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Vessel Strike Risk to Rice's Whale in the Gulf of Mexico: Review of Previous Methodologies, Information Gaps, and Recommendations for Future Efforts to Predict Strike Risks

US Department of the Interior
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New Orleans, LA

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DISCLAIMER

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ABOUT THE COVER

A Rice's whale in the Gulf of Mexico from an aerial survey in April 2024. Photo credit: NOAA Fisheries/Paul Nagelkirk (Permit #21938).

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List of Abbreviations and Acronyms

Short Form	Long Form
AIS	Automatic Identification System
BIA	biologically important area
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
CV	coefficient of variation
DOI	Department of the Interior
eDNA	environmental DNA
EEZ	Exclusive Economic Zone
EIS	environmental impact statements
ESA	Endangered Species Act
GAM	generalized additive modeling
GIS	Geographic Information System
GOM	Gulf of Mexico
GUI	geographic user interface
MARU	marine autonomous recording units
MMPA	Marine Mammal Protection Act
MSP	marine spatial planning
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
OCS	Outer Continental Shelf
OCSLA	OCS Lands Act
OE	Office of Environment
PAM	passive acoustic monitoring
PMRF	Pacific Missile Range Facility
PSO	protected species observer
RPA	Reasonable and Prudent Alternative
SAR	Stock Assessment Reports
SDM	spatial density modeling
SEFSC	Southeast Fisheries Science Center
SME	subject matter experts
SSHA	sea surface height anomalies
SST	sea surface temperature
TDR	time depth recorders
VSR	vessel speed reductions

1 Introduction

The Bureau of Ocean Energy Management (BOEM) is dedicated to overseeing the development of energy and mineral resources on the U.S. Outer Continental Shelf (OCS) in a way that is both environmentally and economically responsible. To achieve this, BOEM funds rigorous scientific research to guide policy decisions related to OCS energy and mineral development, the National Environmental Policy Act (NEPA), and analyses of potential environmental impacts from BOEM-approved activities, such as oil and gas extraction, renewable energy projects, carbon sequestration, and mineral resources in Federal OCS waters. The Office of Environment (OE) evaluates the environmental impacts of BOEM-regulated activities and works to avoid or mitigate these impacts in line with the OCS Lands Act (OCSLA), the Endangered Species Act (ESA), and other environmental laws.

On April 15, 2019, National Oceanographic and Atmospheric Administration (NOAA) Fisheries (National Marine Fisheries Service [NMFS]) issued a final rule listing the Gulf of Mexico (Gulf) Bryde's whale (*Balaenoptera edeni*) as an endangered subspecies under the ESA. Genetic analysis of the population revealed extremely low diversity and an evolutionary distinction from other Bryde's whale populations (Rosel and Wilcox 2014). Subsequently, the Gulf Bryde's whale population was reclassified as a separate species, the Rice's whale (*B. ricei*) (NOAA NMFS 2021; Rosel et al. 2021). Hereafter, reference to the Gulf Bryde's whale will use the reclassified species name (i.e., Rice's whale).

Sightings from vessel and aerial surveys indicate that Rice's whales are primarily located in the northeastern Gulf, particularly in De Soto Canyon at depths of approximately 100 to 400 meters (328 to 1,312 feet), which is considered their core distribution area. There have been several confirmed visual sightings in the western Gulf during NOAA visual line-transect surveys in recent years, including one individual during summer 2017 (Garrison et al. 2020) and two individuals in April 2024 (NOAA 2024). Acoustic monitoring efforts have also detected assumed Rice's whale calls in the northwestern and western GOM, though there is insufficient data to determine any seasonal patterns of use or migration between areas (Soldevilla et al. 2024).

Collisions between whales and vessels can cause serious injury or death to the whales and damage the vessels. Most reported vessel collisions with marine mammals involve large whales, though smaller species are also affected (Van Waerebeek et al. 2007). Research by Laist et al. (2001) shows that most severe and fatal injuries to whales occur from collisions with large ships (>80 meters [262 feet]) traveling at higher speeds, with 89 percent of ship-strike records involving vessels moving at over 14 knots. Rice's whales may spend up to 88 percent of their time at night–and 70 percent of their time overall–within 15 meters (39 feet) of the ocean surface (Soldevilla et al. 2017). This makes them particularly vulnerable to collisions with large ships. NMFS has documented two instances of Rice's whales showing evidence of vessel strikes: a dead lactating adult female found in Tampa Bay, Florida in 2009 with injuries indicative of blunt trauma resulting from a large object (Hayes et al. 2023), and a free-swimming whale in the northeastern Gulf in 2019 with a severely deformed spine, also consistent with a vessel strike (Hayes et al. 2023; Rosel et al. 2021). Neither incident was linked to oil and gas related activities.

NMFS is currently proposing to designate critical habitat for the Rice's whale (NOAA NMFS 2023). Proposed critical habitat includes all waters within the 100- to 400-meter (328- to 1,312-foot) isobaths, extending from the U.S. Exclusive Economic Zone (EEZ) boundary off Texas to the boundary between the South Atlantic Fishery Management Council and the Gulf of Mexico Fishery Management Council (GMFMC) off Florida (88 *Federal Register* [FR] 47453; NOAA NMFS 2023) (**Figure 1**). NMFS anticipates publishing a final rule for Rice's whale critical habitat in late summer of 2024.

To fulfill requirements under the ESA, relative to the Rice's whale, BOEM must assess vessel strike risk posed by vessel traffic specifically related to BOEM-authorized activities. As an initial step, BOEM requires a systematic evaluation of previously used methodologies for predicting Rice's whale strike risk in the northern Gulf, which serves as the objective of this BOEM-funded study.

