenarios for this species occur in our analyses in the late summer and fall.

In terms of overall assessments of the single windfarm installation scenario we make the following conclusions and recommendations regarding potential impacts and mitigation. The assessed higher overall risk for right whales is clearly not surprising, nor is the temporal pattern favoring seasonal mitigation with operations in the late summer and fall months being a logical mitigation. We would add several further observations, however. Such an approach would also be marginally favorable to reducing risk for several other protected species (humpback whales and gray seals), while having little or no change in risk for common dolphins but a slightly elevated risk potentially for harbor porpoise. On balance it would seem an obvious strategy to look toward the 1 July (or later) start scenario as a means of risk reduction using these results in a strategic sense. The developed framework is thus useful for mangers to scenario-test various timing options and look at how risk accumulates across multiple different species or targeted species. This can provide valuable focus for balancing mitigation actions across species.

Further, we suggest it is important to consider the comparative observations from both the mitigated versus unmitigated scenarios as well as the one versus two piles/day comparisons. Clearly, further validation is needed regarding both the disturbance range assumptions and efficacy of mitigation measures to validate the assumptions used herein. We again note that the modular and adaptive nature of the framework enables easily integrating new information. But given the assumptions used herein, the differences in relative risk for the mitigated cases were substantial in many cases. The fact that there is a universally less-than-expected increase in disturbance for two piles/day relative to one pile/day and the fact that for many scenarios, especially during the highest priority months (e.g., Aug-Sept) and when viewed in terms of the aggregate exposure index metric, argues for seriously considering the merits of installation during periods of low visibility as an overall mitigation approach. Notably, when comparing installation of 1 versus 2 piles/day, we have calculated the maximum impact area with the activity index (i.e. no overlap between potential impact areas). These values are 1.6-1.9 times higher (depending on the 5-20 km impact radii) than if one assumes a 1 nautical mile separation between the 2 piles installed in a day and that the two impact areas overlap accordingly. This minimum estimate of impact area assumption results in a significant reduction in estimated exposure when 2 piles/day are installed, but is very reliant on a robust understanding of short term responses of an animal to piling. These results suggest that condensing piling over a shorter period (2 vs. 4 months) reduces overall risk to multiple species during certain periods, notably those with lower overall species presence, even though exposure index values are higher during those active two months. This effect could actually be more prominent if assumptions about the spatial and temporal patterns of pile driving made herein (subsequent piles not necessarily being adjacent to one another, are not representative of real conditions. We suggest consideration of condensing installation disturbance during periods where key species (e.g., right whales) occur at the lowest possible abundance and thus presumed risk of disturbance. We would also note other relevant arguments for such an approach from a behavioral response perspective (animals may be less likely to enter areas where high received levels exist if there are not long periods lacking disturbance during installation periods),

4.2. Installation Year 2 Scenarios: Installation of windfarms #1 and 2 - varying degrees of temporal overlap

For this scenario, installation is presumed to occur in different time windows at both the larger windfarm (#1) and the smaller windfarm (#2), with 60 piles being driven at each site. These temporal patterns include: no overlap ('sequential installation' at windfarm #1 for two months and then windfarm #2 for two months); 'partial overlap' (windfarm #1 only for a month, both windfarms for a month, windfarm #2 for a month); and 'total overlap' (both windfarms simultaneously for two months). The period of the year for these scenarios (late summer/early fall) was selected based on the observations described about most logical seasonal mitigation approaches and likely actual installation periods. The 1 pile/day installation for unmitigated disturbance ranges (10 or 20 km) are presumed for all installations in these scenarios. Exposure index results for each scenario across all species and months, as well as aggregate score results (all months summed for each species), are given for each of the three scenarios (Figs. 14-17). These are followed by integrated assessed risk in each scenario for each focal species (Tables 37-41).

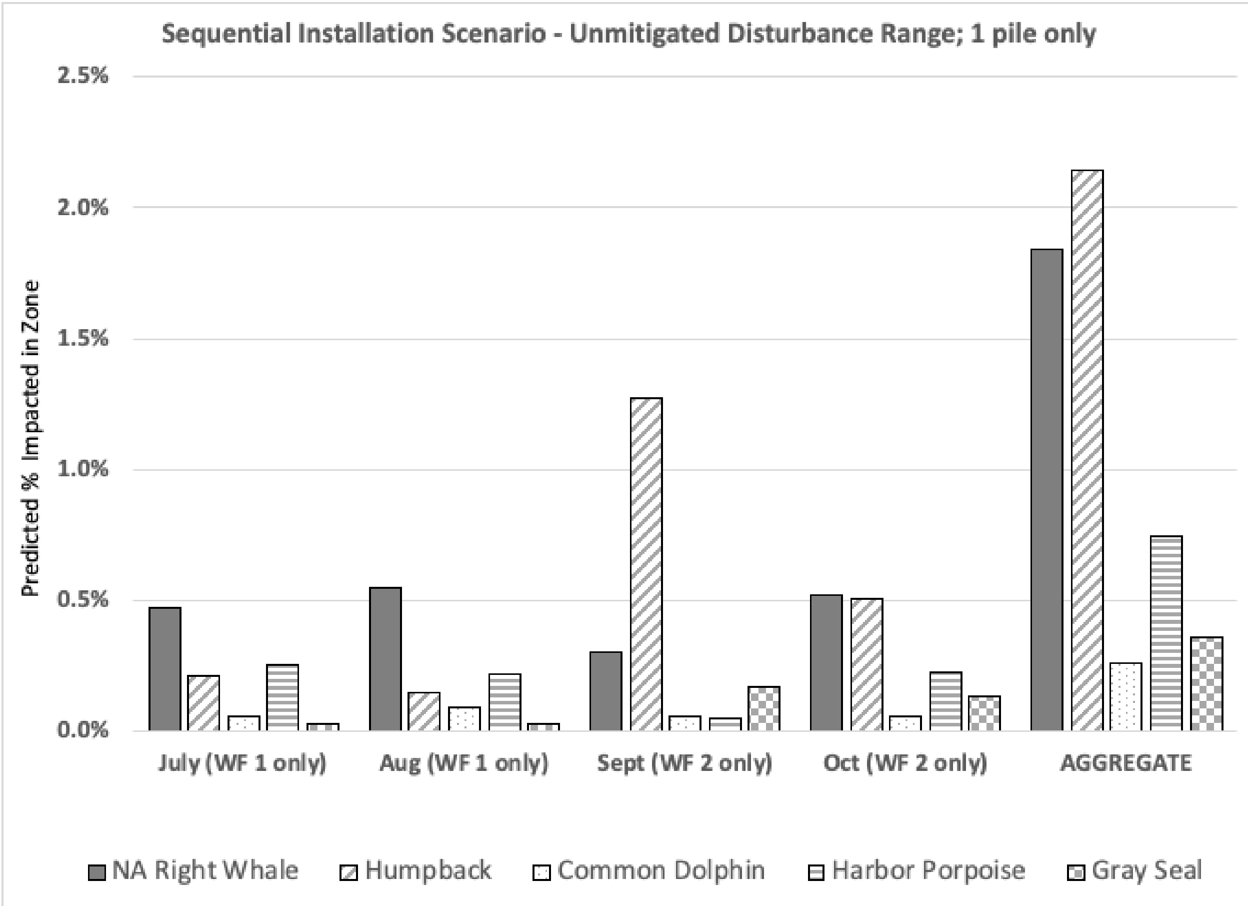


Figure 14. Exposure index values for year 2 sequential installation scenario

[1 pile/day, unmitigated disturbance ranges = 10 km (most species), 20 km (harbor porpoise)]

