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To the reader:

The following report was completed by a multidisciplinary team at California Ocean Alliance (COA), at the request of National Fish and Wildlife Foundation and NOAA as part of the *Deepwater Horizon* (DWH) Reduce Impacts of Anthropogenic Noise to Cetaceans project. Funding for the project was provided by the Open Ocean Trustee Implementation Group to restore natural resources injured by the 2010 DWH oil spill in the Gulf of Mexico. This report brings existing data together and make initial recommendations for pilot projects that have potential to demonstrate noise reduction methods in the Gulf of Mexico. The report completed by COA is intended to provide a roadmap for feasible noise reduction strategies based on the distribution of cetaceans and sound sources in the Gulf of Mexico.

The project established a steering committee of NOAA experts on underwater noise and marine mammals. At our request, this report was produced to assist our further development of pilot project areas and progress industry engagement.

The three planned pilot project areas focus on noise reduction through changes in seismic survey operations, vessel engineering, and vessel operations as recommended in the report. In further developing the pilot projects in each of these areas, the project team is taking into account this report in the context of additional engagement with industries and agencies working the Gulf of Mexico and the likelihood of partners voluntarily participating in the pilot projects.

Ultimately, the final details of the pilot projects will be driven by available project funding, willing partnerships and the ability to complete pilot projects focused on the feasible options to reduce noise for cetaceans that could be adopted more broadly in the future.

We appreciate your interest in our work to restore for the injury to marine mammals from the DWH oil spill.

Leila Hatch, NOAA National Ocean Service, Office of National Marine Sanctuaries
Jason Gedamke, NOAA Fisheries, Office of Science and Technology
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Members of the NOAA Project Steering Committee

Reducing Impacts of Anthropogenic Noise to Cetaceans
in the Gulf of Mexico:
Collaborating with Industry on Noise Reduction Pilot Projects

Recommended Options Paper

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Executive Summary

Background

The Gulf of Mexico (GoMex) environment is impacted by a variety of human-made sound sources including seismic airguns, small and large vessels, explosives, and pile driving. Increased noise levels from these sources may disrupt or displace life function behaviors and cause direct physical harm to whales and dolphins. Impacts from noise may include reduced foraging success, reduced reproductive success, masking of communication and environmental cues, and habitat displacement. In 2019, the Reduce Impacts of Anthropogenic Noise on Cetaceans project was selected as a marine mammal restoration project and funded by the Open Ocean Trustee Implementation Group (OO TIG) in Restoration Plan 2.

NOAA partnered with the National Fish and Wildlife Foundation (NFWF) for assistance in completing the project. NFWF secured a contract team to conduct the assessment, analysis, and preliminary industry engagement tasks. The resulting product is a recommended options paper, which is intended to provide a roadmap for feasible noise reduction strategies based on the distribution of cetaceans and sound sources in the GoMex. The information in this paper was presented to NOAA to inform development of pilot projects, further industry engagement, and/or other noise reduction activities within DWH restoration efforts.

The contract team utilized data from, and focused on areas around, selected Passive Acoustic Monitoring (PAM) stations in conducting a relativistic ecological risk assessment analysis. This process evaluated the relative overlap of different human activities and cetaceans in defined spatial and temporal windows. It enabled the development of a large subset of initial quieting scenarios, which, in combination with industry engagement, ultimately resulted in the refining of a small number of recommended pilot project options. The risk assessment approach, industry engagement, and recommended pilot project options are described briefly below and in detail in the full report.

Data Sources

Based on initial discussions, the team identified a one-year timeframe (1 Aug 2020 – 30 Sept 2021) for the analysis and bounded the study area to include the northern half of the GoMex (defined as all oceanic areas north of 24.5° N latitude). Existing data for 13 marine mammal species (distribution and density) and 4 anthropogenic noise sources were aggregated for this region and period. Density layers of focal species and anthropogenic noise sources (known seismic survey locations, vessel tracks, presence of offshore industry platforms, offshore wind energy lease areas) were determined on a one-month resolution for the study timeframe. Data from existing PAM stations provided comparisons of average noise levels for different areas of the GoMex. The biological and noise data were processed to visualize monthly spatial patterns. The integrated data were then used in the ecological risk assessments, which derived relative comparisons of conditions, or species-specific listening spaces, around existing PAM stations.

Ecological Risk Assessment

Monthly patterns in marine mammal density and anthropogenic noise activity were integrated and visualized for each month. A user-friendly dynamic mapping tool was developed to enable visualization and exploration of the existing data. This tool allows users to choose specific combinations of conditions to plot, such as the overlap in sperm whale distribution and the calculated listening space for a seismic airgun survey for a scenario. Animal density layers change monthly, as do many noise data layers (seismic surveys, vessel activity). Listening space polygons for each marine mammal frequency-specific hearing group and noise source were modeled quarterly and thus change every three months. Some data layers were the same for all months (oil platforms, wind energy lease areas) and could be toggled on and off. The purpose was to have a flexible and relatively simple tool to visualize and calculate the degree of spatial and temporal overlap of focal species and specific noise sources, accounting for perceptual capabilities. This was done both within the context of the risk assessment and scenarios development, as well as a demonstration tool of the overall spatial, temporal, spectral basis of the overall assessment.

The objective of the ecological risk assessment was to assess underwater anthropogenic noise sources in the GoMex relative to marine mammal presence and hearing. Within this analysis, the best available spatial, temporal, and spectral data on species presence and underwater human noise sources was used to conduct a relative ranked assessment of spatially and temporally explicit conditions. The spatial focus centered around existing PAM stations and the relative listening spaces. Each month-site (N = 120) resulted in a relative categorical rank of conditions: High-Noise High-Species, High-Noise Low-Species, Low-Noise High-Species, Low-Noise Low-Species. This categorical ranking approach provided a simple, understandable basis for evaluating the relative magnitude of overlap between species and activities across space and time over the large geographical area considered. To derive this ranking, a relativistic noise activity index based on the degree of overlap in noise sources and species presence were calculated.

Industry Engagement

A central element throughout this project involved open, collaborative engagement with multiple industry sectors that operate seismic surveys and vessels in the GoMex. This included iterative engagement to: (1) listen and learn more about those industries, make new contacts, and introduce the project; (2) help obtain important information for the spatial and temporal data integration and risk assessment processes; (3) inform and guide the development of the initial quieting solution options; and (4) develop and refine provisional rankings of source-specific engineering and operational quieting techniques. Each iterative stage directly informed subsequent industry engagements to evaluate and adapt the initial quieting scenario options based on feasible, viable, and available options. In concert with these subsequent interactions with industry, they also informed the project team in developing the recommended pilot project options presented below.

Modeling of Identified Quieting Approaches

In order to demonstrate simple, understandable, quantitative approaches to compare the predicted results of identified quieting approaches if implemented in the same time and place, additional noise propagation modeling was conducted. The objective was to illustrate approaches where relative differences in modeled radiated noise from different source types or configurations could be evaluated using standard noise propagation modeling and represented in simple, meaningful metrics (areas ensonified, numbers of individuals of focal species exposed) that could ultimately be predicted and then compared with measured noise fields in subsequent pilot projects. This is intended to illustrate relative differences between different potential existing sources and quieting approaches using the available information regarding possible quieting solutions and underlying assumptions.

These are designed to be understandable to a general audience and relatable in terms of the kinds of relative reductions associated with quieting approaches that have been applied in other noise mitigation efforts. Within the context of the current effort to provide recommended options for pilot projects, this is intended to serve as a demonstration of the relative magnitude of possible noise reduction given industry-provided assumptions about noise sources, and as tools that could be applied within pilot efforts to make such predictions ahead of specific field tests and to evaluate predicted noise reduction relative to empirical field measurements.

Recommended Pilot Projects

Testing Existing Alternatives to Traditional Airgun Seismic Surveys

Seismic airguns represent some of the loudest and most broadly detected industrial noise sources. Given their high source levels and broadband frequency output, airgun arrays can have a wide range of potential auditory (hearing), behavioral, and physiological impacts on sound-sensitive species, including marine mammals. The goal of this proposed pilot project would not be to generate new 'quieting solutions', nor to implement existing quieting solutions during ongoing surveying activity in the Gulf,' but to comparatively test and evaluate potential 'quieting solutions' that have already been developed. Some technologies were created for separate operational reasons that additionally rendered them quieter or more efficient, others were specifically created to reduce biological impacts without limiting the desired geophysical characteristics of the sources. One of the key objectives here is to provide a systematic way to measure, evaluate, and compare in a standardized manner the output characteristics of sources in an open and transparent way, with industry participation.

Vessel Quieting – Engineering Solutions

Supply and service class vessels are used throughout the GoMex to provide supplies/equipment to offshore rigs. The focus on vessels in this pilot is on noise associated with point-to-point transit rather than other aspects of operations (e.g., dynamic positioning) or other active noise sources (e.g., echosounders, fathometers, communications systems). Other vessels this Pilot may consider are passenger vessels, ferries, towboats, or tugboats. These vessels generally fall into the 'mid-size' vessel class (~10-100m), which also includes some of the larger fishing vessels. Though variable throughout the year and depending on economic conditions, these vessels combined constitute roughly 40-60% of vessel activity in nearshore and 0-40% of vessel activity in offshore regions of the GoMex.

Noise radiated from transiting medium-sized vessels is less intense and broadband in character than seismic airguns and (to a lesser extent) than large commercial vessels. However, the overall operation of these vessel types, including their offshore stationkeeping activities maintained mostly by thrusters generally centered around offshore facilities with a host of industrial noises, it is a substantial contribution to the overall soundscape of the GoMex given the large number and relatively wide distribution of vessels.

The goal is not to generate new vessel 'quieting solutions,' but to provide a service to those companies who are engaged in use of new methods by providing information on noise quieting benefits, thus incentivizing broader adoption. The project would systematically compare the measured noise signatures of various vessel designs and treatment configurations. It would establish a standardized testing platform in an open ocean environment to evaluate existing, new build, and retrofit designs proposed for emissions reduction targets for their relative sound reduction benefits measured relatively close to sources.

Operational Approaches for Quieting Commercial Vessels while Underway

Large commercial vessels (>100m) are used throughout the GoMex to transport large amounts of dry goods, grain and other foods, fuel and chemicals, vehicles, large cruise ships, and other large sources of cargo. These vessels constitute roughly 20-40% of vessel activity in nearshore areas and 40-70% of vessel activity in the offshore regions of the GoMex. These vessels, which include container ships, tankers, roll-on/roll-off cargo ships, etc., are typically powered by massive low-speed diesel engines and are typically configured with a single large propeller along the centerline of the vessel. However, large cruise ships frequently have multiple propellers. Medium-sized service vessels (up to 100m) provide supplies/equipment to offshore rigs, serve as passenger vessels, tow equipment and other vessels, act as tugs to help larger vessels navigate into port, and include larger fishing vessels. These vessels constitute roughly 40-60% of vessel activity in nearshore areas and 20-40% of vessel activity in the offshore of the GoMex.

Noise radiated from vessels is less intense, impulsive, and broadband than seismic airguns. Large commercial vessels are generally louder overall and more intense at lower frequencies than medium-sized vessels. Faster vessels are typically louder than slower vessels, although this is a complex relationship that varies between classes and other factors (e.g., vessel loading and propulsion plant type). Vessel-associated underwater radiated noise from some of the larger sized vessels and especially large container, tanker, and cargo ships are a substantial contribution to the overall soundscape of the GoMex given their large number and broad distribution.

The goal is not to generate new vessel 'quieting solutions,' but rather to evaluate potential modifications in the operation of existing, unmodified vessel to achieve targeted quieting approaches. The project would systematically compare the measured in water Underwater Radiated Noise (URN) of specific vessel transit speeds in specific locations selected based on propagation modeling to reduce radiated noise into certain areas. Standardized measurements would be made of broadband (10 Hz – 10 kHz) underwater radiated noise (quantified in decidecade and spectrum level standard metrics) for standard near-field (<100m) ranges for vessels of different types and operational profiles traveling in identical paths and locations at common, standard speed(s).

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Appendix II. Initial Quieting Scenario Options

1. Project background, purpose, and guiding principles

The Gulf of Mexico (GoMex) environment is impacted by a variety of human-made sound sources including seismic airguns, small and large vessels, explosives, and pile driving. Increased noise levels from these sources may disrupt or displace life function behaviors and cause direct physical harm to whales and dolphins. Impacts from noise may include reduced foraging success, reduced reproductive success, masking of communication and environmental cues, and habitat displacement.

The Reduce Impacts of Anthropogenic Noise on Cetaceans project was selected and funded in 2019 by the Open Ocean Trustee Implementation Group (OO TIG) in Restoration Plan 2/Environmental Assessment: Fish, Sea Turtles, Marine Mammals, and Mesophotic and Deep Benthic Communities (RP/EA). This project is one of four projects selected for marine mammal injury caused by the *Deepwater Horizon* (DWH) oil spill and supports the OO TIG's goal to identify and implement marine mammal restoration actions that address direct threats such as noise.

The full project budget is $8.9 million dollars over 6 years and includes multiple elements:

- Passive acoustic monitoring of cetaceans and noise sources and associated data analysis
- Assessment of cetacean and noise source distributions
- Analysis of noise reduction opportunities in the Gulf of Mexico
- Industry outreach and engagement
- Implementing voluntary pilot projects
- Analysis of success of industry engagement and pilot efforts to inform future investment

The passive acoustic monitoring and associated data analysis is being led by the National Oceanic and Atmospheric Administration (NOAA). At the end of the project, NOAA will analyze the success of these efforts to inform potential future restoration actions. NOAA partnered with the National Fish and Wildlife Foundation (NFWF) for assistance in completing the remaining project elements. NFWF secured a contract team to implement Phase I to include the assessment, analysis, and preliminary industry engagement tasks. The resulting product is this recommended options paper, which is intended to provide a roadmap for feasible noise reduction strategies based on the distribution of cetaceans and sound sources in the GoMex. The information in this paper is presented to NOAA to inform development of pilot projects, further industry engagement, and/or other noise reduction activities within DWH restoration efforts.

The objectives for Phase I were to identify potential actionable and effective quieting solutions for seismic survey operations and vessels of various categories through direct industry engagement. The large number of the sources involved in these activities and their collective contribution of noise throughout the GoMex was clearly recognized at the outset. These contributions to ambient soundscapes have been monitored and documented through dedicated, sustained passive acoustic monitoring (PAM) led by NOAA that informed the current effort in several ways. The project team utilized data from, and focused on areas around, selected PAM stations in conducting a relativistic ecological risk assessment analysis. This process evaluated the relative overlap of different human activities and cetaceans in defined spatial and temporal windows. It enabled the development of a large subset of initial quieting scenarios, which, in combination with industry engagement, ultimately resulted in the refining of a small number of recommended pilot project options. The risk assessment approach (section 4), industry engagement (section 5), and recommended pilot project options (section 7) are described in detail below. The boundary conditions for the project, as well as the biological and anthropogenic data sources and processing used in this process, are described in detail in these sections.

2. Phase I Team Members and Roles

The team assembled for the Phase I effort culminating in this report included a strategically selected collaboration of biologists, acousticians, noise propagation modelers, and spatial ecologists. Individual team member qualifications and roles are provided below.

Dr. Michael Bahtiarian, INCE Bd. Cert. (Acentech, Inc.) served as the maritime-industry liaison for this project. He was involved with industry engagement and the development of the vessel engineering and operational pilot projects. Industry engagement included attending two maritime conferences, presenting at one conference, and hosting a seminar for vessel operators, naval architects, and noise control treatment manufacturers. Mr. Bahtiarian also attended a special conference at the International Maritime Organization (IMO) in London on reducing ship's underwater radiated noise and vessel efficiency. Mr. Bahtiarian is a board-certified noise control engineer with over 25 years of experience in designing quiet ships, including: the NOAA Fishery Research Vessels (FRV), AGOR-24 Class, and the University of Delaware *R/V Sharp*. Mr. Bahtiarian chaired committees that produced the first two standards for the measurement of underwater noise from ships, namely ANSI/ASA S12.64 and ISO-17208-1. He is the 2018 Distinguished Noise Control Engineer and a fellow of the Institute of Noise Control Engineering (INCE-USA).

Dr. Kevin Boswell (Florida International University) provided data and context on ecological effects of oil and gas industry infrastructure in the northern GoMex. Dr. Boswell is a marine ecologist and expert in fisheries acoustics with extensive experience across coastal, shelf and mesopelagic communities in the GoMex. He has led the water column acoustics program in the GoMex for NOAA and DEEPEND/RESTORE since the Deepwater Horizon Oil Spill as well as leading the acoustics component of the NOAA RESTORE project focused on Rice's whale habitat and prey preferences off the West Florida Shelf. He is the Marine Biology Director and PI of the Marine Ecology and Acoustics lab at Florida International University.

Dr. Michael Jenkerson (MJ.Pegasus, LLC.) was involved in the review and feasibility assessment for the quieting options being considered for the seismic pilot project. He is an expert on seismic sources and in-water acoustics and has been involved in the development of quieter seismic sources and the impact of seismic noise on marine life since the early 1990s. He has been involved with the development of marine vibrators for 25 years and was the research category chair for category 1 (sound sources and propagation) for the International Association of Oil and Gas Producers (IOGP) Sound and Marine Life Joint Industry Program. He participated in the Western Gray Whale monitoring and mitigation program associated with seismic acquisition on the Sakhalin shelf and was closely involved with the development of monitoring and mitigation equipment and procedures in the area from 2001 to 2020.

Mr. John Joseph (Naval Postgraduate School) provided critical technical review and input on acoustic modeling design and approaches applied to seismic and vessel sources. Mr. Joseph is a physical oceanographer with extensive experience in underwater acoustics and acoustic modeling of undersea environments. He led the west coast regional component of the NOAA/Navy Sanctuary Soundscape project, which characterizes the ocean soundscape in several National Marine Sanctuaries. He co-developed highly effective acoustic modeling tools that have been used extensively in support of behavior response studies and collaborated with academic and government scientists on acoustic propagation studies in challenging environments ranging from major estuaries to the Arctic region.

Dr. Tetyana Margolina (Naval Postgraduate School) was involved in setting, conducting, and interpreting ocean propagation modeling experiments. Dr. Margolina is a physical oceanographer and marine bioacoustician. Her area of expertise includes underwater acoustics, acoustic propagation modeling, and analysis of ocean soundscapes. She has co-developed a BRS Sound Exposure Modeling Tool, which has been used for near real-time planning of controlled exposure experiments and post-processing of the field results. She has conducted extensive modeling of sound propagation for a wide variety of sources and underwater environments in the US National Marine Sanctuaries.

Dr. Megan McKenna (California Ocean Alliance) served as a lead analyst for the project. She was involved in developing and implementing the ecological risk assessment, providing design and technical guidance for the data explorer, developing and justifying quieting scenarios, and evaluating potential noise reduction from the pilot project options. Dr. McKenna is an expert in acoustics and data analytics, having published nearly 70 peer-reviewed articles related to noise impacts on protected species and places. She has over a decade of experience working as a research scientist developing and delivering tools, frameworks, and scientific syntheses to build conservation strategies and policy. Dr. McKenna has also helped develop international standards and served on several national and international working groups and committees to understand and manage acoustic impacts on wildlife.

Dr. Doug Nowacek (Duke University) supported the design and assessment of quieting options and feasibility, was directly involved in industry engagement, and contributed to the development of the recommended pilot project options. Dr. Nowacek is an expert on the acoustic ecology of marine mammals, having published over 100 peer-reviewed articles and technical reports on the topic. He has led several large behavioral response studies with marine mammals and various human noise sources and has worked at the intersection of offshore industry and potential impacts to marine mammals for more than 20 years. He has been involved in the efforts on vessel quieting since NOAA first started to address the issue and has worked with various groups of stakeholders (i.e., industry, NGO, government) on issues of noise exposure and quieting. Finally, he has been involved in the development of behavioral response criteria development at the national and international levels.

Dr. Rob Schick (California Ocean Alliance) served as a lead analyst for this project, integrating spatially and temporally explicit data within a quantitative and data visualization tool that supported the development of quieting scenarios, interpretation of propagation modeling results, and proposed pilot projects. He is a quantitative ecologist with over 20 years studying the movements and distributions of a wide variety of taxa, including: North Atlantic right whales, beaked whales, elephant seals, and even humans. The common thread throughout his research projects is the spatial ecology of the different systems. He has a special interest in animal movement, and using statistics to better understand how humans impact the behavior and distribution of marine mammals.

Dr. Brandon Southall (California Ocean Alliance) served as the lead investigator for this project and was involved in all aspects of developing and implementing risk assessment, quieting options and feasibility assessment, industry engagement, and development of the recommended pilot project options. Dr. Southall is an expert on acoustics and marine mammals, having published nearly 200 peer-reviewed articles and technical reports on the effects of noise. He led the development of novel acoustic exposure criteria for marine mammals and several large behavioral response studies with marine mammals and various human noise sources. He was centrally involved in the initial efforts on vessel quieting while running NOAA's Ocean Acoustics Program and in the development of the first guidelines at the IMO.

3. Biological and Anthropogenic Noise Data Sources and Processing

Given the fundamentally spatial and temporal nature of how the intersections of different marine mammal species and noise sources were evaluated, a key early step was to identify the time periods, spatial areas, and their respective resolution to be evaluated. These were necessary boundary conditions for identifying, obtaining, and intersecting biological and anthropogenic noise data sources. Based on initial discussions with the project management team and NOAA steering committee, the team identified a one-year timeframe (1 Aug 2020 – 30 Sept 2021) for the analysis and bounded the study area to include the northern half of the GoMex (defined as all oceanic areas north of 24.5° N latitude).

Existing data on marine mammals and anthropogenic noise sources were aggregated for this region and period using methods and sources described below. Density layers of focal species and anthropogenic noise sources (known seismic survey locations, vessel tracks, presence of offshore industry platforms) were determined on a one-month resolution for the study timeframe. Data from existing PAM stations provided comparisons of average noise levels for different areas of the GoMex. The biological and noise data were processed to visualize monthly spatial patterns. The integrated data were then used in the ecological risk assessments, which derived relative comparisons of conditions around existing PAM stations.

3.1. Marine Mammal Distribution and Density

Marine mammal species considered included all focal GoMex (non-coastal) species identified for DWH restoration actions, specifically: ESA-listed Rice's whale and sperm whale, as well as beaked whales (considered as a species group for density estimation), Risso's dolphin, pantropical spotted dolphin, and oceanic bottlenose dolphin. Five additional species or species groups were also evaluated within the relativistic ecological risk assessment (section 4) to evaluate potential co-benefits of noise reduction approaches for all protected species. These included species for which spatially and temporally explicit density data were available: blackfish (also considered as a species group), oceanic Atlantic spotted dolphins, pilot whales, spinner dolphins, and striped dolphins. For the purposes of the risk assessment, focal Rice's and sperm whales were identified as 'priority species'. This distinction was specified given both their endangered status and the fact that are almost certainly among the most sensitive species in the GoMex to low frequency human noises; Rice's whales are the only species from the low-frequency hearing group species occurring in the GoMex[1].

Marine mammal density estimates for these focal species/groups were provided from analyses conducted by the NOAA's Southeast Fisheries Science Center. Monthly predictions of species distribution and abundance for 13 marine mammal species were determined based on selected predictor variables including: depth, distance to bathymetric features (shore, shelf breaks, canyons), slope, and a host of dynamic oceanographic variables[2]. Monthly predictions were averaged for 2015-2018 within a 40 km hex grid cell and the units for abundance are numbers of animals. To convert to density (number/km^2), these were divided by the area of each hex grid cell.[2]

3.2. Application of Existing Passive Acoustic Monitoring (PAM) Stations

Scripps Institution of Oceanography and Southeast Fisheries Science Center provided geographical locations, depths, and summary acoustic data from selected PAM deployments. NOAA PAM sites with data collected from 11 August 2020 – 30 Sept 2021 were exclusively used in this analysis. For these 10 sites, frequency-specific 1-Hz percentile sound level measurements were extracted on days identified as low wind days from nearby NOAA buoy[3]. Low wind days were defined as days with wind speeds less than 10 knots for more than 90% of the day.

As described in more detail below (see section 4; Appendix 1), species-specific acoustic 'listening spaces' were calculated for three categories of anthropogenic noise sources (seismic surveys, large vessels, medium vessels). These areas were determined based on characteristics of each noise source type, the hearing capabilities of each species based on categorical

[1] 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

[2] Garrison, Lance P., Joel Ortega-Ortiz, and Gina Rappucci. "Abundance of marine mammals in waters of the US Gulf of Mexico during the summers of 2017 and 2018." (2020).

[3] https://www.ndbc.noaa.gov/

characteristics for different 'hearing groups' derived in recent noise exposure criteria[4], and noise propagation modeling using common assumptions. Listening spaces were calculated from the source-specific and animal hearing group-specific transmission loss (TL) fields using specified signal-to-noise thresholds, identified as a received level (RL) at which detection of noise sources by animals was likely for each condition. Standard noise propagation modeling approaches were used to identify areas in which these RLs would be met or exceeded given the location of sources. The respective TLs for each PAM site and context were modeled using a Navy version of the range-dependent parabolic equations (PE) acoustic propagation model[5] and US Navy and NOAA environmental databases: High-Resolution ¼ degree Global Sea Surface Wind Speed and Climatology (NOAA); Bottom Sediment Type (BST; Navy) database and Global Ocean Sediment Thickness Dataset (NOAA).

The estimated listening spaces allowed for relative comparisons of conditions around each PAM station to evaluate the overlap of marine mammal density and noise from anthropogenic activity within these defined areas. The listening spaces also provided a spatial estimate of the area where reducing noise would benefit species in the area, as well as the opportunity to measure a reduction in noise if noise reduction strategies are implemented at scale.

3.3. Seismic Surveys

Identification of the location, type, and magnitude of seismic airgun survey activities over the period evaluated involved multiple stages. Through early engagement with industry colleagues, a broad assessment of survey areas, types, and general timing was obtained. The team then coordinated directly with both the Bureau of Ocean Energy Management (BOEM) and the Bureau of Safety and Environmental Enforcement (BSEE) to obtain known locations and temporal occurrence of seismic survey activity within the specified study period. This included publicly available and openly accessible information from survey ship protected species observer (PSO) data and times and locations of seismic airgun transmissions provided in survey

[4] 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

[5] Collins M.D., A split-step Padé solution for the parabolic equation method, Journal of the Acoustical Society of America 93, 1736 (1993); doi: 10.1121/1.406739.

after-action reports[6]. This also included additional data and interpretation provided directly by BSEE on request using additional information provided through industry colleagues on additional surveys occurring during the specified period.

Data were of variable resolution and accessibility during the survey period. A simplifying assumption was made to identify whether and how many surveys were active for any duration and results were tallied as the number of surveys active per day with a confirmed shot location(s), vessel name, and general seismic technology used.

3.4. Vessel Transit Operations

Data from vessel traffic equipped with Automatic Identification Systems (AIS) and operating within the northern Gulf of Mexico were downloaded from MarineCadastre[7] as daily files. The data were processed to visualize transit patterns of different vessel classes in the northern Gulf and further processed to extract unique vessel counts by size within specified PAM listening spaces. The data were matched using unique MMSI with Coast Guard data (land-based and satellite) that includes the type of vessel.

3.5. Offshore Facilities Infrastructure

Existing offshore rigs and other industrial platforms in the GoMex as well as their operational status were identified based on data available from BOEM.[8] The number of active and inactive rigs were summarized within specified PAM listening spaces.

3.6. Future Offshore Wind Energy Considerations

Areas where future wind energy development is likely to occur based on proposed (at the time of the risk assessment described below) lease areas were also identified from the BOEM digital mapping tools.[8] These were specified as a simple binary answer within the risk assessment and

[6] Searched via: https://www.data.bsee.gov/Other/DiscMediaStore/ScanGGPermits.aspx

[7] https://marinecadastre.gov/ais/

[8] https://www.data.boem.gov/Main/Mapping.aspx

resulting scenarios. These areas were plotted for reference to future development in the northern GoMex and possible opportunities to implement vessel quieting technologies.

4. Data Integration, Visualization, and Ecological Risk Assessment

4.1. Spatial-Temporal Data Integration and Visualization

Monthly patterns in marine mammal density and anthropogenic noise activity were integrated and visualized for each month. A user-friendly dynamic mapping tool was developed to enable visualization and exploration of the existing data[9]. This tool allows users to choose specific combinations of conditions to plot, such as the overlap in sperm whale distribution and the calculated listening space for a seismic airgun survey for a scenario example in August provided below (Fig. 1). Animal density layers change monthly, as do many noise data layers (seismic surveys, vessel activity). Listening space polygons for each hearing group and noise source were modeled quarterly and thus change every three months. Some data layers were the same for all months (oil platforms, wind energy lease areas) and could be toggled on and off. The purpose was to have a flexible and relatively simple tool to visualize and calculate the degree of spatial and temporal overlap of focal species and specific noise sources, accounting for perceptual capabilities. This was done both within the context of the risk assessment and scenarios development, as well as a demonstration tool of the overall spatial, temporal, spectral basis of the overall assessment.

[9] https://sr-analytics.shinyapps.io/NFWF_shinyApp/

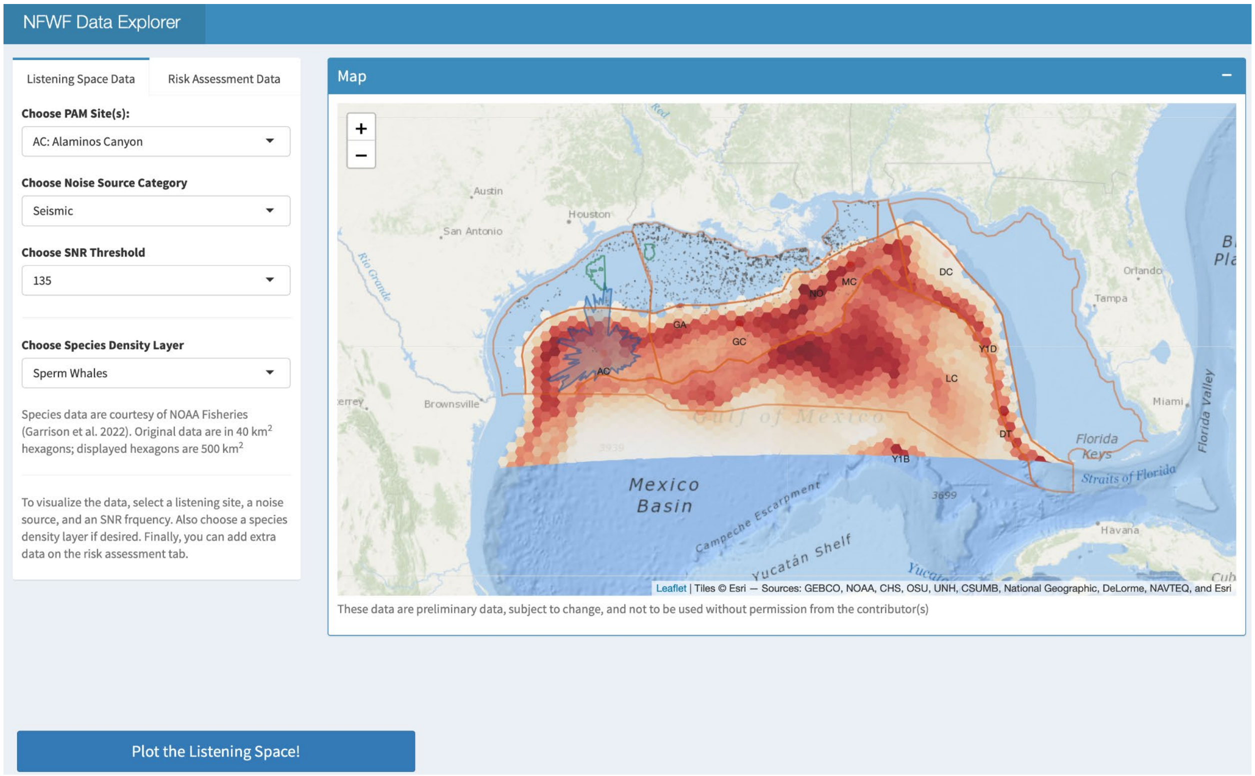

Figure 1. Illustration from data exploration tool highlighting the spatial relationship of the listening space (shown here (blue polygon) for a seismic source at Alaminos Canyon) in relation to sperm whale density (orange hex cells), wind energy lease areas (green polygons), active rigs (black dots), and the BOEM-identified GoMex marine mammal spatial zones used in the relativistic risk assessment (orange polygons).