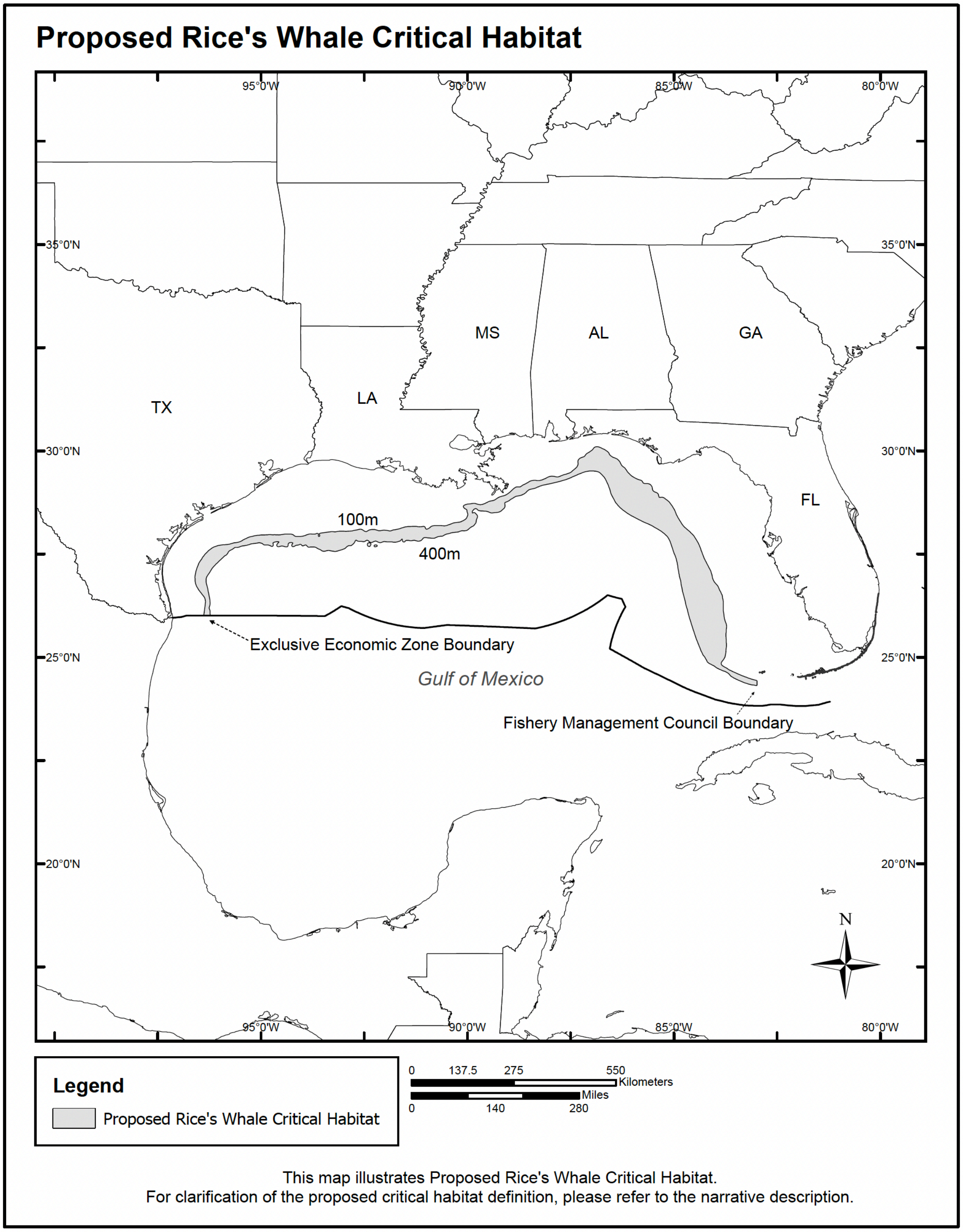

Figure 1. National Marine Fisheries Service (NMFS) proposed Rice's whale critical habitat.
Source: 88 FR 47453

2 Methods

A review of data sources that address the potential for vessel strike to Rice's whales in the Gulf was undertaken. This included evaluation of peer-reviewed literature, published reports, and data sets that describe aspects of Rice's whale distribution, behavior, and ecology; factors that contribute to or elevate their risk for vessel strike were preferentially selected. Since relatively little published literature exist for the Rice's whale, evaluation of other taxonomically similar species (Omura's whale [*B. omuri*]) and Bryde's whale subspecies (i.e., Bryde's whale [*B. e. brydei*]; Eden's whale [*B. e. edeni*]) was also conducted, as applicable. In addition, a review of quantitative and qualitative studies and reports or predictive tools that evaluate vessel strike risk to Rice's whales and other similar species as deemed potentially applicable was conducted. Specifically, the literature review focused on addressing the following questions:

- What are the previous efforts (both quantitative and qualitative) that have evaluated vessel strike risk to Rice's whales or similar large baleen whale species?
- What was the approach used (e.g., calculations) in each effort?
- What are the strengths and weaknesses of each approach?
- What were the baseline data (e.g., field studies, density models) used in each effort and what are the strengths and weaknesses of the data?
- What were the assumptions made in each effort and how did they affect the outcome?
- What were the mitigation measures (e.g., vessel speed restrictions) that were evaluated as part of each assessment, the basis for those measures, and how they affected the outcome?

2.1 Data Sources

The identification of relevant source material was based on a search of numerous bibliographic and library sources using keywords relevant to the objective of this study. An extensive search for all relevant scientific and technical information was conducted using five major sources, described below:

- Proquest Dialog (Dialog);
- OCLC WorldCat (WorlCat);
- Internet search engines to locate relevant websites such as conference proceedings and archives (e.g., Google, Google scholar);
- Digital Repositories, including industry-related sites and web-wide open term searches; and
- Relevant government agency websites.

Proquest Dialog is a unique aggregation of the world's leading bibliographic and full text sources and offers the largest collection of authoritative content that can be searched at one time. OCLC WorldCat is a non-profit, member-driven library community from which relevant books, proceedings, technical reports, and gray literature are located. WorldCat is a cooperative database of more than 450 million bibliographic records contributed to by more than 30,000 member libraries in 123 countries, making it the world's largest, most complete, and most consulted library union catalog of electronic, print, and digital resources. Items found in WorldCat may be purchased or borrowed via the OCLC Interlibrary Loan System.

Internet search engines were also used to locate relevant websites and the digital document repositories, which serve as excellent sources of gray literature and conference papers, including web-wide key word searches and maintained sites. Government agency websites were also searched for documents relevant to NEPA, Marine Mammal Protection Act (MMPA), and ESA contexts.

2.2 Literature Review and Synthesis

A comprehensive literature review followed the systematic identification of potential sources discussed in **Section 2.1**. Title and abstract reviews were conducted as an efficient and effective first step to identify potentially relevant documents. Following the abstract review, if the publication was deemed relevant, a review of methods, results, and findings was conducted for each publication. All selected literature was imported from publisher-provided *.ris files or manually entered into bibliographic management software (i.e., EndNote).