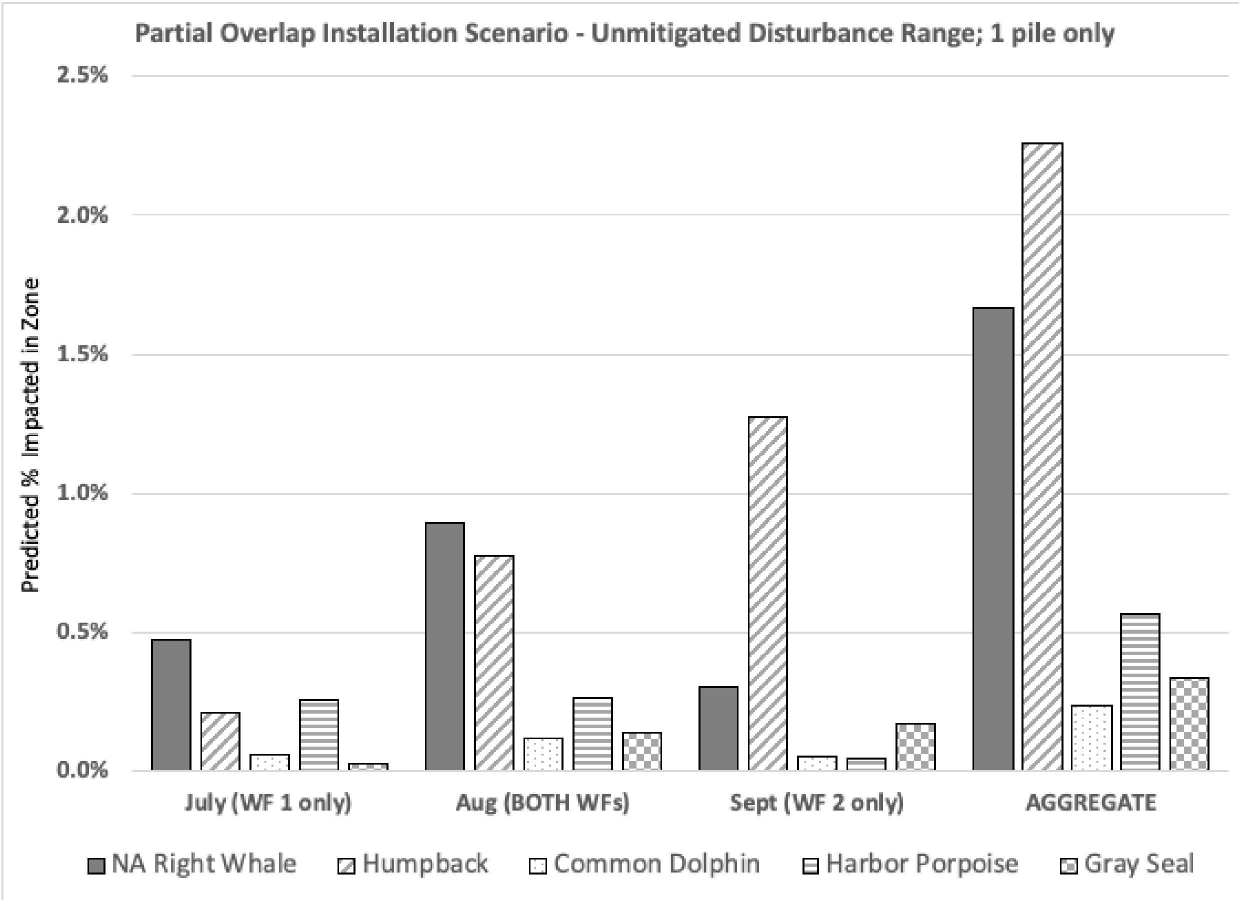


Figure 15. Exposure index values for year 2 partial temporal overlap scenario

[(1 pile/day, unmitigated disturbance ranges = 10 km (most species), 20 km (harbor porpoise)]

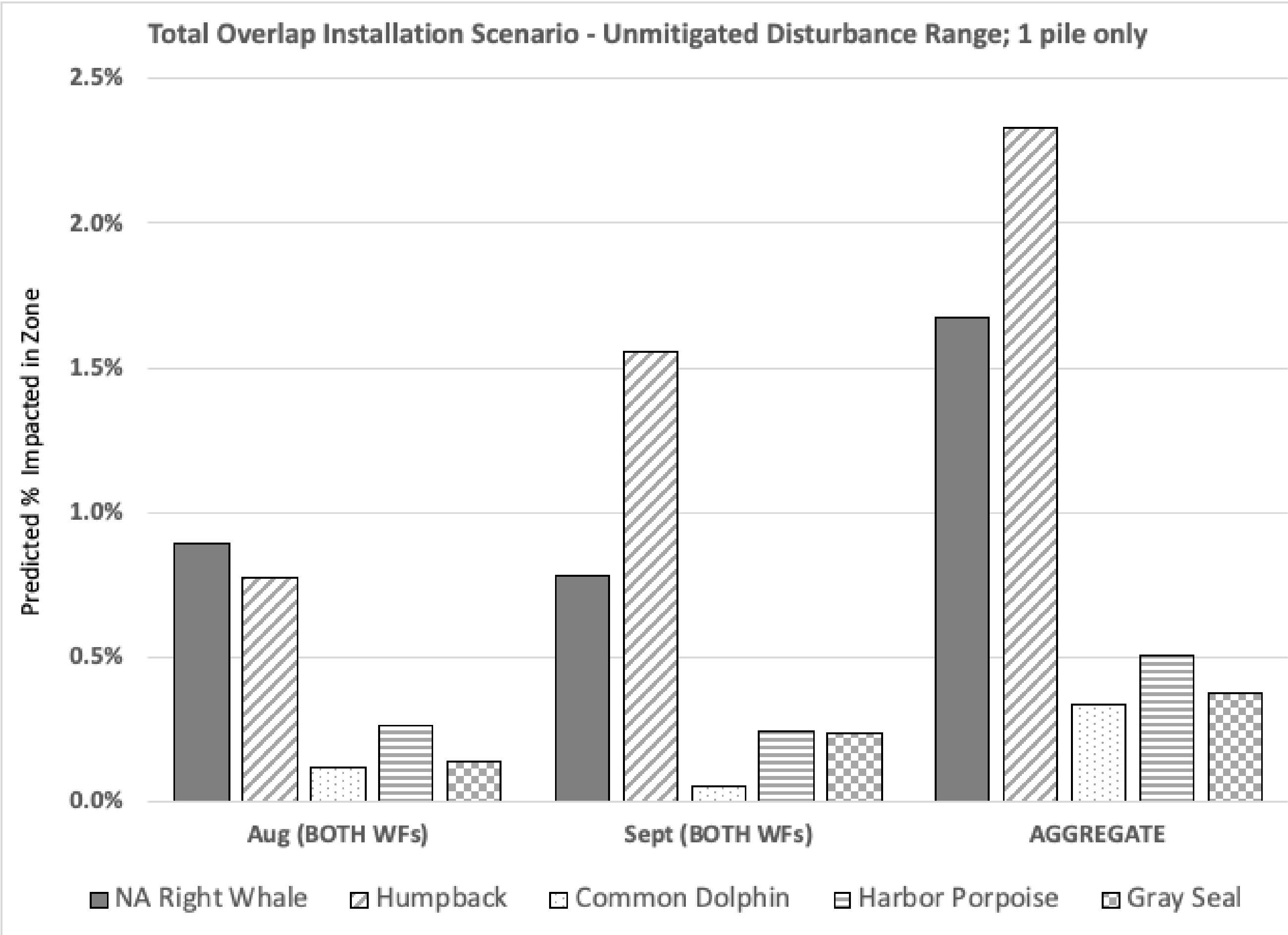


Figure 16. Exposure index values for year 2 complete temporal overlap scenario

[(1 pile/day, unmitigated disturbance ranges = 10 km (most species), 20 km (harbor porpoise)]