4.2. Ecological Risk Assessment Methods

The objective of the ecological risk assessment was to assess underwater anthropogenic noise sources in the GoMex relative to marine mammal presence and hearing. A short synopsis of the process is provided here; for a detailed summary and examples see Appendix 1. Within this analysis, the best available spatial, temporal, and spectral data on species presence and underwater human noise sources was used to conduct a relative ranked assessment of spatially and temporally explicit conditions. The spatial focus centered around existing PAM stations and the relative listening spaces (see description in 3.2).

Each month-site (N = 120) resulted in a relative categorical rank of conditions: High-Noise High-Species, High-Noise Low-Species, Low-Noise High-Species, Low-Noise Low-Species. This categorical ranking approach provided a simple, understandable basis for evaluating the relative magnitude of overlap between species and activities across space and time over the large geographical area considered. To derive this ranking, a relativistic noise activity index based on the degree of overlap in noise sources and species presence were calculated. Each species-month-site was categorized as HIGH or LOW species presence based on the percentage of the populations within the estimated listening space relative to the total modeled population size. For month-sites in which greater than 10% of the total population was within the defined listening space a HIGH categorization was assigned. For each site, the number of species with HIGH categorization assigned were summed and ranked. The process for determining the noise activity index involved determining the presence of seismic activity, number of unique vessels in different categories, and presence of offshore infrastructure, and then ranking the relative activity and measured noise levels.

This relative ranking process was designed to result in a deliberately simple categorical designation to compare conditions across sites and months.[10] Sites generally showed similar noise conditions across months and the presence of relatively higher levels (more days) of seismic activity drove the changes in relative noise conditions. Vessel activity was generally similar across seasons, except for seasonal fishing vessels near some sites. Some sites showed monthly differences in relative densities of species, with assessment results depending on the relative presence of all focal species but especially identified priority species (Rice's and sperm whales).

The four conditions discussed above were further evaluated in considering the relative spatial and temporal presence of species identified as priority species: Rice's whale and sperm whale, or both. In areas and months where these species occurred in relatively high proportions (> 10% of the total modeled population), the associated predominant noise-generating activities were

[10] Results for all month-site relative risk assessment rankings are available at: https://docs.google.com/spreadsheets/d/17WpY4NfW0umapASPFL7X_sERyMl6MpY-huu45P1zOzI/edit#gid=0

considered within the context of the risk assessment results to inform site-specific noise reduction scenarios. For example, DeSoto Canyon had the highest relative densities of Rice's whales and noise activity predominantly from vessel activity, an observation that influenced the derivation of one of the original scenarios (section 5).

4.3. Application of Risk Assessment Outcomes to Identify Initial Scenarios for Pilot Projects

To derive and prioritize noise reduction scenarios in terms of efficacy, feasibility, and potential for industry collaborations, risk assessment results were evaluated across sites to identify scenarios most likely to benefit one or both priority species and/or have co-benefits for multiple other focal species. The noise activity index analyses were then used to identify the type and relative magnitude of noise sources at each site sectors. The interaction of these biological and noise source specific relativistic assessments was used to identify a relatively large number (dozens) of initial noise reduction scenarios identified as a potential location for reducing noise for specific species. Parallel initial industry engagement discussions to evaluate the opportunities for noise reduction for different sources and areas enabled a refinement of these initial scenarios. A total of 12 possible quieting scenarios were identified in this process for subsequent evaluation and consideration through more explicit industry engagement, each of which is described systematically in detail in Appendix II.

5. Industry Engagement

A central element throughout this project involved open, collaborative engagement with multiple industry sectors that operate seismic surveys and vessels operations in the GoMex. This included iterative engagement to: (1) listen and learn more about those industries, make new contacts, and introduce the project; (2) help obtain important information for the spatial and temporal data integration and risk assessment processes; (3) inform and guide the development of the initial quieting solution options; and (4) develop and refine provisional rankings of source-specific engineering and operational quieting techniques. Each stage of iterative industry engagement from initial introduction through the ranking and assessment of potential quieting techniques is outlined below, by industry sector.

5.1. Initial Industry Engagements and Evolving Collaborations

The team assembled for this project was strategically selected in part for their extensive background, expertise, and connections with both seismic survey and vessel operational industries in many direct capacities. Thus, the team began with an understanding of both the industry and current and emerging possibilities for operational and/or engineering solutions. This project, building on and learning from parallel efforts ongoing in other areas, presented new possibilities, collaborations, and opportunities for directed action focused on habitat restoration within the specific region of the northern GoMex. A strategic, iterative approach was taken to industry engagement with deliberately broad initial engagement, supported through existing partnerships, followed by adaptively evolving discussions with industry partners that were interested and willing to engage. The initial engagement strategy for various industry sectors was to reach out through established industry sector contacts working through trade organizations to help identify invitees to informational webinars about the new project. An overview of the initial approach for each sector is described here followed by an iterative approach to identify, refine, and systematically evaluate possible quieting approaches and their potential application in recommended pilot project options.

For seismic surveys, this initial engagement was achieved primarily through the alliance of geophysical contractors and included a sequence of virtual presentations and discussions. Early efforts included emphasizing the intention to collaborate with industry to ensure communication with the relevant industry contacts. This helped the team to identify and understand possible quieting solutions already being considered. An iterative approach with multiple points of industry engagement and verbal and written feedback then supported a systematic evaluation of the feasibility and efficacy of different options (described below).

Vessel operations, required a broader engagement strategy, given that this industry category includes dozens of different industry sub-sectors and stakeholder groups in the GoMex, including many different classes of vessel operators, offshore facilities, and classification societies. The team interacted with representatives from the US Coast Guard (USCG) and Department of Transportation (DOT) Maritime Administration (MARAD) who are working on vessel noise reduction and provided key contacts and updates throughout the process. Multiple broadly focused webinars were conducted, with invitations extended through collaborators at several trade organizations with known awareness and involvement in noise-related issues serving as conduits. In addition to, and informed by these initial engagements, several project team members attended various meetings to directly engage with industry sectors focused on the GoMex region. These included the *International Workboat Show*, *Green Marine Green Tech* conference, *American Waterways Operators* annual meeting (safe and sustainable by design panel), and a special *IMO session on underwater noise and potential synergies with gas emission reductions*. The engagement strategy ultimately evolved into sub-sector approaches focused on medium-sized service vessels (e.g., supply and service vessels, towboats, tugs, and ferries) and large commercial vessels (e.g., container ships, tankers, bulk carriers, roll-on/roll-off cargo ships, and large cruise ships). The team similarly engaged with these different industry sectors through personal meetings and initial webinars to identify interested and engaged parties and to identify and evaluate the feasibility, viability, and availability of different quieting approaches through subsequent focused industry engagement.

5.2. Identifying Engineering and Operational Quieting Approaches

A critical initial step for both seismic surveys and vessel operations was to utilize industry feedback to identify existing or reasonably near-term available relevant quieting approaches.

For each noise type, these were segregated into operational measures (involving changes to how, where, or when existing technologies were used) and engineering approaches (how existing or new sources could be modified or built to reduce radiated noise output).

For seismic surveys, the list of possible solutions considered included the following options:

Operational Approaches:

- Temporal or areal (spatial) avoidance of key areas
- Reduce the number of active elements in existing array

Engineering Approaches

- Modify airgun design to reduce noise output bandwidth
- Modify array design to drive output frequencies lower
- Alternative approaches to high-pressure impulsive airguns (e.g., vibroseis)
- Very low frequency sources
- Alterations of the timing of the element activation
- Physical barriers and mufflers

For vessel operations, the focus here is on noise associated with typical transit operations. For many vessels this represents essentially all their operations. For some vessels, especially during vessels servicing offshore facilities, station-holding with dynamic positioning can generate different and substantial kinds of low frequency noise. It is noted that these can be locally important, especially in areas near offshore platforms of which there are many in the GoMex. However, this was one of several additional known kinds of radiated noise from vessels that beyond the scope of this assessment focused on the broader issue of transit operations. The initial list of possible solutions related to noise associated with vessel transits considered included the following options:

Operational Approaches:

- Reduce speed, including consideration of cavitation inception speed
- Strategic routing based on noise modeling/measurement
- Reduce speed to below cavitation inception speed
- Secure (shut down) any unused or unnecessary machinery
- Clean hull & propeller

Engineering Approaches

- Propeller & Thrusters
  - Replace propeller(s) with an increased skew, higher grade finish, etc.
  - Add anti-singing edge
  - Add wake flow devices to propeller and hub
  - Add propeller ducts
  - Add air bubble system
- Hull
  - Hull modifications to improve water inflow into the propeller
  - Evaluate, modify (or remove) problematic appendages such as bilge keels, exterior coolers, rudder struts, and others.
  - Add air bubble system
- Inboard Machinery
  - Select quiet/quieter machinery (rotary engines, diesel electric plant)
  - Select quiet propulsion plant designs (battery, fuel cell)
  - Vibration isolation
  - Place noisy equipment inside acoustic enclosure
  - Add "High Transmission Loss" insulation on machinery room hull plating
  - Add vibration damping material (tile, spray, or trowel) on machinery room hull plating
  - Add sound absorptive material in machinery rooms
- Sea-Connected Systems
  - For systems with sea chests, line the sea chest with acoustically absorptive material that can withstand sea water immersion.

- Hydraulic pulsation dampers on pump inlet and outlet pipes

5.3. Evaluating Viability, Efficacy, Cost, and Logistical Consideration of Quieting Options

A systematic ranking approach was then developed with common assessment criteria for both seismic surveys and vessels with which to evaluate the large range of possible options, and to consider known or emerging approaches specific to each industry. For each industry sector, the quieting techniques described in the tables below were evaluated according to four specified metrics:

- *Environmental efficacy***:** The degree to which the technique reduces any energy above 100 Hz (or the excess energy below 100 Hz). [1 - Maximum; 5 - None].
- *Operational impact*: The impact the technique may have on the specific operation. [1 - Low; 5 - High].
- *Cost of the quieting technique***:** The cost of applying the technique. [$ - Minimal; $$$$$ - High].
- *Timing for the quieting technique to be operational*: The time to apply the quieting technique. [1 - Immediate; 2 - <1 year; 3 - 1-3 years; 4 - 3-5 years; 5 - >5 years].

These assessment criteria for operational and engineering quieting solutions were applied in assessments conducted for possible quieting solutions within each industry, with direct industry participation and engagement to evaluate sources accordingly. The specific approaches identified as among the most viable and effective through this process for seismic airgun surveys (Table 1) and vessel operations (Table 2) are provided below.

Table 1. Structured evaluation of possible quieting solutions for seismic airgun surveys.

Method	Envt. Efficacy	Operational Impact	Order of Magnitude Est. Cost	Quieting Timing	
Temporal avoidance	1	1	I-$0 E-$0	1	Low environmental impact and minimal cost or operational impact if no overlap between optimum operational and temporal closure periods.
Marine Vibroseis	2	3	I-$$$$ E-$$$$$	3	Marine vibrators will allow an output signature that is highly controllable. The cost and operational inefficiencies are expected to be reduced over time.
Hypercluster air guns (Harmony, Gemini)	3	2	I-$$ E-$$	2	Hyperclustering is an efficient way to tilt the spectrum to lower frequencies at minimal cost and operational impact. Note: *techniques are restricted by IP.*
Tuned Pulse Source (TPS)	3	2	I-$$ E-$$$ *(depends on whether higher frequencies are required)*	1	The TPS use lower operating pressures (6-1000 psi) and larger volume chambers (4800 in^3). It releases a large volume of air over a controlled time generating a long rise time and low frequency bubble oscillations with less bubble turbulence and cavitation.
Modify air gun mechanical design (eSource, Bluepulse)	3-4	2-3	I-$$ E-$$$	2	The techniques reduce the high frequency output from the array with minimal operational impact.
Desynchronize air gun arrays (eSeismic, Popcorn)	4	2	I-$$ E-$$$	1	The techniques are mainly to increase the sampling of the wavefield. If goal is overall noise reduction, it is likely more effective to reduce array output directly.
Reduce array output	4	1	I-$0 E-$0	1	It is generally a permit requirement to reduce the array output to the minimum required for imaging, so there is probably not significant leeway to further reduce the output from an array.
Temporal avoidance	*	5	I-$0 E-$0	1	If the only effective operational times overlap with the temporal closure periods the cost and impact can be significant.
Areal avoidance	*	5	I-$0 E-$0	1	Closing an area permanently will not allow operations to be conducted on a license.
I = Implementation E = Equipment	**1 - Max**	**1 - Low**	**$ <$10,000**	**1 - 0 yrs**	
	5 - None	**5 - High**	**$$$$$ <$100M**	**5 - >5 yrs**	

Relative Cost Keys: [1-immediate; 2 - <1 yr; 3: 1-3 yr; 4: 3-5 yr; 5: > 5yr]

$0	no cost	$	<$10,000
$$	<$100,000	$$$	<$1,000,000
$$$$	<$10,000,000	$$$$$	<$100,000,000

Table 2. Structured evaluation of possible quieting solutions for vessel transit operations.

Method	**Envt. Efficacy**	**Operational Impact**	**Order of Magnitude Est. Cost**	**Quieting Timing**	
Operational; Re-routing	1	4	I-$$* E-$0	1	Benefit greatly depends on a vessel's existing route relative to sensitive areas and the ability to increase distance to "stay away" from the sensitive areas.
Operational; Reduce Speed	1	3	I-$$* E-$0	1	Significant speed reduction can result in greatest vessel quieting, but at the cost of added transit time. This may not be an issue if the vessel waits on dock space.
Engineering; New Vessel Acquisition (design to be quiet)	1	1	I-$$ E-$$$$	4	Ship designed to be quiet from start. Quiet propeller and propulsion systems (fuel cell or battery), vibration isolated machinery, insulated machinery rooms.
Engineering; Vessel Rehab (add quieting features)	1-2	1	I-$$ E-$$$	3	Quieting features such as quiet propeller, vibration isolated engines and large components, other sound reduction materials. Need to evaluate ship-by-ship and fix noisy equipment.
Operational; Reduce Speed to below Cavitation Inception Speed (CIS)	2	2	I-$$* E-$0	2	Reducing speed to just below CIS will give "best value an effective for the minimum speed reduction. However, the Environmental Efficacy may not be as good as full slow down due to assumption that reduction in speed will be just below CIS
Operational; Clean Hull & Propeller	3	1	I-$ E-$0	2	A clean hull and propeller cavitate less and thus produce less sound.

** Depends on other operational factors*

I = Implementation
E = Equipment

1 - Max	**1 - Low**	**$ Minimal**	**1 - 0 yrs**
5 - None	**5 - High**	**$$$$$ High**	**5 - > 5 yrs**

[1-immediate; 2 - <1 yr; 3: 1-3 yr; 4: 3-5 yr; 5: > 5yr]

<u>Relative Cost Keys</u>:

$0	no cost	$	<$10,000
$$	<$100,000	$$$	<$1,000,000
$$$$	<$10,000,000	$$$$$	<$100,000,000

These assessments directly informed subsequent industry engagements to evaluate and adapt the initial quieting scenario options based on feasible, viable, and available options. In concert with these subsequent interactions with industry, they also informed the project team in developing the recommended pilot project options presented below (section 7).

5.4. Targeted Engagement to Refine Quieting Options and Inform Potential Pilot Projects

The above assessments and associated subsequent industry engagements directly informed the project team in evaluating and adapting the initial quieting scenario options based on feasible, viable, and available options. These interactions, feedback, and assessments informed the development of the recommended pilot options presented below (section 7). The information below describes these targeted industry engagements as they evolved within each industry sector and informed this process.

5.4.1. Seismic Surveys

The project team continued to work closely with this industry sector through the assessments described above and in periods thereafter in developing the potential pilot study on seismic surveys. This was done primarily through the trade organization for geophysical contractors. Additional key stakeholders and contacts within the industry working on specific noise quieting technologies were subsequently identified through this engagement. It is recommended that all these collaborators and the associated technologies be included in the consideration and planning of any potential pilot project related to quieting solutions for seismic airguns.

5.4.2. Vessel Engineering and Operations

As the project team continued to engage with the complex and multifaceted suite of industries related to vessel operations in the GoMex, an adaptive engagement strategy evolved. This included more specifically engaging the supply and service vessel sector (medium-size vessels) on potential engineering quieting solutions while focusing efforts in the large commercial vessel sector on possible operational quieting measures. Conversations were focused on quieting vessels while in transit.

Interaction with and feedback from industry partners in the service and supply vessel sectors indicated a host of relevant and dynamic market factors relevant to the consideration of and potential participation in subsequent pilot projects. These were related to emerging and ongoing efforts regarding reductions in air emissions and sustainability, with potential ancillary benefits in terms of noise reductions, and the impending transition of the GoMex oil and gas service fleet to the offshore wind energy industry. Consequences of each of these factors meant that various retrofit and/or new power plant type vessels were already being designed or considered. Through sustained outreach and engagement with the industries involved in these kinds of developments, the team identified many contacts that should be included in subsequent consideration and planning of any potential pilot project related to engineering solutions for supply and service vessels.

Engagement with the large commercial vessel class sectors was largely limited to providing information on the project goals and development of the potential operational scenarios. The team identified multiple relevant contacts who expressed interest and willingness to consider possible participation in a demonstration and validation assessment of operational solutions. Notably, however, many industry contacts in this sector indicated their awareness and interest in the ongoing IMO processes for new quieting goals for large vessels and how these intersect with greenhouse gas emission objectives and requirements. Based on feedback received through these engagements, the project team believes there would likely be specific interest and participation in a potential pilot effort related to voluntary operational measures, particularly if it were coordinated within areas where large vessels already operate. However, representatives of this sector wanted to see more details about a potential pilot considering other ongoing efforts before expressing more interest.

6. Comparative Noise Footprint Modeling of Identified Quieting Approaches

In order to demonstrate simple, understandable, quantitative approaches to compare the predicted results of identified quieting approaches if implemented in the same time and place, additional noise propagation modeling was conducted. The objective was to illustrate approaches where relative differences in modeled radiated noise from different source types or configurations could be evaluated using standard noise propagation modeling and represented in simple, meaningful metrics (areas ensonified, numbers of individuals of focal species exposed) that could ultimately be predicted and then compared with measured noise fields in subsequent pilot projects. This is intended and presented here as a demonstration of this approach with which to consider relativistic difference between sources. As described below, source specific information regarding noise source levels was applied from generalized and in some cases extrapolated data available. For potential pilot studies where different times, locations, and specific sources were participating and additional data were available or applicable, absolute modeled and predicted results would certainly differ from those predicted here. The goal here was to show how relativistic differences could be predicted and to provide some relative differences in simple terms using the approaches and assumptions made in these calculations.

Unlike the initial species and source-specific listening space calculations evaluating areas of which an animal at a specific location (PAM stations) could detect different sources, these approaches consider radiated noise fields outward from a location at which multiple sound sources with different radiated noise characteristics occur. Similar approaches are taken in terms of different hearing characteristics for species in different hearing groups and detection thresholds based on these characteristics. However, many (most) of the underlying calculations used different assumptions and approaches related to the use of multiple frequencies, explicit spectral differences in source levels for multiple source types of the same overall category (e.g., seismic sources, transiting vessels), and the evaluation of modeling results different depths. Given the different objectives and considerably different assumptions, methodologies, and locations, direct comparison of listening space modeling for whole classes of industry sources and source-, depth-, and frequency-specific modeling described here are not appropriate. The approaches and results described below are intended to illustrate relative differences between different potential existing sources and quieting approaches using the available information regarding possible quieting solutions and underlying assumptions.

6.1. Modeling Methods and Outputs

Noise propagation modeling was conducted for selected example locations, conditions, and noise sources. Modeling was conducted for both seismic survey and vessel operations using source parameters identified as available and feasible noise quieting approaches during industry engagement. The objective was twofold. The first was to demonstrate methods to quantify the spatial extent of radiated noise using common, identified parameters for different noise sources and conditions using standard three-dimensional propagation methods. The second was to present these results in relatively simple metrics (total area ensonified; total animals impacted) allowing relative comparisons between sources.

These are designed to be understandable to a general audience and relatable in terms of the kinds of relative reductions associated with quieting approaches that have been applied in other noise mitigation efforts. Within the context of the current effort to provide recommended options for pilot projects, this is intended to serve first as a demonstration of the relative magnitude of possible noise reduction given industry-provided assumptions about noise sources, and second, as tools that could be applied within pilot efforts to make such predictions ahead of specific field tests and to evaluate predicted noise reduction relative to empirical field measurements.

The following methods were applied:

- Transmission loss (TL) was modeled using a Navy version of the range-dependent parabolic equations (PE) acoustic propagation model and US Navy and NOAA environmental databases: Bottom Sediment Type (BST; Navy) database, Global Ocean Sediment Thickness Dataset (NOAA), the high-resolution NAVOCEANO Digital Bathymetric Database. Geoacoustic parameters were extracted from published (unclassified) sources.

- Range-dependent environment parameters (sound speed profiles) were calculated along acoustic propagation paths using temperature and salinity fields for each specified date and location modeled using the Hybrid Coordinate Ocean Model (HYCOM).
- Stationary omni-directional sources were modeled at each of four identified frequencies (63, 125, 500 and 1000 Hz)
- Sources were assumed to be operated at a common depth of 6 m.
- TL was modeled along 1° bearings (360 total) from a source location out to a maximum range of 1000 nm.
- Two dimensional fields of transmission loss were extracted from 3D acoustic model outputs for receiver depths of 50, 100 and 500 m, as well as the depths of each of the 13 PAM stations operated in the GoMex.
- The received level (RL) field is calculated as a difference between a frequency-specific source level (SL) for each source (determined through industry engagement or as available reference levels) and the modeled TL.
- The total ensonified area for each source at each frequency and each depth is bounded by a polygon with a spatial extent determined along each bearing where the RL corresponds to a species-specific threshold.
- We identified these potential impact thresholds as being 10 dB above the estimated frequency-specific hearing threshold for marine mammal hearing groups[11].
- Polygons were thus determined as the area bounded along all bearings out to RLs corresponding with the frequency-specific values (Table 3 below) for low-frequency cetaceans (Rice's whale) and high frequency cetaceans (all other species).

[11] Identified in: 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

Table 3. Estimated hearing and associated model polygon thresholds for central frequencies modeled for low and high frequency cetaceans.

		CENTRAL FREQUENCY (Hz)			
Hearing Group	*Thresholds (dB re: 1uPa)*	**63**	**125**	**500**	**1000**
Low Frequency (Rice's whale)	Estimated Hearing Threshold:	**71**	**65**	**59**	**56**
	Extent of Model Polygon (+10 dB):	**81**	**75**	**69**	**66**
High Frequency (all other species)	Estimated Hearing Threshold:	**137**	**130**	**108**	**96**
	Extent of Model Polygon (+10 dB):	**147**	**140**	**118**	**106**

- To estimate the number of individuals of each species impacted for each specified noise source condition, calculations begin with a simple geographic overlay between the estimated acoustic footprints of each respective polygon and the spatially explicit, species-specific density surface estimates. Specifically, the area of each location-, depth-, frequency- and source-specific noise footprint polygon was overlaid with the density shapefile for different species. An example for this overlap for Rice's whale and four different vessel noise conditions in the month of September is given below (Fig. 2).

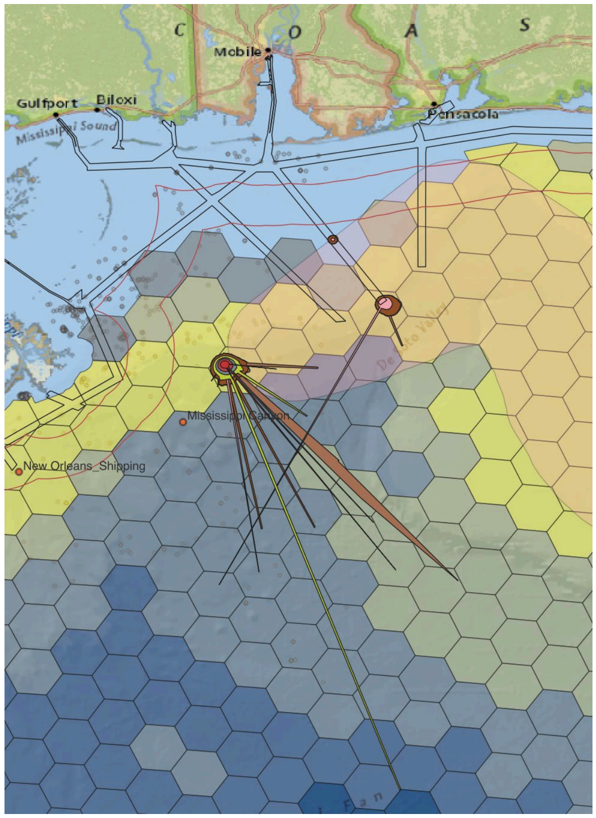

Figure 2. Example overlay schematic between 3 modeled sites in and around the ports of Biloxi, Mobile and Pensacola. Each polygon stacked at each site represents a different vessel category / speed combination. Background hexagons depict estimated density of Rice's whales—lighter colors correspond to higher density. The orange polygon represents Rice's whale core distribution area[12].

- For each source, frequency, depth, and animal hearing group, both the area statistics of each polygon, as well as the number of whales contained within that polygon were calculated.
- While there can be large radial-specific differences in the modeled levels for some sources, it is noted that these may reflect both highly site- and time-specific differences as well as modeling assumptions related to spatial resolution. The overall size and patterns of the polygons as well as, especially, spatial differences in the total area for each source/polygon are the important comparisons.

[12] https://www.fisheries.noaa.gov/resource/map/rices-whale-core-distribution-area-map-gis-data

- In comparing relative areas ensonified to the specified threshold and the number of individuals predicted to be impacted for each of multiple noise sources, the largest polygon is used as the reference case. For example, for scenarios with a container vessel operating at 18 knots and 10 knots, the faster speed corresponds to a larger noise footprint (polygon) and is the reference case.
- To evaluate putative reduction in impact, both the geographical size of respective polygons in test versus reference conditions, as well as the number of whales impacted are compared. These numbers are presented simply as % reduction in both area and impacted individuals, to serve as simple metrics of relative benefit.

6.2. Results

These modeling and evaluation methods were applied to evaluate multiple possible noise reduction approaches identified through the industry engagement and openly available source information. These included multiple engineering approaches to noise reduction for seismic surveys and operational approaches for vessel operations.

6.2.1. Seismic Surveys

As described in detail above (see: 5.3.), several of the most promising viable noise reduction approaches to conventional airgun surveys were identified and evaluated. This included some available source information through presentations at technical meetings, specification sheets for sources that were publicly available, and much of it through direct industry engagement with the project team from developers. As noted above, much of this is limited in terms of publicly available information and in some instances (reflected as n/a below) frequency band specific source levels were simply not available. The team identified source level parameters for each source (to the extent available) at each of the four target frequencies such that each source could be modeled and evaluated using common assumptions and methods (Table 4 below).

Table 4. Frequency-specific source levels (average spectral density levels (dB re: 1μPa^2/Hz) for 1/3rd octave bands) for five modeled seismic survey sources.

Central frequency (Hz):	63	125	500	1000
Source 1. Conventional Airgun Array:				
4140 in^3 (Measured)	**212.0**	**205.0**	**187.5**	**168.0**
Source 2. Marine Vibrator:				
MV-IPN (5-100,5s)	**204.7**	**160**	n/a	n/a
Source 3. Hypercluster:				
Harmony	**204.1**	**199.8**	n/a	n/a
Source 4. eSource:				
eSource:	**211.0**	**202.0**	**166.5**	**158.0**
Source 5. TPS:				
26k TPS	**192.0**	**182.0**	**156.0**	**151.0**

Modeling was conducted at two selected locations (27.42517°N, 91.5353°W; 26.56611°N, 94.8108°W) on two specified dates (09/04/2020 and 12/09/2020) for which conventional seismic airgun operations were known to occur (from analysis of available reported industry data). This modeling yielded hundreds of resulting noise footprints for different sources (5), frequencies (4), depths (up to 16), and hearing groups (2). Selected examples of comparative noise footprints, and relative ensonified areas and impacted individuals are shown for a selected location (27.42517°N, 91.5353°W) and depth (100m) for both low-frequency cetaceans (Rice's whale; Fig. 3; Table 5) and high-frequency cetaceans (all other species; Fig. 4, Table 6).

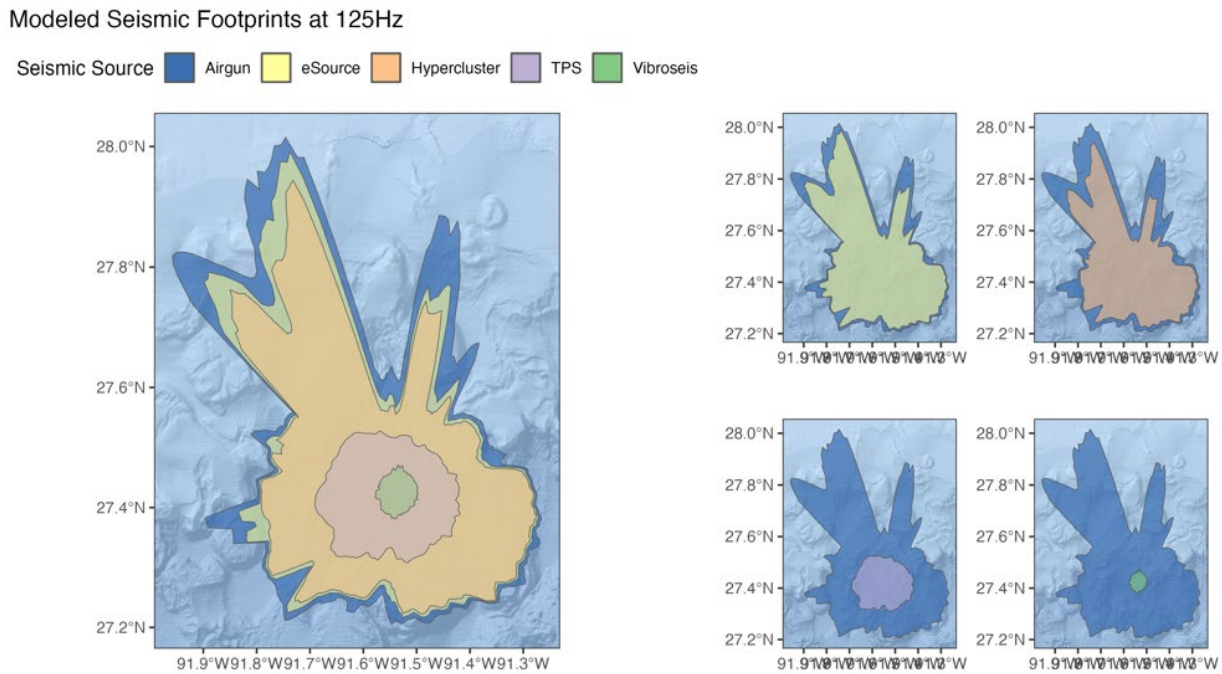

Figure 3. Modeled noise footprints at 125 Hz for five seismic survey sources for low-frequency cetaceans. All sources are shown relative to one another in the stacked plot (left) and each alternative technology shown relative to conventional seismic airgun for reference (right).