This review and synthesis step recognizes the primary objective of the project—to compare and contrast the findings from various analyses regarding potential risk of vessel strike to Rice's whales. A secondary objective of the data review effort was to review, summarize, and synthesize relevant data sources to be used by BOEM subject matter experts (SMEs) in future impact assessment tasks (e.g., NEPA documents, Biological Opinions, Incidental Take Statements). These objectives underscore a need to: 1) support future impact analyses; 2) identify viable and effective mitigation measures; and 3) identify key data gaps and provide a basis for future research needs to fill those gaps.

Data sources were evaluated on the basis of three perspectives: 1) scientific merit; 2) applicability and relevance; and 3) relative value in a NEPA context (e.g., suitability for use in future environmental impact statements [EISs]):

- **Scientific merit metric**: Broad characterization categories include *High* and *Acceptable*. This metric provides further insight into the relative scientific merit of each data source relative to this study's objectives. The intent behind this metric is to qualitatively establish the relative value of each data source for BOEM's purposes.
- **Rice's whale vessel strike risk**: Categorization levels include *Directly Relevant*, *Moderately Relevant*, and *Peripheral Interest* relative to this study's objectives. This metric effectively separates Rice's whale-specific studies from others, creating a de facto listing of primary data sources (*Directly Relevant*), secondary data sources (*Moderately Relevant*), and tertiary data sources (*Peripheral Interest*).
- **ESA/NEPA context**: More detailed assessment of data sources using topic categorization as likely applicable NEPA-related impact analyses. This metric provides an assessment of each data source and its utility in a NEPA-type analysis primarily based on subject/topic review.

All relevant data sources were classified using the metrics noted above in a presence-absence context (i.e., *yes* or *no*). A Microsoft Excel matrix was developed to manage this classification process, as well as to organize the subject/topic review, summaries, and evaluation for each relevant data source. The classification matrix for primary and secondary data sources is presented in **Appendix A** (**Table A-1**).

During this literature review and synthesis, limitations, and data gaps were identified. These were the basis for recommendations for BOEM to perform a rigorous, statistically meaningful vessel strike risk assessment methodology that could be realistically implemented and peer-reviewed for validating a future risk assessment.

3 Results

The initial bibliographic literature search yielded 247 potentially relevant publications and reports, inclusive of peer-reviewed papers, published and unpublished reports, and dissertations. An initial title review eliminated 142 papers that were duplicative or deemed not relevant. The remaining 105 documents underwent a systematic review of the abstract, methods, results, and findings. Through this process, an additional 7 reports were excluded from analysis as they lacked applicability to this study, resulting in a total of 98 documents considered for inclusion in this study.

Out of 98 documents considered, 78 were peer-reviewed studies, 13 were government reports, one was an unpublished report, and six were other document and data types, including one dissertation. Further screening of the 98 documents designated 35 as primary source documents and 10 as secondary source documents. The primary and secondary papers were scrutinized for analytical quality and validity of conclusions with focus on statistical analyses, if conducted. An additional 53 documents were considered tertiary source documents, which provided useful species or other data and were reviewed primarily for conclusions. No obvious issues regarding experimental design or application of statistical methods (e.g., sample independence, absent transformations) were detected in any study documents assessed.

4 Vessel Strike Risk Factors

Three fundamental components are essential to understanding and assessing vessel strike risk to any marine mammal population:

1. Distribution, occurrence, and habitat selection of the population
2. Dive and surface behavior of individuals
3. Vessel characteristics, activity, and mitigation measures

Relatively few publications directly assess Rice's whale vessel strike risk. However, using what is known about the behavior and ecology of the species, and supplementing with behavioral data on the broader Bryde's whale complex, can help to inform risk analyses and NEPA assessments.

Vessel speed and vessel size are of note when assessing strike risk. The speed at which vessels travel affects their ability to detect and react to whales in their path. For example, faster vessels have shorter reaction times and may pose a higher risk of collision. The size of a vessel also influences its maneuverability: larger vessels are unable to change course or slow down to avoid a collision as quickly as smaller, more maneuverable vessels. Also, larger vessels have deeper drafts, which increase the three-dimensional strike zone ahead of a moving vessel. Vessel size is typically reported in length. However, that length is associated with classes of vessel that are also larger in mass (gross tonnage), which subsequently influence the vessels maneuverability, including its ability to change course or stop. Wang et al. (2007) demonstrated that the lethality of a strike was even more correlated to the vessel's speed than size for vessels over 500 tons. When these factors are combined, strikes involving large vessels (i.e., over 80 meters [262 feet]) traveling at speeds of 10 knots or faster are more likely to result in severe injuries and mortality (Laist et al. 2001; Jensen and Silber 2004; Vanderlaan and Taggart 2007; Conn and Silber 2013). Mitigation measures designed to reduce strike risk typically manage vessel speeds, though other methods are also frequently employed (**Section 4.3.1**).

4.1 Distribution, Occurrence, and Habitat Selection

Visual vessel-based and aerial line-transect surveys serve as the baseline for documenting Rice's whale distribution and occurrence patterns in the Gulf. These data indicate Rice's whale occur in a very small area of the Gulf in the northeast portion, particularly around De Soto Canyon and in water depths of 100 to 400 meters (328 to 1,312 feet) (Mullin and Hoggard 2000; Mullin and Fulling 2004; Maze-Foley and Mullin 2006; Mullin 2007; Garrison et al. 2020, 2023; Rappucci et al. 2023). The visual data is corroborated by several acoustic studies also documenting their occurrence in the northeast GOM (Rice et al. 2014; Sirovic et al. 2014; Soldevilla et al. 2022a)

Water depth, surface chlorophyll concentration, bottom temperature, and bottom salinity are physical descriptors that broadly define Rice's whale's habitat that are subsequently influenced by oceanographic features like upwelling and circulation patterns to produce key habitat features necessary for biological functions (Garrison et al. 2024). The species' known core distribution area (hereafter referred to as the "core area"), as of June 2019, is located in the northeastern Gulf shelf break, particularly around De Soto Canyon and in water depths of 100 to 400 meters (328 to 1,312 feet) (Garrison and Rosel 2019) (**Figure 2**). This area encompasses the biologically important area (BIA) previously identified for Rice's whales (LaBrecque et al. 2015). The Rice's whale core area features seasonal advection of low salinity, high productivity surface waters, and persistent upwelling driven by winds and Loop Current intrusions. The confluence of these features leads to a mixing area with intermediate *chlorophyll-a* concentrations, temperatures, and high salinity bottom water, which is where Rice's whales are most commonly observed (i.e., in the mixing area) (Farmer et al. 2022). Though other regions in the Gulf have similar features, nearly all Rice's whale sightings have occurred within the core area.

