Marine Mammal Disturbance Risk Assessment Framework (RAF)

SPECIES-SPECIFIC VULNERABILITY SCORING CRITERIA AND METHODOLOGY

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The novel risk Assessment Framework (RAF) developed and adapted by a team of biologists and acousticians (see: Southall et al. 2023) has two fundamental elements that form the axes of a marine mammal relative risk matrix. The effective exposure to a particular kind of disturbance is quantified with a relativistic 'exposure index' which intersects the spatial, temporal, and spectral aspects of different types of activity with species-specific distribution and hearing sensitivity. Exposure index results are segregated into quintiles with an associated exposure 'severity' rating of 1-5. These results, for specified time periods and by species, are crossed in the risk matrix with risk ratings from another analysis, described here, of species-specific 'vulnerability". The objective of this assessment is to evaluate species population, life history, distribution, and environmental factors that determine how susceptible the species is to disturbance and how this can vary in space and time. Species-specific vulnerability in defined geographical areas (termed zones) and time windows are based on systematic methods of evaluating these factors independently of the industrial activity being considered.

This document provides a detailed description of the current scoring criteria and methodology for determining species-specific vulnerability. It provides a step-wise guide for applying these methods to evaluate species-specific vulnerability either in new regions where scoring has yet to be conducted or in updating existing vulnerability scores. The species-specific vulnerability rating is determined discretely for each species, area, and temporal period being considered using a structured evaluation of key species and context-specific factors. These factors, and their relative weighting in the overall score, have evolved through iterations of the RAF, including from the version presented in Southall et al. (2023). These iterations have occurred with the goal of maintaining a transparent, understandable, biological and ecological basis using objective criteria where possible and a small number of subjective elements.

They include the following factors, each of which has multiple sub-factors and are used to determine an overall vulnerability rating between 1-5, also using a quintile basis, as described below:

Factor 1. Population factor

Factor 2. Species habitat use and compensatory abilities

Factor 3. Other stressors factors

Within the current project, in which the RAF has been adapted for operationalization and use by BOEM, a fourth factor considering auditory masking was removed from the vulnerability scoring scheme. This was previously quantified (Southall et al., 2023) as a project-specific signal-to-noise ratio differentially calculated for different hearing groups. Here it was removed given that the spatial-temporal-spectral exposure index assessment was deemed to effectively account for this potential auditory effect of specific industrial activities. It should also be noted that the calculation of values using an ambient-noise-to-noise ratio with empirical data that underpinned the masking factor (presented in Southall et al., 2023) required a substantial amount of both data and analysis that might not be readily available or feasible in other contexts. However, that approach is clearly spelled out in Southall et al. (2023) and our previous BOEM reports and for certain context and applications (e.g., to inform a comparative cumulative impact assessment) could be considered as a potentially informative supporting analysis. Additionally, several key modifications were made within Factor 3 sub-elements to consider broader-scale issues of hearing-group specific masking from other industrial activities within the assessed areas.

Herein we describe the criteria, assessment methods, data sources, and assumptions for each sub-factors of these species- and temporal-specific factors. Aggregate scores (30 total possible) for each of these sub-elements are used collectively used to determine the overall species-specific vulnerability rating (ordinal values of 1-5) using a quintile scoring approach as detailed in the table below.

Total Vulnerability Score (aggregate of factors 1-3)	**Risk Probability** (% of total possible)	**Relative Vulnerability Rating**
24 – 30	**80 – 100%**	**Highest (5)**
18 – 23	**60 – 79%**	**High (4)**
12 – 17	**40 – 59%**	**Moderate (3)**
6 – 11	**20 – 39%**	**Low (2)**
0 – 5	**0 – 19%**	**Lowest (1)**

VULNERABILITY FACTOR 1: Population Factor (10 of 30 possible)

A key consideration for evaluating species-specific vulnerability include aspects of a species' overall population status and trajectory. Criteria and descriptions for each sub-factor are provided below (Table 1), followed by a methodological description for determining sub-factor scores. The population factor includes three defined sub-factors:

1.1. Population status
1.2. Population trend
1.3. Population size

Table 1. Species population factor scoring criteria (defined for regional population or stock)

Population Factor Elements	Score (max 10)
Sub-factor 1.1 Population status: • *Endangered* (U.S. Endangered Species Act (ESA)) = **6** • *Threatened (ESA) or depleted* (U.S. Marine Mammal Protection Act (MMPA)) = **4** • *MMPA-listed or Special concern* (various statutes) = **1**	**max = 6**
Sub-factor 1.2. Population trend: • *Decreasing* (statistically supported trend identified in most recent stock assessment report (SAR), status review, or peer-reviewed publication) = **2** • *Unknown*: no population trend analysis performed or data deficient = **1** • *Stable* (statistically supported trend identified in most recent SAR, status review, or peer-reviewed publication) = **0** • *Increasing* (statistically supported trend identified in most recent SAR, status review, or peer-reviewed publication) = **-1**	**max = 2**
Sub-factor 1.3. Population size: • *Small* (n < 2,500, as specified by International Union for the Conservation of Nature [IUCN] designation) = **2** • *Unknown* (last three SARs or status reviews) but possibly below 2,500 = **1** • *> 2,500* = **0**	**max = 2**

Sub-factor 1.1. Population status scoring methods:

This is among the most straightforward sub-factor to score. Population conservation status is clearly defined under various statutes for the criteria identified for all species. The current approach includes a slight upweighting for both endangered and threatened status and a slight down weighting for MMPA-listing (which includes all marine mammals). This status changes infrequently and this is considered an objective, static annual value – there is no monthly variance.

Sub-factor 1.2. Population trend scoring methods:

For some well-studied species, this sub-factor is straightforward to determine (i.e., where a recently evaluated trend is explicitly provided in the SAR and/or supporting peer-reviewed publication). In some instances, population trend can be more difficult to determine, for instance where varying or even conflicted degrees of supporting information exist. In those instances, some expert elicitation or agency assessment may be required. However, an explicit score is included for conditions where uncertainty exists. This is also intended as an annual score without monthly variance. It is the only sub-factor score in which a negative value is possible – in the case of a documented increasing population.

Sub-factor 1.3. Population size scoring methods:

The population size sub-factor is also generally straightforward to obtain (via SARs). This sub-factor element was included, using the IUCN criteria specified for identifying small populations, given that not all endangered nor listed marine mammal species necessarily have low populations. Population estimates can be dated or differentially supported; some contingency for an unknown value is made if size estimates have not been updated in the three most recent SARs and the population could reasonably be below 2,500. This is also an annual value with no variance in monthly scores.

VULNERABILITY FACTOR 2: Species Habitat and Temporal Factor (12 of 30 possible)

A second consideration for evaluating species-specific vulnerability include the relative presence of a species within the zone being evaluated and key contextual factors related to biological activities within the period being evaluated. This is the most heavily weighted of the total factor scores. Criteria and descriptions for two sub-factors are provided below (Table 2), followed by a methodological description for determining sub-factor scores. The habitat and temporal factor includes two defined sub-factors:

2.1. Habitat use
2.2. Temporal overlap

Table 2. Species habitat and temporal factor scoring criteria

Species habitat and temporal factor elements	Score (max 12)
Sub-factor 2.1. Habitat use: • Specified zone contains ≥ 40% of total regionwide or estimated population during specified period) = 9 • < 40% and ≥ 35% = 8 • < 35% and ≥ 30% = 7 • < 30% and ≥ 25% = 6 • < 25% and ≥ 20% = 5 • < 20% and ≥ 15% = 4 • < 15% and ≥ 10% = 3 • < 10% and ≥ 5% = 2 • < 5% and ≥ 1% = **1** • < 1% = **0**	**max = 9**
Sub-factor 2.2. Temporal overlap: • *High probability* that activity will overlap with concentrated breeding/maternal care periods and/or key migration periods within specified area = **3** • *Med probability* that activity will overlap with concentrated breeding/maternal care periods and/or key migration periods within specified area = **2** (also assigned when insufficient data on species biology exists by which to assess potential overlap) • *Low probability* = that activity will overlap with concentrated breeding/maternal care periods and/or key feeding or migration periods within specified area (where 1-5% of population is within zone during period) = **1** • *No probability* – species effectively not present in zone during period (where <1% of population is within zone during period) = **0**	**max = 3**