Table 5. Relative ensonified areas, individuals within model polygons, and percentage changes for five seismic sources at four modeled frequencies for low-frequency cetacean hearing group (Rice's whale).

63 Hz				Density	Percentage Change	
Source	Source Level [dB]	Sensitivity	Area	Rice's Whale	Area	Rice's Whale
Airgun	212	lo_freq	6.83 × 10^10	0.93	0%	0%
eSource	211	lo_freq	7.03 × 10^10	0.60	3%	-35%
Vibroseis	205	lo_freq	2.68 × 10^10	0.40	-61%	-57%
Hypercluster	204	lo_freq	2.54 × 10^10	0.15	-63%	-84%
TPS	192	lo_freq	1.55 × 10^9	0.00	-98%	-100%

125 Hz				Density	Percentage Change	
Source	Source Level [dB]	Sensitivity	Area	Rice's Whale	Area	Rice's Whale
Airgun	205	lo_freq	3.12 × 10^9	0.73	0%	0%
eSource	202	lo_freq	2.53 × 10^9	0.43	-19%	-42%
Hypercluster	200	lo_freq	2.16 × 10^9	0.26	-31%	-64%
TPS	182	lo_freq	4.94 × 10^8	0.00	-84%	-100%
Vibroseis	160	lo_freq	5.15 × 10^7	0.00	-98%	-100%

500 Hz				Density	Percentage Change	
Source	Source Level [dB]	Sensitivity	Area	Rice's Whale	Area	Rice's Whale
Airgun	188	lo_freq	2.36 × 10^9	0.12	0%	0%
eSource	167	lo_freq	9.75 × 10^8	0.00	-59%	-99%
TPS	156	lo_freq	1.73 × 10^8	0.00	-93%	-100%

1000 Hz				Density	Percentage Change	
Source	Source Level [dB]	Sensitivity	Area	Rice's Whale	Area	Rice's Whale
Airgun	168	lo_freq	9.68 × 10^8	0.02	0%	0%
eSource	158	lo_freq	3.01 × 10^8	0.00	-69%	-100%
TPS	151	lo_freq	5.72 × 10^8	0.62	-41%	2,606%

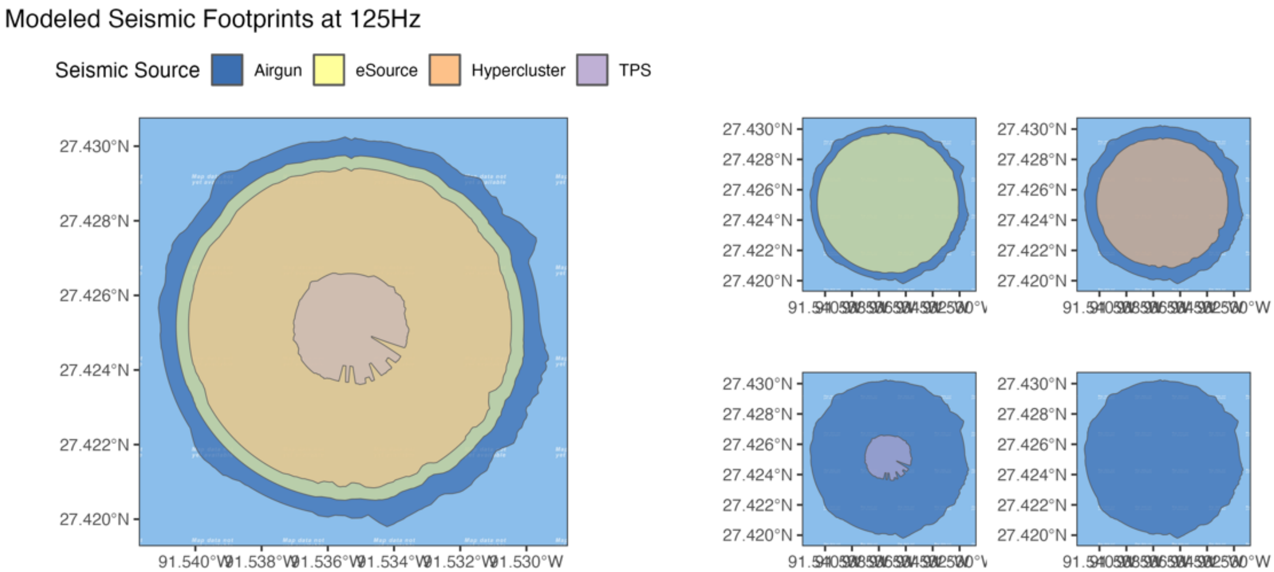

Figure 4. Modeled noise footprints at 125 Hz for five seismic survey sources for high-frequency cetaceans. All sources are shown relative to one another in the stacked plot (left) and each alternative technology shown relative to conventional seismic airgun for reference (right).

Table 6. Relative ensonified areas, individuals within model polygons, and percentage changes for five seismic sources at four modeled frequencies (high-frequency cetaceans; sperm whale and Risso's dolphin examples shown).

63 Hz

Source	Source Level [dB]	Sensitivity	Area	Density: Sperm Whale	Density: Risso's Dolphins	Percentage Change: Area	Percentage Change: Sperm Whale	Percentage Change: Risso's Dolphins
Airgun	212	hi_freq	6.16 × 10^9	93.10	28.36	0%	0%	0%
eSource	211	hi_freq	1.45 × 10^10	161.63	53.64	135%	74%	89%
Vibroseis	205	hi_freq	3.76 × 10^9	91.52	23.37	-39%	-2%	-18%
Hypercluster	204	hi_freq	3.83 × 10^9	82.30	22.40	-38%	-12%	-21%
TPS	192	hi_freq	7.16 × 10^8	22.87	9.09	-88%	-75%	-68%

125 Hz

Source	Source Level [dB]	Sensitivity	Area	Density: Sperm Whale	Density: Risso's Dolphins	Percentage Change: Area	Percentage Change: Sperm Whale	Percentage Change: Risso's Dolphins
Airgun	205	hi_freq	1.06 × 10^6	0.33	0.09	0%	0%	0%
eSource	202	hi_freq	8.63 × 10^5	0.33	0.09	-19%	0%	0%
Hypercluster	200	hi_freq	7.38 × 10^5	0.33	0.09	-31%	0%	0%
TPS	182	hi_freq	8.84 × 10^4	0.33	0.09	-92%	0%	0%
Vibroseis	160	hi_freq	0.00	0.00	0.00	-100%	-100%	-100%

500 Hz

Source	Source Level [dB]	Sensitivity	Area	Density: Sperm Whale	Density: Risso's Dolphins	Percentage Change: Area	Percentage Change: Sperm Whale	Percentage Change: Risso's Dolphins
Airgun	188	hi_freq	6.17 × 10^8	46.09	14.22	0%	0%	0%
eSource	167	hi_freq	4.00 × 10^8	34.74	10.31	-35%	-25%	-27%
TPS	156	hi_freq	0.00	0.00	0.00	-100%	-100%	-100%

1000 Hz

Source	Source Level [dB]	Sensitivity	Area	Density: Sperm Whale	Density: Risso's Dolphins	Percentage Change: Area	Percentage Change: Sperm Whale	Percentage Change: Risso's Dolphins
Airgun	168	hi_freq	7.32 × 10^8	30.72	11.37	0%	0%	0%
eSource	158	hi_freq	4.79 × 10^8	21.16	8.69	-35%	-31%	-24%
TPS	151	hi_freq	6.93 × 10^7	7.70	2.69	-91%	-75%	-76%

6.2.2. Vessel Operations

Selected vessel operational conditions (variable speed) for different vessel classes and locations were identified to broadly represent typical medium and large vessel classes. The goal was to make relative evaluations for categories of vessels using data from many measured vessels under well controlled measurement conditions (i.e. for background sound and multiple vessels in the area during measurement). Standard 50th percentile (L50) sound levels from many years of measurements made in the ECHO program conducted through the Port of Vancouver[13] were applied as the base-case for measured vessel classes and speeds. These data have been used within an ongoing series of assessments and recommendations on vessel radiated noise levels and quieting targets developed with the support of Transport Canada related to developing IMO standards. Available information regarding variation with vessel speed from vessels in the ECHO database were applied to determine the speed-specific levels for different frequencies[14]. This enabled identification of source level parameters for generic vessels in medium and large vessel classes for different speeds at each of the four target frequencies such that each source could be modeled and evaluated using common assumptions and methods (Table 7 below).

It is important to note that source level estimates from thousands of individual passages of known vessels in the GoMex have been made from the NOAA-supported PAM stations through ongoing acoustic monitoring. Because the location and time-specific modeling conducted here is done using transmission loss calculations, any of these individual specific vessels could be evaluated for the same time-area-frequency context modeled here. This could be a useful exploratory assessment for specific potential candidate vessels (or similar size/operational class ones) in considering potential future pilot projects (see section 7 below).

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[13] https://www.portvancouver.com/environmental-protection-at-the-port-of-vancouver/maintaining-healthy-ecosystems-throughout-our-jurisdiction/echo-program/echo-program-annual-reports-and-peer-reviewed-papers/

[14] MacGillivray, A.; de Jong, C. A Reference Spectrum Model for Estimating Source Levels of Marine Shipping Based on Automated Identification System Data. J. Mar. Sci. Eng. 2021, 9, 369. https://doi.org/10.3390/jmse9040369

Table 7. Frequency-specific source levels (given as decidecade (dB re: 1μPa) and spectrum level (dB re: 1μPa^2/Hz) for four modeled vessel operational contexts and four frequency bands (medium and large vessels at each of two transit speeds).

Central frequency (Hz):	63	125	500	1000
Source 1. Med Size Vessel: 10 knots (Tugboat)				
Decidecade RNL @ 1m	**167**	**170**	**173**	**171**
Values dB re 1mPa-m/Hz	**155**	**155**	**152**	**147**
Source 2. Med Size Vessel: 16 knots (Tugboat)				
Decidecade RNL @ 1m	**179**	**182**	**185**	**184**
Values dB re 1mPa-m/Hz	**167**	**167**	**164**	**160**
Source 3. Large Vessel: 10 knots (Container Ship)				
Decidecade RNL @ 1m	**163**	**158**	**153**	**150**
Values dB re 1mPa-m/Hz	**151**	**143**	**132**	**126**
Source 4. Large Vessel: 18 knots (Container Ship)				
Decidecade RNL @ 1m	**178**	**174**	**168**	**165**
Values dB re 1mPa-m/Hz	**166**	**159**	**147**	**141**

Three geographical locations were selected based on the preliminary modeling using climatological acoustic environment parameters. Two points were located within existing shipping lanes on the shelf (Site A; 29.752°N, 87.722°W) and shelf break (Site B; 29.442°N, 87.471°W), and one proposed location on the shelf break (Site C; 29.136°N, 88.26°W) outside the modeled listening space polygon for Rice's whales centered on the De Soto Canyon PAM station (Fig. 5).

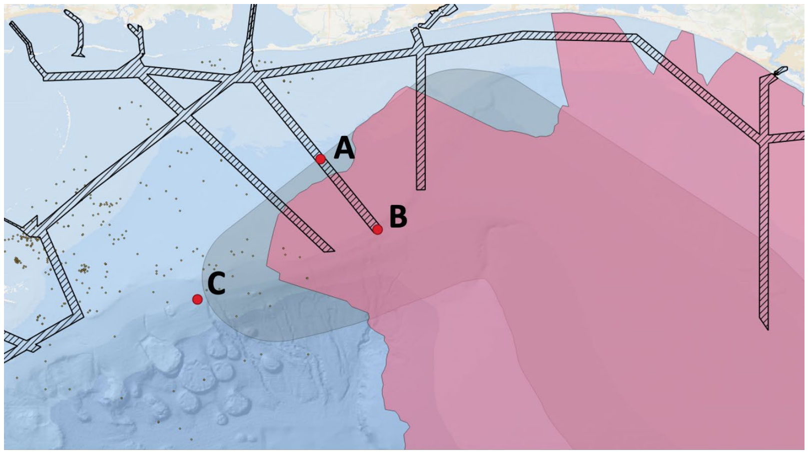


Figure 5. Selected locations for vessel operational parameter modeling. Points A and B are within existing shipping lanes on the shelf and shelf break respectively. Point C was selected on the shelf break but out of the Rice's whale modeled listening space at the De Soto Canyon PAM station (pink polygon) and Rice's whale core distribution area (gray polygon).

Comparative noise footprints are shown for each vessel type and speed at Site C at a selected depth (100m) for low-frequency cetaceans (Rice's whale; Fig. 6). Relative ensonified areas and impacted individuals are shown for each location at a selected depth (100m) for low-frequency cetaceans (Rice's whale; Table 8).

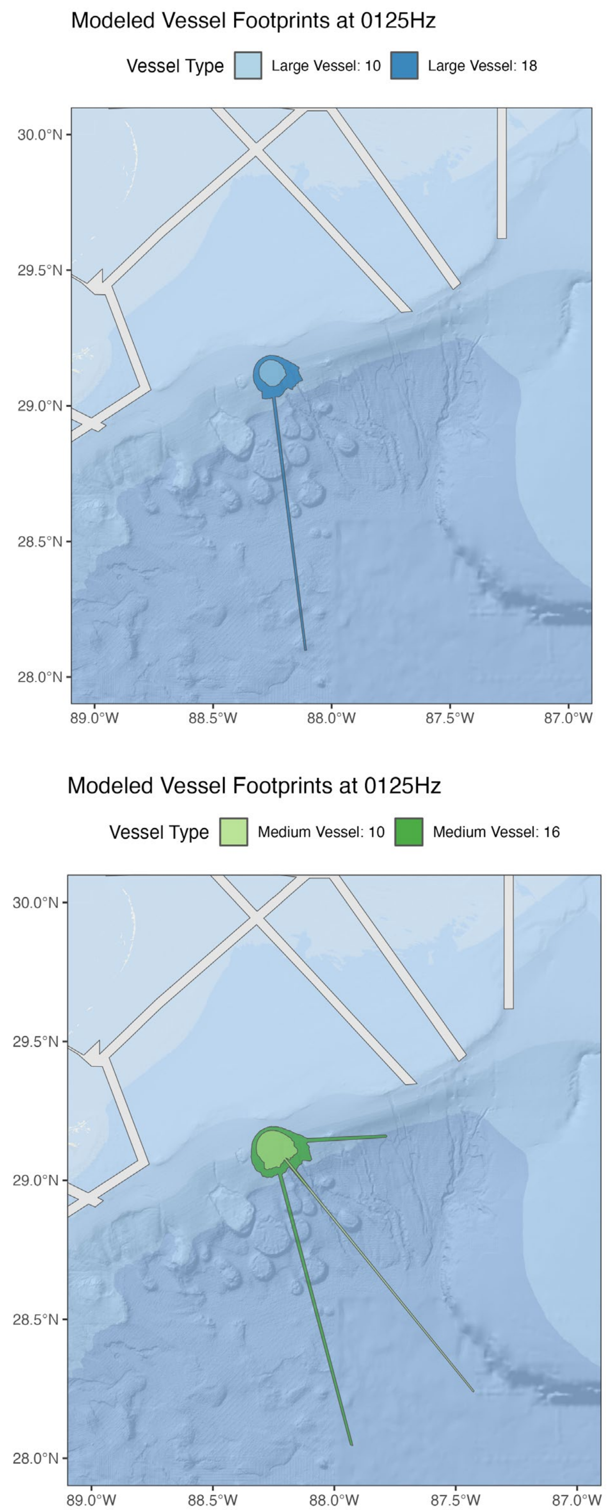


Figure 6. Modeled noise footprints at 125 Hz for four vessel operation contexts (large vessel at 10 and 18 knots (top); medium vessel at 10 and 16 knots (bottom)) for low-frequency cetaceans.

Table 8. Relative ensonified areas, individuals within model polygons, and percentage changes for four vessel operational contexts at three sites at 125 Hz (low-frequency cetaceans).

Site A

Source	Region	Source Level [dB]	Area	Density Rice's Whale	speed	Percentage Change Area	Percentage Change Rice's Whale
Large Vessel							
Baseline	ExistBreak	SL176dB	3.14 × 10^8	0.18	18	0%	0%
Proposed Change	ExistBreak	SL163dB	4.34 × 10^7	0.18	10	-86%	-1%
Medium Vessel							
Baseline	ExistBreak	SL183dB	1.81 × 10^8	0.23	16	0%	0%
Proposed Change	ExistBreak	SL171dB	1.83 × 10^8	0.20	10	1%	-11%

Site B

Source	Region	Source Level [dB]	Area	Density Rice's Whale	speed	Percentage Change Area	Percentage Change Rice's Whale
Large Vessel							
Baseline	ExistShelf	SL176dB	2.03 × 10^7	0.00	18	0%	NaN
Proposed Change	ExistShelf	SL163dB	3.25 × 10^6	0.00	10	-84%	NaN
Medium Vessel							
Baseline	ExistShelf	SL183dB	2.71 × 10^7	0.00	16	0%	NaN
Proposed Change	ExistShelf	SL171dB	1.11 × 10^7	0.00	10	-59%	NaN

Site C

Source	Region	Source Level [dB]	Area	Density Rice's Whale	speed	Percentage Change Area	Percentage Change Rice's Whale
Large Vessel							
Baseline	PropBreak	SL176dB	3.64 × 10^8	0.12	18	0%	0%
Proposed Change	PropBreak	SL163dB	9.11 × 10^7	0.12	10	-75%	-0%
Medium Vessel							
Baseline	PropBreak	SL183dB	5.47 × 10^8	0.17	16	0%	0%
Proposed Change	PropBreak	SL171dB	2.71 × 10^8	0.12	10	-51%	-27%

6.3. Implications for Pilot Projects

The modeling conducted here was intended primarily to demonstrate the utility of these quantitative methods to predict relative changes in ensonified areas and individuals for different noise source parameters using common assumptions. It should be noted that locations selected, sources selected, and source characteristics identified were developed for the purposes of demonstrating this approach and identifying relative predicted efficacy in simple metrics using these assumptions.

These results should be interpreted in a relativistic sense given many of the underlying assumptions and the source and location-specific nature of the modeling assessments. Additionally, some of the frequency-specific source parameters include information for sources that are still in developmental stages (e.g., seismic engineering approaches) where the available frequency-specific information is very limited in the number of controlled measurements. For transiting vessel sources, considerably more calibrated measurements of frequency-specific levels exist, including a growing database on vessel source levels in the GoMex from the NOAA PAM stations. For this modeling exercise, generic class-specific source levels for two vessel classes and different speeds from a large database of controlled measurements were applied. For subsequent pilot project planning and evaluation the same model runs conducted here could easily be applied using specific GoMex vessels for which source level measurements are available, as they are calculated as transmission loss. The objective here was again to evaluate the magnitude of relative differences using more generic vessel source levels from available sources. It should be noted that results presented here represent a very small subset of all conditions modeled but results have been made available with this final report.

Given these caveats, as mentioned above direct comparison to the listening space modeling for generalized source types used in the risk assessment analysis is not made or appropriate. Direct application of modeled results to potential pilots designed for a specific location or approach is also not necessarily appropriate, depending on the extent to which future efforts include sources in similar geographic areas and with similar noise output parameters. Nevertheless, several key observations may be made. First, presuming that sources used in pilot projects have noise parameters like those assumed for alternative engineering approaches (seismic) and operational approaches (vessel speed), substantial reductions in noise footprints and ensonified individuals may occur. Second, the magnitude of these reductions are highly dependent upon frequency, location, and animal hearing group. Alternative seismic sources generally retain higher source levels in the lowest frequency band (<100 Hz) and thus have similar noise footprints to conventional airguns in this band, but show greater reduction at higher frequencies, especially for high-frequency cetaceans. Third, vessel speed reduction is likely to reduce noise footprints at all locations, whereas different locations/routing is likely to have much more variable effects on noise reduction that would require substantial additional modeling and analysis.

The primary implication of these modeling exercises for the pilot projects is a demonstration of the quantitative means of demonstrating the source-specific, spatio-temporal-spectral differences in noise footprints in relatively simple metrics. These metrics can be predicted using location and source specific modeling for sources to be included in future pilot efforts. Further, these model predictions can and should be evaluated and validated with empirical measurements using available acoustic recordings from targeted near-source monitoring and longer-range propagation to existing PAM stations.

7. Recommended Pilot Projects: Summary, Objectives, Industry Perspective, Key Parameters

7.1. Testing Existing Alternatives to Traditional Airgun Seismic Surveys

Description of Conventional Sound Source: Standard seismic airguns are active acoustic sources used in surveys from surface vessels to examine the layers of the seafloor for oil and gas exploration and development, as well as geophysical research. Seismic vessels tow arrays of airguns and receivers (hydrophones) behind them. Airguns rapidly release high pressure compressed air every 10 to 15 seconds causing a bubble to be formed, resulting in intense impulsive, broadband signals that travel through the water and into the ocean floor. Reflected pulses are received and analyzed as a means of visualizing sub-surface features. Emitted pulses are predominately low frequency (<500Hz) in terms of total energy and returning echoes at frequencies of <200 Hz are of primary interest in geophysical imaging. However, they also include substantial, unnecessary higher frequency energy at frequencies above 500 Hz and extending up to 10 kHz at moderate ranges from sources. While the lowest predominant frequencies can be best propagated over long ranges and are of most concern for the low-frequency cetaceans (Rice's whale in GoMex), these higher frequencies may be a concern for other species. The intermediate (1-10 kHz) frequency components of seismic airgun noise occur in a range where non-anthropogenic ambient noise is also often lower and a range where the hearing sensitivity of odontocete cetaceans is rapidly increasing[15]. These may thus be detectable over moderate (up to 10s of km) and potentially impactful to odontocete species that produce echolocation clicks (sperm whales) or communication signals in this band (most GoMex delphinids). The presence of unnecessary (from an industry perspective) noise energy above 100 Hz, as well as unwanted noise energy transmitted horizontally not downward, offers opportunities for quieting conventional surveys while retaining their commercial viability.

[15] 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

Description of Impact: Seismic airguns represent some of the loudest and most broadly detected industrial noise sources. Given their high source levels and broadband frequency output, airgun arrays can have a wide range of potential auditory (hearing), behavioral, and physiological impacts on sound-sensitive species, including marine mammals[16]. Within a few km of sources, this can include temporary or permanent hearing loss and/or injury. Over tens of km, impacts can include interference (masking) of sound communication, behavior disturbance, and/or physiological stress. The low-frequency components of airgun signals can be readily detected over hundreds and even thousands of km. The extent and magnitude of impacts depend heavily upon the exposure context and species exposed. Low-frequency sensitive species (Rice's whale for GoMex) are generally the most sensitive, followed by moderate-frequency species (e.g., sperm, beaked whales), and then higher frequency species (e.g., dolphins) typically being the least sensitive. Seismic airguns are used throughout the year in the GoMex, with recent years demonstrating a concentration of activity in continental shelf lease areas off Louisiana and Texas. Therefore, engineering approaches to reduce the overall noise energy within non-essential bands or temporal avoidance of key periods for sensitive species (if identified and applicable) are likely more promising and realistic than any spatial mitigation.

Pilot Summary and Objectives: The goal of this proposed pilot project would not be to generate new 'quieting solutions', nor to implement existing quieting solutions during ongoing surveying activity in the Gulf,' but to comparatively test and evaluate potential 'quieting solutions' that have already been developed. Some technologies were created for separate operational reasons that additionally rendered them quieter or more efficient, others were specifically created to reduce biological impacts without limiting the desired geophysical characteristics of the sources. Many of these sources have been evaluated at frequencies useful to seismic imaging (up to 100 Hz) largely to ensure they retain functional utility. However, while some have been evaluated up to 500 Hz, few have been systematically tested at higher frequencies). Some of these sources have been characterized with results presented in publications and at meetings, whereas others have been tested internally but results have remained internal for various reasons, including proprietary ones. One of the key objectives here is to provide a

[16] Southall, B.L. (2017). Noise. In (B. Würsig and H. Thiewesson, Eds.) Encyclopedia of Marine Mammals, 3rd Edition (pp. 699-707). Academic Press, New York. ISBN: 9780128043271.

systematic way to measure, evaluate, and compare in a standardized manner the output characteristics of sources in an open and transparent way, with industry participation. Accordingly, the goals of the proposed pilot project would be to:

1) Systematically evaluate multiple technologies in an open ocean environment in direct collaboration and coordination with industry partners
2) Determine the extent to which frequencies above 100 Hz are reduced relative to conventional airguns
3) Evaluate potential implications of quieting solutions for key marine mammal species in terms of detectability and potential modeled impact
4) Compare measured noise output and propagation characteristics to propagation models of various sources.

Each of these will inform an evaluation of the potential opportunities to scale up these approaches for potential future implementation.

Pilot Project Scope of Work and Methodology:

Pilot Stage I - Planning and Coordination**:** A targeted and public solicitation of interest would be sent to all known technology owners and industry partners via the industry-specific trade organization describing the proposed project and inviting interested parties to provide interest in making their technologies available for testing and evaluation and specific logistical information (when their technology could be in the GoMex, rigging needs, etc.) for consideration and coordination. Establishing a calendar of testing events based on when technologies are available with the commitment of at least three industry participation partners is a recommended milestone for the development of Pilot Stage I planning and coordination.

Establishment of a small workgroup from a subset of interested industry, agency, and other appropriate parties to work through logistical planning and monitoring methods, including source availability, location, rigging, tracks, authorizations, This would include communication of methodologies, timing, and possible incentives (if needed) to participate broadly with oversight to plan and coordinate participation in deploying and transmitting sources in strategic locations relative to monitoring arrays of sensors. This would also include detailed planning of the type, number, and configuration of monitoring recorders in the receiving array. One of the first questions that must be answered in the planning stage is the style of recording array that is optimal for this study. If the goal were to deploy the recording array for an extended period to conduct multiple recordings from multiple sources in the same location, which would be ideal, a bottom-mounted array with an expression in the mid-water would probably be more efficient. This is also true in that to get a clean signature from a source array there needs to be a significant time difference between the direct arrival and the first bottom or surface reflection. One of the goals of the measurements would be to get the vertically-down response, which will be the highest-level signal. This will require the transmitting sources being tested to pass directly over the recording array while operational. Additional methodological considerations include ensuring the receiving systems contain sufficient dynamic range, given that some of the signals can have large differences in peak output levels but different temporal parameters.

Pilot Stage 1, Year 1 objectives would be to identify and coordinate testing opportunities and partners, plan logistics for passive acoustic monitoring, and conduct fine-scale detailed propagation modeling based on *a priori* information. Working group discussions among potential industry participants, agency partners, and participating subject matter experts would identify the interests and incentives needed to participate in the test for each technology owner and map out possible window(s) of participation. A technical subset of this working group would establish standard methods and protocols for passive acoustic measurements for both near-source measurements and long-range propagation to existing sites at which extensive baseline data are available. The team envisions four main components to this planning phase, the details of which would need to be considered within the scope of the time and resources available for field execution and analysis:

1. Determine the measurements that are needed and the precision and resolution that is required for each source, as well as the signal/noise of the measurements.
2. Work with the willing seismic contractors to estimate the availability of each alternative source(s), how much time will be required to reconfigure the source, and what locations could be used with limited transit time.

    a. A set of iterations will be required to determine a location that is optimal, the duration of the measurements, and whether multiple deployments or locations will be necessary.

3. Determine the shot patch that is required to obtain the required measurements and as efficiently as possible (minimize vessel time which is the most expensive part), while acquiring the required redundancy of measurements.

4. Optimize the recording array to obtain the required measurements over the desired time period (with the required dynamic resolution, again while acquiring the required redundancy of measurements. This requires the specification of a recorder with the necessary recording duration and disc capacity.

    a. Steps 3 and 4 are iterated to minimize the execution cost.

Key substantive questions that would need to be addressed in these stages within the planning phase will greatly affect whether and how the pilot would be proceed. They include:

1. How willing are companies to participate in a cooperative, comparative set of measurements? How sensitive will they be to results being openly compared and evaluated?
2. How many technologies exist or could be brought to the table in the Gulf of Mexico or might be over the next two years?
3. What is the motivation to participate in this pilot for an owner of an array? Will access to the sound source verification data be a possible incentive for them?
4. What are barriers to participation in this pilot for an owner of an alternative source technology?
5. What and who are the 'influencers' driving the interest and investment in these technologies right now that could drive demand for this technology?
6. Is this similar to and possibly congruent with any individual company initiatives or what trade organizations may already be planning? Will a trade organization be willing to serve a direct coordinating, collaborating role with alternative source technology owners/operators?

7. Are there questions/measurements/criteria that if included, would influence the debate around impulsive vs. continuous sources?
8. Are there BOEM, NOAA or permit requirements above and beyond existing authorizations that may be required? Could a combined/overarching authorization be considered for the purposes of this demonstration/validation study?

Pilot Stage II Execution and Analysis - During scheduled periods, industry operators would transmit known sources, precisely monitoring the location, timing, and output conditions of their source(s) in specified locations. The amount of time required will vary to some extent based on which of the specific sources is operated, and the extent to which it can be coordinated relative to ongoing activities. However, the on-site time commitment for each source would be several hours to at most half a day. It would be most optimal for vessels to be configured with the technology as it would be used without any reconfiguring or port calls. Ideally vessels could be configured with multiple source options so that vessel costs are shared. This was done in a recent comparison of a seismic airgun and a marine vibroseis source in France, from which methodological approaches and lessons should be leveraged here, as appropriate. While there are many considerations of how sources (and different source configurations) will work relative to one another in various areas, shallow versus deep water, in different seasons, it will not be possible or advisable to attempt to test all of these. It is strongly recommended that each source be operated in a representative configuration with multiple replicates of the same source over more shots and that a single site that is reasonably representative of operational conditions where such sources would be operated in the GoMex be selected for execution. This should be selected as a site off the shelf, if possible, as more effective measurement can be obtained in deeper water due to the reasons discussed above This also best represents conditions for current and likely future seismic surveys for the oil and gas industry based on multiple interactions and feedback from industry. If the operational criteria allow measurements to be made at a deep-water site, there should be no need to test different configurations. There are different operation configurations (e.g., different bandwidth sweeps for marine vibrators), but a reasonable comparison can be made between the systems without needing to test all the configurations.

Pilot Stage II field execution objectives would be to conduct testing and evaluation of as many alternative technologies as possible and those from a conventional seismic airgun array in the same area(s) in similar time periods using identical methods. This will require flexibility in timing to capitalize on pre-planned industry trips as a means of increasing the feasibility of cooperation and reducing costs. Ideally all testing would occur at one site, as described. Within the analyses and modeling conducted in the current project (sections 4-6 above), two locations of concentrated recent seismic activity off Louisiana and Texas were identified, evaluated within the risk assessment conducted. These locations were used to model different seismic sources to understand relative noise reduction at different depths and PAM stations, including nearby sites and distant sites evaluated within the initial scenarios (S1-S3) that informed the development of this plan.

The locations are near two PAM stations (GC and GA), which had relatively high noise activity compared to other sites, including 22 active oil and gas lease areas, and high levels of medium vessel traffic and high species density for multiple species, including sperm whales, and relative proximity to the now-expanded Flower Garden Banks National Marine Sanctuary. Testing would focus on frequencies from 10 Hz to 10 kHz using passive acoustic recording systems deployed in both the near field, at set intermediate distances from the source location, and from existing sensors deployed at fixed locations with extensive baseline data at much longer ranges. The frequency range is significantly larger than needed for seismic surveys but critical for environmental impact assessments. Industry operators would provide metadata on the precise location, timing, and operating characteristics of their sources.