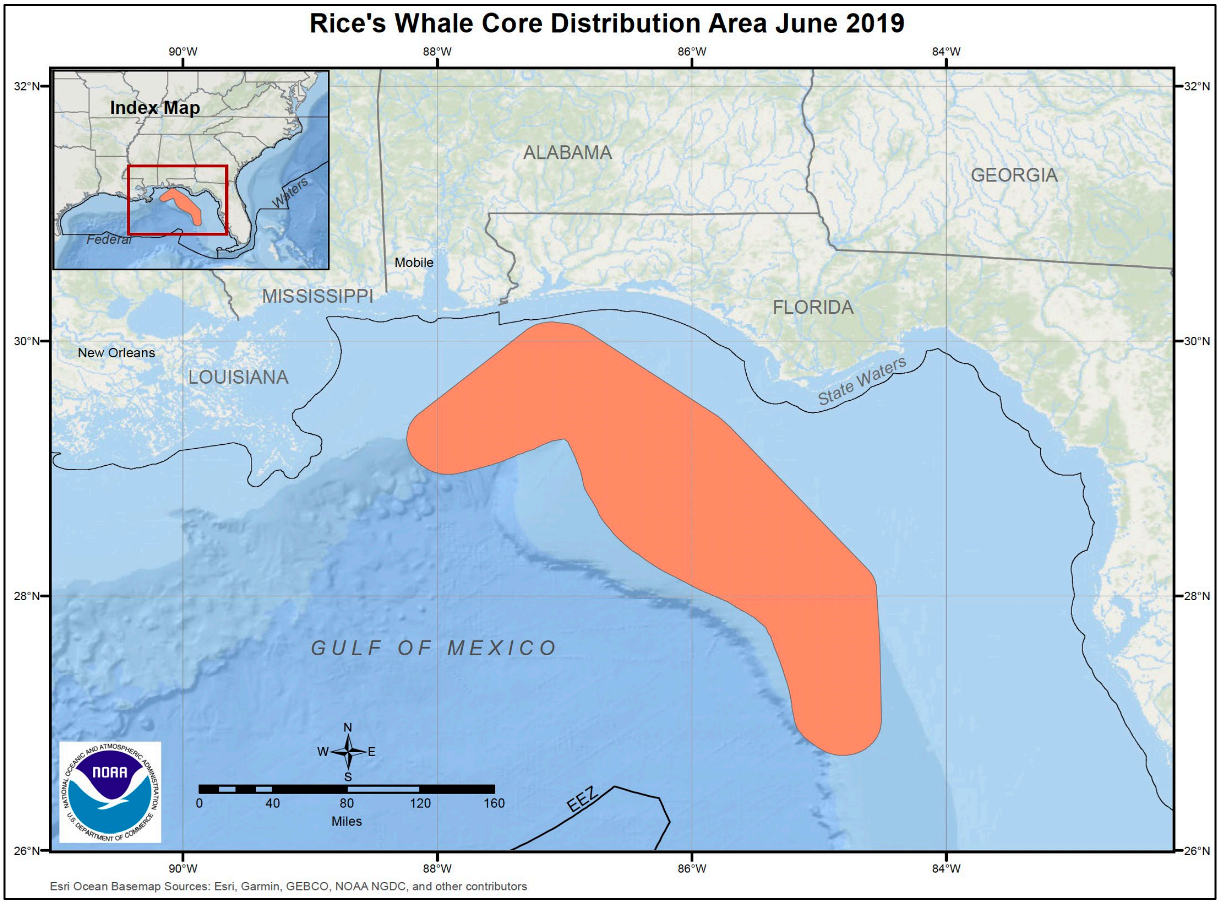

Figure 2. Rice's whale core distribution area (orange).
Source: Rosel and Garrison (2019)

Rice's whale presence outside the core area in the northeastern Gulf is considered low, which may be a product of its low population size in the Gulf or may indicate limited use of non-core habitats. Indeed, the population size of Rice's whale is very low, with abundance estimated at 51 individuals (coefficient of variation [CV] 0.53; confidence interval [CI] 20, 130), based on line-transect surveys conducted during 2017 and 2018 (Garrison et al. 2020; Hayes et al. 2023). Though their historical presence was likely much broader in the Gulf (Reeves et al. 2011), recent acoustic studies (Rice et al. 2014; Soldevilla et al. 2022b; Soldevilla et al. 2024) and two visual surveys (Garrison et al. 2020; Rappucci et al. 2023; NOAA 2024) detected the presence of Rice's whales outside of the core area, most notably in the northwestern Gulf.

Soldevilla et al. (2022b) collected long-term acoustic data from five locations across the northern Gulf shelf break from July 2016 to August 2017 and identified a unique long-moan variant call attributed to Rice's whales outside of the core area. The authors acknowledge uncertainties about the origin of the unique call variant as compared to those made by Soldevilla et al. (2022a), which obtained acoustic-directed visual confirmation of calls attributable to Rice's whales in the core area. Confirmed identification for calls recorded by Soldevilla et al. (2022b) has not been made but, rather, are presumed to originate from Rice's whales because of their call characteristics and that they are the only resident baleen whale in the Gulf. Vocalizations recorded in the western Gulf were relatively sparse in comparison to the number of calls recorded in the northeast Gulf (Soldevilla et al. 2022b). For example, fewer calls were detected on fewer days in the western Gulf, potentially indicating fewer whales or more sparse occurrences of individuals in the northwestern Gulf. In addition, long-term acoustic monitoring in the western Gulf detected Rice's whales regularly and throughout the year in both U.S. and Mexican

EEZ waters, present on up to 33 percent of recorded days (Soldevilla et al. 2024). While it is unknown if Rice's whales occur in the north-central Gulf (e.g., off Louisiana) or travel between the northwestern and northeastern areas, the data indicate a persistent presence of Rice's whales in the northwestern and western Gulf, which coincides with high levels of anthropogenic activities (Soldevilla et al. 2022b; 2024).