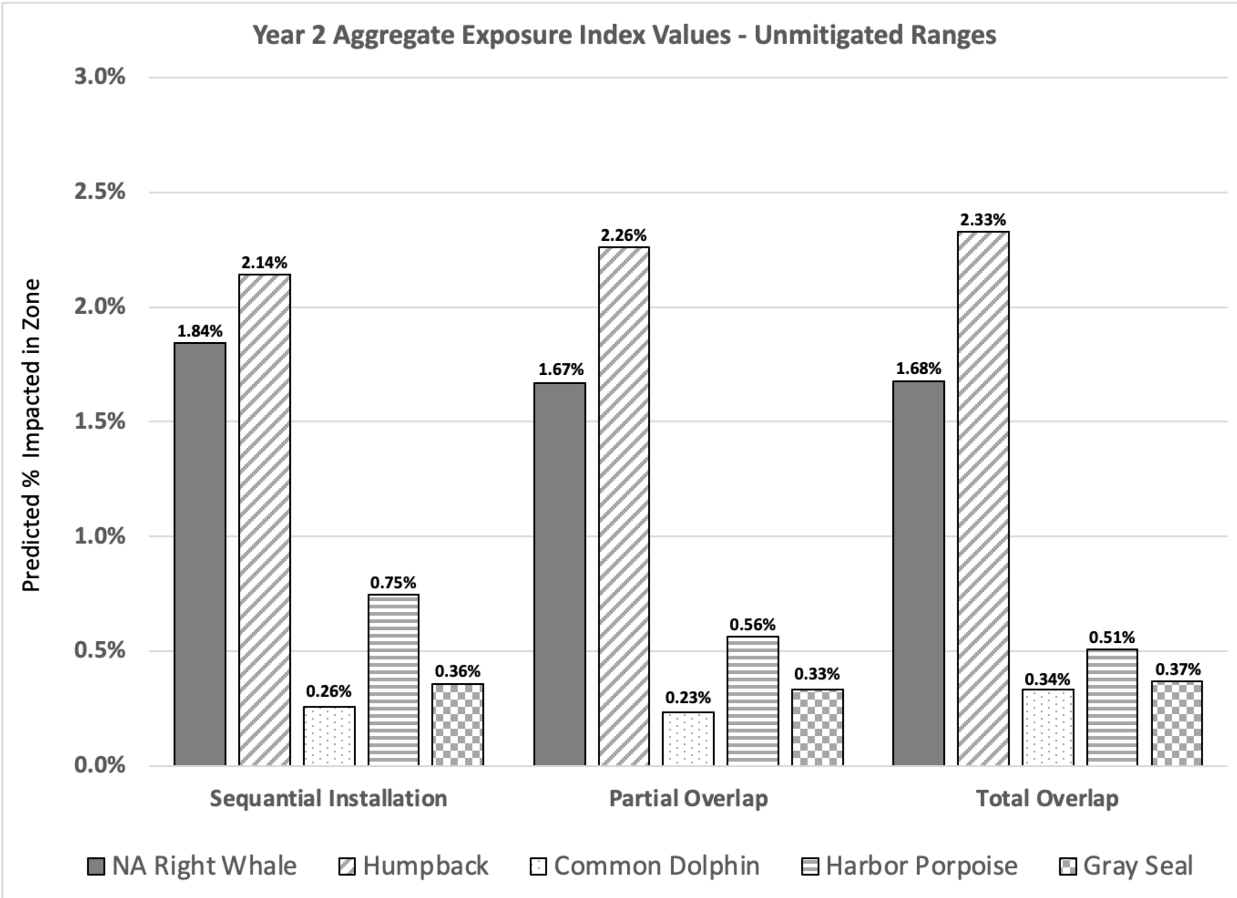


Figure 17. Aggregate exposure index values for all focal species for each year 2 temporal overlap installation scenarios

[(1 pile/day; unmitigated disturbance ranges = 10 km (most species), 20 km (harbor porpoise)]

Table 37. Year 2 temporal overlap scenarios – North Atlantic right whale risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
SEQUENTIAL INSTALLATION (WF1 July-Aug; WF2 Sept-Oct)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0098%	0.0177%	0.0094%	0.0447%	n/a	n/a	0.0816%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.4704%	0.5484%	0.3012%	0.5215%	n/a	n/a	1.8415%
	VULNERABILITY RISK SCORE	20	20	21	21	19	17	23	21	21	22	18	20	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	HIGHEST	HIGHEST	HIGHER	HIGHEST	n/a	n/a	
PARTIAL OVERLAP (WF1 July-Aug; WF2 Aug-Sept)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0098%	0.0289%	0.0094%	n/a	n/a	n/a	0.0480%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.4704%	0.8949%	0.3012%	n/a	n/a	n/a	1.6665%
	VULNERABILITY RISK SCORE	20	20	21	21	19	17	24	24	24	17	18	20	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	HIGHEST	HIGHEST	HIGHEST	n/a	n/a	n/a	
TOTAL OVERLAP (WF1 Aug-Sept; WF2 Aug-Sept)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.0289%	0.0243%	n/a	n/a	n/a	0.0533%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.8949%	0.7826%	n/a	n/a	n/a	1.6775%
	VULNERABILITY RISK SCORE	20	20	21	21	19	17	16	24	24	17	18	20	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	HIGHEST	HIGHEST	n/a	n/a	n/a	

Table 38. Year 2 temporal overlap scenarios – Humpback whale risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
SEQUENTIAL INSTALLATION (WF1 July-Aug; WF2 Sept-Oct)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0143%	0.0073%	0.0877%	0.0419%	n/a	n/a	0.1512%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.2132%	0.1448%	1.2747%	0.5092%	n/a	n/a	2.1419%
	VULNERABILITY RISK SCORE	11	8	11	11	9	9	17	14	14	14	9	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	MODERATE	LOWER	HIGHER	HIGHER	n/a	n/a	
PARTIAL OVERLAP (WF1 July-Aug; WF2 Aug-Sept)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0143%	0.0388%	0.0877%	n/a	n/a	n/a	0.1408%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.2132%	0.7731%	1.2747%	n/a	n/a	n/a	2.2610%
	VULNERABILITY RISK SCORE	11	8	11	11	9	9	17	17	17	9	9	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	MODERATE	HIGHER	HIGHER	n/a	n/a	n/a	
TOTAL OVERLAP (WF1 Aug-Sept; WF2 Aug-Sept)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.0388%	0.1070%	n/a	n/a	n/a	0.1458%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.7731%	1.5556%	n/a	n/a	n/a	2.3287%
	VULNERABILITY RISK SCORE	11	8	11	11	9	9	9	17	17	9	9	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	n/a			n/a	n/a	n/a	