Pilot Stage II analysis objectives would be to conduct analyses, compare results to model predictions, and evaluate efficacy and environmental implications for all technologies tested. Reporting and products developed will be determined through feedback on specific questions identified for the pilot presented to the Steering Committee (see below); potential products could include infographics, comparative assessment costs/benefits, technical reports, and/or publications.

Pilot project success hinges on three primary points:

1) A version of technologies from willing industry partners being available in the GoMex

2) Identification of area(s) where multiple vessels are willing, able, or already planning to work so that location can be standardized

3) Careful planning and coordination of passive acoustic measurements with both bottom-mounted and vertical line array sources for source verification measurements

Questions to be Answered by the Pilot:

Pilot project questions include:

1. How well do these sources achieve the desired noise reduction in actual operational areas?
2. How do these sources compare to one another for different frequencies that may differentially impact various marine mammal species?
3. Which species are most likely to benefit?
4. How well do the current models predict sound impacts as extrapolated by distance? For instance, noise propagation modeling conducted with the standard approaches described above (section 6) take a priori predictions of frequency-specific source levels for different sources and predict received levels at different depths and distances. This project could use such predictive tools to predict, then measure and evaluate how radiated noise footprints compare with model predictions by using band specific differential values.
5. What were the surveyed reasons for participation or non-participation in the pilot of known technologies from the industry perspective?
6. How viable and likely are industry partners to implement technologies in the short term?

Future project questions include:

1. How does this inform the matrix of cost/benefits?
2. What are actual and hidden costs of incentivizing the retrofit for use of quieter source arrays over the next 5-10 years in the GoMex?
3. What are non-monetary barriers to use of these sources in actual surveys funded by oil and gas companies?

Modeled Potential Benefit of Pilot vs. Realistic Uptake in Future:

While there is no direct environmental benefit of testing and evaluation, the successful testing and evaluation of these promising nascent technologies has been identified as a necessary step through industry engagement. Successful testing and evaluation should increase the probability of broader implementation of quieting technologies and benefits include:

1. Many of the technologies have not been systematically recorded at higher frequencies. Participation will provide access to the measurements for their specific source(s).
2. Systematic evaluation of each of these technologies and interpretation of results relative to predicted ecological risk reduction based on species-specific hearing, distribution, and predicted impacts should give a significant benefit to a technology provider during environmental submissions, discussions, and future project design and marketing.
3. Direct coordination between industry partners and scientists with the support and engagement of federal scientific and regulatory agencies on quieting technologies is expected to increase the available data and awareness of their viability and impacts, with the hope of accelerating their acceptance and implementation.

Expected Costs and Project Scalability: The pilot would include what may be considerable coordination and logistical planning costs. Pilot Stage I planning and coordination costs could be on the order of 20% of the total project cost depending on the complexity of the project scope identified and the number of industry partners. Year one costs could include staffing to map out logistics and potentially marketing/outreach campaigns to drive interest and facilitation of working groups, as well as staffing to help establish the listening monitoring/sound measurement, methods, and protocols.

Pilot stage II field execution costs would be the large bulk of the expected cost (~60%) and would include standardized measurement capabilities (deployment, retrieval, analysis of hydrophone PAM data), noise propagation model prediction, and potentially offset logistical costs for participants. The later costs could include funding to offset boat retrofits/dry dock, fuel and transit cost support as participation incentives.

Pilot stage II analysis final year costs would include funding for analysis and model assessment, which also could represent on the order of 20% of the total budget. The resulting radiated noise levels, comparisons within sources across frequencies, comparisons across sources, measured versus modeled results are the key products of this effort and will take considerable time to analyze and present. This should be recognized as a key phase of the overall effort and not shortchanged.

The budget estimate of $2-3M provided is a rough estimate that presumes considerable collaborations and in-kind contributions occur to offset actual costs. The true cost of configuring and fielding real industry vessels with four or five such sources for even a week to transit to and operate on site alone would easily exceed this total value. To put these costs in perspective, several examples are included in this regard. In an ongoing study off California, fielding a single marine vibroseis element with expert personnel to stage and operate it with configuration and vessel costs is on the order of $750k for a two-week effort. Historically, a single multi-azimuth, multi-sensor 3D airgun calibration study conducted in the Gulf of Mexico in 2007 had a total cost of over $10M. Such an intensive and high-resolution approach is not necessarily needed here, but this underscores the importance of both identifying specifically what is needed in terms of complexity and resolution as well as finding ways to try and offset costs through collaboration and partnerships.

The presumption made in the estimate is that through coordination and planning with industries that are interested in testing and advancing these systems and coordinating with ongoing activities, this portion of the field costs, and the largest estimated cost of the project, could be reduced to be on the order of $1-2M in logistical costs, which is a rough estimate and highly dependent on how many sources would be fielded and the willingness of the industry operators to participate in some in-kind manner. The planning and coordination phase could cost on the order of $250-500k, again depending on the number of industry partners, coordination, and complexity of the approach. It is estimated that deploying, fielding, and providing data from a specialized array of recorders for the mid-water vertically-down measurements for weeks or months to be available for multiple efforts would be on the order of $300k. The assumption was that the existing PAM stations would already be in place and operational and could yield long-range propagation data with which to evaluate model predictions; that is, this was not part of the original cost estimate. It is estimated that analysis, reporting, and publication could also cost on the order of $250-500k, again depending on the complexity of the experiment, nature of the results, and the intended products.

The project team did not identify nor recommend an easy or advisable way to scale this effort down substantially while remaining reasonably viable as a field demonstration effort. As noted, this estimate is already substantially scaled from what actual costs would be of attempting something like what is presented here.

Industry Perspective: Unlike other noise quieting options being considered, several potential ‘quieting solutions’ evaluated were developed to increase efficiency/function by focusing only on the desired frequencies of sound that are most valuable for geophysical imaging. Others were specifically created to reduce environmental impacts of airgun use without limiting their desired function in assessing geophysical characteristics. However, technologies have undergone limited *in situ* testing and generally only for the very low frequencies needed to meet industry objectives. The goal would be to test these technologies in a standardized manner, evaluating relative ecological benefit relative to associated implementation costs, while ensuring no loss of survey viability. This is likely only beneficial if operationally advantageous, economically neutral, or if there is an increased ‘demand’ or regulatory requirement for environmentally friendly alternatives, thus providing a potential competitive edge.

Existing Barriers for Implementation of Quieting Technology: Even while these technologies were created for an industry benefit, there are still existing barriers to uptake that need to be acknowledged and considered for eventual implementation, including:

1) Some of the technologies are owned by survey industry companies and thus protected, sometimes tightly, by proprietary limitations.
2) The cost to switch to a different type of survey technology is significant and therefore companies are unlikely to do so without demand and offsets.
3) Noise regulations apply very different impact thresholds for impulsive (e.g., airguns) and continuous (e.g., marine vibroseis) sources and this is perceived by industry to

disincentivize implementation of some technologies. Some of these regulations are currently under revision. Both NOAA and BOEM have expressed interest in incentivizing quieter technologies. This pilot could inform continuing dialog with permit applicants to ensure that existing or perceived barriers to broader implementation are addressed.

Next Steps and Transition: A clear awareness about the project, including the demonstration/validation nature of comparatively measuring different source options, has been established with the contractors/developers. Logical next steps in designing the Pilot Stage I planning and coordination would make sense to go through industry partners. The team also strongly suggests engaging BOEM in discussions related to the potential planning of this pilot effort given their historical and current interest and involvement in quieting technologies and their implementation. Finally, it is important to emphasize the inclusion and engagement of industry openly and collaboratively in all phases, via people involved in the project with understanding and awareness of industry practices, expectations, and sensitivities.

7.2. Vessel Quieting – Engineering Solutions for Conventional and Alternative Fuel Powered Supply and Service Vessels

Description of Sound Source: Supply and service class vessels are used throughout the Gulf of Mexico (GoMex) to provide supplies/equipment to offshore rigs. As noted above, the focus on vessels in this pilot is on noise associated with point-to-point transit rather than other aspects of operations (e.g., dynamic positioning) or other active noise sources (e.g., echosounders, fathometers, communcations systems). Other vessels this Pilot may consider are passenger vessels, ferries, towboats, or tugboats. These vessels generally fall into the 'mid-size' vessel class (~10-100m), which also includes some of the larger fishing vessels. Though variable throughout the year and depending on economic conditions, these vessels combined constitute roughly 40-60% of vessel activity in nearshore and 20-40% of vessel activity in offshore regions of the GoMex. Medium sized vessels such as platform supply vessels (PSVs), offshore supply vessels (OSVs), ferries, tugboats and tow boats typically use a medium speed diesel engine with a pair of propeller shafts in port/starboard arrangements. Cruise ships and research vessels may employ a diesel electric plant where all diesel power is converted to electricity and electric motors rotate propeller shafts. Ongoing and upcoming transition to renewable energy propulsion will involve numerous designs wherein the diesel engine is replaced by batteries, fuel cells, and other technologies. In most cases renewable energy produces clean electrical energy. It is believed that any renewable propulsion system could eliminate the second loudest URN source, the inboard machinery; propellers are typically the loudest source over most transiting speeds. This vessel class has been identified as a target for quieting solutions given their common occurrence, but also due to currently planned or in process retrofits and new builds brought on by the transition from servicing offshore oil and gas to planning for offshore wind leases. As part of this transition and general pushes for more sustainability in vessel fleets, many of these retrofits include new vessel technologies for powering vessels designed to meet emissions and carbon targets. Given that these transitions are occurring, and they impact the propulsion systems, they have the potential to also reduce marine sound significantly. However, this relationship and possible synergies have not been systematically addressed for GoMex supply vessels.

Description of Impact: Noise radiated from transiting medium-sized vessels is less intense and broadband in character than seismic airguns and (to a lesser extent) than large commercial vessels. However, the overall operation of these vessel types, including their offshore station-keeping activities maintained mostly by thrusters generally centered around offshore facilities with a host of industrial noises, it is a substantial contribution to the overall soundscape of the GoMex given the large number and relatively wide distribution of vessels. The primary impacts to marine mammals that occur are likely interference (masking) of sound communication and/or physiological stress in areas of concentrated activity (e.g., coastal lanes, ports, near offshore facilities). The extent and magnitude of impacts depend heavily upon the exposure context and species exposed. Low-frequency sensitive species (Rice's whale for GoMex) are generally the most sensitive, followed by moderate-frequency species (e.g., sperm, beaked whales), and then higher frequency species (e.g., dolphins) typically being the least sensitive, given the predominately low frequency nature of these sources.

Noise generated by vessels of this class when underway are primarily from the propeller and secondarily from the propulsion engine, which can also have impact to crew comfort and safety although this is seen as a more ancillary benefit rather than a reason to make change. While any vessel noise reduction would be environmentally beneficial in the heavily noise impacted GoMex, results from this pilot project would need to inform strategic targets for future implementation of quieting technologies in priority regions to meet identified noise reduction objectives.

Pilot Summary and Objectives: The goal is not to generate new vessel 'quieting solutions,' but to provide a service to those companies who are engaged in use of new methods by providing information on noise quieting benefits, thus incentivizing broader adoption. The project would systematically compare the measured noise signatures of various vessel designs and treatment configurations. It would establish a standardized testing platform in an open ocean environment to evaluate existing, new build, and retrofit designs proposed for emissions reduction targets for their relative sound reduction benefits measured relatively close to sources.

Pilot Project Scope of Work and Methodology:

Pilot Stage I - Planning and Coordination**:** The potential pilot project would implement a comparative, multi-treatment test and evaluation for sound reduction of the two greatest known contributors to marine underwater sound from transiting vessels, namely the propeller and propulsion plant. The first step would be to identify and concur on the overall objectives and the scope of what could be tested relative to the multiple questions proposed here.

The proposed project as envisioned would have two field measurement elements: (A) evaluate the URN differences between traditional vessel propulsion plants and new renewable energy type vessel propulsion systems, and (B) evaluate each of the above, ideally within the same vessel, with additional noise reduction technologies. These would primarily focus on noise reduction for propulsion systems, including new propeller designs (custom, toroidal,[17] Voith-type) that have recently become available for these size vessels that may have significant sound benefits, although other noise treatments should be considered as available and applicable for testing on either vessel types. Table 9 shows four different test conditions to be evaluated with common operational and measurement methods. Ideally vessels of either Type A (traditional propulsion plant) or B (alternative/renewable fuel propulsion plant) would be tested with and without noise mitigation.

TABLE 9: Summary of Vessel Operation Test Segments

Vessel Type A	***Vessel Type B***
Traditional Propulsion Plant	Renewable Propulsion Plant
Above with Propeller or other Noise Mitigation	Above with Propeller or other Noise Mitigation

Pilot Stage I objectives. This targeted pilot would solicit participation of vessels that have both traditional (existing) power systems and are scheduled to have new alternative power

[17] See: https://sharrowbyveem.com/

technologies and retrofits. Much of the focus here is on propulsion systems, given that the propeller is the primary source of noise. Much of the focus here is on propulsion systems, given that the propeller is the primary source of noise. Supporting an explicitly designed propeller for noise reduction for potentially participating vessels is likely well beyond the scope of what could be supported in a pilot effort. Thus, the approach presented here is that the pilot would include funds to either pay for the fabrication or acquisition of an existing propeller or other noise reduction technology for participating (medium-sized) vessels or it would solicit the participation of vessels that already have or will be testing such technologies. Initial discussions with interested parties will likely focus on monetary incentives needed to participate in the tests (drydock times to swap out the propeller or other technology) and developing a calendar of when and where vessels would be available for testing. Many new noise control technologies are in development, evaluation, and early stages of implementation, including many presented at the recent IMO conference on noise mitigation technologies, with at least a few installed on vessels in the GoMex. One such example is an air masking system which is installed within the hull of a GoMex ported cruise ship.

Within Pilot Stage I planning and coordination, it is strongly recommended that specified targets of the evaluation be identified and that a project team involving URN experts, and industry representatives from participants, URN experts, and potential federal partners (e.g., DOT MARAD) be brought together to address the questions below (and others that will certainly emerge).

Objectives for the planning and coordination phase would include:

1. Identification of existing and new design vessel types, noise reduction technologies, and specific possible candidate vessels to be tested.
2. Feasibility, logistics, and cost evaluation with industry.
3. Coordination and scoping of potential leveraging with other ongoing efforts, including other federal and non-federal initiatives and funding.

Key questions to be addressed during the planning and coordination phase include the following:

1. How can this project best be coordinated with, and informed by, the related, ongoing efforts DOT (MARAD). Given their increased and current engagement on issues related to underwater radiated noise and relationships with air emissions and greenhouse gas reduction, which specifically include supply and service vessels, this seems to be an especially important potential linkage for this pilot effort.
2. What are the real synergies with new and retrofit builds in relation to supply vessels for offshore wind? Would focus be on a particular wind lease applicant/operator or port for marketing and awareness lead to a more finite geography or supply vessel sector? Through industry engagement in the current project there were considerable discussions regarding the transition that is ongoing and projected to increase, but also that this will be strongly shaped by larger market forces. In the last few months of industry engagement, as well as the tepid response to lease sales for offshore wind in the GoMex, the magnitude and urgency of this transition looks to be cooling. Where the industry is on this dynamic topic at the time of the pilot will be a real question to consider in the planning and coordination phase.
3. What does a 'dry dock' calendar for potential participants in test and evaluation of alternative propeller types look like? What is the realistic cost/time to industry that is suggested to test one of these propellers? What are the potential safety and navigational concerns/constraints and are they simply prohibitive to this approach? What are the size class vessels that would be willing to consider this? How would the USCG need to be engaged in this issue, particularly around safety related to alternative propulsion systems. How do they need to be engaged and at what point in the process to make sure the pilot addresses their criteria and provides the information needed?
4. What are the interests, incentives, and coordination needed by vessel owners/operators to participate in such measurements both with and without noise reduction changes to vessels?

5. Is this similar to, or possibly congruent with, any individual company initiatives or anything trade organizations may already be planning? There has been some progress with individual companies and sustainability officers who are very interested in staying involved in this, but it is such a diverse and broad set of industry sectors and there are so many rapid developments occurring there is possibly more out there and/or that will be evolving.

Pilot Stage II Execution and Analysis – Field execution would involve direct measurements of URN differences between traditional and alternative vessel propulsion plants as well as existing and new vessels with noise reduction technologies. The magnitude, complexity, and number of vessels participating in field execution will depend on the outcome of the planning and coordination in Stage I and will depend upon the available funding. However, it is envisioned that field execution of noise measurements would be relatively straightforward. It would include standardized measurements would be made of broadband (10 Hz – 10 kHz) radiated noise (quantified in decidecade and spectrum level standard metrics) of vessels of different types and treatments traveling in identical paths and locations at common, standard speed(s). This could be done using mobile NOAA URN measurement (PAM) stations if they could be coordinated with appropriate vessel coordination locations and/or contracted vertical line arrays of PAM sensors. In addition to measurements of URN in these conditions, relative efficiency of vessel operations would be measured in terms of energy consumption. From the vessel perspective, this requires precise knowledge of vessel speed and the distance from the vessel to the measurement station. The project should seek to employ existing standardized URN measurement methodologies to the extent this is possible given logistical considerations and possible locations for industry participation. This includes standards ISO-17208-Part 1 or ANSI S12.64, or other similar methods such as those suited for shallower water. Such methodologies are scalable and can be performed in any open ocean water with appropriate depth and background ambient noise levels. Both standards specified above require sufficiently 'deep' water, which is defined as at least one vessel length or 100 meters (whichever is greater) and very specific hydrophone arrangements and procedures. These are all described in detail within the standards, and they require two to six vessel passes depending on the measurement grade (per ANSI S12.64). The hydrophones need to be suspended in the water column by a support vessel or special buoy. This may require a second vessel on station or deployment from the vessel to be tested, depending on specific methodology used by the contractor(s) conducting the measurements. To meaningfully measure differences in URN from Vessel A vs. Vessel B or from Vessel A with and without noise mitigation, the ANSI/ISO methods given above will need to be used. While they may provide relative insights, opportunistic methods including positioning PAM stations in vessel lanes and tracking single passes without control may produce contaminated and/or insufficient data in terms of scrutiny of results from the URN measurement community and/or industry. The ANSI and ISO methods have multiple facets that ensure quality and comparable URN is being measured. This includes multiple passes, potentially multiple vessel machinery configurations, relatively short measurement distances (typically 100 m), background sound adjustments, multiple hydrophones, and other data quality checks. It is possible that treatment is effective at one condition and not at others (for example speed) and this should be part of the survey design.

Using the ISO, ANSI, or other relevant shallow-water methods will likely mean taking the measurement equipment to the ship. In many cases, the measurement equipment can be deployed from the ship to be measured, making logistics very easy. We do not believe it would be worthwhile to measure far-field (> 1 km) vessel URN. This is largely because the large number of untreated/uncontrolled vessels operating in these areas will likely mean it would be very difficult to measure reduction in radiated noise from single vessels over appreciable distances. Far-field noise metrics could be evaluated using propagation models.

Pilot Stage II objectives would be to conduct testing and evaluation of as many conventional and alternative power plant vessels with and without noise reduction treatments as possible in the same area(s) in similar time periods using identical methods. How many such test/evaluation combinations would be sufficient to characterize noise profiles was raised within discussions and in questions provided thereafter related to statistical power for testing differences between different vessel classes. It should be noted that almost no such standardized measurements exist for service and supply vessels with existing and (particularly) alternative power supply sources in the GoMex or elsewhere. Achieving sufficient sample size to statistically significant results to compare vessels of different power plant types/classes with and without noise treatments is well beyond the scope of the pilot we recommend here and almost certainly beyond that of what the project could support even if this was the only pilot selected. It should be recognized that the proposed approach here recognizes that researchers are within the initial characterization phase and something on the order of three to five vessel/noise reduction approach combinations is the magnitude envisaged.

While it is anticipated the project planning and coordination in Pilot Stage I would take a full year, if staged correctly, it possible that field execution (transit past a known location using well established methods), analysis, and reporting could also occur within a single year. If the full scope of the pilot project here were identified as the path forward for Pilot Stage 2 execution, confirming the participation of at least one non-diesel-powered vessel and three vessels of conventional or alternative power plant designs being willing to apply alternative propeller treatments would be a recommended milestone for advancing to Stage 2.

Questions to be Answered:

Pilot project questions include:

1. What are the URN characteristics of conventional and alternative power plant vessels operated in the GoMex measured under controlled conditions?
2. Does implementing an alternative to a diesel engine in a medium-size vessel make a significant reduction in total vessel sound relative to the vessel that was replaced/converted?
3. How much sound reduction can be achieved by implementing a quiet-design propeller or other noise reduction treatment, in addition to alternative propulsion or in isolation?
4. Are there efficiency gains or losses with the addition of a quiet propeller?
5. What are the direct and indirect (time in drydock, efficiency, propeller fabrication) industry costs for use of alternate over traditional propellers for both vessel types?
6. What are reasons for participation/non-participation in the pilot using alternative propulsion technologies?

Questions for future advancement include:

1. Are there alternative propellers for either conventional or alternative power plant service and supply vessels that is at least 'efficiency neutral' that provides significant URN reduction benefits to marine mammals?
2. How many vessels of this class would we need to retrofit to have a restoration benefit to marine mammals?
3. What are the actual and hidden costs of providing/incentivizing quiet-designed propellers to the anticipated medium-size supply ships being built/retrofitted in the next 5-10 years in the Gulf of Mexico?
4. What are the non-monetary barriers to broader participation?

Modeled Potential Benefit of Pilot vs. Realistic Future Uptake:

Per above, this study would make use of existing plans to convert vessels or design vessels that are/will be in active service in the Gulf of Mexico, specifically focused on those with influence on noise conditions in marine mammal offshore habitats. Focusing on providing an information service through the testing and evaluation of noise signatures of conventional and new power plant technologies, is expected to encourage marking opportunities and broader implementation. Potential benefits that have been identified include:

1. To our knowledge, supply and service vessels for the construction and servicing of offshore wind energy industry operations, being retrofit or designed for use in the Gulf of Mexico are not being designed with URN or even shipboard airborne noise reduction in mind. Participating in this Project will allow new vessel owners to quantify those parameters and market the advantages of their vessel.
2. The quieting treatments may have been tested with limited means and this testing will provide a high degree of efficacy to the provided mitigation. It will also uncover barriers to uptake by vessel owners and operators.
3. With the measurements made in conjunction with U.S. regulatory bodies, the measurements will have a high degree of credibility both within the U.S. and externally.

4. This project will interpret the noise reduction results relative to marine mammal risk assessment in the Gulf of Mexico (completed work). Interpretation of these relative ecological benefit for each technology should give a significant benefit to a technology provider during environmental submissions and discussions.
5. Findings can be used in marketing increase demand for a specific technology. This approach allows for multiple 'winners' so as not to single out competitors.

Expected Costs Expected Costs and Project Scalability: Funding for the pilot would cover the overarching coordination and logistical planning, standardized URN measurement capabilities (deployment/retrieval of arrays), associated logistical offset costs for participating vessels (~3-5 per type), possible associated offset costs for access to alternative propellers or other treatment types, and data analysis and reporting. For the scope of the pilot project envisaged, and with a relatively large margin associated with industry participation costs, the team estimates an implementation budget of $1-2M with the lower end of the spectrum associated with leveraging existing, planned, and otherwise financed treatments and focusing on measurements, while the higher end is associated with purchasing/implementation of treatments.

Pilot Stage I planning and coordination costs could be on the order of 20% of the total project cost depending on the complexity of the project scope identified and the number of industry partners. Year one costs would include staffing to identify industry partners, coordinate logistics of measurement array(s) and coordination timing, methods, and protocols of vessel measurements.

Pilot Stage II field execution costs would be the large bulk of the expected cost (~70%) and would include standardized URN measurement capabilities (deployment, retrieval, analysis of hydrophone PAM data), and offset logistical costs for vessel participation (fuel and transit costs, boat retrofits/dry dock) and access to noise reduction technologies. Vessel URN measurements are estimated to be on the order of $50k per vessel if considered discretely, which could be reduced the more vessels could be coordinated closely in space and time. The offset costs for participation and access to technologies are estimated to be the largest cost and the largest uncertainty, perhaps ranging from $300k to $1M depending upon the number of vessels engaged, with which technologies tested, and specifics related to their participation and how it could be coordinated with ongoing operations and goals.

Something considered but not recommended here would be the design of propellers specifically tuned for noise reduction on new or existing vessels being tested. There are many standard propeller shapes and characteristics, but tuning one for noise reduction for each ship class will be slightly different. Ideally, one would need to start with naval architect or propeller designer looking at the current design and recommending a different style, manufacturing of the new propeller, installation on the ship and then testing for both URN. This would require vessel owners, measurement and evaluation entities, marine engineering or naval architects, and others to be involved. This is certainly beyond the scope of the pilot envisioned and likely well outside the scope of what even an expanded project could support for even a few vessels in existing or new build categories. Such treatments on military or specialized fisheries research vessels are easily into the millions or tens of millions of dollars per vessel. Thus this is noted as something that has been and could be done but that is well beyond the scope of the proposed pilot.

Pilot Stage II analysis and reporting costs should be relatively straightforward and could represent on the order of 10% of the total budget. The resulting radiated noise levels, comparisons within sources across frequencies, comparisons across sources are key products of this effort, but are expected to be relatively standard reporting products according to the measurement standards referenced for competent noise measurement contractors.

Unlike the seismic pilot option, there are ways to scale this effort down substantially while remaining reasonably viable as a field demonstration effort. For instance, a substantially reduced approach like that taken in a recently issued RFP from MARAD for a comparative study of single vessels of conventional and alternative power tugboats could provide initial insightful measurements like those described here.[18] Such an approach could also be taken with noise reduction to focus on a single vessel with and without noise mitigation using identical approaches. Such discrete projects would make more incremental progress than the broader

[18] https://sam.gov/opp/3cd43aa13a794f1ab5d66206ea73f1bd/view

approach aiming to build in some efficiencies by testing multiple vessel types with and without treatments for more vessels here. However, this pilot likely has greater flexibility given that the relative costs of operations are so much less for these vessels than those operating specialized seismic survey operations.

Industry Perspective: Based on extensive engagement with the supply and service vessel industry sectors during efforts to develop this pilot project, it is fair to say the issue of incidental URN and quieting technologies is not widely known or currently prioritized within the industry, at least within the GoMex. There is clearly an awareness and extensive measures underway to increase the sustainability and performance of vessels regarding fuel efficiency and engine exhaust emissions targets; this was extensively discussed within the Green by Design panel in which the project was invited to participate in at the AWO conference in St. Louis. This includes a wide spectrum of ideas including modifications of existing power and fuel approaches, retrofit of different designs, entirely new designs for different fuel types and full transition to electric. As designs are for sustainability, additional environmental benefits (noise pollution reduction) were seen as a positive, and most feedback was around possible connections between reduced noise and efficiency, to the extent that it does not reduce performance or substantially increase costs. Barring any requirements or strong relationships between noise treatments and efficiency, the interest in noise reduction that was expressed needs to be incentivized in some way (directly or through some marketing approaches) to be economically viable.

Barriers to Success: Identified current barriers to transitioning to a 'quieter' service/supply medium-sized vessel include:

1. Uncertainty over whether alternative power plant vessels are quieter than conventional diesel-powered ones under water and how quieter propellers would work on either
2. A presumed 20-30% increase in cost over 'standard' design for conventional noise quieting approaches
3. Associated costs of having ships in dry dock and associated costs for retrofit.

This pilot proposes to capitalize a movement in the supply-sized vessel fleet to retrofit or build new emissions reduced vessels to both meet GHG targets and meet a potential growing offshore wind energy supply needs in the next 5-10 years. This pilot therefore proposes to work with vessels that are already making or planning such changes, cover the cost of any new changes (propeller) and potentially capitalize on a time where dry dock times are less of an issue as they were already in for retrofits.

Opportunities for Success: The opportunity for this pilot to be successful is in the funding available to identify the potential benefits to a wide range of marine mammals from technologies that are already prioritized by the industry for a different purpose. This could potentially be amplified through marketing regarding common benefits to increase demand, coupled with the funding in future restoration projects to incentivize the application of noise reduction treatments for different medium-size vessel classes and power plant types, pending the results of the pilot effort. Therefore, the biggest unaddressed hurdle is the scale of adoption that would likely be needed to have any demonstrative impact to marine mammals given the number of vessels, the funds available and the number of ships that are likely to transition. To ensure the pilot is a worthwhile investment, a foundational goal will be to provide concrete measurements that address both sound and emissions/efficiency and can be modeled for the relative cost/benefit to both industry and marine mammals.

Next Steps and Transition: Throughout extensive industry engagement at trade meetings, with individual operators, technology developers or engineering firms, and with trade group representatives, the team noted relatively little awareness or dedicated efforts in noise reduction. Most of the awareness and discussion was around sustainability initiatives for reduced or different forms of fuel use and reduced greenhouse reduction, as well as the progressive/projected transition of the supply and service fleets from oil and gas to offshore wind. The team identified more than a dozen representatives of the groups mentioned above that were interested or at least willing to consider some form of participation in potential pilot efforts such as those identified here.

7.3. Operational Approaches for Quieting Commercial Vessels while Underway

Description of Sound Source: Large commercial vessels (>100m) are used throughout the Gulf of Mexico to transport large amounts of dry goods, grain and other foods, fuel and chemicals, vehicles, large cruise ships, and other large sources of cargo. These vessels constitute roughly 20-40% of vessel activity in nearshore areas and 40-70% of vessel activity in the offshore regions of the Gulf of Mexico. These vessels, which include container ships, tankers, roll-on/roll-off cargo ships, etc., are typically powered by massive low-speed diesel engines and are typically configured with a single large propeller along the centerline of the vessel. However, large cruise ships frequently have multiple propellers. Medium-sized service vessels (up to 100m) provide supplies/equipment to offshore rigs, serve as passenger vessels, tow equipment and other vessels, act as tugs to help larger vessels navigate into port, and include larger fishing vessels. These vessels constitute roughly 40-60% of vessel activity in nearshore areas and 20-40% of vessel activity in the offshore of the Gulf of Mexico. Medium-sized vessels such as platform supply vessels (PSVs), offshore supply vessels (OSVs), ferries, tugboats and tow boats typically use a medium speed diesel engine with a pair of propeller shafts in port/starboard arrangements. There has been extensive and increasing international attention and efforts to reduce underwater radiated noise (URN) from commercial vessels. New and expanded quieting guidelines and approaches include a myriad of engineering and operational solutions, the focus here being on the latter and targeted in a specific location identified in Phase I of this program through analyses of vessel routing, bathymetry, noise propagation modeling, and ecological risk assessment based on the location of key protected species in noise-impacted environments. The convergence of these factors has led to the recommended pilot project elements considered here which include operational modifications related to vessel speed and routing. While both are known to have extensive and, in some ways, predictable impacts on URN for various vessel classes, this has not been systematically addressed in a controlled manner for commercial vessels in these areas.

Description of Impact: Noise radiated from vessels is less intense, impulsive, and broadband than seismic airguns. Large commercial vessels are generally louder overall and more intense at lower frequencies than medium-sized vessels. Faster vessels are typically louder than slower vessels, although this is a complex relationship that varies between classes and other factors (e.g., vessel loading and propulsion plant type). Vessel-associated URN from some of the larger-sized vessels and especially large container, tanker, and cargo ships are a substantial contribution to the overall soundscape of the GoMex given their large number and broad distribution. The primary impacts that occur are likely interference (masking) of sound communication and/or physiological stress in areas of concentrated activity (e.g., coastal lanes, ports, near offshore facilities). The extent and magnitude of impacts depend heavily upon the exposure context and species exposed. Low-frequency sensitive species (Rice's whale for GoMex) are generally the most sensitive, followed by moderate-frequency species (e.g., sperm, beaked whales), and then higher frequency species (e.g., dolphins) typically being the least sensitive, given the predominately low frequency nature of these sources. Both engineering and operational approaches exist and are strategically recommended to reduce the overall radiated noise energy; operational approaches are considered here. Noise in the 40 to 5,000 Hz band generated by vessels of these classes is primarily from the propeller and secondarily from the engine, which can also have impact to crew comfort and safety although this is seen as a more ancillary benefit rather than a reason to make change. Any vessel noise reduction would be environmentally beneficial, but results from the proposed pilot would need to inform strategic targets for future implementation in priority regions to meet specific noise reduction objectives.