It is important to note that there is a lack of occurrence and genetic data from the southern Gulf and the wider Caribbean region. This knowledge gap may be significant, as illustrated by the Omura's whale: initially thought to have a limited distribution in the eastern Indian Ocean, focused data collection over the last 15 years revealed that Omura's whale actually inhabits a much broader area of the Indian Ocean and tropical Atlantic (Cherchio et al. 2019). Though isolated populations of Bryde's whales are well documented globally, a lack of data in the broader Gulf and Caribbean limits the ability to fully assess Rice's whale baseline status and risk in the Gulf.

Distribution and occurrence of Bryde's whales is likely strongly linked to oceanographic variables for some populations, with seasonal peaks in occurrence likely related to high prey abundances and concentrations (Penry et al. 2011; Salvadeo et al. 2011; Watanabe et al. 2012; Sasaki et al. 2013; Lodi et al. 2015; Tardin et al. 2017; Maciel et al. 2018; Purdon et al. 2020). Strong upwelling and high productivity as governed by seasonal and inter-annual climate variability patterns in the eastern North Pacific, in particular, likely drive prey availability and, in turn, Bryde's whale occurrence patterns (Kerosky et al. 2012). In the Gulf, the Rice's whale core area features seasonal advection of low salinity, high productivity surface waters, and persistent upwelling driven by winds and Loop Current intrusions. The confluence of these features leads to a mixing area with intermediate *chlorophyll-a* concentrations, temperatures, and high salinity bottom water, which is where Rice's whales are most commonly observed (Farmer et al. 2022).

Habitat-based spatial density modeling (SDM) used large vessel survey data from the Gulf from 2003 through 2019 taking into account the effect of oceanographic variables (in particular, depth, surface chlorophyll, bottom temperature, bottom salinity, and geostrophic velocity) to predict the abundance and distribution of the species (Garrison et al. 2023). As shown in **Figure 3**, suitable habitat exists for the Rice's whale well beyond the core area, and potentially exists Gulf-wide along the 100- to 400-meter (328- to 1,312-foot) isobath. Of note, the densities depicted in **Figure 3** are very low, even in the core area, due to the assumed limited population size of the Rice's whale. Areas that share similar bathymetric and current characteristics to the core area, particularly near the Campeche Bank (Southern Gulf off the Yucatan Peninsula), may also represent suitable Rice's whale habitat. However, projections of the SDM beyond the northern Gulf should be treated cautiously, as it assumes consistent species-habitat relationships. Importantly, this data does not represent recorded animal densities; instead, the SDM represents abundance *prediction* maps generated based on environmental variables understood to likely influence habitat selection and suitability. Garrison et al. (2024) found that water depth, surface chlorophyll concentration, bottom temperature, and bottom salinity are crucial factors defining the whale's habitat, influenced by oceanographic features like upwelling and circulation patterns.

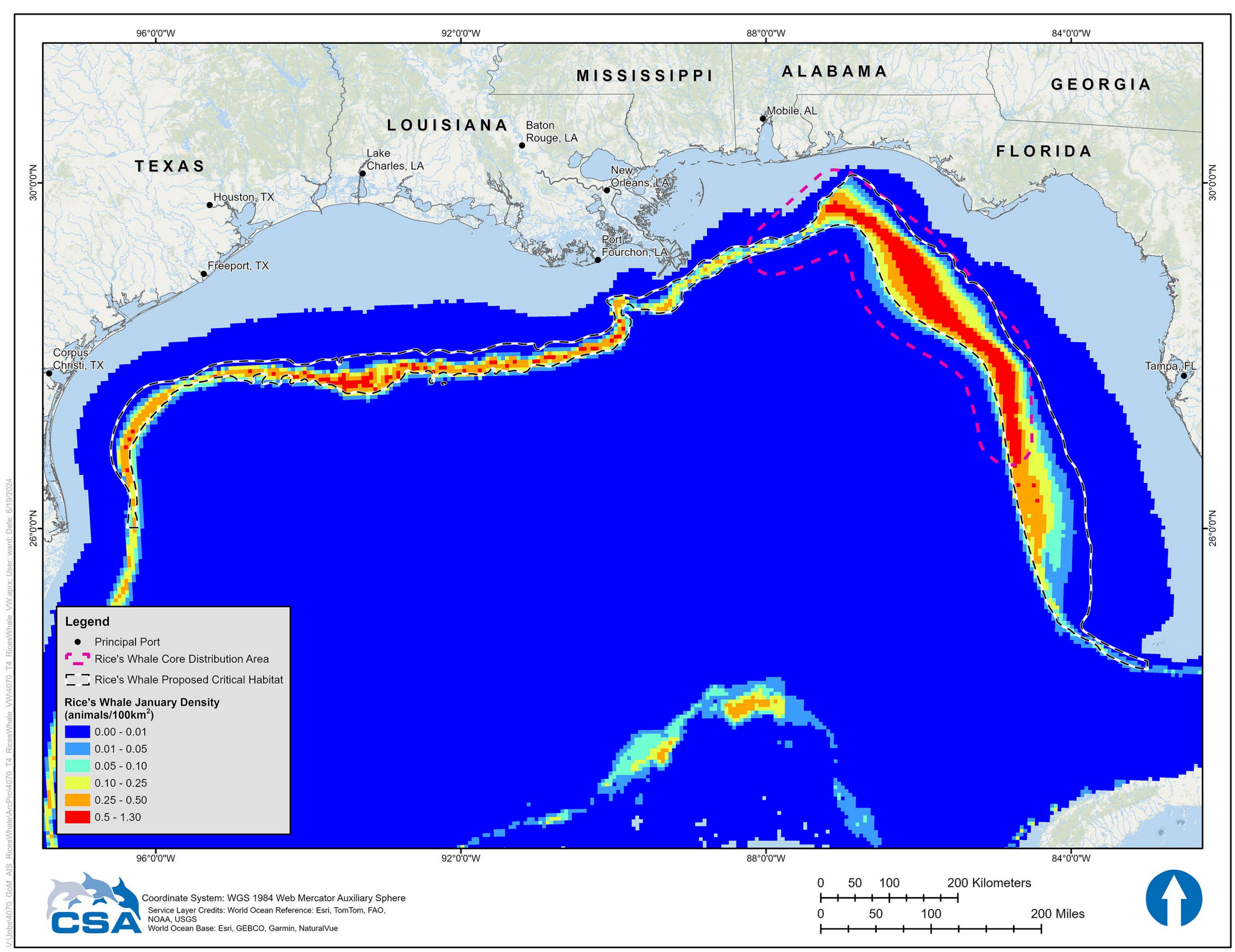

Figure 3. Habitat-based predicted Rice's whale density (January).
Source: Rappucci et al. (2023); Garrison et al. (2023)