Table 39. Year 2 temporal overlap scenarios – Common dolphin risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
SEQUENTIAL INSTALLATION (WF1 July-Aug; WF2 Sept-Oct)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0034%	0.0073%	0.0043%	0.0050%	n/a	n/a	0.0200%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.0593%	0.0900%	0.0537%	0.0562%	n/a	n/a	0.2592%
	VULNERABILITY RISK SCORE	9	8	7	7	7	8	8	8	8	8	8	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	LOWEST	LOWER	LOWEST	LOWEST	n/a	n/a	
PARTIAL OVERLAP (WF1 July-Aug; WF2 Aug-Sept)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0034%	0.0098%	0.0043%	n/a	n/a	n/a	0.0175%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.0593%	0.1212%	0.0537%	n/a	n/a	n/a	0.2341%
	VULNERABILITY RISK SCORE	9	8	7	7	7	8	8	8	8	8	8	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	LOWEST	LOWER	LOWEST	n/a	n/a	n/a	
TOTAL OVERLAP (WF1 Aug-Sept; WF2 Aug-Sept)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.0098%	0.0171%	n/a	n/a	n/a	0.0269%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.1212%	0.2146%	n/a	n/a	n/a	0.3358%
	VULNERABILITY RISK SCORE	9	8	7	7	7	8	8	8	8	8	8	9	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	LOWER	MODERATE	n/a	n/a	n/a	

Table 40. Year 2 temporal overlap scenarios – Harbor porpoise risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
SEQUENTIAL INSTALLATION (WF1 July-Aug; WF2 Sept-Oct)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0020%	0.0014%	0.0004%	0.0088%	n/a	n/a	0.0127%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.2543%	0.2215%	0.0476%	0.2222%	n/a	n/a	0.7455%
	VULNERABILITY RISK SCORE	11	11	11	10	10	9	8	8	7	8	10	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	MODERATE	MODERATE	LOWER	MODERATE	n/a	n/a	
PARTIAL OVERLAP (WF1 July-Aug; WF2 Aug-Sept)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0020%	0.0017%	0.0004%	n/a	n/a	n/a	0.0041%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.2543%	0.2629%	0.0476%	n/a	n/a	n/a	0.5649%
	VULNERABILITY RISK SCORE	11	11	11	10	10	9	8	8	7	8	10	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	MODERATE	MODERATE	LOWER	n/a	n/a	n/a	
TOTAL OVERLAP (WF1 Aug-Sept; WF2 Aug-Sept)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.0017%	0.0022%	n/a	n/a	n/a	0.0039%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.2629%	0.2461%	n/a	n/a	n/a	0.5090%
	VULNERABILITY RISK SCORE	11	11	11	10	10	9	8	8	7	8	10	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	MODERATE	MODERATE	n/a	n/a	n/a	

Table 41. Year 2 temporal overlap scenarios – Gray seal risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
SEQUENTIAL INSTALLATION (WF1 July-Aug; WF2 Sept-Oct)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0015%	0.0012%	0.0081%	0.0125%	n/a	n/a	0.0233%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.0271%	0.0266%	0.1696%	0.1346%	n/a	n/a	0.3579%
	VULNERABILITY RISK SCORE	11	11	11	11	11	9	8	7	7	8	11	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	LOWEST	LOWEST	LOWER	LOWER	n/a	n/a	
PARTIAL OVERLAP (WF1 July-Aug; WF2 Aug-Sept)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	0.0015%	0.0061%	0.0081%	n/a	n/a	n/a	0.0157%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	0.0271%	0.1361%	0.1696%	n/a	n/a	n/a	0.3327%
	VULNERABILITY RISK SCORE	11	11	11	11	11	9	8	7	7	8	11	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	LOWEST	LOWER	LOWER	n/a	n/a	n/a	
TOTALOVERLAP (WF1 Aug-Sept; WF2 Aug-Sept)	EXPOSURE INDEX (REGION)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.0061%	0.0113%	n/a	n/a	n/a	0.0173%
	EXPOSURE INDEX (ZONE)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.1361%	0.2354%	n/a	n/a	n/a	0.3715%
	VULNERABILITY RISK SCORE	11	11	11	11	11	9	8	7	7	8	11	11	
	INTEGRATED RISK ASSESSMENT SCORE	n/a	n/a	n/a	n/a	n/a	n/a	n/a	LOWER	MODERATE	n/a	n/a	n/a	

Installation Year 2 Scenario Discussion

We evaluated three temporal overlap scenarios for the second installation year involving the installation of 60 piles at each of two windfarm sites off the MA coast within the existing lease areas. The general period (late summer/early fall) was selected based on observations and conclusions from the risk assessment of the first installation year and either no, partial, or total temporal overlap for installation at the two wind farms was evaluated. Here again we consider risk assessments both across species in the same scenarios and within species across multiple scenarios.

Looking across scenarios, several patterns emerge:

- Temporal variance within species, and thus variability in exposure index and vulnerability, is less pronounced for these scenarios across species, largely because they span just two to four months.
- In comparing analagous scenarios (1 pile/day, unmitigated disturbance ranges) for year 2 conditions with multiple windfarms in variable degrees of overlap with the single (larger only) windfarm installation in year 1, only minor differences are evident. That is, while in several conditions, especially total overlap, we predicted slightly higher (up to 33%) assessed risk for several species (common dolphins and gray seals), for the majority of scenarios similar relative risk levels are assessed for multiple operations. When and where this occurs during periods of overlap could be explored, potentially, with finer resolution spatio-temporal species distribution of information for subsequent analyses.
- We see clear indications of potential benefits of condensing activity in periods with relatively low distribution of key species. This is similar to the reduced aggregate risk assessed in some time windows for the installation of two piles/day versus one pile/day for the same number of piles in the year 1 scenarios. For four of the five species (humpback whales being the exception) in year 2 variable temporal patterning scenarios, relative risk assessed was identical or lower and aggregate exposure index scores were lower for the partial temporal overlap versus sequential installation scenarios. This pattern was less evident for total overlap relative to partial overlap or sequential installation.

In terms of evaluating results across species or within individual species:

- Assessed relative risk was again relatively high among species evaluated in comparison to North Atlantic right whales for the same underlying factors as in the first year. However, a smaller percentage of the zone population was predicted to be impacted than for humpback whales, for the period of the year selected. It is notable that, the aggregate risk scores for right whales for both the partial and total overlap were lower than for the sequential installation scenario.
- Humpback whales had relatively higher risk than other species in most scenarios, and higher as noted in terms of the aggregate risk across scenarios in terms of the zone population. This does not necessarily equate to the highest overall risk category forhumpbacks however, primarily because of lower overall vulnerability scores given the

relatively healthy and stable populations in these areas for this species (relative to right whales).

- Common dolphins again generally had relatively low risk overall, resulting from generally low exposure index values, resulting from the normalization to the large regional population, and consistently low vulnerability scores, with the only moderate risk scores occurring in the total overlap scenario
- Harbor porpoise were again intermediate in exposure index scores and overall evaluated risk relative to other species for these scenarios. Exposure index scores were again relatively higher in terms of risk scores than vulnerability scores for this species.
- Gray seals had relatively low overall risk in each of these three scenarios, with results being quite similar to those observed in common dolphins.