Pilot Summary and Objectives: The goal is not to generate new vessel 'quieting solutions,' but rather to evaluate potential modifications in the operation of existing, unmodified vessel to achieve targeted quieting approaches. The project would systematically compare the measured in water Underwater Radiated Noise (URN) of specific vessel transit speeds in specific locations selected based on propagation modeling to reduce radiated noise into certain areas. These areas would be focused within vessel transit lanes feeding south from the ports of Pensacola, Mobile, Pascagoula, and Biloxi; potential alternate transit routing would also be explored in nearby surrounding areas. Earlier ecological risk assessment results from Phase I indicate these areas have relatively low nearby seismic activity, yet relatively high large vessel activity, suggesting focusing on vessels would have the most noise reduction benefit. The shelf areas near the ends of these vessel corridors also include concentrated areas of ESA-listed and mid-frequency sperm whales. Further, noise modeling results indicate preferential propagation of noise from vessels along these shelf areas into the core distribution area for endangered and low-frequency Rice's whale.

To understand relative noise reduction, the team used the risk assessment to understand vessel traffic patterns near DC PAM site. Specifically, they looked at AIS vessel traffic pattern near the northwest edge of the Rice's whale core distribution area. Initial propagation models indicate small modifications in routing in strategic areas could have substantial results near key habitat areas around the Mississippi Canyon and Desoto Canyon listening stations. This project would implement a standardized testing platform in an open ocean environment to evaluate various operational conditions for their relative sound reduction benefits measured at various ranges from sources, leveraging similar stations measuring vessel noise in both controlled and incidental operations for the Ports of Vancouver, Seattle, in the traffic lanes accessing LA/Long Beach off Southern California, as well as datasets that have been generated from existing ship noise measurement stations funded under this overall project in the lanes accessing the Ports of New Orleans and Galveston.

Pilot Project Scope of Work and Methodology:

Pilot Stage I – Planning and Coordination: The potential pilot project would apply a comparative, multi-treatment test and evaluation for sound reduction in relation to two known factors related to underwater noise footprints: (1) vessel speed (note these are nominal values for purposes of modeling here and would be revisited/evaluated in the pilot) and (2) vessel routing. Table 10 shows eight different test segments to be evaluated with common operational and measurement methods.

TABLE 10: Summary of Vessel Operational Test Segments

Large Commercial Vessel Type	***Medium Supply Vessel Type***
Traditional Routing: Typical Transit Speed (18 knt)	Traditional Routing: Typical Transit Speed (16 knt)
Traditional Routing: Reduced Transit Speed (10 knt)	Traditional Routing: Reduced Transit Speed (10 knt)
Alternative Routing: Typical Transit Speed (18 knt)	Alternative Routing: Typical Transit Speed (16 knt)
Alternative Routing: Reduced Transit Speed (10 knt)	Alternative Routing: Reduced Transit Speed (10 knt)

Pilot Stage I, Year 1 objectives would include planning and coordination. This targeted pilot would solicit participation of vessels of both large commercial and medium-size service vessel classes with traditional (existing) power systems. The primary objective in Stage I planning and coordination year would include identifying and engaging with potential project participants to complete vessel passes of PAM stations in some or all the controlled conditions identified above. Extensive noise propagation modeling, as well as engagement with both companies and other federal agencies, notably NOAA and the USCG, would be conducted to identify specific testing locations both within and outside existing transit corridors. Not all vessels may be able to participate in all four conditions for each class but would be expected to conduct at least the typical and reduced speed transits in each location. Discussions with interested parties may focus on developing a schedule of when and where vessels would be available for as well as incentives needed to participate in the testing, or any follow-on efforts related to voluntary speed reduction (via ports or via positive marketing—see reviews in IMO Guidelines section 9).

Key questions

1. Whether and how regional ports and the USCG would need to be engaged in this issue. How do they need to be engaged and at what point in the process to make sure the pilot

addresses their criteria and provides the information needed to make them comfortable?

2. Identify how best to directly engage certification NGOs. They have been approached in multiple direct ways, including giving a technical presentation at the 2023 *GreenTech* conference in Seattle. This was extremely useful in engaging multiple other projects and industry partners, but the team has not been able to make direct inroads via Green Marine or their member ports even after multiple attempts. This may reflect the perspective heard multiple times that it is hard for companies to specifically commit to any engagement without a better understanding of whether a project will occur and what the details of engagement and participations would look like. There is likely more opportunity here if/when there is a specific pilot project.
3. It is necessary to understand what a schedule for participation looks like based on existing routes for willing partners and the likely cost/time to industry for passing measurement stations in different conditions.
4. Understanding the interests and incentives needed by both the vessel owners and the noise reduction technology providers to participate.
5. Is this similar to, or possibly congruent with, what any individual company initiatives, trade organizations, and/or certification programs may already be planning? There has been some progress with trade organizations and some individual companies and sustainability officers, but it is such a diverse and broad set of industry sectors there is possibly more out there.

Pilot Stage II Execution and Analysis - Standardized measurements would be made of broadband (10 Hz – 10 kHz) underwater radiated noise (quantified in decidecade and spectrum level standard metrics) for standard near-field (<100m) ranges for vessels of different types and operational profiles traveling in identical paths and locations at common, standard speed(s). This could be done using mobile NOAA URN measurement stations if they could be coordinated with appropriate vessel locations and/or contracted vertical line arrays of PAM sensors. In addition to measurements of URN in these conditions, relative efficiency of vessel operations would be measured in terms of energy consumption. For the speed reduction measurements, the project will employ existing URN measurement methodologies standardized under ISO-

17208-Part 1 or ANSI S12.64 or other similar methods. Such methodologies are scalable and can be performed in any open ocean water with appropriate depth and background ambient noise levels. Specifically, both standards require sufficiently ‘deep’ water, which is defined as at least one vessel length or 100 meters (whichever is greater) and very specific hydrophone arrangements and procedures. These are all described in detail within the standards, but briefly they require two to six vessel passes depending on the measurement grade (per ANSI S12.64). The hydrophones need to be suspended in the water column by a support vessel or special buoy. This may require a second vessel on station or deployment from the vessel to be tested, depending on specific methodology used by the contractor(s) conducting the measurements.

To meaningfully measure differences in URN from Vessel A vs. Vessel B or from Vessel A at variable speeds, the ANSI/ISO methods given above will need to be used. While they may provide relative insights, opportunistic methods including positioning PAM stations in vessel lanes and tracking single passes without control may produce contaminated and/or insufficient data in terms of scrutiny of results from the URN measurement community and/or industry. The ANSI and ISO methods have multiple facets that ensure quality and comparable URN is being measured. This includes multiple passes at each specified speed, relatively short measurement distances (typically 100 m), background sound adjustments, multiple hydrophones, and other data quality checks. It is possible that treatment is effective at one condition and not at others (for example speed) and this should be part of the survey design.

Pilot Stage II, Year 2 objectives are to conduct testing and evaluation of as many vessels of each vessel class in each condition in similar time periods using identical methods.

Pilot Stage II, Year 3 objectives are to conduct analyses, compare results to model predictions, and evaluate efficacy and environmental implications for all conditions tested. Reporting and products developed will be determined through feedback on specific questions identified for the pilot presented to the Steering Committee; potential products could include infographics, comparative assessment costs/benefits, technical reports, and/or publications.

Pilot project success hinges on three primary points:

1) Identifying both typical and alternative routes based on modeling approaches that are feasible from an operational and regulatory perspective
2) Identification multiple vessels are that are willing to participate in standardized test in specified area(s)
3) Careful planning and coordination of passive acoustic measurements with both bottom-mounted and/or vertical line array sources

These are individual vessel tests that could be captured by transit past a known location using well established monitoring methods. Planning, testing, and analysis is anticipated to be possible within two years, but an analysis and model evaluation period is expected to take a third year. The willingness of at least three vessels of each sized class to participate in at least one set of tests at each transit speed is a recommended milestone for advancing this pilot.

Questions to be Answered. *Pilot questions include*:

1. What are the URN characteristics of conventional large commercial and medium-sized service vessels operated in the GoMex measured under controlled, experimentally altered conditions? Do location-specific modeled conditions match near (~ 1 km) and moderate (10-100 km) range propagation conditions for large commercial vessels?
2. How much noise reduction can be achieved through vessel speed reduction?
3. How much noise reduction can be achieved through strategic vessel routing?

Questions for future advancement include:

1. Are there viable options for scaling up speed or routing approaches to noise quieting in adaptively targeted ways?
2. How many vessels of these classes would need to be needed to adopt such approaches in speed and routing to have a strategic restoration benefit to marine mammals?
3. What are the actual and hidden costs of providing/incentivizing operational modifications to meet quieting objectives?
4. What are the non-monetary barriers to broader participation?

Modeled Potential Benefit of Pilot I vs. Realistic Future Uptake:

The successful test and evaluation of how potential operational modifications could work if tested and evaluated was identified as a necessary precursor to any broad consideration for implementation industry engagement. Potential benefits that should increase the probability of future broader implementation of quieting technologies have been identified:

1. Obtaining direct measurements of how well they may work and whether modeling predictions can be matched with real operations to strategically achieve quieting would provide proof of concept to inform cost-benefit analyses for industry. Potential operational quieting approaches have not been tested in the GoMex.
2. With the measurements made in conjunction with U.S. regulatory bodies, the measurements will have a high degree of credibility both within the U.S. and externally.
3. Systematic evaluation of the relative ecological benefit of each of these approaches should give a significant benefit to operators during environmental submissions and discussions. These may also enable them to meet certification standards (e.g., Green Marine).

Expected Costs Expected Costs and Project Scalability: The pilot would provide the overarching coordination and logistical planning, standardized measurement capabilities (deployment/retrieval of arrays), detailed modeling and mode evaluation of site-specific operations, and potentially fuel and time cost offsets for participating vessels. Assuming overall project coordination and planning, PAM measurement costs for controlled near-vessel measurements and industry participation costs we estimate an implementation budget of ~$2M. This assumes engagement of on the order of 4-6 vessels in each class transiting at multiple speeds with measurements in multiple locations.

Pilot Stage I planning and coordination costs could be on the order of 20% of the total project cost depending on the complexity of the project scope identified and the number of industry partners. Year one costs would include staffing to identify industry partners, coordinate logistics of measurement array(s), coordination of timing, methods, and protocols of vessel measurements, and what could be substantial coordinating discussions of potential alternative routing of vessels for the purposes of targeted measurements.

Pilot Stage II field execution costs would be the large bulk of the expected cost (~70%) and would include standardized URN measurement capabilities (deployment, retrieval, analysis of hydrophone PAM data), and offset logistical costs for vessel participation (fuel and transit costs). As with the engineering proposed pilot, vessel URN measurements are estimated to be on the order of $50k per vessel if considered discretely, which could be reduced through the inclusion of more vessels that could be coordinated closely in space and time. The offset costs for participation and access to technologies are estimated to be the largest cost and the largest uncertainty, perhaps ranging from $500k to $1.5M depending upon the number of vessels engaged (a relatively ambitious goal), with which technologies tested, and specifics related to their participation and how it could be coordinated with ongoing operations and goals.

As with the engineering pilot, the Pilot Stage II analysis and reporting costs are anticipated to be relatively straightforward and could represent on the order of 10% of the total budget. The resulting radiated noise levels, comparisons within sources across frequencies, comparisons across sources are key products of this effort, but are expected to be relatively standard reporting products according to the measurement standards referenced for competent noise measurement contractors.

While the team would still advocate for a broader, more comprehensive measurement and engagement program such as that proposed here, there are ways to scale this effort substantially while remaining somewhat viable as a field demonstration effort. This could focus on single vessels in each class operating at variable speeds within existing lanes, for instance. It may simply be too difficult on multiple levels to consider alternative locations/routing than the existing lanes (although AIS data demonstrates these are sometimes not adhered to). The team strongly believes the geographic area identified is the most important region of the GoMex to consider potential operational changes to reduce vessel noise for all the reasons specified in detail above (geographic location of multiple lanes converging near the shelf break, preferential noise propagation off the shelf into Rice’s whale critical habitat areas, local presence of the two highest priority species from both a regulatory and an acoustic perspective).

The team recognizes the inherent sensitivity of the vessel industry to speed reductions, having heard this expressed directly in several fora and individual feedback. This included awareness of strong views expressed in meetings and direct engagement related to recent petitions for speed reductions for vessels for protection of Rice's whale. The team believes that there is sufficient industry precedent (e.g., Port of Vancouver ECHO program and their extensive industry participation initially in such controlled measurements) for the need for simple demonstration/validation studies within local areas vice extrapolations form other regions, that clear lines can be made between measurements and regulation. Particularly given these considerations, some overarching planning, coordination, and reporting to work with industry, even if a subset of conditions or a smaller number of vessels were engaged, would be important to retain.

Industry Perspective: Based on extensive engagement with various vessel industry sectors during Phase I efforts to develop this pilot project, the issue of incidental URN and quieting technologies is more widely known within portions of the industry, notably the large vessel sector. As noted in the engineering pilot, there is clearly an awareness and extensive measures underway to increase the sustainability and performance of vessels about fuel efficiency and engine emissions targets, with this increasingly intersecting with underwater noise as was recently discussed at meetings at the IMO, including a member of the Phase I team. This includes a wide spectrum of ideas including modifications of existing power and fuel approaches, retrofit of different designs, entirely new designs for different fuel types and full transition to electric. As designs are for sustainability, additional environmental benefits (noise pollution reduction) were seen as a positive, and most feedback was around possible connections between reduced noise and efficiency, to the extent that it does not reduce performance or substantially increase costs. Barring any requirements or strong negative relationships between noise treatments and efficiency, the interest in noise reduction that was expressed needs to be incentivized in some way (directly or through some marketing approaches) to be economically viable. In terms of operational modifications, speed reductions may be a non-starter with some sectors of the industry, although the relative cost-benefit of these with demonstrated results may inform and modify those assessments.

Opportunities for Success: The opportunity for this pilot to be successful is in the funding available to identify the potential benefits to a wide range of marine mammals from changes in operational profiles that are already prioritized by the industry for a different purpose. This could potentially be amplified through marketing regarding responsible practices and achieving sustainability goals/certifications programs. To ensure the pilot is a worthwhile investment, a foundational goal will be to provide concrete measurements for specified operational conditions that could be modeled for the relative cost/benefit to both industry and marine mammals.

Next Steps and Transition: Industry engagement was more limited with the large commercial vessel sectors in relation to this project than the supply and service vessel sectors. This was not for lack of effort, but limited responses reflected an awareness of the IMO processes and of the transition to alternative fuels and interaction with sustainability and noise. Most operators and trade organizations we interacted with at trade meetings, with individual operators, technology developers or engineering firms, and with trade group representatives. These groups indicated they were largely watching the issue to see what technological options would be available at little or no cost while considering other changes or whether the issue would eventually become a regulatory one. Many entities said that they would be potentially interested in participating and/or knowing more about a potential pilot once the details and opportunities of something specific were known.

Appendix 1.

Ecological Risk Assessment: Detailed Summary and Examples

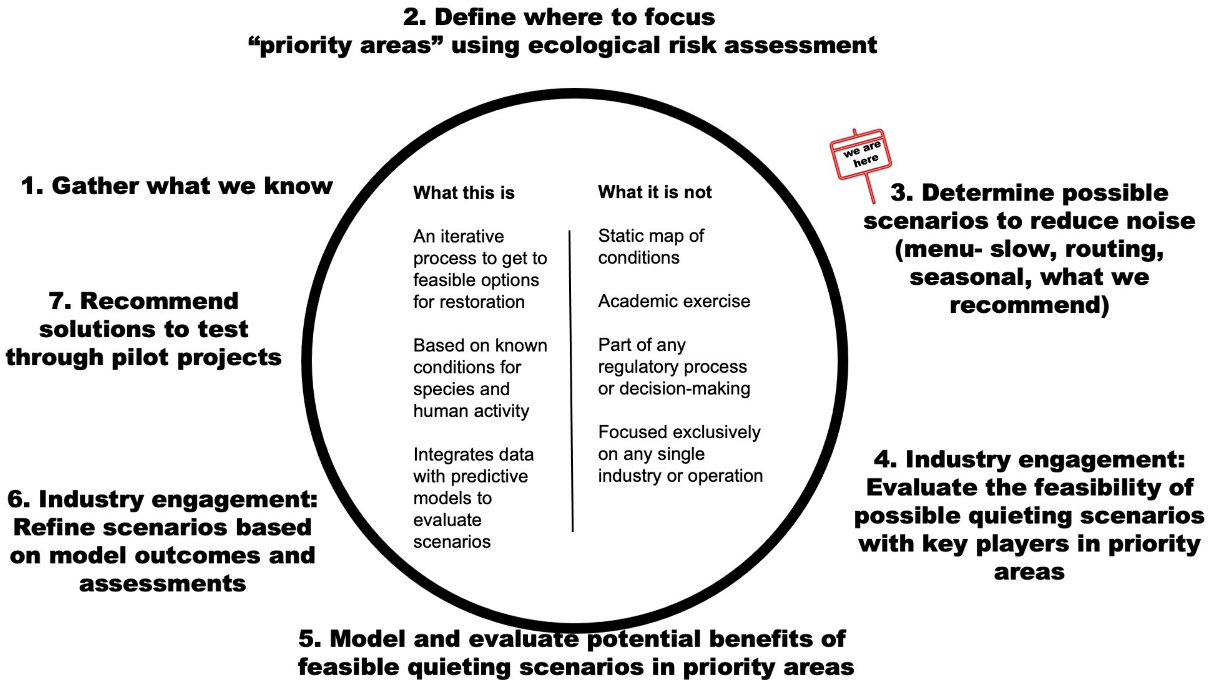
Overview

The following provides the methodology developed and a step-by-step example of the relativistic, spatially, and temporally explicit risk assessment approach we have developed and intend to apply in task 1 of this project. It provides key definitions and methodologies. The objective of this first phase of the project is to aggregate and then integrate biological and anthropogenic data in a spatially and temporally explicit manner with quantitative metrics. These are then applied using a transparent, relativistic risk assessment approach to assess impacts of underwater anthropogenic noise in defined categories for specified categories on marine mammals with variable hearing sensitivity. The overall approach integrates best available and consistently determined marine mammal density data with known locations and operation of vessels, offshore infrastructure, and seismic surveys during specified time periods. Noise propagation modeling is applied to determine areas around specified locations within which source types are predicted to be audible based on source-specific noise frequencies and source levels given species-specific hearing capabilities and site-specific ambient noise levels determined from passive acoustic monitoring (PAM) measurements and/or wind-driven noise models. Four categorical interactions of noise and mammal interaction are identified, each with generalized possible future mitigation strategies) including:

1) High noise, many animals (restore/ reduce noise in these areas).
2) High noise, few animals (relatively low priority areas, though consider habitat quality and whether animals would be expected there and are excluded).
3) Low noise, many animals (protect these areas from more noise).
4) Low noise, few animals (potential to increase/move activity here from areas of greater importance if possible).

The quantitative approaches to these categorical distinctions (derived below) will be consistently applied by each defined species, location, and time period. Space and time resolution are constant here, but it is noted that the approach is inherently scalable to spatial and temporal resolutions of interest for which key information is available (e.g., mammal density models). It is deliberately relativistic, providing results using comparable methodology and assumptions. It is intended to be transparent, inherently visual, understandable at a non-specialized level, and designed to inform the future assessment of potential strategically focused noise mitigation scenarios (for further development in Tasks 2 and 3; see workflow below). Specifically, the outputs of the iterative quantitative steps applied in this risk assessment identify spatially and temporally explicit, relativistic assessments of risk intended to strategically focus on priority areas. This will inform follow-on identification of potential noise mitigation scenarios for these priority areas (specific to time, space, species, and source type) within which targeted, informed mitigation efforts could be designed, evaluated, and applied in subsequent pilot projects.

Overall Project Workflow '



Key Terminology

The following are key distinctions of terms and definitions:

Relativistic ecological risk assessment: A stepwise integration of biological and anthropogenic noise data to provide comparable, relative magnitude evaluation of noise impact for defined times and areas to focus noise mitigation scenarios.

Listening space: Geographic areas around a focal location over which noise sources are audible to focal marine mammal species based on source frequency-specific propagation modeling, hearing characteristics, and ambient noise characteristics. It is a spatial estimate of the distance at which a specific noise source would be detected at the PAM location. It is meant to help understand where to focus efforts and ultimately measure a change in condition.

Noise activity index: A quantitative metric based on the presence of noise sources (vessels, offshore infrastructure, seismic) in defined sectors for specific times and areas determined by listening spaces. The index is based on spatial data of activity and results are combined with PAM data predict the relationship between noise levels and noise activity.

Exposure index**:** Combination of the presence of species and noise activity within relevant listening spaces to define one of the four possible categories of noise and mammal interactions.

Species-specific vulnerability: A relativistic assessment of potential sensitivity to disturbance based on species-specific population, life history, and hearing and behavioral parameters.

Noise mitigation scenarios: Possible options for either reducing or preventing subsequent noise impacts based on strategically identified approaches from the ecological risk assessment.

Boundary conditions for relativistic ecological risk assessment

Overall Time Period: August 1, 2020 – September 30, 2021

Study Area: Northern half of Gulf of Mexico; defined all oceanic areas north of 24.5° N latitude

Initial Focal Study Sites: Strategically selected PAM stations (n=10), additional sites may be added depending on risk assessment results

Focal Marine Mammal Species: Rice's whale, sperm whale, beaked whales (species group), blackfish (species group), oceanic Atlantic spotted dolphins, oceanic bottlenose dolphins, pantropical spotted dolphin, pilot whales, Risso's dolphins, spinner dolphins, and striped dolphins.

Marine Mammal Spatial Resolution: 10x10 km grid cells based on marine mammal distribution models that are then summarized in listening spaces around focal study sites

Risk Assessment Spatial Resolution: Time and area specific geographic areas for marine mammal listening spaces around focal study sites

Temporal resolution: Monthly integration of marine mammal density and noise sources

Risk Assessment methodology and data summary

Here we provide an overview of the ecological risk assessment methodology showing data inputs and integration steps for the relativistic ecological risk assessment process (**Figure 1**). Definitions of all the terms in **Figure 1** follow the diagram.

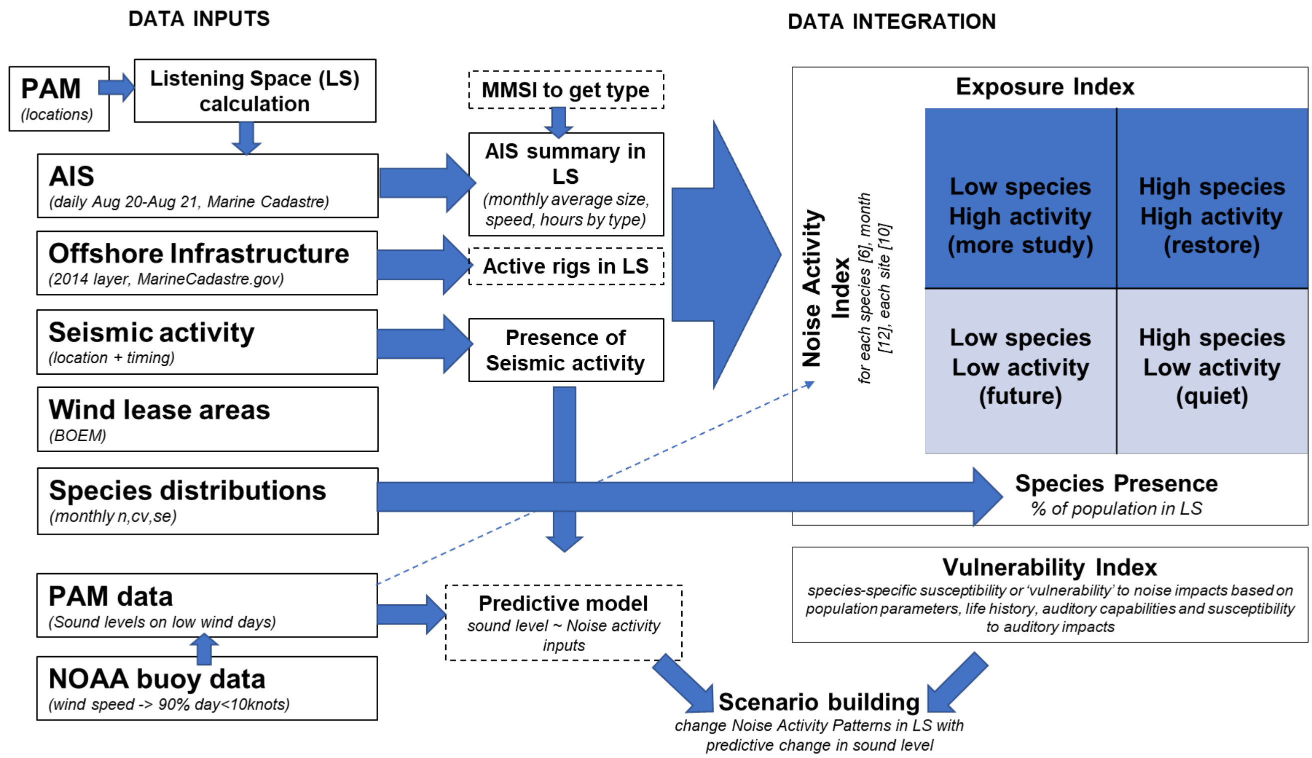


Figure 1. Overview of Ecological Risk Assessment Process. First, step was gathering data inputs for a variety of source listed in first column (description of the inputs follow this section). The second step was integrating the data for each priority location (PAM station). The final step will be a regional comparison of the site-month-species data integration results. Dashed boxes indicate that steps are currently underway.

Data Inputs

Passive Acoustic Monitoring (PAM) sites

Geographical locations of existing PAM station in GoMex. Only sites with data collected between August 1, 2020 – September 30, 2021 were used in further analysis (labeled on **Figure 2**).

Listening Space (LS)

The received sound level (RL) field around a specific point (PAM station) is calculated as the difference between a nominal, representative sound source level (SL) and transmission loss (TL). W which is modeled using a Navy version of the range-dependent parabolic equations (PE) acoustic propagation model[1] and US Navy and NOAA environmental databases: High-Resolution ¼ degree Global Sea Surface Wind Speed and Climatology (NOAA); Bottom Sediment Type (Navy) BST database and Global Ocean Sediment Thickness Dataset (NOAA).

Listening Space Signal-to-noise (SNR) Thresholds

These thresholds were chosen to draw a boundary around each PAM station as the likely detection range for different categories of noise sources (**Table 1**). Seasonal variation in boundaries will be captured; however, we are not accounting for variation in vessel source levels at this point: the source level represents level for typical vessels in different size categories. The geographical area within these thresholds is considered the listening space.

Table 1: Summary of Listening Space Parameters

Source category	**Source level***	**Source frequency**	**Source depth**	**Receiver depth (10 m off from bottom)**	**SNR Threshold wind induced ambient (at source frequency) + 10 dB****
Large Vessel	185 dB re 1uPa @1m (rms)	125	6	257	64
Medium Vessel	165 dB re 1uPa @1m (rms)	1000	6	257	74
Seismic	245 dB re 1uPa @1m (rms)	63	6	257	81

**Source level was based on knowledge of industry-typical provided through industry contacts under optimal* (*operational conditions.* (

***10 dB was added because of generally high activity in Gulf of Mexico and the likelihood for other sources to be contributing to the wind-induced ambient.* (

Automatic Identification System (AIS)

Data on commercial vessel traffic operating within the northern Gulf of Mexico (labeled on **Figure 2A**) were downloaded from MarineCadastre.gov as daily files and processed to extract unique vessels counts

[1] Collins M.D., A split-step Padé solution for the parabolic equation method, Journal of the Acoustical Society of America 93, 1736 (1993); doi: 10.1121/1.406739.

by size within specified listening spaces. *These data will be matched using unique MMSI with Coast Guard data (land-based and satellite) that includes the type of vessel (MMSI to get type).*

Offshore Infrastructure

Identified as existing offshore rigs and other industrial platforms from 2014 BOEM data (labeled on **Figure 2A**). To characterize if rigs as active, we are collaborating with authors of previous study that characterized status of the offshore infrastructure[2]. *It is possible to include other offshore infrastructure if data are available.*

Seismic Activity

Locations and temporal occurrence of activity within the specified study period. The current data are from initial discussion with industry representatives **(Figure 2B-D**). These data were subsequently validated and enhanced with data obtained through coordination with both the Bureau of Ocean Energy Management (BOEM) and the Bureau of Safety and Environmental Enforcement (BSEE) to obtain locations and temporal occurrence of seismic survey activity within the specified study period. This included some periods for which this information was publicly available after-action reports[3] and protected species observer (PSO) data from seismic survey ships as well as additional data and interpretation provided by BSEE on request. Data were of variable resolution and accessibility during the survey period. A simplifying assumption was made to identify whether and how many surveys were active for any duration and results were tallied as the number of surveys active per day with a confirmed shot location(s), vessel name, and general seismic technology used.

Wind Lease Areas

Area where future wind energy development is likely to occur (labeled on **Figure 2A**).