The proposed designated critical habitat for Rice's whale includes all Gulf U.S. EEZ waters within the 100-meter to 400-meter (328- to 1,312-foot) isobaths, spanning from Texas to Florida (**Figure 1**) and is based on occurrence and habitat suitability data (NMFS 2023). Three key habitat attributes that are necessary to support Rice's whale are identified in the proposed rule (NOAA NMFS 2023), which are:

- Sufficient density, quality, abundance, and accessibility of small demersal and vertically migrating prey species;
- Marine water with elevated productivity, bottom temperatures of 10 to 19°C, and levels of pollutants that do not preclude or inhibit any demographic function; and
- Sufficiently quiet conditions for normal use and occupancy, including intraspecific communication, navigation, and detection of prey, predators, and other threats.

These key attributes are applicable to broad regions of the Gulf, including areas where limited or no Rice's whale detections (visual or acoustic) have been made. Similar to the discussion above regarding the habitat-based SDM, caution must be applied when interpreting the spatial expanse of the proposed critical habitat versus actual habitat selection by Rice's whales. However, Farmer et al. (2022) highlight the importance of recognizing broader distinct habitat regions for the Rice's whales (i.e., the core area and the extended area) as a conservative measure when assessing risk until more is known about the species' distribution and density.

4.2 Dive and Surface Behaviors

Availability for a vessel strike is directly related to the surface presence of the animal and the proportion of its time that it spends in the upper water column within the draft of vessels. Tagging data indicate that Bryde's whale subspecies spend up to 91 percent of their time within 12 meters (39 feet) of the ocean's surface (Constantine et al. 2015). This is a general understanding that Bryde's whales spend a large portion of their time at the surface. Several studies indicated a higher proportion of deeper dives during the daytime, with more resting at the surface and shallower dives overnight (Alves et al. 2010; Constantine et al. 2015; Izadi et al. 2022). These generalized behaviors make Bryde's whales particularly vulnerable to being hit by ships, especially at night and by large vessels with limited maneuverability that do not see them in time to take evasive action. However, many studied Bryde's whale populations occur in shallow coastal waters (Cerchio et al. 2019), which may not actually be representative of Rice's whales, thus necessitating the need for dedicated dive data analyses for Rice's whales.

A few studies exist that examine diving behavior of Rice's whales in the Gulf. Soldevilla et al. (2017) tagged a single individual (female; age class not specified) in the core area to track vertical positioning with time spent at depth (duration: 2.7 days), plus longer-term tracking with location-only information (duration: 33 days). The tagged individual exhibited a diel dive pattern, with deep (>70 meters [230 feet], maximum: 271 meters [889 feet]) daytime dives and shallow (<30 meters [98 feet]) nighttime dives (Soldevilla et al. 2017). The authors suggest the animal was likely foraging at or near the bottom, based on lunge patterns and supported by additional tagging data from Kok et al. (2023). During the daytime, the individual spent 47 percent of its time in the top 15 meters [49 feet] of the water column. During nighttime, the animal remained close to the surface, made shallow dives with occasional deeper dives (maximum: 150 meters [492 feet]); only 3.25 percent of deep dives occurred at night. The whale spent 88 percent of its time in the top 15 meters (49 feet) of the water column at night. Overall, the animal spent 70 percent of its total time within 15 meters (49 feet) of the surface, which overlaps with the draft of deep-draft vessels that transit the region. These data represent highly consistent diel dive behavior with presumed foraging at/near the bottom mainly during the daytime and extended periods spent at the surface during the nighttime. (Kok et al. 2023; Soldevilla et al. 2017). Though these studies collectively tracked a very small number of individuals, representing severe limitations from which to infer dive and surface behaviors of the population, Soldevilla et al. (2017) indicate that it is reasonable to assume that this behavior is representative of the GOM Rice's whale population as other tagged baleen whales also display similar stereotypical diel dive behaviors linked to foraging and prey distribution.

These dive behaviors are further supported by reported prey selection by Rice's whales. Based on skin and blubber biopsy samples collected in 2010 (n=1) and 2018 to 2019 (n=9), Kiszka et al. (2023) found Rice's whales in the northeastern Gulf preyed primarily on high-energy content species, particularly *Ariomma bondi* (a small schooling fish found in demersal habitats over muddy bottoms at depths of 50 to 500 meters [164 to 1,640 feet]), while other abundant species appeared less significant in their diet. These results suggest Rice's whales selectively forage on high-energy content prey, even if lower-quality prey are more abundant (Kiszka et al. 2023). The authors also postulate that the deep dives exhibited by Rice's whales in the Gulf are energetically expensive and therefore high quality prey would be needed to meet their energetic requirements

4.3 Vessel Activity and Documented Vessel Strikes

Vessel traffic in the Gulf is highest in the north-central and western regions; less traffic is evident within the core area, though several shipping routes do bisect it, as evidenced by 2022 Automatic Identification System (AIS) vessel transit count data (**Figure 4**). Gulf vessel traffic and port utilization is expected to increase into the future. For example, the expected demand for port handling capabilities is expected to double or even quadruple by 2050, resulting in either more vessel traffic, larger vessel capacity, or both (Hanson and Nicholls 2020). Therefore, it is expected that larger and faster ships will increasingly use the Gulf, posing greater risk to Rice's whales (Rosel et al. 2016). Specific to BOEM-regulated activities, BOEM's oil and gas forecast for 2022 to 2031 (Zeringue et al. 2022) indicates that Gulf oil and gas production is expected to experience continued growth and that the transition to renewable sources of energy is underway; there is not an expected decrease in oil and gas vessel requirements even with the introduction of renewable energy leases, which will introduce a new set of vessel type and transit conditions.