Overall assessments of the multiple windfarm installation scenarios are as follows. While the relative risk assessed for right whales remains in the higher or highest overall category, it should be noted again that this assumes the 1 pile/day and unmitigated disturbance ranges. The relatively lower aggregate exposure index score percentages relative to many of the temporal scenarios for a single windfarm in year 1 were higher and values for these scenarios were lower than those for humpback whales. The selection of this period of the year for installation remains clearly logical in terms of reducing risk for right whales. Condensing operations into shorter periods when distribution is as low as possible is another logical action. There may be limits to these potential benefits however, as values were slightly higher for total overlap in right whales and especially in other species with lower overall risk but whose highest relative risk in these scenarios occurred in total overlap scenarios (e.g., common dolphin, harbor porpoise, gray seal). Overall, we see only marginal differences in assessed risk for multiple installations versus a single windfarm for the same periods and assumptions and that, at least for the contexts considered here. Again, there may be conservation benefits (less aggregate risk to key species) of concentrating activity that managers would want to consider. For these scenarios as well, however, there is not a uniform change in the magnitude of risk and the specific species and such consideration should be strategically done within species across time and across species within the same time windows.

4.3. Installation Year 3 Scenario: Simultaneous operation of windfarms #1 and 2

The final scenario considers the simultaneous operation of both presumed windfarms using simplifying assumptions regarding their operation and maintenance. It should be clearly noted that, as there are yet to be any large-scale windfarms in operation off the U.S. east coast, key elements of these assumptions are limited in terms of direct information in practice. These limitations in key operational parameters include aspects of operational turbines, but most notably temporal and spatial distribution of service vessel activity. Estimates provided indicated that crew vessels are expected to be the most prevalent vessel in the wind farm area during the operational phase. This type of vessel will make an average of 30.8 trips per month to a 180 turbine wind farm and 10.3 trips per month to a 60 turbine wind farm. These values were used to calculate the exposure index for vessel operations.

Results are presented for each species across all months of the year presuming a uniform distribution of operational turbine and vessel activity, though it is clearly noted that we might expect a more heterogenous distribution of activity on each front in practice. We present and apply exposure index results here only for vessel operations because, based on the assumptions above with the associated caveats, as a conservative approach given that these result in higher exposure index values than operating turbines in all scenarios. Exposure index results for this scenario are given for each month of the year along with aggregate (annual) exposure index values (Figs. 18-20) followed by integrated assessed risk for each focal species (Tables 42-46).

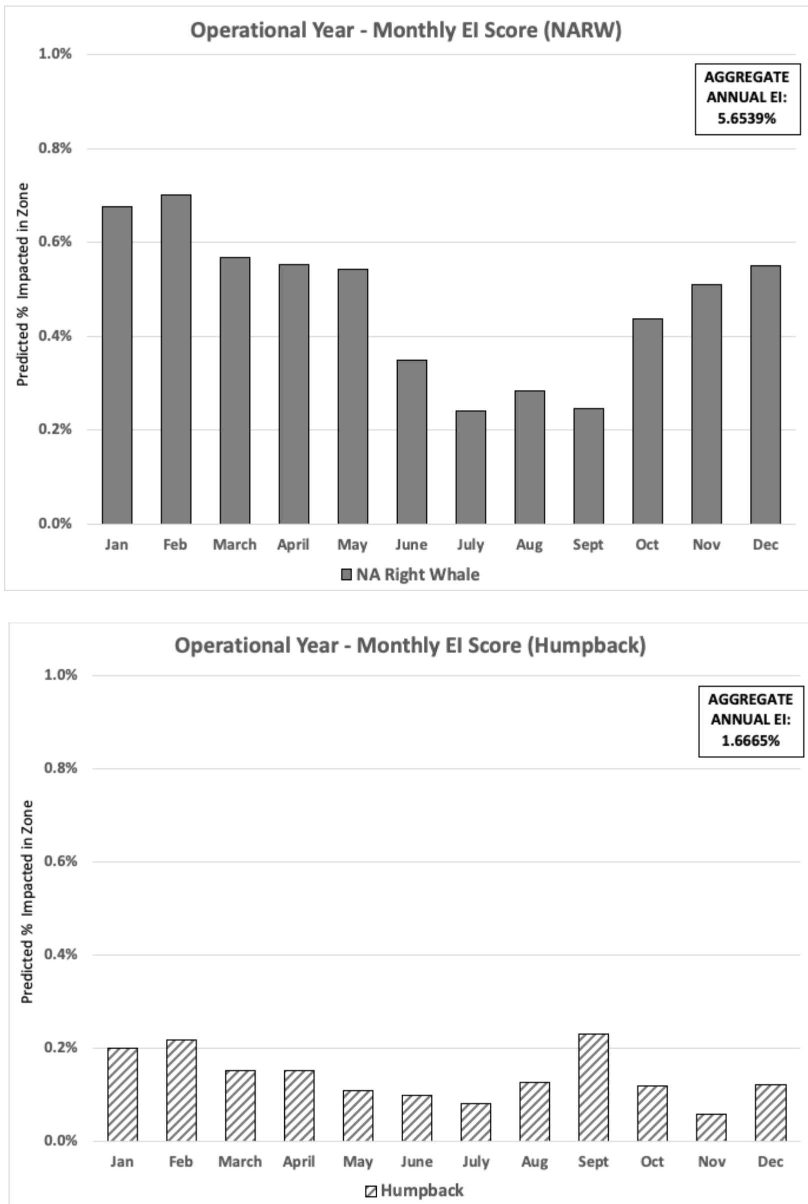
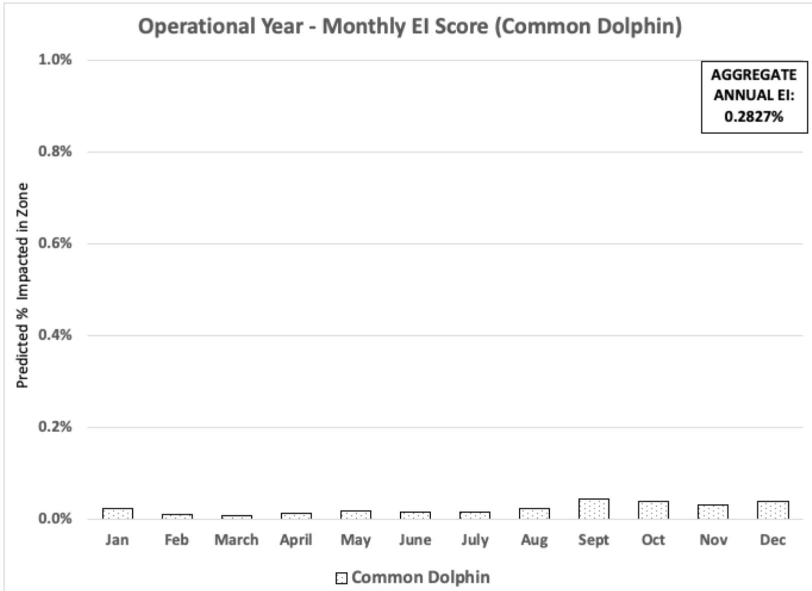


Figure 18. Exposure index values (all months and annual aggregate) for year 3 operational scenarios for North Atlantic right whale and humpback whales