[2] Liu, Y., Sun, C., Yang, Y., Zhou, M., Zhan, W., & Cheng, W. (2016). Automatic extraction of offshore platforms using time-series Landsat-8 Operational Land Imager data. *Remote Sensing of Environment*, *175*, 73-91.
[3] Searched via: https://www.data.bsee.gov/Other/DiscMediaStore/ScanGGPermits.aspx

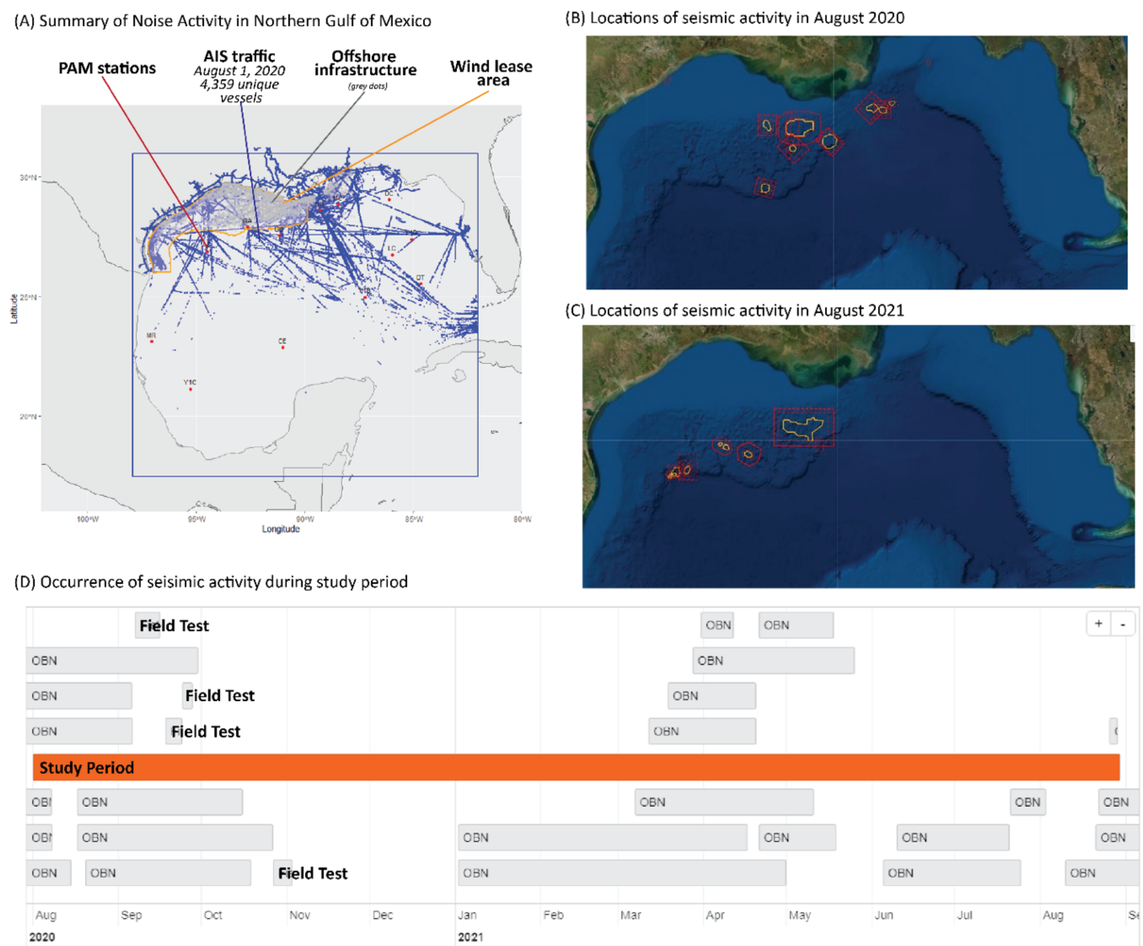


Figure 2. Summary of Noise Activity in northern Gulf of Mexico. (A) includes locations of PAM stations, example of AIS traffic for one day, locations of offshore infrastructure and wind energy lease areas. (B-C) Are locations of seismic surveys in August 2020 and 2021- screen shot from industry database. (D) Occurrence of seismic activity during the study period- exact locations of these surveys are yet to be determined, although August locations are shown in B-C. Note: OBN refers to Ocean Bottom Node surveys which involve the placing of bottom-mounted sensors for monitoring seismic survey pulses.

Species Distributions

Monthly predictions were averaged from 2015-2018 data provided over spatial areas given (40 km hex cells). The units for abundance are numbers of animals, which are converted to density (number/km^2) by simply dividing by the area of each hexgrid cell. Predictor variables in species distribution models include: depth, distance to (shore, shelf breaks, canyons), slope, oceanographic variables (Sea surface temperature, Chlorophyl A, sea level anomalies, current parameters), salinity, mixed layer depth.

PAM data

Extracted daily 1-Hz percentile sound level measurements for each site on days identified as low wind days on nearby ***NOAA buoy***. Low wind is defined as days with windspeeds less than 10 knots greater than 90% of the day.

Data Integration

Scoring process for noise activity index

This process is designed to result in a deliberately simple categorical designation for the relative magnitude of noise activity for each source type within species-specific listening space around each site and month as either HIGH or LOW **(Figure 3)**. While this is a very simple designation, notably the actual values determined for each listening space context are retained as continuous variables for use in further resolution assessments during potential mitigation scenarios in efforts following the risk assessment. The decision points for these categorical distinctions are estimates of the relative occurrence of noise activity in the local area to the entire region. For instance, if the number of unique vessels in each category is greater than 10% of total unique vessels in the northern Gulf of Mexico (which would indicate higher than expected activity by chance, given the number of initial focal sites), the site is considered to have *relatively* high noise from vessel traffic. We ask four specific questions relative to seismic, vessel, and offshore facilities, with the following decision points. A binary answer for each activity is returned for each species, location, and time.

1. *Was seismic was present in that month? If yes, score is: +*

2. *Were the number of unique large vessels (>100 m) within the defined listening space, greater than 10% of the total unique vessels in the entire region? If yes, score is: +*

3. *Were the number of unique other vessels (<100 m) within the defined listening space, greater than 10% of total? If yes, score is: +*

4. *Is there offshore infrastructure withing 10 km? If yes, score is: +*

Lowest possible score = 0; Highest possible score = ++++

For each site, we compared these noise activity index results to a rank of sites based on average sound levels measured on low-wind days. Noise activity index score will be validated with PAM ranking of low-wind sound levels across the PAM locations (**see Figure 4**).

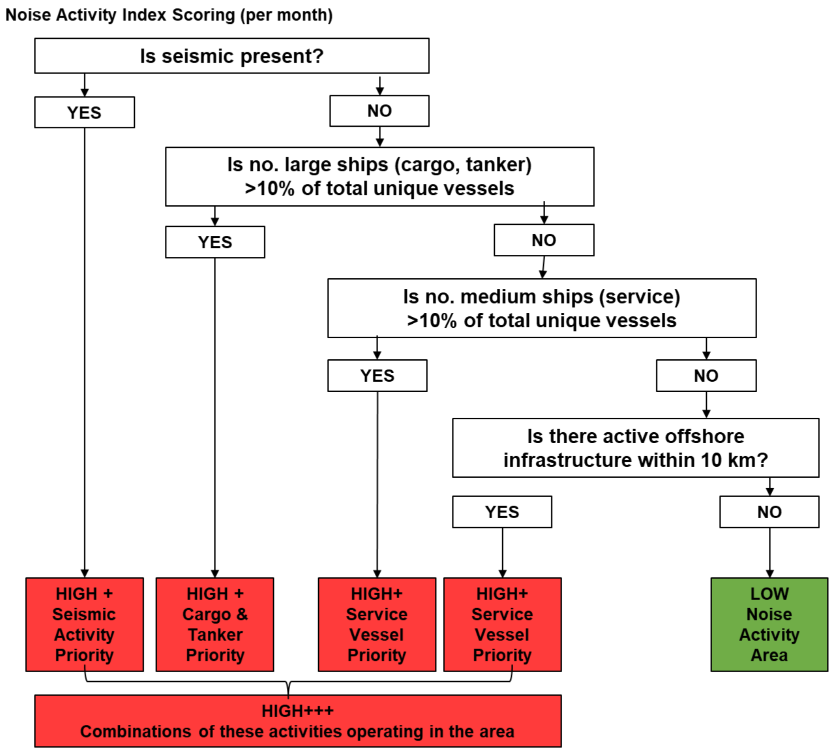


Figure 3. Process for determining score for Noise Activity Index. Seismic survey activity includes areas identified by industry with presence of seismic survey activity in defined time-period.

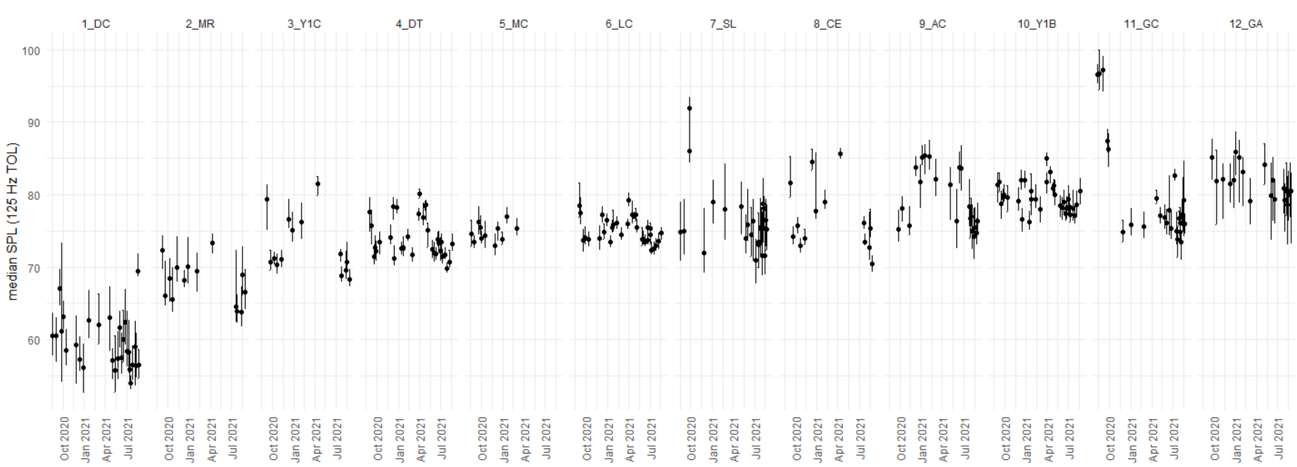


Figure 4: Summary of variation in PAM data across sites. *

Days shown are only low-wind days based on NOAA buoy statistics (approximately 30 days per site). Sites are ordered from lowest to highest mean values for all days. Pressure spectral density (PSD) levels in units of 1 µPa^2/Hz were calculated using Welch's Method in Matlab (FFT length = 48000 points, Hann window length = 48000, FFT overlap = 0%), resulting in PSD estimates of mean-square pressure amplitude (µPa^2) with a frequency resolution of 1 Hz and temporal resolution of 1 second. For every 1-Hertz (Hz) frequency band from 20 Hz to 4,000 Hz, daily percentile levels (25^{th}, 50^{th}, 75^{th}) were calculated. The 1-Hz percentiles summarized as 125 Hz 3^{rd} octave band levels (88-180 Hz) by mean-square pressure amplitude (µPa^2). PSD levels per day across both 3^{rd} octave bands, and broadband (20-4000 Hz) were converted to decibels (dB re 1 μPa^2/Hz).

Scoring process for species presence

Each species-month-site is categorized as HIGH or LOW based on the % of the populations within the estimated listening space. High species presence was defined if greater than 10% of the population was located in the defined listening space for each noise category.

Species-specific vulnerability

For this metric we reference previously conducted assessments[4] of species-specific susceptibility or 'vulnerability' to noise impacts based on population parameters, life history, auditory capabilities and susceptibility to auditory impacts. Within these NOAA and BOEM funded risk assessment efforts we evaluated species-specific vulnerability for all GoMex species to seismic survey disturbance across seasons. For each site, species, and season, evaluated vulnerability on a five-point scale was calculated based on four parameters specified for the example here below. We will use the above criteria to quantitatively rank the relative interactions of focal species and noise by time/area but will provide these previously calculated vulnerability assessments for context in summarizing the relativistic risk assessment across species within an area. Vulnerability assessments were calculated for all GoMex areas and species for all seasons, although selected values are reported in the report referenced above. For this specific area, the following vulnerability assessments were made for Rice's whale (noted as Bryde's whale in this report completed several years ago, which is provided as an appendix). The total score is composed of a series of 'factors' with a combination of quantitative and expert-elicited distinctions. Each are listed below with the total possible scores for each factor, the total of which determines the species, time, and area-specific vulnerability score (out of 30), which is segregated into five relative scores of vulnerability based on quintiles.

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[4] Southall B., Ellison, W., Clark, C., Tollit, D., and Amaral, J. (2021). 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. Report No: OCS Study BOEM 2021-020.

1. Species Population Factor (includes listing status, pop trend – possible scores: 0-7)

2. Habitat Use and Compensatory Abilities Factor (considers residency and other natural history parameters; timing of key life functions – possible scores: 0-7)

3. Masking Factor (includes a quantitative, band-specific calculation of ambient noise (from activity) to background noise values (SNR effectively) – possible scores: 0-9)
4. Other Environmental Risk Factor (includes known other stressors in the area both $ anthropogenic and environmental – possible scores: 0-7) $

TOTAL POSSIBLE SCORES range from 0-30 where relative overall vulnerability is based on quintiles: Lowest vulnerability (0-5); Low (6-11); Moderate (12-17); High (18-23); Highest (24-30)

Species-specific vulnerability scores will be reported across species by area/season to contextualize activity index assessments.

Ecological risk assessment

For each month-site-species combination, one of four possible categorical distinctions for the species, area, time will be determined, based on noise activity index, species presence, and vulnerability assessments:

1) High noise, many animals (restore/ reduce noise in these areas).
2) High noise, few animals (relatively low priority areas, though consider habitat quality and whether animals would be expected there and are excluded).
3) Low noise, many animals (protect these areas from more noise).
4) Low noise, few animals (potential to increase/move activity here from areas of greater importance if possible).

After ranking sites based on these categories, for HIGH NOISE sites the metrics derived from the noise activity index will be used to inform possible mitigation scenario options.

Predictive model of daily noise levels

Existing PAM data for all low-wind days across sites will be combined with noise activity conditions on the specific days and in listening spaces around PAM sites to build a predictive model that can be used estimate a change in noise levels under different scenarios.

Global model formula:

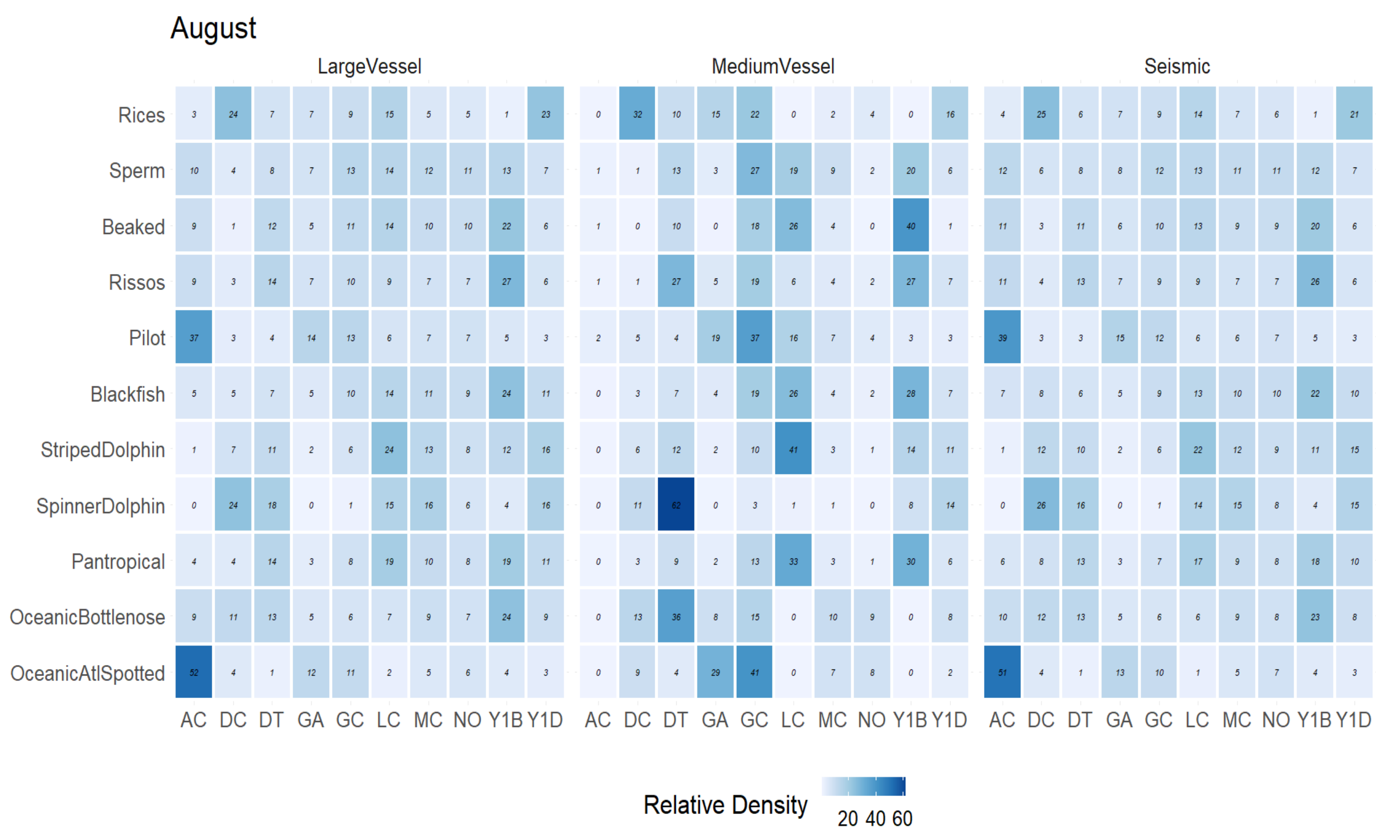
daily noise level ~ f(# large vessels) + + f(average large speed) + f(# medium vessels) + f(average medium speed) + f(wind speed) + f(# offshore infrastructure) + f(prop days with seismic activity) + month, random = site

While the model can be used to compare existing conditions, the purpose is to use the model to predict changes in noise levels based on scenario options (quieting ships, routing changes, fewer seismic activities, etc).

Risk Assessment Results Summary – Aug examples

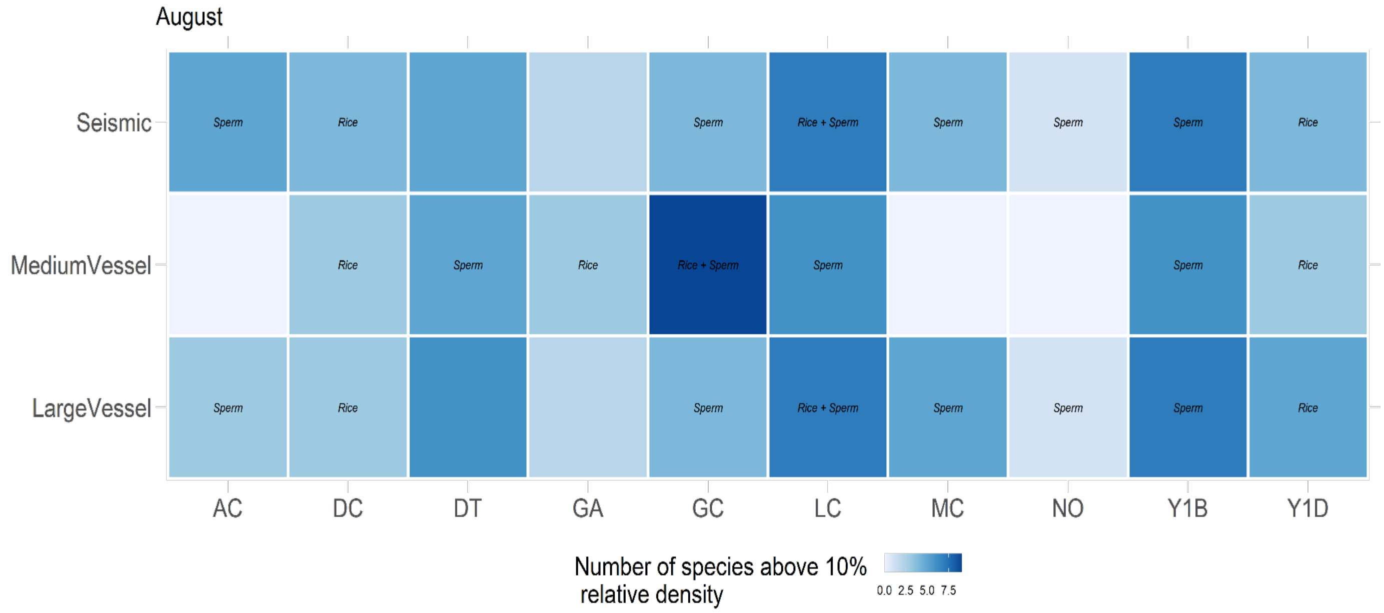
Step 1: Relative density of species across sites

Relative densities are summarized across site (n=10) and species (n=11) for monthly conditions as percent of total density across listening areas. High priority species (sperm and rice's whale) are shown in the top two rows. Values in boxes are relative density values, also represented by the shading; darker boxes indicate higher density. The relative densities were calculated as species density in a listening area at a PAM site divided by the total density in all listening areas for the same source and SNR threshold. All species except Rice's whale, the higher SNR thresholds were used to represent frequency hearing capabilities (less sensitive in low frequencies).



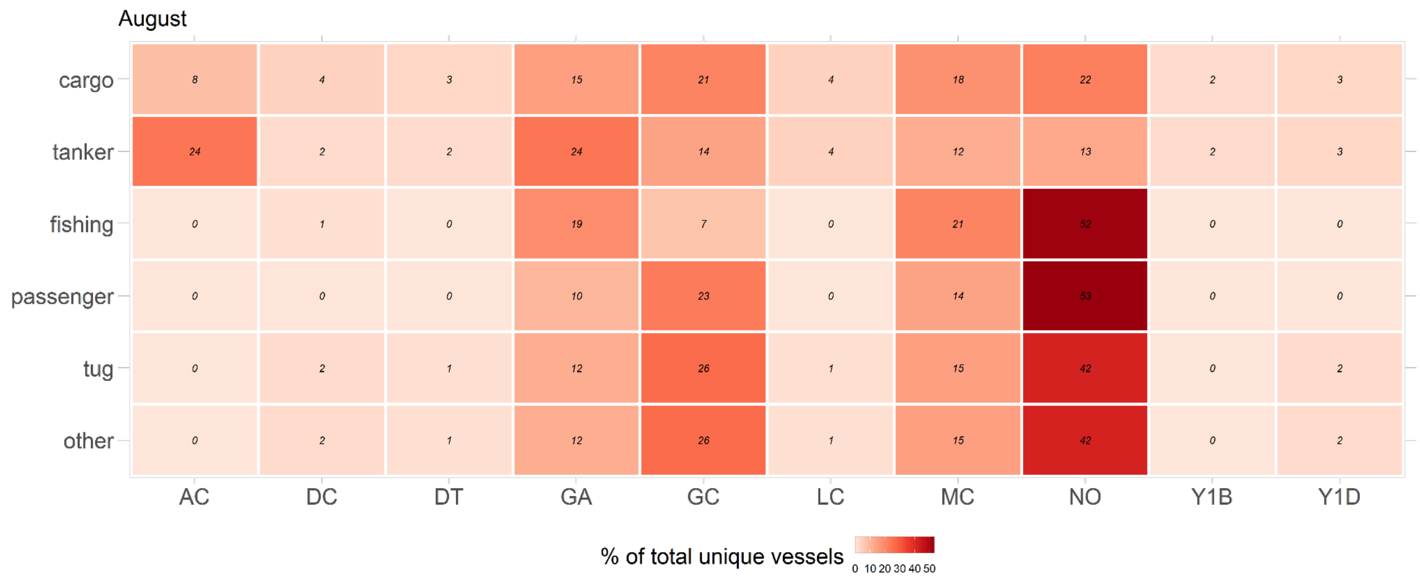
Step 2: Species presence across sites

Results step 1 are summarized across species as the the number of species with relative densities above 10% at a given site and noise source. If a priority species is included in that count, a label is added to the box *(e.g. for medium vessel noise, site GC has both high priority species present in relative densities above 10%)*.



Step 3: Relative vessel traffic across sites

The number of unique vessels was calculated within the corresponding listening area. For cargo and tanker the large vessel listening area was used and for all other types the medium vessel listening area was used. Values in boxes are percent of total unique vessels, also represented by the shading; darker boxes indicate higher percent of vessel activity.



For large vessels, the difference from median speed of all vessels was also calculated to determine if vessels in the area are traveling above or below average speeds across all sites.

Step 4: Other noise activity

Additional monthly conditions were summarized, including

1) Total seismic days
2) Low-frequency sound levels (median 120 Hz sound pressure level on low-wind days)

Additional site conditions were summarized for each site, including

1) Number of rigs operating within 20 km of the site and the names of the companies operating the rigs $
2) Number of non-operating rigs within 20 km of the site $
3) Site within wind lease area $

Step 5: Risk assessment table

Summarize species presence and noise activity across sites and rank sites based on values for species presence and noise activity. All data for August are given here: https://docs.google.com/spreadsheets/d/1fwHKFdnGLqcvloOwz5If_P9gOFet67nEJLCqcR-RGVk/edit#gid=0

Step 6: Categorize conditions across sites and noise sources

From the risk assessment results, we identify four possible categorical distinctions for each location, time period, and species: high species-high noise activity; high species-low noise activity, low species-high noise activity, and low species-low noise activity. While these can be categorized for each individual species and context, the risk assessment process allows us to identify context in which either priority species or large numbers of species (or both) are driving the categorization. Further, the risk assessment allows us to identify contexts in which single or multiple categories of human activity are driving the noise activity context, and to pinpoint which specific source types are occurring.

For each of these four categorical risk assessment outcomes, there are four distinct strategies as they relate to potential quieting solutions. We categorize these below in terms of priority as we understand the goals of this effort to include:

1) $RESTORE: reduce existing levels of noise in areas with high noise activity and high species presence and/or priority species

2) $PROTECT: maintain existing levels of noise in area with lower noise activity with high species presence and/or priority species

3) $MORE STUDY: recommend targeted steps to investigate targeted areas with high noise activity and low species presence (could species be avoiding this area and therefore an opportunity to reduce noise and encourage use of habitat?)

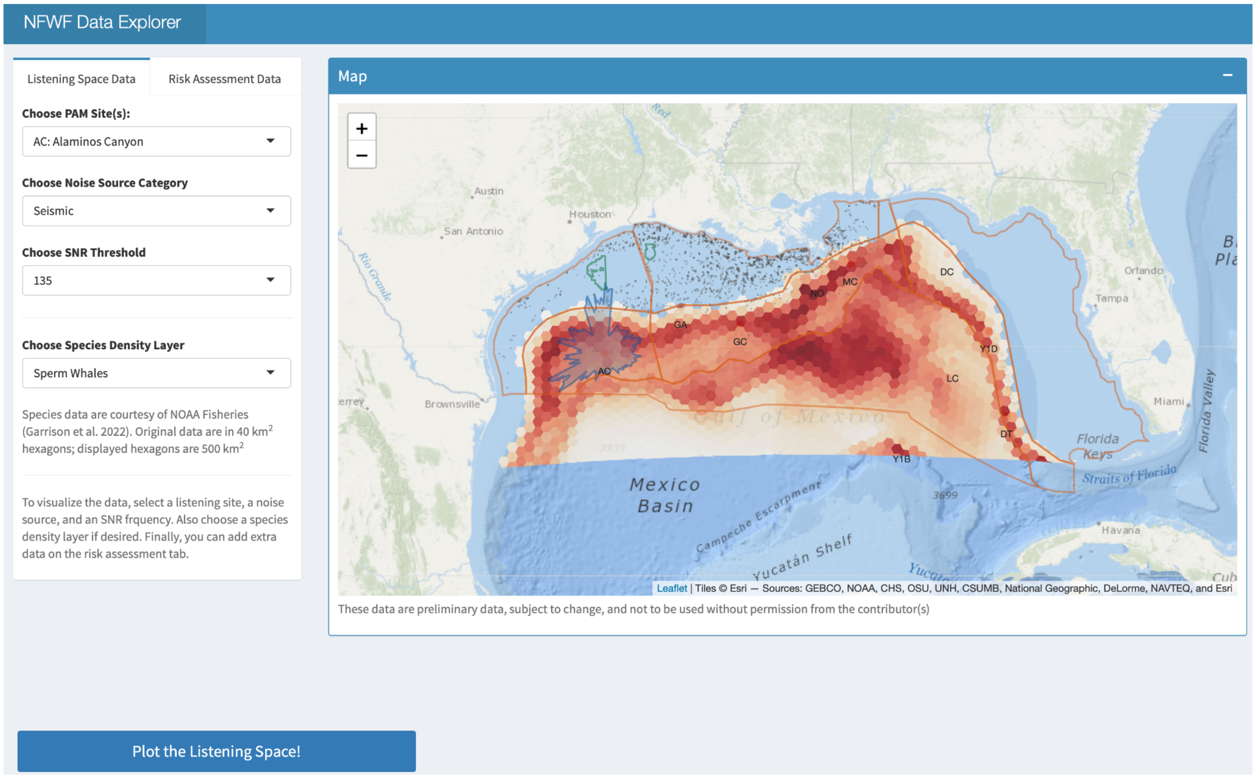
4) $Not priority: low noise and low species presence

For the August example, the outputs of the risk assessment process can be integrated for each listening site to categorize all possible quieting strategies by noise activity type, with an identification of the species drivers. A table of these outcomes is given below and the full results may be seen here: https://docs.google.com/spreadsheets/d/1fwHKFdnGLqcvloOwz5If_P9gOFet67nEJLCqcR-RGVk/edit#gid=1814332989

large vessels	AC	DC	DT	GA	GC	LC	MC	NO	Y1B	Y1D
	PROTECT priority species	PROTECT priority species (speed)	RESTORE lots species (speed)	more study	PROTECT priority species	PROTECT priority species (speed)	RESTORE lots species	RESTORE priority species	PROTECT lots species (speed)	PROTECT lots species (speed)
medium vessels	AC	DC	DT	GA	GC	LC	MC	NO	Y1B	Y1D
	not priority	PROTECT priority species	PROTECT lots species	RESTORE priority species	RESTORE lots species	PROTECT lots species	more study	more study	PROTECT lots species	PROTECT priority species
seismic activity	AC	DC	DT	GA	GC	LC	MC	NO	Y1B	Y1D
	RESTORE lots species	PROTECT priority species	PROTECT lots species	more study	RESTORE priority species	PROTECT lots species	RESTORE priority species	RESTORE priority species	RESTORE lots species	PROTECT priority species
other noise	AC	DC	DT	GA	GC	LC	MC	NO	Y1B	Y1D
	RESTORE	PROTECT	PROTECT	RESTORE rigs option	RESTORE	PROTECT	PROTECT	RESTORE rigs option	RESTORE	No acoustic data

These categorizations provide prioritized and explicit strategies for every site, time period, and noise activity type specific to the occurrence of priority and/or many species. Further interpretation of the risk assessment results is used to identify the highest priority locations and approaches among these many possible locations and strategies.

Dynamic Mapping Tool !



Screenshot from draft shiny app, which highlights the spatial relationship of the listening space (shown here for a seismic source at Alaminos Canyon) in relation to sperm whale density, wind energy area, active rigs, and the seismic vulnerability zones. See this url for live map: https://sr-analytics.shinyapps.io/NFWF_shinyApp/

Current data layer Inputs

PAM stations $
Listening Ranges (source and SNR threshold) $
Species Densities (coarser resolution for Rice and Sperm whales) $
Seismic surveys $
Infrastructure (operational rigs) $
Wind lease areas $
Seismic vulnerability zones $

Data input layers in progress

Monthly AIS tracks by types (Living Atlas layers) $
Other species densities $

Identifying Possible Quieting Scenarios

There are multiple options for deciding priority scenarios from the risk assessment results. Interpretations are necessary to identify these quieting scenarios.

First we used an overall rating, across sites and noise activity categories to find sites to prioritize based not only on the categorization of high-low, but the relative ranking from 0-1 of high categories across species and noise activity types.

	AC	DC	DT	GA	GC	LC	MC	NO	Y1B	Y1D
SPECIES PRESENCE	0.33	0.00	1.00	0.00	0.67	1.00	0.33	0.00	1.00	0.33
NOISE ACTIVITY	0.75	0.25	0.50	1.00	0.75	0.25	0.75	1.00	0.50	0.33

Rating is simply how many of the species or noise activities fell in the high category of risk assessment. This integrated rating provides a simplified integrated metric (0-2) across species presence and noise activity categories. This integrated metric could be simply and linearly used to identify the highest priority sites based on the risk assessment outcomes, compared across sites and across time periods. We intend on using this integrated metric as a first order initial assessment, but note that there are multiple strategic priorities that we think are relevant considerations, based on the following assumptions. These assumptions help focus the site, species, and noise scenario assumptions, as evidenced in the three possible quieting scenario options identified below. These assumptions are given below as we presently understand them, but we especially note this as a topic of discussion with the PMT/SC on the 3 Nov call.