As shown in **Figure 5**, Rice's whale core distribution area and the proposed critical habitat overlap with high volumes of vessel transits by a variety of vessel categories, but most prominently cargo vessels. This overlap increases the likelihood of encounters between whales and vessels. Soldevilla et al (2017) reported on vessel activity in the BIA from October 2009 to 2010 based on AIS data and found that less than one vessel transit was recorded per week in 98.5 percent of the BIA, with the remainder averaging one transit per week to two transits per day. Importantly, though, vessel traffic reported by Soldevilla et al. (2017) and presented in **Figure 4** and **Figure 5** is likely underrepresented based on the limitations of AIS data[1].

[1] Recreational vessels, small craft, and military vessels are not required to carry AIS and therefore are not represented in the data analyzed by Soldevilla et al. (2017). Additionally, offshore spatial coverage of AIS throughout the GOM is limited due to distance from port for port-based AIS receivers, which have a maximum receiving rage of approximately 23 miles (37 kilometers) (United States Coast Guard [USCG] n.d.).

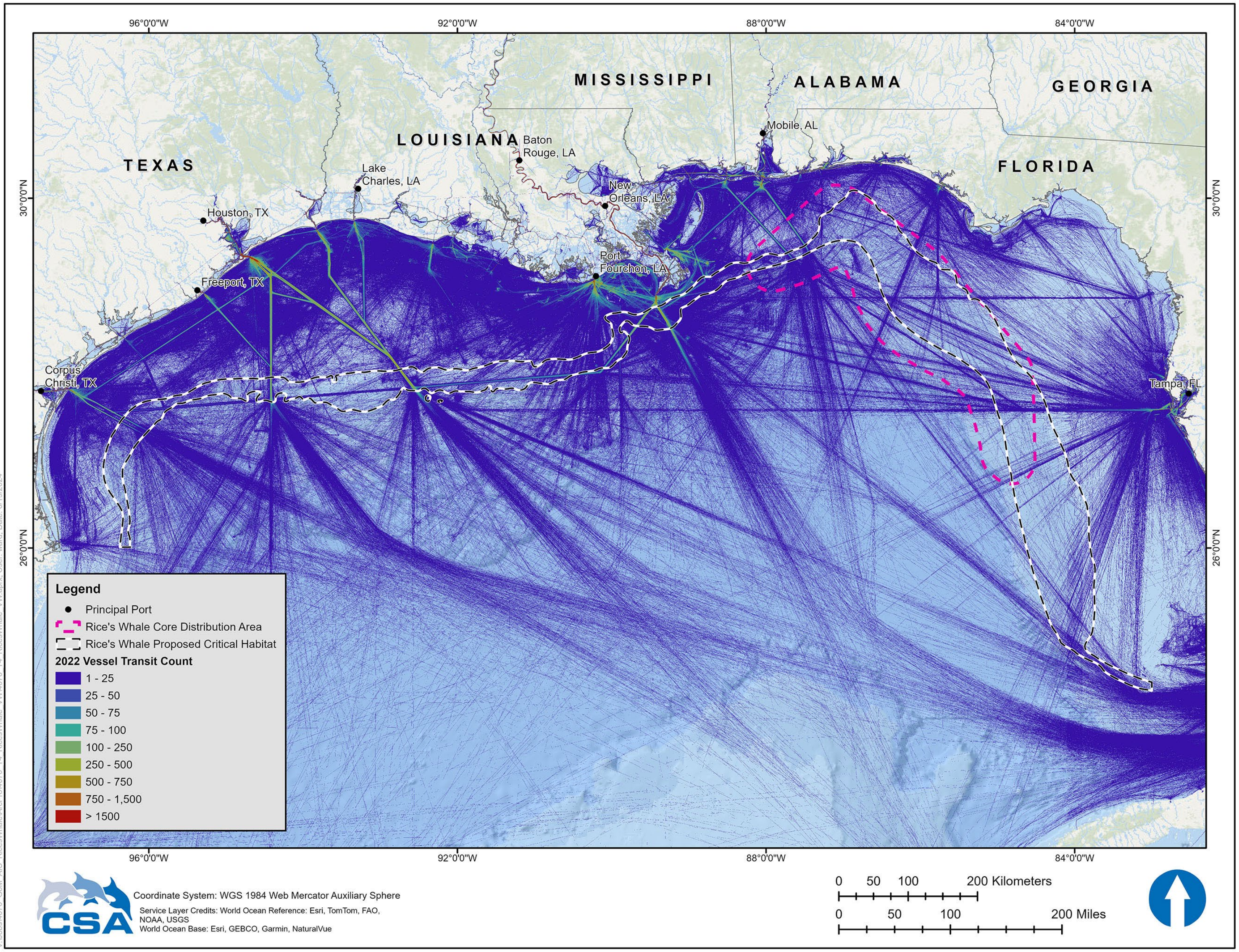

Figure 4. Automatic Identification System (AIS) vessel transit count data for 2022 for all vessel types.
Source: BOEM and NOAA 2024a.