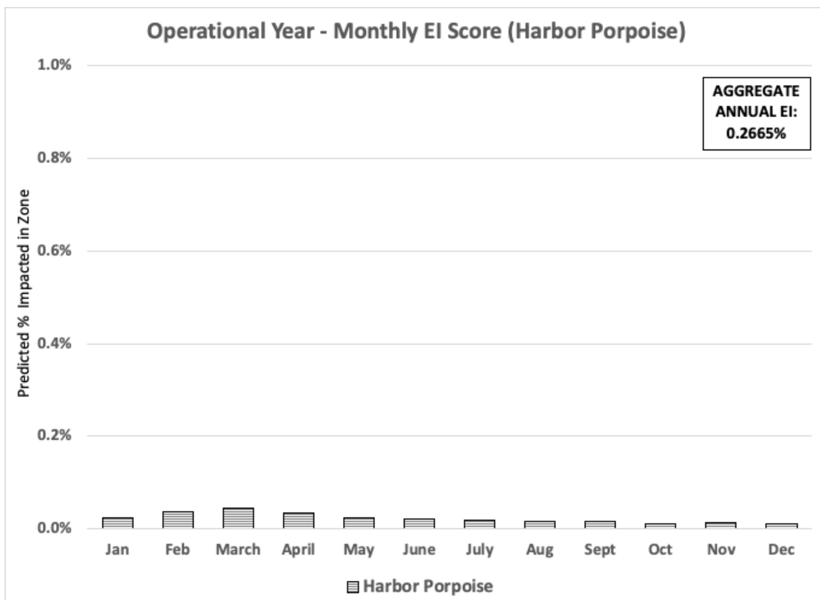


Figure 19. Exposure index values (all months and annual aggregate) for year 3 operational scenarios for common dolphin and harbor porpoise

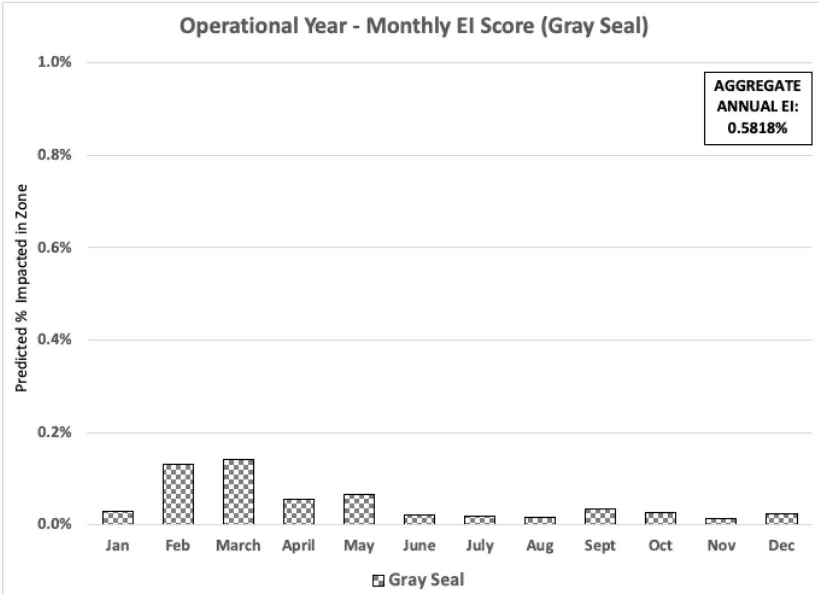


Figure 20. Exposure index values (all months and annual aggregate) for year 3 operational scenarios for gray seals

Table 42. Year 3 operational scenario – Right whale risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
OPERATIONAL YEAR SCENARIO	EXPOSURE INDEX (REGION)	0.2986%	0.3420%	0.2581%	0.2596%	0.1665%	0.0213%	0.0050%	0.0091%	0.0076%	0.0374%	0.0987%	0.2191%	1.7230%
	EXPOSURE INDEX (ZONE)	0.6753%	0.7001%	0.5670%	0.5535%	0.5417%	0.3483%	0.2418%	0.2828%	0.2455%	0.4357%	0.5110%	0.5512%	5.6539%
	VULNERABILITY RISK SCORE	21	21	22	22	20	18	17	17	17	18	19	21	
	INTEGRATED RISK ASSESSMENT SCORE	HIGHEST	HIGHEST	HIGHEST	HIGHEST	HIGHEST	HIGHER	MODERATE	HIGHER	MODERATE	HIGHEST	HIGHEST	HIGHEST	

Table 43. Year 3 operational scenario – Humpback whale risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
OPERATIONAL YEAR SCENARIO	EXPOSURE INDEX (REGION)	0.0251%	0.0210%	0.0156%	0.0195%	0.0091%	0.0095%	0.0054%	0.0063%	0.0159%	0.0098%	0.0050%	0.0121%	0.1543%
	EXPOSURE INDEX (ZONE)	0.2001%	0.2169%	0.1520%	0.1525%	0.1079%	0.0995%	0.0808%	0.1258%	0.2315%	0.1193%	0.0583%	0.1220%	1.6665%
	VULNERABILITY RISK SCORE	12	9	12	12	10	10	10	10	10	10	10	10	
	INTEGRATED RISK ASSESSMENT SCORE	MODERATE	MODERATE	LOWER	LOWER	LOWER	LOWER	LOWER	LOWER	MODERATE	LOWER	LOWEST	LOWER	

Table 44. Year 3 operational scenario – Common dolphin risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
OPERATIONAL YEAR SCENARIO	EXPOSURE INDEX (REGION)	0.0039%	0.0010%	0.0003%	0.0006%	0.0008%	0.0008%	0.0009%	0.0020%	0.0035%	0.0036%	0.0022%	0.0042%	0.0236%
	EXPOSURE INDEX (ZONE)	0.0241%	0.0114%	0.0069%	0.0129%	0.0174%	0.0149%	0.0162%	0.0244%	0.0445%	0.0402%	0.0314%	0.0383%	0.2827%
	VULNERABILITY RISK SCORE	9	8	7	7	7	8	8	8	8	8	8	9	
	INTEGRATED RISK ASSESSMENT SCORE	LOWEST	LOWEST	LOWEST	LOWEST	LOWEST	LOWEST	LOWEST	LOWEST	LOWEST	LOWEST	LOWEST	LOWEST	

Table 45. Year 3 operational scenario – Harbor porpoise risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
OPERATIONAL YEAR SCENARIO	EXPOSURE INDEX (REGION)	0.0056%	0.0085%	0.0101%	0.0064%	0.0034%	0.0005%	0.0001%	0.0001%	0.0001%	0.0004%	0.0021%	0.0023%	0.0396%
	EXPOSURE INDEX (ZONE)	0.0242%	0.0379%	0.0434%	0.0338%	0.0247%	0.0216%	0.0175%	0.0158%	0.0147%	0.0102%	0.0125%	0.0100%	0.2665%
	VULNERABILITY RISK SCORE	11	11	11	10	10	9	8	8	7	8	10	11	
	INTEGRATED RISK ASSESSMENT SCORE	LOWEST	LOWEST	LOWEST	LOWEST	LOWEST	LOWEST	LOWEST	LOWEST	LOWEST	LOWEST	LOWEST	LOWEST	

Table 46. Year 3 operational scenario – Gray seal risk assessment results

SCENARIO	RISK SCORE	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AGGREGATE EI % FOR SCENARIO
OPERATIONAL YEAR SCENARIO	EXPOSURE INDEX (REGION)	0.0123%	0.0521%	0.0546%	0.0303%	0.0387%	0.0037%	0.0011%	0.0007%	0.0017%	0.0026%	0.0080%	0.0134%	0.2191%
	EXPOSURE INDEX (ZONE)	0.0286%	0.1307%	0.1418%	0.0563%	0.0657%	0.0219%	0.0194%	0.0163%	0.0348%	0.0275%	0.0140%	0.0248%	0.5818%
	VULNERABILITY RISK SCORE	12	12	12	12	12	10	9	8	8	9	12	12	
	INTEGRATED RISK ASSESSMENT SCORE	LOWER	LOWER	LOWER	LOWER	LOWER	LOWEST	LOWEST	LOWEST	LOWEST	LOWEST	LOWER	LOWER	

Installation Year 3 Scenario Discussion

This assessment included a single scenario, the simultaneous operation of two windfarms at locations in the current lease areas off MA. Given the uniform operational context, we consider here observations within species across this scenario:

- We note the substantial caveats in interpreting the results here for operational years due largely to the uncertainty regarding key spatial and temporal aspects of service vessel operational details. We consider this a preliminary assessment using broadly averaged conditions and assumptions. Caution should be taken consequently and in directly comparing risk assessed between installation and operational scenarios.
- Common dolphins, harbor porpoise, and gray seals consistently had the lower or lowest risk category across all months with very little evident temporal variability in assessed risk for operational scenarios.
- Humpback whales had relatively low risk throughout the operational year but interestingly had the highest relative exposure index and associated integrated risk assessed in the winter and early spring months.
- The clearest temporal pattern of relative risk assessed occurred in North Atlantic right whales, with lowest risk values in the June through September period. It should be noted that the risk assessment conducted here is presumed disturbance as a function of noise, but given that the risk here is associated with the spatial and temporal intersection of whales and vessels, this would also relate to the relative risk of other impacts such as vessel strikes.