Assumptions for identifying possible quieting scenarios

Species presence

- ESA listed species (Rice's, sperm whales) with presumably more sensitivity to low frequency noise are higher priority, followed by particularly sensitive species generally (e.g., beaked whales), followed by all other species.
- Contexts where relative species occurrence is high for multiple species are also higher priority (especially where priority species and particularly sensitive species are included)

Noise activity

- High levels of all noise activity and existing measured high noise levels
- Targeted selection for specific sectors with high noise activity

We provide here three identified potential quieting scenarios in a standardized template of scenario drivers and options. Each is accompanied by static images from the shiny ap layered visualization described below that will be shown in operation on the 3 Nov call (and would be used interactively in eventually describing and presenting these to industry)

Example Quieting Scenario 1- Green Canyon

RESTORE approach for medium vessel noise and seismic activity near Green Canyon (GC) site to benefit multiple species, including both high priority species

Risk Assessment Species Drivers: *Why high species presence?*

- Multiple species with relative densities above 10% are present within the respective listening space, including both priority and sensitive species for all noise source categories $
- For large vessels, 6 of the 11 species (see step 1 Table- left) $
- For medium vessels, 9 of 11 (see step 1 Table- middle) $
- For seismic activity, 4 of the 11 species (see step 1 Table- right) $

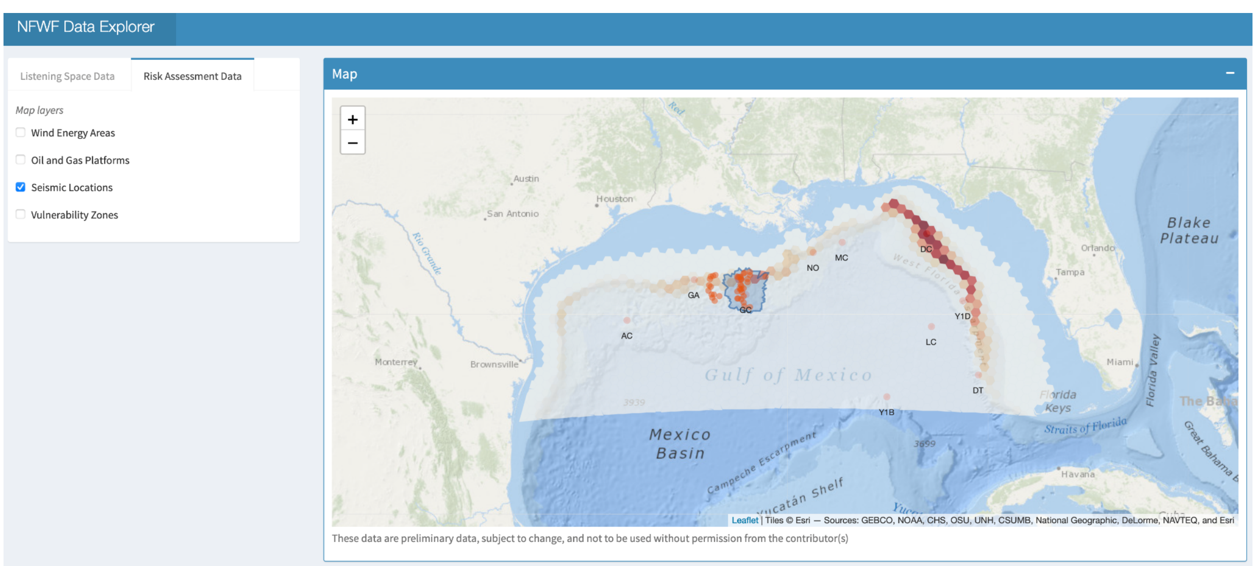
Risk Assessment Noise Activity Drivers: *Why high noise activity?*

- 3 of the 4 noise activities fall in relatively high noise activity category
- Relatively high measured noise levels
- Relatively high medium vessel traffic (passenger, tug, other above 10% relative traffic activity)
- This area is also relatively close to seismic activity and 22 active lease areas

Risk Assessment Seasonal Drivers: *Does this pattern hold across months?*

Possible Quieting Scenario Options: I*dentify specific potential mitigative actions could be most applicable*

- Quieting medium vessels (use AIS traffic routes and AIS vessel names to determine specific vessel activity)
- Reducing seismic noise using menu of quieting options



Example Quieting Scenario 2- Dry Tortugas $

RESTORE approach for risk assessment outcome of high species-high noise activity focusing on large vessel noise near Dry Tortugas (DT) site to benefit multiple species.

Risk Assessment Species Drivers: *Why high species presence?*

- Multiple species with densities above 10% relative density are present within the respective listening space $
- For large vessels, 8 of the 11 species (see step 1 Table- left) $
- For medium vessels, 7 of 11 species, including priority species (step 1 Table- middle) $
- For seismic activity, 7 of the 11 species (see step 1 Table- right) $

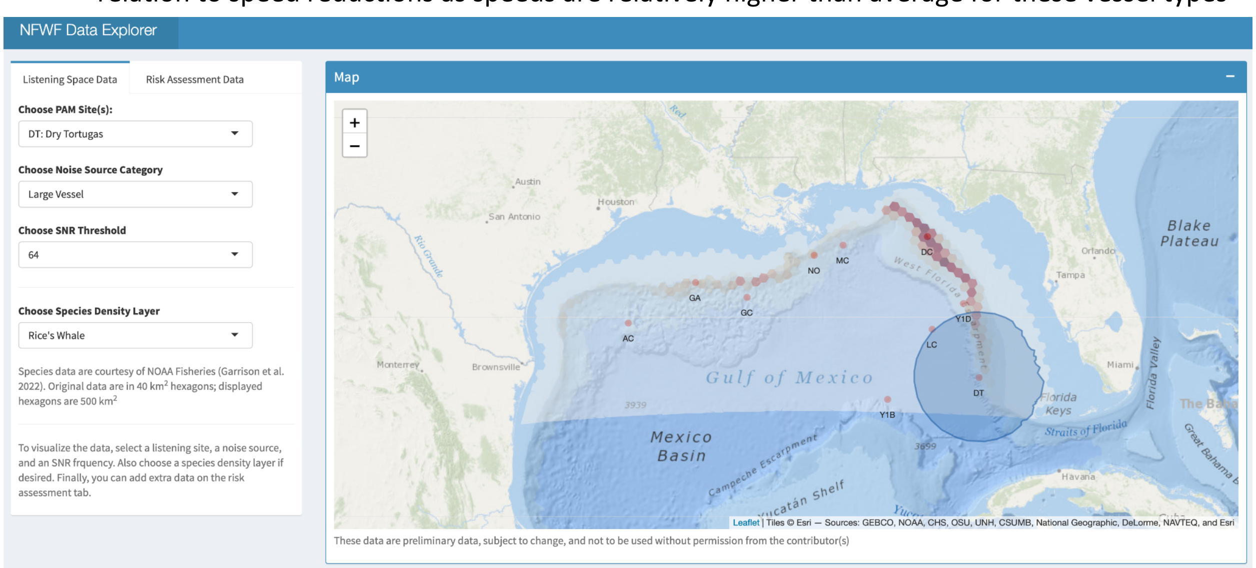
Risk Assessment Noise Activity Drivers: *Why high noise activity?*

- Two of the four noise activities (large vessel and seismic) fall in the relatively high noise activity category. This includes both tanker and cargo traffic above 10% of unique vessels $
- Relative lower measured noise levels $
- This site has the highest average large vessel speed across all sites for this period $

Risk Assessment Seasonal Drivers: *Does this pattern hold across months?*

Possible Quieting Scenario Options: *Identify specific potential mitigative actions could be most applicable*

- Risk assessment results identify this as high species (many species) - high noise activity (restore) priority
- Mitigative focus for this option is solely large vessels
- While all options among the menu of quieting approaches for large vessels should be considered (engineering and operational), risk assessment results highlight potential effective action in relation to speed reductions as speeds are relatively higher than average for these vessel types



Example Scenario 3- DeSoto Canyon

Recommend PROTECT approach for large vessels, medium vessels, and seismic activity near DeSoto Canyon from because of relatively low current noise activity and noise levels, but high species presence and priority species.

Risk Assessment Species Drivers: *Why high species presence?*

- Priority species (rice's whale) with densities above 10% relative density are present within the respective listening space across all noise source

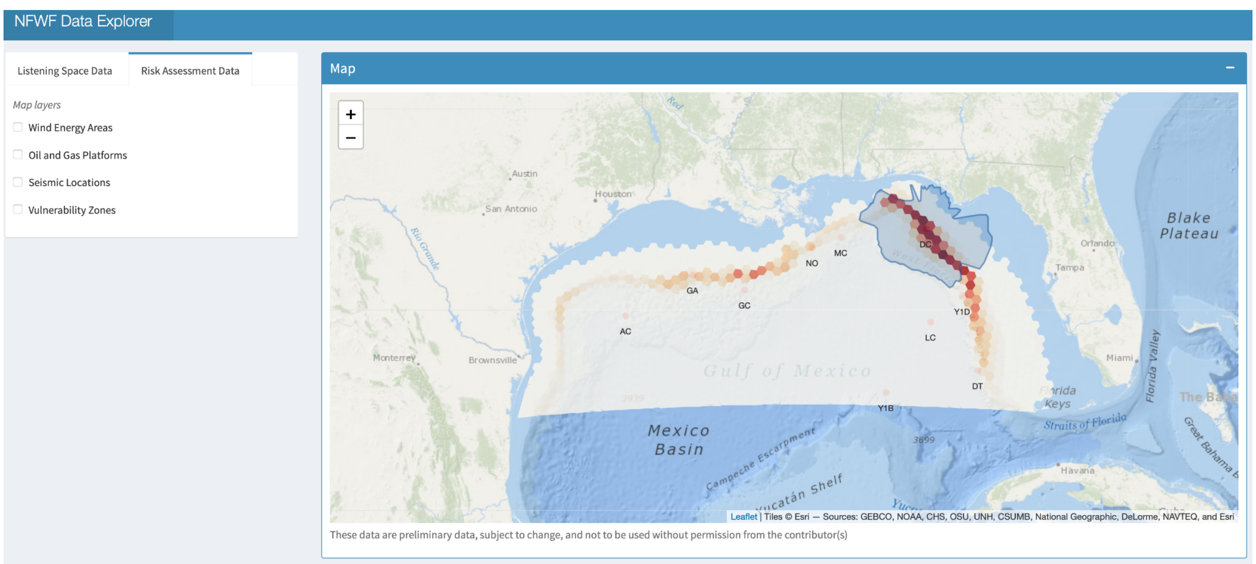
Risk Assessment Noise Activity Drivers: *Why high noise activity?*

- Relatively low measured noise levels
- Relatively lowest large, medium, and seismic noise activity

Risk Assessment Seasonal Drivers: *Does this pattern hold across months?*

Possible Quieting Scenario Options: *Identify specific potential mitigative actions could be most applicable*

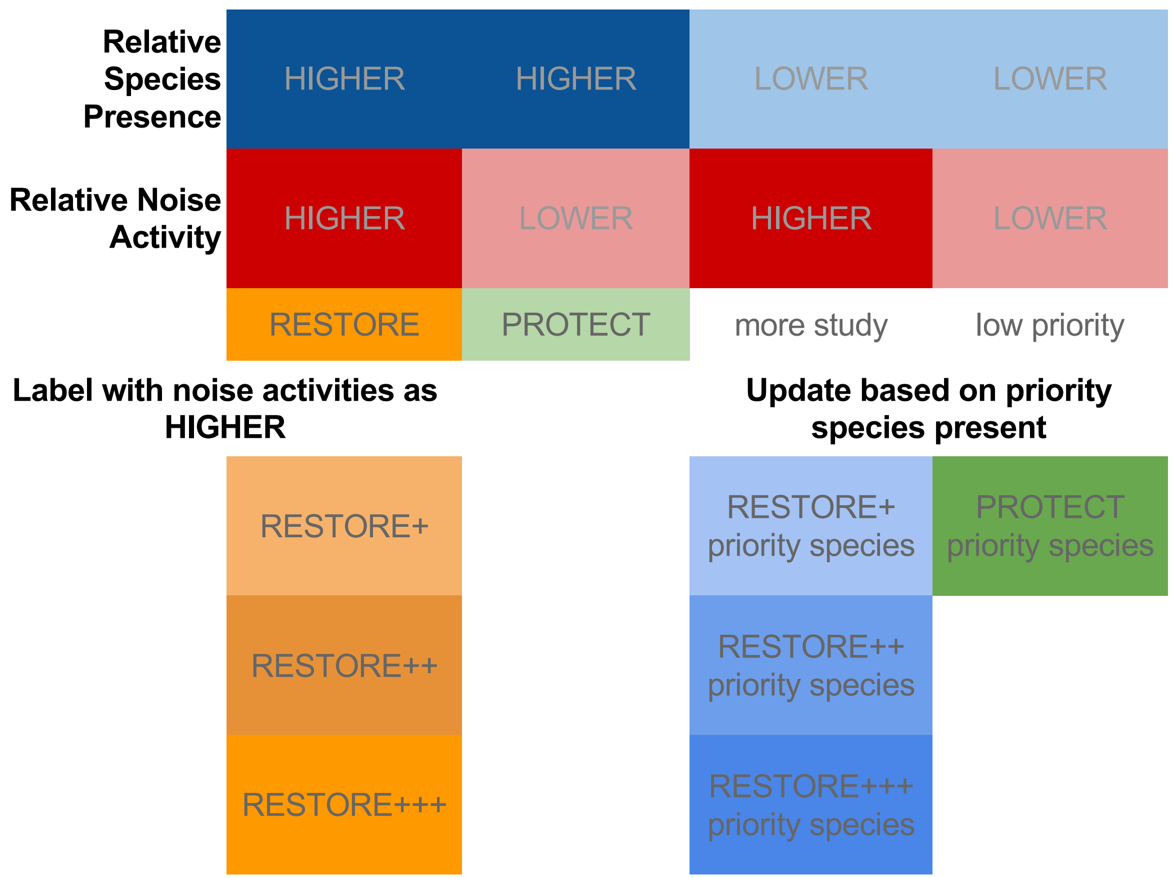
- No new noise sources
- Reducing noise levels of nearby large vessels (northwest)- routing or speed



GoMex Risk Assessment Quieting & Scenario Recommendations &

Dec 2022 &

Assigning Scenario Categories &



Risk Assessment Monthly Outcomes

	AC	DC	DT	GA	GC	LC	MC	NO	Y1B	Y1D
January **+ = noise sources '**	RESTORE++	RESTORE+ priority species	PROTECT	RESTORE++ priority species	RESTORE++	PROTECT	more study	more study	PROTECT	PROTECT priority species
February '	RESTORE+	RESTORE+	PROTECT	RESTORE++ priority species	RESTORE++	PROTECT	RESTORE++ priority species	more study	PROTECT	PROTECT priority species
March '	RESTORE++	RESTORE++	RESTORE+	RESTORE+++	RESTORE+++	RESTORE+	RESTORE+++ priority species	more study	RESTORE+	RESTORE+ priority species
April '	RESTORE++	RESTORE+	RESTORE+	RESTORE+++ priority species	RESTORE+++	RESTORE+	RESTORE+++ priority species	more study	RESTORE+	RESTORE+
May '	more study	RESTORE+	RESTORE+	RESTORE+++	RESTORE+++	RESTORE+	more study	RESTORE+++	RESTORE+	RESTORE+ priority species
June	RESTORE++	RESTORE+	RESTORE+	RESTORE+ priority species	RESTORE+++	RESTORE+	RESTORE+++	RESTORE+++ priority species	RESTORE+	RESTORE+
July	RESTORE++	RESTORE+ priority species	RESTORE+	RESTORE+++ priority species	RESTORE+++	RESTORE+	RESTORE+++	RESTORE+++ priority species	RESTORE+	RESTORE+
August '	RESTORE++	RESTORE+ priority species	RESTORE++	RESTORE+++ priority species	RESTORE++	RESTORE+	RESTORE+++	RESTORE+++ priority species	RESTORE+	RESTORE+
September '	RESTORE++	RESTORE+ priority species	RESTORE+	RESTORE+++	RESTORE+++	RESTORE+	RESTORE+++	RESTORE+++ priority species	RESTORE+	RESTORE+
October '	RESTORE+	RESTORE+	PROTECT	RESTORE++ priority species	RESTORE++	PROTECT	RESTORE++	RESTORE++ priority species	PROTECT	PROTECT
November '	more study	PROTECT	PROTECT	RESTORE++ priority species	RESTORE+	PROTECT	RESTORE++	more study	PROTECT	PROTECT
December '	RESTORE+	PROTECT priority species	PROTECT	RESTORE++ priority species	RESTORE+	PROTECT	RESTORE++ priority species	more study	PROTECT	PROTECT priority species

Current Risk Assessment Links

Overall Risk Assessment Monthly Summary Link:
https://docs.google.com/spreadsheets/d/17WpY4NfW0umapASPFL7X_sERyMl6MpY-huu45P1zOzI/edit#gid=0

Monthly links are embedded in main summary but given here:

January: https://docs.google.com/spreadsheets/d/16WTCh_Ljhc8x76PjedYn8aUXlqThfmUMjvLrIJD1yqE/edit#gid=1814332989

February: https://docs.google.com/spreadsheets/d/1bq5YY79gY47AqrZYJG3aioRGzxi5n_vM1vD7wOQXXS8/edit#gid=1814332989

March: https://docs.google.com/spreadsheets/d/1FUNFQl2DWcAizg3KrWxUYW2EQjwjb06ceC9W8zn1OJQ/edit#gid=1814332989

April: https://docs.google.com/spreadsheets/d/1xzKB-dToOeBxgusCWorh4VniDch9HtbjNlMAX5NB2bs/edit#gid=1814332989

May: https://docs.google.com/spreadsheets/d/1ocn0kVQHuxcX8sa2qqumBgrcodil5q1s4FLXkd-h3e8/edit#gid=1814332989

June: https://docs.google.com/spreadsheets/d/1ivRALH3lh7UsiZFVKnohBAZX4S_AXRoiFSc9VmhSJg0/edit#gid=1299669048

July: https://docs.google.com/spreadsheets/d/1CYoTpBgQbANJ9AaiQ1HtgpnmX5_tA5Ku1eDDmIgVL5Y/edit#gid=1814332989

August: https://docs.google.com/spreadsheets/d/1fwHKFdnGLqcvloOwz5lf_P9gOFet67nEJLCqcR-RGVk/edit#gid=1814332989

September: https://docs.google.com/spreadsheets/d/1kVzDmalu3BxCP32YwTNYKXVciSkZWliKnj0qIgwaF2g/edit#gid=1814332989

October: https://docs.google.com/spreadsheets/d/166dwhkKzNZI5hUN2BK3MdgFenRqYqpYmu-i8Cqi8ZEo/edit#gid=1814332989

November: https://docs.google.com/spreadsheets/d/125fPgDM9R7wnAUGxjVvqrf3udegC-4xLpJw2ZYbgG0o/edit#gid=1814332989

December: https://docs.google.com/spreadsheets/d/14g3HVAJmRwnzwM0-r7VTGUe7D3sBWk9c_kBeAMUwUdk/edit#gid=1814332989

Scenario Formatting Approach

- We summarize here the (12) draft quieting scenarios developed using the outputs of the risk assessment and a strategic interpretation of the assumptions related to species, spatial, and temporal dimensions discussed and agreed to with the SC and PMT on our most recent group call.

- We present these scenarios here in a deliberately systematic and concise manner as we discussed and as we would envision them being shared to open the discussion with industry.

- We would envision each being shared in a manner where a deeper dive in with the shiny app and into the underlying data would be possible for more detailed discussion. Each scenario consists of two slides with the following information:
  - **Risk Assessment Species Drivers**: *Why high species presence?*
  - **Risk Assessment Noise Activity Drivers**: *Why high noise activity?*
  - **Scenario Driver Visualization**
  - **Risk Assessment Seasonal Patterns:** *What months are these conditions present?*
  - **Possible Quieting Scenario Options**: *Identify specific potential mitigative actions could be most applicable*
  - **Benefit from other scenarios**

Scenarios Defined by Industry Sector (n=12)

Seismic (3)

- **S1**: GC-focused quieting option for (broadband) seismic noise focused benefiting multiple species, including many odontocetes
- **S2**: DC-focused temporal mitigation option for (low-frequency) seismic noise relative to rice's whale summer calling periods
- **S3**: DT-focused (YIB, DT, DC-relevant) long-range mitigation options for (low-frequency) seismic noise

Medium service vessels (3)

- **MV1**: GC-service vessel focused benefiting multiple species, including many odontocetes
- **MV2**: GA-service vessel focused (but relevant area/period for seismic surveys) mainly related to Rice's whale 1
- **MV3**: MC-fishing vessel focused for benefit to sperm whales and seasonally some other species 1

Large vessels (4)

- **LV1**: MC-off-shelf vessel traffic routing scenario focused primarily on high presence of many species
- **LV2**: GC-traffic lane focus in area with other sources – driven by many species relatively high including priority sperm whales
- **LV3**: DT- large vessel quieting focus with specific mitigation options identified – many species with one priority species
- **LV4**: AC- large vessel traffic with cognizance of future traffic with offshore wind lease areas – many species and both priority

More study (2)

- **MS1**: (any site) 'Measurement station' capability for vessel noise measurements - especially any that use quiet technology in pilot projects
- **MS2**: NO- rice's suitable habitat- predicted to be there but not see or heard and New Orleans site sperm and beaked whales

Scenarios by Area, Species, and Temporal Focus *

Area Focus (# times primary site included)

- GC: 3
- DC: 2
- MC: 2
- LC: 1
- GA: 1 #
- DT: 1 #
- AC: 1 #
- NO: 1 #

Species Focus

- Primarily Rice's Whale: 2 #
- Primarily Sperm Whale: 2 #
- Primarily Many Species: 0 #
- Mix of Many and Priority Species: 6 #

Temporal Focus

- Annually focused scenarios: 6 #
- Temporally focused scenarios: 6 #

Seismic-Focused Scenarios (3))

Scenario: Seismic (S1)

RESTORE category focused on seismic activity near Green Canyon (GC) site to benefit multiple species, including both high priority species

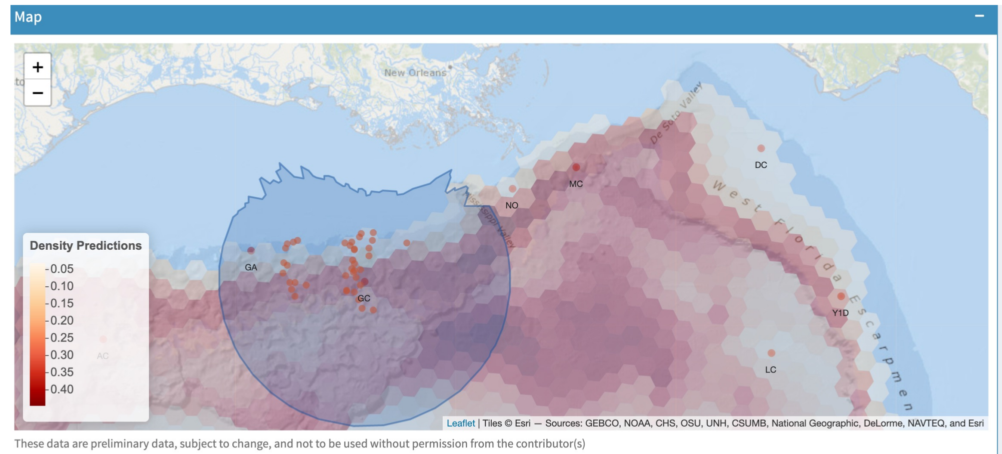
Risk Assessment Species Drivers: *Why high species presence?*

- Multiple species (up to 8 of 11 considered depending on month) 1
  with relative densities above 10% are present within the respective listening space, including both priority species 1

Risk Assessment Noise Activity Drivers: *Why high noise activity?* $

- Relatively high noise activity for multiple sources 1
- This area is close to seismic activity and 22 active lease areas
  and known locations of seismic activity 1
- Relatively high medium vessel traffic 1
  (passenger, tug, other >10% relative traffic activity) 1
- Relatively high measured noise levels 1

Scenario Driver Visualization



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Risk Assessment

Risk Assessment for PAM Sites in Gulf of Mexico

Only high-level summaries are shown

Criteria	AC	DC	DT	GA	GC	LC	MC	NO	Y1B	Y1D
Species presence max = +++	HIGH+	LOW+++	HIGH+++	LOW*	HIGH++***	HIGH+++***	HIGH+**	LOW**	HIGH+++***	HIGH+***
Noise activity max = +++	HIGH+++	HIGH+	HIGH++	HIGH+++	HIGH++	HIGH+	HIGH+++	HIGH+++	HIGH+	HIGH+
Recommendation	RESTORE+++	PROTECT priority species	RESTORE++	RESTORE+++ priority species	RESTORE++ priority species	RESTORE+	RESTORE+++	RESTORE+++ priority species	RESTORE+	RESTORE+

Scenario: Seismic (S1)

RESTORE category focused on seismic activity near Green Canyon (GC) site to benefit multiple species, including both high priority species 1

Risk Assessment Seasonal Patterns: *What months are these conditions present?*
Across all months this area falls in the RESTORE category, meaning relatively high noise activity consistently detected and high species presence. This is relatively consistent across all source types, including seismic sources with the exception of a few lower relative months

Possible Quieting Scenario Options: *Identify specific potential mitigative actions could be most applicable* $
Reduce seismic noise footprint (broadband focus) across months using menu of quieting options, possibly considering: 1
Operational options: Reduce overall acoustic output of existing arrays to sufficient amount needed 1
Engineering options:

- Modified design to reduce bandwidth – particularly important for this site given relatively highest occurrence of high frequency 1 odontocete cetaceans and proximity
- Desynchronization and/or scatter of air gun activation – again may be particularly more effective for odontocetes particularly present at this location

New Technologies: Marine vibroseis

Benefit from other scenarios

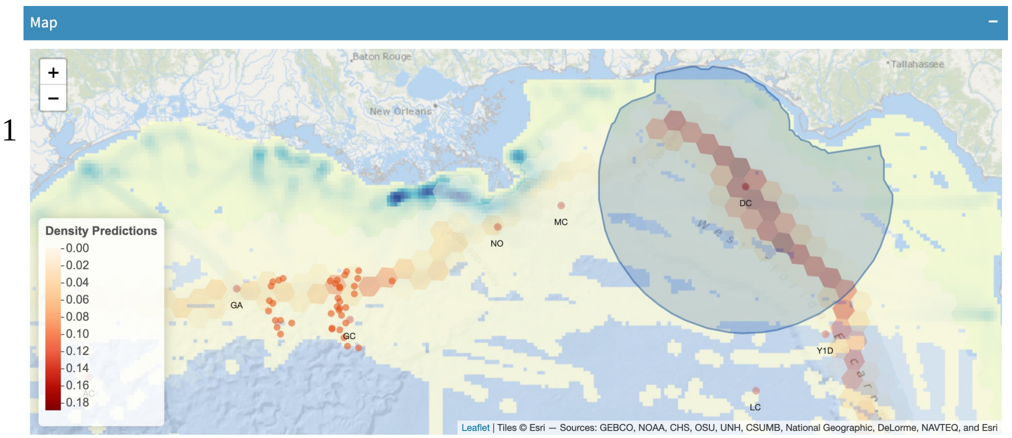
- MV1 1
- LV2 1

Scenario Seismic (S2)

RESTORE category focused on seismic activity near Desoto Canyon (DC) site focused on high activity periods coinciding with known 1 Rice's whale key calling periods 1

Risk Assessment Species Drivers: *Why high species presence?*
- Multiple species (up to 4 of 11 considered depending on month) 1 with relative densities above 10% are present within the respective listening space, notably core habitat area for endemically present and 1 critically endangered Rice's whale 1
- While spatiotemporal patterns in Rice's whale calling are subject of 1 ongoing investigation, recent studies indicate concentrations of low frequency vocal activity during summer months 1

Risk Assessment Noise Activity Drivers: *Why high noise activity?* $
- Driven largely by occurrence of seismic noise that is seasonally 1 present but with highest concentrations during summer months 1
- Medium vessel traffic relatively high in a few months but only in winter 1
- Relatively low measured noise levels overall but still detectable above ambient



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	DC
July	RESTORE+ priority species
August	RESTORE+ priority species
September	RESTORE+ priority species

Soldevilla, M. S., Debich, A. J., Garrison, L. P., Hildebrand, J. A., & Wiggins, S. M. (2022). Rice's whales in the northwestern Gulf of Mexico: call variation and occurrence beyond the known core habitat. Endangered Species Research, 48, 155-174.