Sub-factor 2.1. Habitat use scoring methods:

This is the most heavily weighted sub-factor score of any of the eight included. The use of baseline density for the species being assessed is central in several ways to the overall spatial-temporal risk assessment framework developed by Southall et al. (2023) and is the basis of this sub-factor score. It is noted that the spatial density data are the underpinning of the exposure index calculation that is the basis of the other axis of the overall risk matrix. However, those calculations are made on relatively small grid cells considering density in the region immediately around the area of disturbance (windfarm in the current application). The application of the density data in this sub-factor is intended to identify overall presence of the species in a defined temporal period within the entire zone as a function of the overall regional population. This allows an evaluation and inclusion of broad scale seasonality of movement and identification of variable temporal risk for transient/migratory species that may not exist for less seasonal or especially highly resident species (e.g., Forney et al., 2017). The approach presented here is entirely objective and transparent but requires robust spatially and temporally explicit density layers (e.g., Roberts et al. databases for the east coast zones considered in the current project). Such density layers provide a means of calculating the zone-specific population (by month) as a percentage of the overall, regionwide population. The RAF team has used varying degrees of resolution for the breakpoints in this scoring scheme in different contexts (e.g., on the U.S. west coast where few such density layers exist). The approach presented is the most refined and explicit given the existing density data layers for the zones and species considered here. These values (with min/max and 95% Confidence Intervals) are presented graphically and accessible digitally in the RAF tool developed for operationalization by BOEM. Less granular resolution and/or expert elicitation to determine scores, or the inability to derive values, will be required in other regions and/or species for which less explicitly derived density data exist.

Sub-factor 2.2. Temporal overlap scoring methods:

This sub-factor is relatively subjective, requiring some expert assessment of the relative probability of a period including critical biological functions. Recent modifications include the

use of zone density data as markers for low and no probability scores. Subjective assessments for moderate or high probability are now focused on seasonally-important reproductive and migration periods, which may be more readily known or identified than key foraging periods. The SAR and/or supporting peer-reviewed publications are primarily used for this determination. The challenges of evaluating this sub-factor in a rapidly changing climate are noted. Given the challenges and subjective nature of these assessments, where uncertainty exists a moderately high (2 of 3) score may be assigned. This is a monthly sub-factor score. Highest potential vulnerability is assessed for areas where species have high site fidelity (e.g., Forney et al., 2017), and by default engage in key biological functions within the evaluated area.

VULNERABILITY FACTOR 3: Other Stressors Factor (8 of 30 possible)

The final vulnerability scoring factor considers existing contexts of other stressors for the species both within the zone and population-wide. These include anthropogenic factors on and environmental (non-anthropogenic) three sub-factor elements (see: Table 3), including:

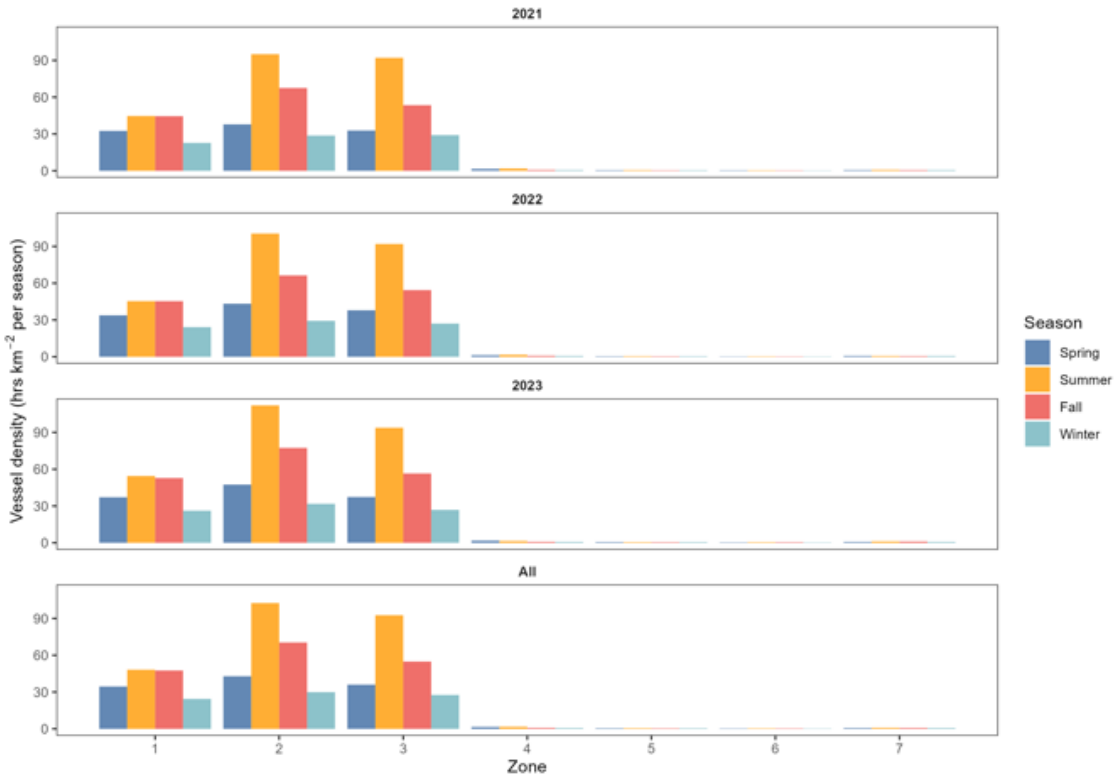
3.1. Zone-specific anthropogenic stressors
3.2. Population level chronic anthropogenic risk factors
3.3. Chronic biological risk factors

Table 3. Other stressors scoring criteria

Other Stressors Factor Elements	Score (max 8)
Sub-factor 3.1. ZONE-SPECIFIC anthropogenic stressors: Species subject to variable levels of current or near-future (5-years) chronic anthropogenic stressors. These include but are not limited to acoustic stressors. Stressors include dense or overlapping concentrations of industrial activity such as shipping lanes (50% of total score) and other anthropogenic activities including sonar testing ranges, areas of regular seismic surveys, whale watching, or research activities (50% of total score). Non-acoustic anthropogenic risks include vessel strikes, fisheries interactions, and entanglement; vessel activity is used as a general proxy for these risks. Since most noise associated with these stressors is low frequency in nature and highest risk of injurious non-acoustic stressors occurs for baleen whales, total potential scores are scaled by hearing group as follows: • Baleen whales: **Up to 3** • Seals (LF hearers): **Up to 2** • Odontocete cetaceans, Other pinnipeds: **Up to 1**	**Up to 3**
Sub-factor 3.2. POPULATION LEVEL chronic anthropogenic risk factors: Total annual known or estimated direct anthropogenic mortality, as documented in last SAR, status review, or peer-reviewed publication, evaluated relative to species-specific potential biological removal (PBR). • Annual mortality ≥ PBR: 3 • Annual mortality ≥ 50% PBR or mortality unknown/unreliable: **2** • Annual mortality ≥ 10% PBR: **1** • Annual mortality < 10%: **0**	**Up to 3**
Sub-factor 3.3. 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, status review, or peer-reviewed publication as reference). • Documented instances of multiple such stressors in recent SARs, status reviews, and/or available recent peer-reviewed literature: **2** • Documented instance of one such stressor in recent SARs, status reviews, or available recent peer-reviewed literature: **1** (also assigned when insufficient data is present) • No documented instances of such stressors where species are sufficiently monitored: **0**	**Up to 2**

Sub-factor 3.1. Zone-specific anthropogenic stressors scoring methods:

This is the only sub-factor score that is entirely subjective, but specific evaluation criteria are provided. The objective is to provide a zone-wide assessment of relative presence of a range of acoustic and non-acoustic anthropogenic stressors that already exist (i.e., not associated with the activity being evaluated), similar to the kinds of broader cumulative impact assessments conducted in NEPA analyses. Given the disproportionate presence of shipping in many areas as well as the range of auditory and non-auditory impacts (including potential mortal impacts such as vessel strike), 50% of the entire possible score is based on vessel distribution with the assumption that AIS tools for evaluating relative concentrations would be applied. For this assessment, we applied a three-point assessment (low-med-high) for multiple categories of some of the larger and/or more common vessel types (container ships, tankers, large fishing vessels) using available AIS data. These were aggregated into total vessel density for each zone across the entire region (7 zones) for the current example across the three most recent years (see example below). This was done seasonally and values were assumed to apply for each month within the season. A subjective elicitation of these values in terms of relatively low-to-high density across each zone and season was made in the current scoring. An explicit quantitative calculation method could be developed but was deemed overly complex and not necessary for the purposes of the relativistic assessment conducted here.



Other known potential stressors are considered and comprise the other 50% of the possible score allocated. These include the presence of known seismic surveys in the region – no surveys within a season is allocated a score of none, a single survey is considered moderate, multiple surveys considered high respectively. terms of occurrence with a single. Sonar testing is treated similarly with the absence of any activity allocated none, any known/intermittent testing being scored as low or moderate, and the presence of a sonar range being considered high. Offshore wind energy construction and operation is treated similarly in that an absence of development and windfarms is considered none, a single development or existing farm in a region is considered moderate, and multiple developments is considered high. Relative magnitude of both whale watching, and research activities are subjectively determined based on whether they are completely absent or known to occur more or less intensively in certain seasons. Each of these five activities has a maximum possible contribution of 10% of the total score, comprising the remaining 50% of possible scores. The overall score (including the vessel operational score) is evaluated seasonally with identical scores used for each of (3) months

sequentially. An example scoring table for Zone 1 of the east coast region is provided below showing the seasonal scores determined for each of the compositve factors

Stressor Type	Occurrence, Density (Spring)	Seasonal Max Score (Spring)	Occurrence, Density (Summer)	Seasonal Max Score (Summer)	Occurrence, Density (Autumn)	Seasonal Max Score (Autumn)	Occurrence, Density (Winter)	Seasonal Max Score (Winter)
Vessel Operations	Moderate	**1**	High	**1.5**	High	**1.5**	Moderate	**1**
Seismic Surveys	None	**0**	None	**0**	None	**0**	None	**0**
Sonar ranges	None	**0**	None	**0**	None	**0**	None	**0**
Offshore wind	Moderate	**0.2**	High	**0.3**	High	**0.3**	Moderate	**0.2**
Whale Watching	Low	**0.1**	Moderate	**0.2**	Moderate	**0.2**	Low	**0.1**
Research activities	Moderate	**0.2**	Moderate	**0.2**	Moderate	**0.3**	Low	**0.1**
TOTAL MAX SCORE		**1.5**		**2.2**		**2.2**		**1.4**

Given the acoustic and low-frequency nature of most of these stressors, a relative weighting that accounts for hearing group specific perception (weighting baleen whales highest, followed by seals, and odontocete cetaceans) is also applied (see table above).

Sub-factor 3.2. Population level chronic anthropogenic risk factors scoring methods:
This is an objective and straightforward scoring determination. It requires estimates of mortality relative to specified criteria for population impacts (PBR) as accessed from the most recent SARs. This is an annual score for the entire population that is constant across seasons and areas. Where insufficient or recent data on mortality or PBR are available, an unknown/unreliable score option is provided.

Sub-factor 3.3. Chronic biological risk factors scoring methods:
This is also an objective and relatively straightforward scoring determination. It requires documentation of non-acoustic existing environmental risk factors as documented in the most recent SARs, peer-reviewed publications, and other appropriate sources. This is also an annual score for the entire population, constant across seasons and areas. Where insufficient or recent data are available, an unknown/unreliable score option is provided.