Our results suggest lower overall levels of assessed risk for most species (right whales being the exception) for the operational year relative to installation years. However, it should be clearly stated that this preliminary assessment of a single year of windfarm operation relative to the installation of two windfarms in different temporal scenarios is not an absolute or cumulative assessment of the relative risk of installation relative to operation. Further, it should also be clearly stated again that the simplified and uniform assumptions regarding operational turbine and vessel operation for both windfarms across the entire year are almost certainly not representative of how such farms will operate in practice. In fact, one lesson that may be drawn here regarding operational periods and the servicing of facilities in these areas with regard to the potential impact on these species is that, to the extent practical, they should not be uniform. Rather, given the uniform and low assessed risk across the year for the odontocete and pinniped species and the relatively lower risk for humpbacks and especially right whales during the summer and early fall months, as much of the service activity as possible should be concentrated during the summer and early fall periods.

5 Conclusions and Next Steps

Here we provide an overall assessment of the adaptation of the risk assessment framework from a quite different scenario (seismic surveys in the Gulf of Mexico) to the installation and operation of offshore windfarms on the U.S. east coast. This is followed by a synthesis of the specific conclusions derived across the various installation and operational scenarios. Finally, we provide some thoughts on next steps for the further development and application of this framework.

Assessment of Risk Assessment Methods Adapted for Offshore Wind Farm Installation

- Overall, the adaptation of the aggregate risk assessment framework from scenarios in a different location (Gulf of Mexico) and for different, mobile sound sources (seismic surveys) was, following fairly extensive development and manipulation particularly regarding the exposure index, successful. We emphasize the intent of this approach is to provide a relativistic, largely quantitatively based and consistent, common sense means of assessing risk in different scenarios. This is a biologically based, decision-making tool founded on the conclusion that the spatial, temporal, and spectral intersection of animals and potential disturbance will drive the magnitude of exposure related to a host of potential negative consequences.

- Substantial analytical modifications were necessitated and made, highlighting the adaptable and scalable nature of the risk assessment framework. These included:

    - Novel development of biologically and oceanographically based operational zones. Whereas these were defined through management distinctions in the Gulf of Mexico, they were not for the U.S. east coast. The fundamental design of the risk assessment framework considers an overall mesoscale area over which species and activities may occur with discrete sub-areas (‘zones’) in which specific activities and sub-sets of the larger population occur. These were derived explicitly in the adaptation of the risk assessment to wind farm scenarios considered here.

    - Given the highly seasonal nature of many of the focal species, a monthly temporal resolution for exposure index calculations was applied and aspects of the vulnerability rating were also calculated and varied substantially across months. Monthly variability within species habitat and temporal factor scoring ranged between 3-5, with NARW highest. Scoring relies on accurate assumptions on monthly densities as well as timing of key life-cycle activities. Monthly variability in masking scoring varied for baleen whales by 3 and is dependent on ANNR assumptions and baseline noise levels.

    - Additional quantitative metrics for several of the vulnerability factors, including greater resolution on habitat usage parameters and the use of realized mortality relative to PBR for other anthropogenic stressors, were applied. The continued integration of quantitative rather than subjective benchmarks within the risk assessment framework is an important development.

    - Entirely new taxa (pinnipeds) were considered in this scenario. This required the integration of additional information on sound perception and the consideration of factors related to their amphibious nature.

- The static nature of the disturbance associated with wind farm construction relative to previous mobile sources required a number of different considerations, including the relative potential disturbance zones around portions of the farm being constructed. We evaluated the relative impacts of mitigation measures (bubble curtains) to reduce the acoustic footprint of impact pile driving and used smaller potential disturbance zones in calculating exposure index values for a mitigated versus unmitigated condition accordingly.

- Data limitations, notably regarding the underlying quality and nature of distribution data as well as data and analyses conducted (or missing) from the SARs were limiting in multiple instances, requiring more precautionary conclusions. Additional distinctions were made in several of the vulnerability scores assigning scores specific for data deficiency.

- The risk assessment approach provides a common way to evaluate risk in multiple different temporal scenarios across multiple species through a common core set of assumptions. The approach is inherently scalable to finer or longer time scales, and allows for contingency testing of different scenarios, as we have begun to do here. Further, given the inherenty spatial and temporal nature of integrating disturbance and animal presence, it is fundamentally capable of evaluating non-acoustic as well as acoustic disturbance, although this will require some development.

General Conclusions for Offshore Wind Scenarios Considered

- *Critical importance of spatial and temporal distribution of focal species*: The distribution and abundance of species within the overall area and within the zone of operations is the main driver of the overall evaluated risk of disturbance. The relative density and abundance of species within the focal zone for a specified period is the primary driver of the exposure index scores and also influences the habitat use factor for the vulnerability assessment. Based on our risk assessment, a primary mitigation measure to reduce potential risk of disturbance is, consequently, temporal mitigation measures, focusing on the most important species from a conservation perspective but also considering distribution issues related to the suite of protected species being considered.

- *Timing of start of construction*: While the year 1 scenario considered just the installation of piles at a single location (Wind Farm #1), the three different start dates selected for this hypothetical scenario provided several key insights regarding potential risk. Most notably, for species with the more temporally ephemeral distributions in the zone (2) where operations were presumed to occur, the highest predicted risk values (resulting from both the exposure index and secondarily the habitat use vulnerability score) occurred when installation overlapped with relatively higher distribution. Looking at these patterns across species, certain periods (notably installation in late summer and early fall) are clearly associated with lower risk for multiple focal species. By looking across time periods for construction phases across species, periods that may reduce risk for multiple protected species may be identified. These were identified as effectively late summer and early fall especially relative to critically endangered North Atlantic right whales, though this emphasis was generally congruent with risk assessment conclusions for other species in this analysis.

- *Relative size of presumed disturbance zones (effect of mitigation)*: Based on empirical measurements of noise reduction from bubble curtains in some previous wind farm installations, we determined that potential disturbance zones would be reduced by about 5 km (from 10 km (to 5) for most species at a nominal 160 dB RMS value and from 20 km (to 15) for harbor porpoise at a nominal 120 dB RMS value. Assuming these disturbance zones for mitigated and unmitigated conditions revealed reduced presumed risk in mitigated conditions. Aggregate exposure index values were reduced by around 4-fold for all species, other than for harbor porpoise where the reduction was a little below 2-fold. While the overall reduction in the final integrated risk values were often only modestly lower, they were reduced to some degree in all instances as a result of such mitigation.