Scenario Driver Visualization

Scenario: Seismic (S2)

RESTORE category focused on seismic activity near Desoto Canyon (DC) site focused on high activity periods coinciding with known Rice's whale key calling periods

Risk Assessment Seasonal Patterns: *What months are these conditions present?*
Focus for this scenario on summer period during known Rice's whale high calling windows

Possible Quieting Scenario Options: *Identify specific potential mitigative actions could be most applicable*
Reduce seismic noise footprint (low frequency focus) focusing on summer months using menu of quieting options, possibly considering:
Operational options: Reduce overall acoustic output of existing arrays to sufficient amount needed
New Technologies:
- Marine vibroseis
- Very low frequency sources
- Vibratory low frequency sources

Benefit from other scenarios
- LV1

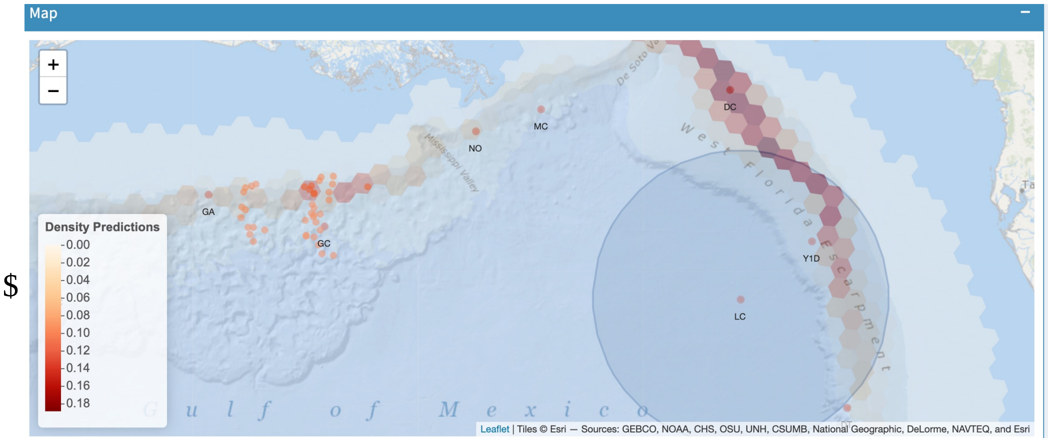
Scenario: Seismic (S3)

RESTORE category focused on seismic noise received at LC, but relevant to DT, Y1B, and Y1D sites with similar risk assessment temporal patterns

Risk Assessment Species Drivers: *Why high species presence?*
- Highest number of multiple species reported at LC site (up to 9 of 11 considered depending on month) with relative densities 1 above 10% are present within the respective listening space, 1 including both priority species 1

Risk Assessment Noise Activity Drivers: *Why high noise activity?* $
- LC site, as well as DT, Y1B, and Y1D, have distinct temporal 1 patterns in risk assessment results for noise activity 1
- Monthly noise ratings are relatively low at each site from October 1 to February. With a few exceptions, from March through 1 September relative noise ratings at each switch to high based 1 on relatively higher number of seismic days during this period

Scenario Driver Visualization



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Risk Assessment

Risk Assessment for PAM Sites in Gulf of Mexico

Only high-level summaries are shown

Criteria	AC	DC	DT	GA	GC	LC	MC	NO	Y1B	Y1D
Species presence max = +++	HIGH+	LOW+++	HIGH+++	LOW*	HIGH++***	HIGH+++***	HIGH+**	LOW**	HIGH+++***	HIGH+***
Noise activity max = +++	HIGH+++	HIGH+	HIGH++	HIGH+++	HIGH++	HIGH+	HIGH+++	HIGH+++	HIGH+	HIGH+
Recommendation	RESTORE+++	PROTECT priority species	RESTORE++	RESTORE+++ priority species	RESTORE++	RESTORE+ priority species	RESTORE+++	RESTORE+++ priority species	RESTORE+	RESTORE+

Scenario: Seismic (S3)

RESTORE category focused on seismic noise received at LC, but relevant to DT, Y1B, and Y1D sites with similar risk assessment temporal patterns

Risk Assessment Seasonal Patterns: *What months are these conditions present?*
- Distinct seasonal pattern common in multiple sites in the eastern and more offshore 1 portions of the northern GoMex further away from major ports. While some sites have higher vessel activity in a few months, this seasonal switch is 1 driven by relatively higher seismic activity during this period. In the absence 1 of this activity, these sites would remain in higher animal/lower noise outcome 1

Possible Quieting Scenario Options: *Identify specific potential mitigative actions* $ *could be most applicable* $
- Reduce seismic noise footprint (low frequency focus) focusing in March-Sept period 1 using menu of quieting options, possibly considering: 1
  - *Operational options*: Reduce overall acoustic output of existing arrays to 1 sufficient amount needed 1
  - *New Technologies*:
    - Marine vibroseis 1
    - Very low frequency sources 1
    - Vibratory low frequency sources 1

	DT	LC	Y1B	Y1D
January + = noise sources	PROTECT	PROTECT	PROTECT	PROTECT priority species
February	PROTECT	PROTECT	PROTECT	PROTECT priority species
March	RESTORE+	RESTORE+	RESTORE+	RESTORE+ priority species
April	RESTORE+	RESTORE+	RESTORE+	RESTORE+
May	RESTORE+	RESTORE+	RESTORE+	RESTORE+ priority species
June	RESTORE+	RESTORE+	RESTORE+	RESTORE+
July	RESTORE+	RESTORE+	RESTORE+	RESTORE+
August	RESTORE++	RESTORE+	RESTORE+	RESTORE+
September	RESTORE+	RESTORE+	RESTORE+	RESTORE+
October	PROTECT	PROTECT	PROTECT	PROTECT
November	PROTECT	PROTECT	PROTECT	PROTECT
December	PROTECT	PROTECT	PROTECT	PROTECT priority species

Benefit from other scenarios: MV3; LV1; LV2; LV3

Medium Vessel-Focused Scenarios (3))

Scenario: Medium Vessels (MV1))

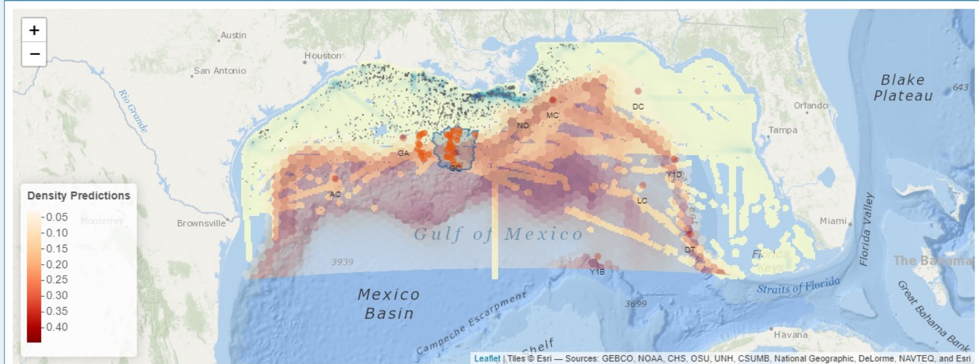
RESTORE category focused on medium vessel noise near **Green** (**Canyon (GC)** site to benefit multiple species, including one of the 1 high priority species 1

Risk Assessment Species Drivers: *Why high species presence?* $
-Multiple species with relative densities above 10% are present within 1 the respective listening space, including sperm whales (density 1 shown on map) 1

Risk Assessment Noise Activity Drivers: *Why high noise activity?* $
- Relatively HIGH medium vessel traffic, including passenger, tug, 1 other above 10% relative traffic activity (shown on map) 1
- This area is also relatively close to known locations of seismic activity (orange dots on map) and 22 active lease areas with relatively high measured noise levels 1

Scenario Driver Visualization (map and table for August on right)

Map



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Risk Assessment

Risk Assessment for PAM Sites in Gulf of Mexico

Only high-level summaries are shown

Criteria	AC	DC	DT	GA	GC	LC	MC	NO	Y1B	Y1D
Species presence max = +++	HIGH+	LOW+++	HIGH+++	LOW*	HIGH++***	HIGH+++***	HIGH+**	LOW**	HIGH+++***	HIGH+***
Noise activity max = +++	HIGH+++	HIGH+	HIGH++	HIGH+++	HIGH++	HIGH+	HIGH+++	HIGH+++	HIGH+	HIGH+
Recommendation	RESTORE+++	PROTECT priority species	RESTORE++	RESTORE+++ priority species	RESTORE++	RESTORE+	RESTORE+++	RESTORE+++ priority species	RESTORE+	RESTORE+

Scenario: Medium Vessels (MV1)

RESTORE category focused on medium vessel noise near **Green Canyon (GC)** site to benefit multiple species, 1 including one of the high priority species 1

Risk Assessment Seasonal Patterns: *What months are these conditions present?*
Across all months this site falls in the RESTORE category, meaning relatively HIGH species presence and relatively HIGH noise activity for medium vessels (except November and December).

Possible Quieting Scenario Options: *Identify specific potential mitigative actions could be most applicable* $
-Quieting medium vessels through design (e.g. Sharrow MX propeller design) 1

Benefit from other scenarios
-Reducing seismic noise using menu of quieting options (see S1)

Scenario: Medium Vessels (MV2)

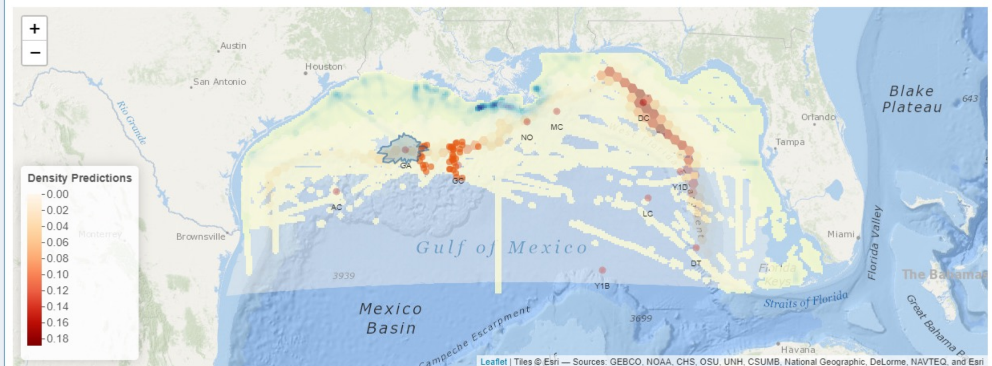
RESTORE category focused on medium vessel noise near **Galveston Shipping (GA)** site to benefit Rice's whale habitat with some seasonal benefit to other species

Risk Assessment Species Drivers: *Why high species presence?*
-Relative densities above 10% are present within the respective listening space for Rice's whale *(shown on map)* and in some months (March, September) other species have relatively high densities

Risk Assessment Noise Activity Drivers: *Why high noise activity?*
- Relatively HIGH medium vessel traffic, including passenger, tug, other above 10% relative traffic activity (shown on map). Also, 4 active rigs within 20 km of this site that some of these vessels are likely visiting.
-This area is also relatively close to known locations of seismic activity (orange dots on map) and 4 active lease areas with relatively high measured noise levels

Scenario Driver Visualization (map and table for August on right)

Map



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Risk Assessment

Risk Assessment for PAM Sites in Gulf of Mexico
Only high-level summaries are shown

Criteria	AC	DC	DT	GA	GC	LC	MC	NO	Y1B	Y1D
Species presence max = +++	HIGH+	LOW+++	HIGH+++	LOW*	HIGH++***	HIGH+++***	HIGH+**	LOW**	HIGH+++***	HIGH+***
Noise activity max = +++	HIGH+++	HIGH+	HIGH++	HIGH+++	HIGH++	HIGH+	HIGH+++	HIGH+++	HIGH+	HIGH+
Recommendation	RESTORE+++	PROTECT priority species	RESTORE++	RESTORE+++ priority species	RESTORE++	RESTORE+	RESTORE+++	RESTORE+++ priority species	RESTORE+	RESTORE+

Scenario: Medium Vessels (MV2)

RESTORE category focused on service vessel noise near **Galveston Shipping (GA)** site to benefit Rice's whale habitat with some seasonal benefit to other species

Risk Assessment Seasonal Patterns: *What months are these conditions present?*
Across most months this area falls in the RESTORE- priority species category, meaning relatively HIGH species presence for Rice's whales and HIGH noise activity for medium vessels. In March and September multiple species also fall above the 10% relative densities.

Possible Quieting Scenario Options: *Identify specific potential mitigative actions could be most applicable* $
-Quieting medium vessels through design (e.g. Sharrow MX propeller design) 1

Benefit from other scenarios
-Reducing seismic noise using menu of quieting options (see S1) 1
-More study to understand suitability of habitat for Rice's whale (see MS2) 1

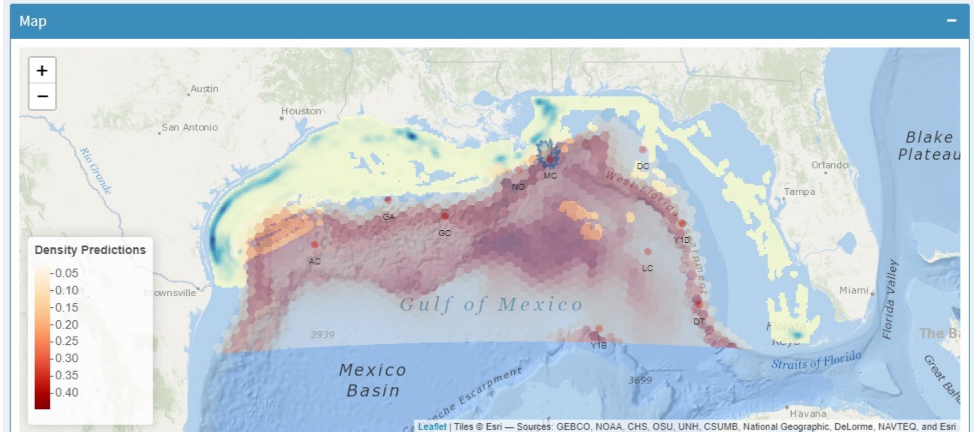
Scenario: Medium Vessels (MV3))

RESTORE category focused on fishing vessel noise near 1 **Mississippi Canyon (MC)** site to benefit sperm whales and in some 1 months multiple species would benefit. 1

Risk Assessment Species Drivers: *Why high species presence?* $
-Relative densities above 10% are present within the respective listening space for Sperm whales *(shown on map)* across months 1 (except January and May), and other species have relatively high densities June-November. 1

Risk Assessment Noise Activity Drivers: *Why high noise activity?*
- Relatively HIGH medium vessel traffic (above 10% relative traffic 1 activity), with fishing vessels shown on map 1
- Also, relativey HIGH large vessel activity and 33 active lease 1 areas within 20 km of the site 1

Scenario Driver Visualization (map and table for August on right)



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Risk Assessment

Risk Assessment for PAM Sites in Gulf of Mexico
Only high-level summaries are shown

Criteria	AC	DC	DT	GA	GC	LC	MC	NO	Y1B	Y1D
Species presence max = +++	HIGH+	LOW+++	HIGH+++	LOW*	HIGH++***	HIGH+++***	HIGH+**	LOW**	HIGH+++***	HIGH+***
Noise activity max = +++	HIGH+++	HIGH+	HIGH++	HIGH+++	HIGH++	HIGH+	HIGH+++	HIGH+++	HIGH+	HIGH+
Recommendation	RESTORE+++	PROTECT priority species	RESTORE++	RESTORE+++ priority species	RESTORE++	RESTORE+	RESTORE+++	RESTORE+++ priority species	RESTORE+	RESTORE+

Scenario: Medium Vessels (MV3)

RESTORE category focused on fishing vessel noise near **Mississippi Canyon (MC)** site to benefit sperm whales and in some months multiple species would benefit.

Risk Assessment Seasonal Patterns: *What months are these conditions present?*
For some months this site falls in the RESTORE- priority species category (Feb-Apr and Dec), meaning relatively HIGH species presence for sperm whales and HIGH noise activity for medium vessels. In June-November multiple species also fall above the 10% relative densities. In January and May, no species are present above the 10% relative density, resulting in more study category given the relatively HIGH levels of noise activity near the site.

Possible Quieting Scenario Options: *Identify specific potential mitigative actions could be most applicable* $
-Quieting fishing vessels through propeller changes or other design features (primarily July-September) 1

Benefit from other scenarios
-Reducing seismic noise to benefit further away sites (see S3) 1
-Reducing large vessel noise (see LV1) 1

Large Vessel-Focused Scenarios (4))

Scenario Scenario Large Vessels (LV1))

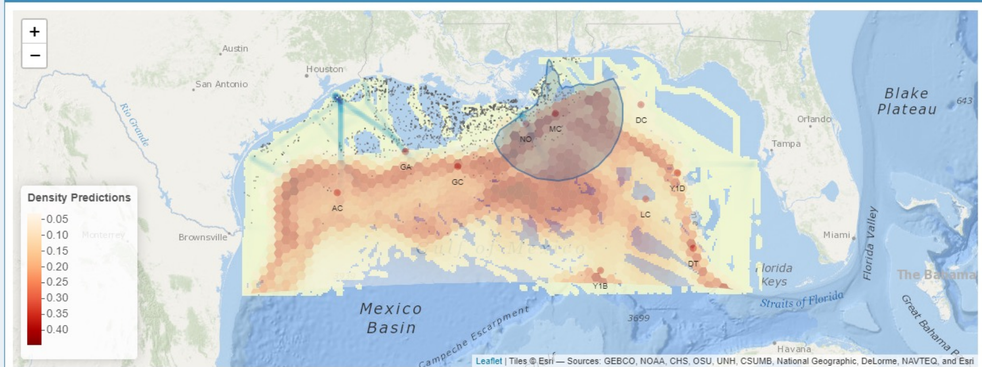
RESTORE category near **Mississippi Canyon (MC)** site focused on 1 large vessel noise to benefit multiple species including one priority 1 species in some months. 1

Risk Assessment Species Drivers: *Why high species presence?* $ -Relative densities above 10% are present within the respective listening space for sperm whales *(shown on map)* across months 1 (except January and May), and other species have relatively high densities June-November. 1

Risk Assessment Noise Activity Drivers: *Why high noise activity?* $
- Relatively high noise activity from large vessel traffic (cargo and tanker above 10% relative traffic activity) year-round 1
- Also, relativey HIGH medium vessel activity and 33 active lease 1 areas within 20 km of the site. 1

Scenario Driver Visualization (map and table for August on right)

Map



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Risk Assessment

Risk Assessment for PAM Sites in Gulf of Mexico

Only high-level summaries are shown

Criteria	AC	DC	DT	GA	GC	LC	MC	NO	Y1B	Y1D
Species presence max = +++	HIGH+	LOW+++	HIGH+++	LOW*	HIGH++***	HIGH+++***	HIGH+**	LOW**	HIGH+++***	HIGH+***
Noise activity max = +++	HIGH+++	HIGH+	HIGH++	HIGH+++	HIGH++	HIGH+	HIGH+++	HIGH+++	HIGH+	HIGH+
Recommendation	RESTORE+++	PROTECT priority species	RESTORE++	RESTORE+++ priority species	RESTORE++	RESTORE+	RESTORE+++	RESTORE+++ priority species	RESTORE+	RESTORE+

Scenario Large Vessels (LV1)

RESTORE category near **Mississippi Canyon (MC)** site focused on large vessel noise to benefit multiple species including one priority species in some months.

Risk Assessment Seasonal Patterns: *What months are these conditions present?*
The MC site falls in the RESTORE category in all months except January and May, meaning relatively HIGH noise activity and HIGH presence of multiple species or sperm whales. However, both HIGH noise activity and species presence is strongly variable at seasonal scales. For example, multiple species with relatively high density are present in November, but January and May are LOW species presence while noise activity remains HIGH for large vessels.

Possible Quieting Scenario Options: *Identify specific potential mitigative actions could be most applicable*

- Rerouting large vessels (most important for June to November) away from shelf edge northwest of the site. This would also benefit DC site by reducing propagation from large vessels.

Benefit from other scenarios
-Reducing seismic noise to benefit further away sites (see S3) 1
-Reducing medium vessel noise (see MV3) 1

Scenario Large Vessels (LV2))

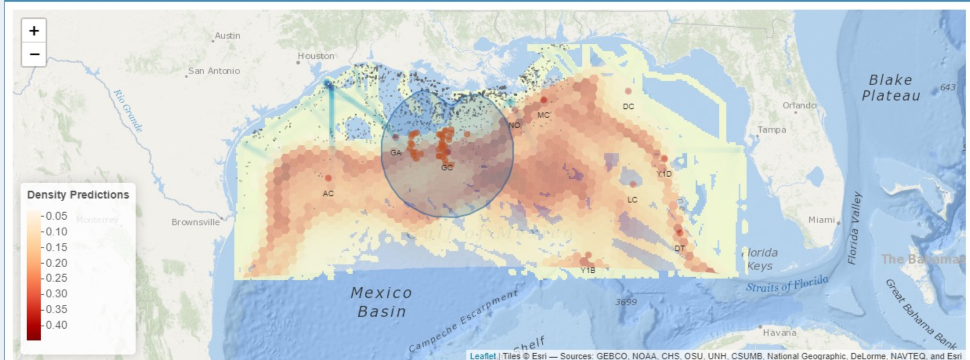
RESTORE category focused on large vessel near **Green Canyon (GC)** site to benefit multiple species, including one of the high priority species across all months.

Risk Assessment Species Drivers: *Why high species presence?*
-Multiple species with relative densities above 10% are present within the respective listening space, including sperm whales (density shown on map)

Risk Assessment Noise Activity Drivers: *Why high noise activity?*
- Relatively HIGH large vessel traffic (cargo and tanker- shown on map)
- This area is also relatively close to seismic activity and 22 active lease areas and known locations of seismic activity (orange dots on map) with relatively high measured noise levels

Scenario Driver Visualization (map and table for August on right)

Map



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Risk Assessment

Risk Assessment for PAM Sites in Gulf of Mexico

Only high-level summaries are shown

Criteria	AC	DC	DT	GA	GC	LC	MC	NO	Y1B	Y1D
Species presence max = +++	HIGH+	LOW+++	HIGH+++	LOW*	HIGH++***	HIGH+++***	HIGH+**	LOW**	HIGH+++***	HIGH+***
Noise activity max = +++	HIGH+++	HIGH+	HIGH++	HIGH+++	HIGH++	HIGH+	HIGH+++	HIGH+++	HIGH+	HIGH+
Recommendation	RESTORE+++	PROTECT priority species	RESTORE++	RESTORE+++ priority species	RESTORE++	RESTORE+	RESTORE+++	RESTORE+++ priority species	RESTORE+	RESTORE+

Scenario Large Vessels (LV2)

RESTORE category focused on large vessel near **Green Canyon (GC)** site to benefit multiple species, including one of the high priority species across all months.

Risk Assessment Seasonal Patterns: *What months are these conditions present?*
Across all months this site falls in the RESTORE category, meaning relatively HIGH species presence and 1 relatively HIGH noise activity for large vessels. 1

Possible Quieting Scenario Options: *Identify specific potential mitigative actions could be most applicable*

- Quieting large vessels 1
    - Speed Reduction (?) 1
    - Shift Shipping Lanes from Houston North (?) 1

Benefit from other scenarios
-Reducing seismic noise to benefit further away sites (see S3) 1
-Reducing medium vessel noise (see MV1) 1

Scenario Large Vessels (LV3))

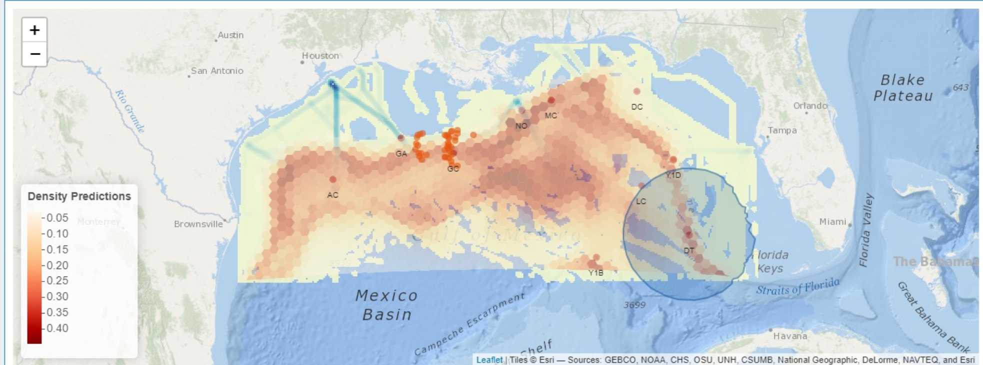
PROTECT category focused on large vessels near Dry Tortugas (DT) site to benefit multiple species, including one of the priority 1 species 1

Risk Assessment Species Drivers: *Why high species presence?* $
-Multiple species with relative densities above 10% are present 1 within the respective listening space, including sperm whales in some of the months 1

Risk Assessment Noise Activity Drivers: *Why high noise activity?*
- Noise activity is relatively LOW at this site Oct-Feb, unless seismic activity was relatively HIGH (Mar-Sep)
- This site has the highest average large vessel speed across all sites
- Relatively lower measured noise levels at this site across all months

Scenario Driver Visualization (map and table for August on right)

Map



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Risk Assessment

Risk Assessment for PAM Sites in Gulf of Mexico

Only high-level summaries are shown

Criteria	AC	DC	DT	GA	GC	LC	MC	NO	Y1B	Y1D
Species presence max = +++	HIGH+	LOW+++	HIGH+++	LOW*	HIGH++***	HIGH+++***	HIGH+**	LOW**	HIGH+++***	HIGH+***
Noise activity max = +++	HIGH+++	HIGH+	HIGH++	HIGH+++	HIGH++	HIGH+	HIGH+++	HIGH+++	HIGH+	HIGH+
Recommendation	RESTORE+++	PROTECT priority species	RESTORE++	RESTORE+++ priority species	RESTORE++	RESTORE+	RESTORE+++	RESTORE+++ priority species	RESTORE+	RESTORE+

Scenario Large Vessels (LV3)

PROTECT category focused on large vessels near Dry Tortugas (DT) site to benefit multiple species, including one of the priority species

Risk Assessment Seasonal Patterns: *What months are these conditions present?*
Five months (Oct-Feb) fall in the PROTECT category, meaning relatively LOW noise activity and HIGH species presence. Seven months (Mar-Sep) had relatively HIGH seismic activity within the gulf which changed the category to RESTORE for those months. Only one month (August) had relatively high large vessel traffic.

Possible Quieting Scenario Options: *Identify specific potential mitigative actions could be most applicable*
-Mitigative focus for this option is solely large vessels
-While all options among the menu of quieting approaches for large vessels should be considered (engineering and operational), risk assessment results highlight potential effective action in relation to speed reductions as speeds are relatively higher than average for these vessel types

Benefit from other scenarios
-Reducing seismic noise to benefit further away sites (see S3)

Scenario Large Vessels (LV4))

RESTORE category focused on large vessel, and future wind lease activity near Alaminos Canyon (AC) site to benefit multiple species, including both high priority species

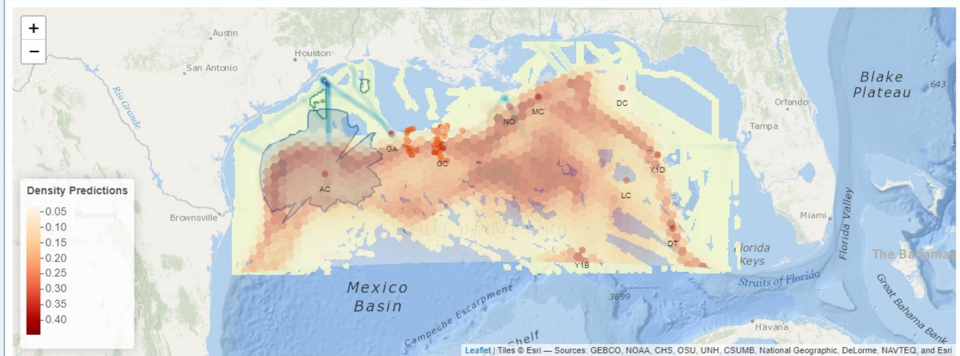
Risk Assessment Species Drivers: *Why high species presence?*
-Multiple species with relative densities above 10% are present within the respective listening space, including sperm whales in all months and Rice's whales in four months

Risk Assessment Noise Activity Drivers: *Why high noise activity?*

- Relatively HIGH large vessel traffic (cargo & tanker) with relatively HIGH measured noise levels
- This area is also relatively close to future wind lease areas with potential future medium vessel noise (green areas on the map) 1

Scenario Driver Visualization (map and table for August on right)

Map



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Risk Assessment

Risk Assessment for PAM Sites in Gulf of Mexico

Only high-level summaries are shown

Criteria	AC	DC	DT	GA	GC	LC	MC	NO	Y1B	Y1D
Species presence max = +++	HIGH+	LOW+++	HIGH+++	LOW*	HIGH++***	HIGH+++***	HIGH+**	LOW**	HIGH+++***	HIGH+***
Noise activity max = +++	HIGH+++	HIGH+	HIGH++	HIGH+++	HIGH++	HIGH+	HIGH+++	HIGH+++	HIGH+	HIGH+
Recommendation	RESTORE+++	PROTECT priority species	RESTORE++	RESTORE+++ priority species	RESTORE++	RESTORE+	RESTORE+++	RESTORE+++ priority species	RESTORE+	RESTORE+

Scenario Large Vessels (LV4)

RESTORE category focused on large vessel, and future wind lease activity near Alaminos Canyon (AC) site to benefit multiple species, including both high priority species

Risk Assessment Seasonal Patterns: *What months are these conditions present?*
Across TEN months (not May and November) this area falls in the RESTORE category, meaning relatively HIGH noise activity and HIGH species presence. In May and November, species presence is relatively LOW, yet noise actity remains HIGH.

Possible Quieting Scenario Options: *Identify specific potential mitigative actions could be most applicable*

- Quieting large vessels 1
    - Speed reduction from Port of Houston 1
    - Shift shipping lanes 50% east and 50% west of current route 1
- Quieting medium vessels (future wind construction vessels) 1
    - Design new Wind C/V's to have low transit URN 1
    - Design new Wind C/V's to have low stationkeeping URN 1

Benefit from other scenarios
-Reducing seismic noise to benefit further away sites (see S3)

More Study Scenarios (2))

Scenario: More Study (MC1)

MORE STUDY option for adaptable vessel noise measurement capability

- # Overarching recommendation thinking ahead to capabilities needed across multiple pilot # projects (not really a quieting scenario
- # Calibrated, multi-element, mobile PAM array would be useful for both baseline assessment of existing radiated noise signatures and levels for known vessels at known speeds/distances as well as efficacy of noise reduction treatments
- # This should be systematically coordinated with the extensive PAM monitoring already underway and planned
- # Mobile/adaptive system would increase chances of participation with multiple vessels in a # controlled manner, but would still require direct coordination with industry #

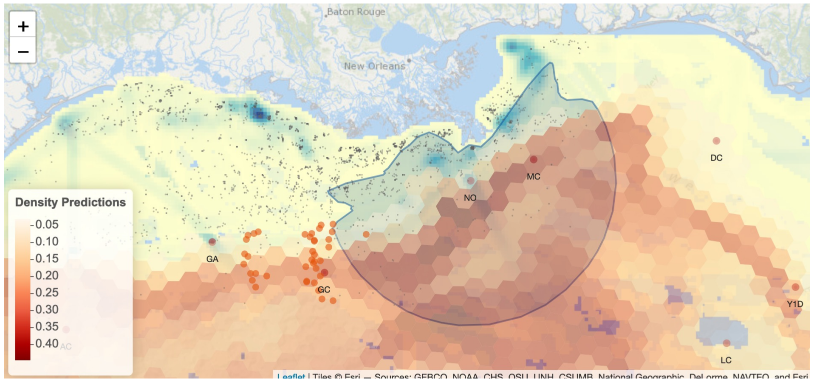
Scenario: More Study (MC2)

MORE STUDY category focused on data gaps linking animal distributions to specific habitats or regions in the Gulf of Mexico where overlapping impacts may exist and include priority species as well as their forage base. Concerted effort is recommended during winter-spring periods to identify potential impacts from vessel and seismic activities.

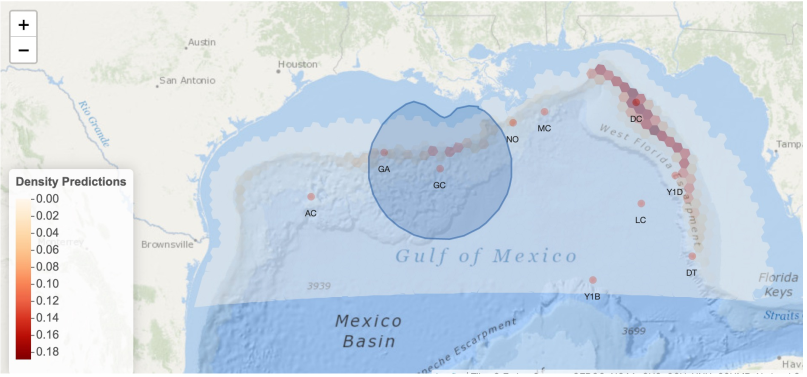
Risk Assessment Species Drivers: *Why high species presence?* $
- Areas determined to require more study largely focus on temporal and 1
seasonal overlap of multiple species as well as prey responding to system 1
pulses in productivity (e.g., site NO in close proximity to and affected by 1
Mississippi River discharge). 1

Risk Assessment Noise Activity Drivers: *Why high noise activity?*
- Most consistent area requiring more study (as evidenced in RA results) are centered on NO, but other important areas include:
- Areas toward GC that are areas of high vessel and seismic activity and relatively high modeled Rice's whale habitat but limited evidence of actual utilization from sighting data
- Areas toward MC which is an area of high vessel traffic and high probability of priority species, namely sperm and beaked whales as well as pantropical spotted dolphins.

Sperm whale Aug density estimates – NO site (



Rice's whale Aug density estimates – GC site (



Scenario More Study (MC2)

MORE STUDY category focused on NO site data gaps linking animal distributions to specific habitats or regions in the Gulf of Mexico (extending to other areas) where overlapping impacts may exist and include priority species as well as their forage base.

Risk Assessment Seasonal Patterns: *What months are these conditions present?*
Periods of winter through spring require additional study and represent important times in the ecology of the system 1
as pulses through the Mississippi River tend to peak in spring and coincide with strong water column mixing (e.g., 1
productivity pulses). Pelagic consumers are likely to respond to pulses along the shelf break and put them at risk for 1
impacts from noise and vessel activity. 1

Recommended More Study Options: 1
Concerted effort environmental and prey sampling coupled with marine mammal distribution and density sampling recommended, specifically during winter-spring periods to identify potential impacts from vessel and seismic activities. 1

Benefit from other scenarios

- MV1 1
- LV1 1
- LV2 1