- *Concentration of installation periods*: While it may not be possible or common that multiple monopiles may be driven within one day, if and when it would occur would likely require nighttime or low-visibility piling. The mitigation and monitoring requirements for such operations notwithstanding, we evaluated potential differences in driving a single versus two piles within a day as well as the lack of or variable temporal overlap for multiple windfarm installations in order to evaluate the potential relative risk if such operations were possible and allowed. While we clearly state that additional consideration of other mitigation and practicality considerations are required, the risk assessment conducted for the contexts considered here clearly suggests that there could be conservation benefits to concentrating potential disturbance in strategic periods given the large reduction in overall risk by having it occur for a shorter interval overall, particularly when focused in periods when key species are relatively scarce.

- *Relative risk of focal species*: Detailed discussions regarding relative sensitivity for each focal species are provided for each of the installation and operational years above. In general, right whales had the highest overall risk (not surprisingly), followed by humpback whales with harbor porpoise, gray seals, and common dolphins having generally low overall risk except for in limited specific scenarios. A key component of this relative risk across species is the application of the spectral index, which weights for the low frequency noise sources in this assessment. The impact on baleen whales was 5.6-9 times higher than on MF and HF cetaceans. Clearly this would vary depending on the frequency of the activity sound source.

Next Steps

We identify several further developments and adaptations of this ongoing risk assessment process, including:

- Further quantitative metrics for additional aspects of species-specific vulnerability, including habitat use and other stressors. Clarification of the extent to which species vulnerability might change over time when considering other stressors scoring criteria (e.g., future noise effects, climate change).
- Potential modification of masking factor components of vulnerability rating to include non-auditory kinds of potential stressors for certain kinds of operations (e.g., entanglement for floating offshore wind; vessel-strikes).
- Integration of dynamic environmental covariates (e.g., concentrating oceanographic conditions, prey layers) that could result in more heterogenous distribution of key species than may be reflected in density databases. This could allow specific scenario testing with different conditions dynamic variables for scenario testing using ecosystem model forecasts.
- Develop quantitative means of assessing certainty/quality of underlying density data within areas of operations to put potential error bounds on exposure index calculations.
- Apply framework to current and planned future projects (5-year horizon?) - focus on best way to combine results from different regions via %region or %stock metrics and apply to and test with real world scenarios.
- Derive uncertainty around exposure index (risk) point estimates and assess sensitivity to main assumptions (e.g., piling duration/buffer selection/SL/m-weighted ratio).
- Refine vessel operational noise exposure index and masking vulnerability methodology for operations, particularly once specific types and patterns of operations are possible.
- Investigate the context under which animals react in an operating wind farm area. What factors do they react to and is it more acoustic or context based. The current method assumes acoustic for an operating turbine and contextual for vessel operations. The current framework can be adapted to both methods easily.
- Refine methods to partition risk rating breakpoints – consider moving away from defining VH, H, M, L, VL i.e., using continuous risk variables.
- Ensure up-to-date information on pile-driving SL and operational windfarm SL for largest turbine foundation installations planned; integrate empirical data for offshore turbines off US east coast once operational including refined monthly density estimates for key species from monitoring and mitigation efforts.

6 References

Ellison, W.T., Southall, B.L., Frankel, A.S., Vigness-Raposa, K. and Clark. C. (2018). An Acoustic Scene Perspective on Spatial, Temporal, and Spectral Aspects of Marine Mammal Behavioral Response to Noise. *Aquatic Mammals* 44, 239-243, DOI 10.1578/AM.44.3.2019.239.

Ellison, W.T., Racca, R., Clark, C.W., Streever, B., Frankel, A.S., Fleishman, E., Angliss, R., Berger, J., Ketten, D., Guerra, M., Leu, M., McKenna, M., Sformo, T., Southall, B., Suydam, R., and Thomas, L. (2016). Modeling the aggregated exposure and responses of bowhead whales Balaena mysticetus to multiple sources of anthropogenic underwater sound. *Endangered Species Research* 30, 95-108.

Ellison, W.T., Clark, C.W., Mann, D.A., Southall, B., and Tollit, D.J. (2015). A risk assessment framework to assess the biological significance of noise exposure on marine mammals. *21st Biennial Conference on the Biology of Marine Mammals*, San Francisco, CA, USA, 13-18 December.

Ellison, W.T., Southall, B.L., Clark, C.W. and Frankel, A.F. (2012). A new context-based approach to assess marine mammal behavioral responses to anthropogenic sounds. *Conservation Biology* 26, 21-28.

Forney, K. A., Southall, B. L., Slooten, E., Dawson, S., Read, A. J., Baird, R. W., & Brownell Jr, R. L. (2017). Nowhere to go: noise impact assessments for marine mammal populations with high site fidelity. *Endangered species research*, *32*, 391-413.

HDR (2020). Field Observations During Offshore Wind Structure Installation and Operation, Volume I. Final Report to the U.S. Department of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs. OCS Study BOEM 2021-225. 332 pp.

Holt M.M., Tennessen, J.B., Ward, E.J., Hanson, M.B., Emmons, C.K., Giles D.A., and Hogan, J.T. (2021) Effects of vessel distance and sex on the behavior of endangered killer whales. Front. Mar. Sci. 7:582182. doi: 10.3389/fmars.2020.582182

Ørsted. 2020. Final Noise and PSO Monitoring Report – Coastal Virginia Offshore Wind Farm. Available at: https://media.fisheries.noaa.gov/2021-01/Dominion_CVOW_2020IHA_MonRep_OPR1.pdf?null=

Roberts JJ, Schick RS, Halpin PN (2020) Final Project Report: Marine Species Density Data Gap Assessments and Update for the AFTT Study Area, 2018-2020 (Option Year 3). Document version 1.4. Report prepared for Naval Facilities Engineering Command, Atlantic by the Duke University Marine Geospatial Ecology Lab, Durham, NC.

Southall B., Ellison, W., Clark, C., Tollit, D., and Amaral, J. (2021a). Marine mammal risk assessment for Gulf of Mexico G&G activities. Sterling (VA): US Department of the Interior, Bureau of Ocean Energy Management. 99 p. OCS Study BOEM 2021-020.

Southall, B., Ellison, W., Clark, C., Tollit, D. (2019). Aggregate (chronic) noise exposure risk assessment report (task 5, Part 1). Aptos (CA): US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 20xx-xx. 66 p.

Southall, B.L., Amaral, J., Clark, C.W, Ellison, W., Joy, R., Tollit, D., and Ponirakis, D.W. (2018). A Risk Assessment Framework to Evaluate the Potential Relative Effects of Noise on Marine Mammals. *6th Conference on the Effects of Sound on Marine Mammal*, Den Haag, Netherlands, 10-14 September.

Southall, B.L., Bowles, A.E., Ellison, W.T., Finneran, J.J., Gentry, R.L., Greene, C.R., Jr., Kastak, D., Ketten, D.R., Miller, J.H., Nachtigall, P.E., Richardson, W.J., Thomas, J.A., and Tyack, P.L. (2007). Marine mammal noise exposure criteria: initial scientific recommendations. *Aquatic Mammals* 33, 411-521.

Tougaard, J., Hermannsen, L., & Madsen, P. T. (2020). How loud is the underwater noise from operating offshore wind turbines?. *The Journal of the Acoustical Society of America*, *148*(5), 2885-2893.

Wood, J., Southall, B.L. and Tollit, D.J. (2012) PG&E offshore 3-D Seismic Survey Project EIR – Marine Mammal Technical Draft Report. SMRU Ltd.

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