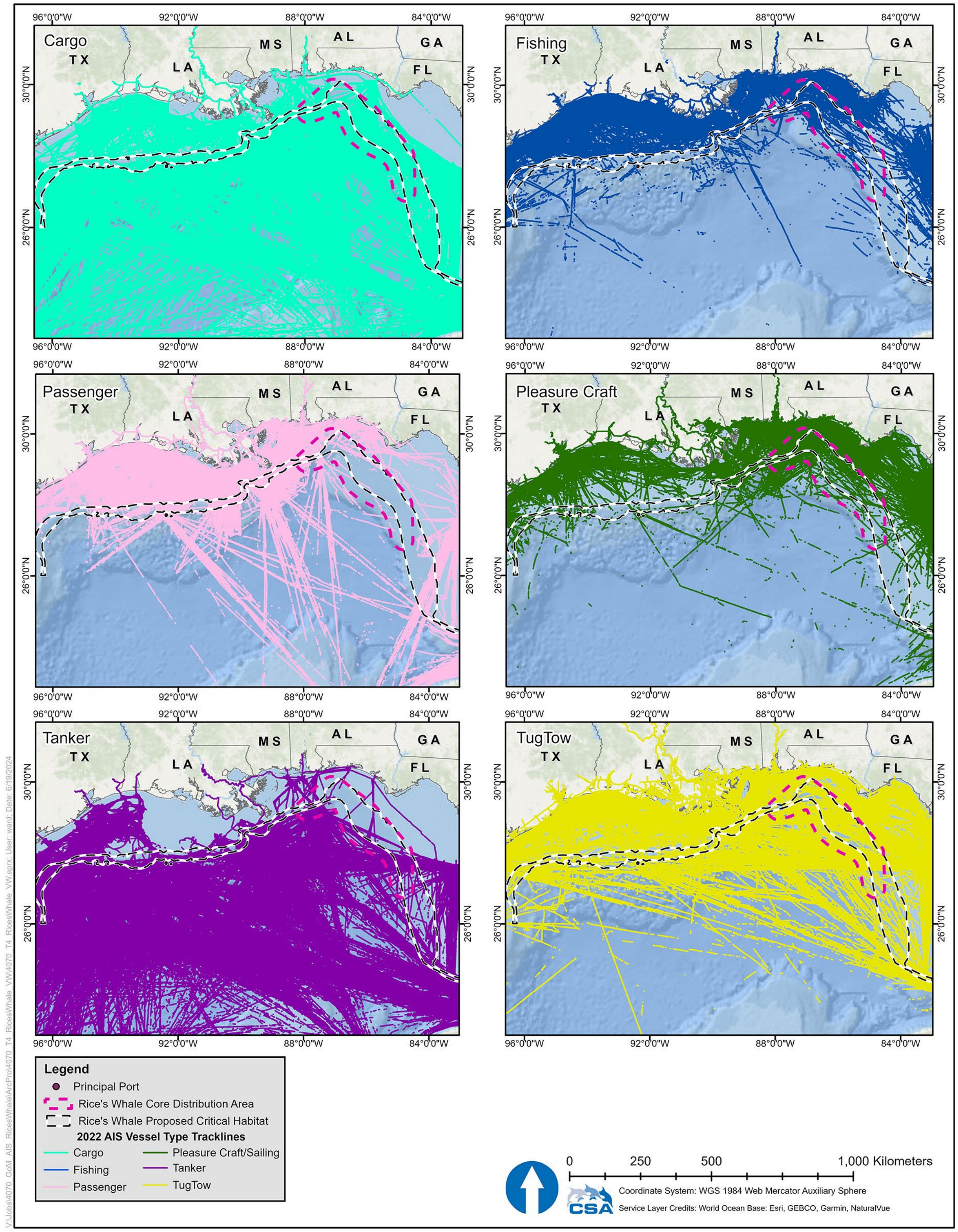

Figure 5. Automatic Identification System (AIS) vessel trackline data for different vessel categories in 2022.
Source: BOEM and NOAA 2024b

As noted above, only one Rice's whale vessel strike mortality is documented within the Gulf: a dead lactating adult female found in Tampa Bay, Florida in 2009, likely having been carried into the port across the bow of a vessel following a lethal vessel strike (Hayes et al. 2023). A free-swimming Rice's whale in the northeastern Gulf was recorded in 2019 with a severely deformed spine, consistent with a vessel strike (Rosel et al. 2021; Hayes et al. 2023). Although only one mortality has been recorded, the incidence of Rice's whale vessel strikes in the Gulf is likely underreported. For example, Williams et al. (2011) suggest only about 2 percent (range: 0 to 6.2 percent) of cetacean carcasses are recovered, indicating true mortality rates may be much higher than realized.

Globally, populations of the Bryde's whale complex are also at high risk for vessel strike. Many Bryde's whale populations are non-migratory and occur in coastal areas that overlap with high levels of vessel activity (Constantine et al. 2018). Constantine et al. (2015) reports high levels of vessel strike in Hauraki Bay, New Zealand, likely driven by their distributional overlap with shipping lanes and their surface/dive behavior (i.e., individuals spend 91 percent of their time at night in the top 12 meters [39 feet] of the water column). In this study, 85 percent of mortalities with a known cause of death had injuries consistent with vessel strike. Soldevilla et al. (2017) report Gulf Bryde's whales spend 88 percent of their time in the top 15 meters [49 feet] of the water column at night, which is when visual detection and aversion would be severely limited due to reduced or no visibility. Athayde et al. (2022) report 4 percent (n=3) of adult Bryde's whales identified off the northern coast of São Paulo, Brazil show scars from vessel propellers, indicating sub-lethal vessel collisions. Felix and Van Waerebeek (2005) indicate that instances of Bryde's whale complex bow-draping, which is when a struck individual is draped across the bow of the vessel as the vessel continues to transit and enter port, is likely lower than that for larger rorquals. This would contribute to lower recovery and reporting of vessel strikes. Vessel strikes, though still relatively rare, are yet reported for other Bryde's whale complex populations globally (Van Waerebeek et al. 2007; Van Waerebeek and Leaper 2008; Nanayakkara and Herath 2017; Cerchio et al. 2019; Ransome et al. 2021). It is likely that underreporting of Bryde's whale complex vessel strikes contributes to underestimates of strike risk for the species globally (Laist et al. 2001).

In addition to the implementation of vessel strike mitigation measures (discussed below in **Section 4.3.1**), strike risk is also affected by an individual's response to an approaching vessel, and if any avoidant or evasive actions are taken by the individual animal that removes it from the "strike zone" (i.e., the area in front of the vessel where a strike would be unavoidable and occur). Aversion behavior may include movement away from the vessel or a dive response. However, no evidence suggests that Rice's (or Bryde's) whales avoid approaching vessels. Dong et al. (2022) observed Bryde's whales altering their dive behavior when approached by whale watching vessels; deep dives (defined as dives greater than 3 meters [9.8 feet] in a total water column depth of up to 10 meters [33 feet]) decreased by approximately 17 percent when approached within 300 meters (984 feet). Therefore, it cannot be assumed that individuals will take evasive actions to avoid vessel collisions and some reactive behaviors may actually heighten their strike risk.

4.3.1 Vessel Strike Mitigation

A number of mitigation recommendations have been proposed for some regions with high strike risk. Collisions often result in severe injuries, particularly when involving large vessels (i.e., over 80 meters [262 feet]) traveling at speeds of 10 knots or faster (Laist et al. 2001; Jensen and Silber 2004; Vanderlaan and Taggart 2007; Conn and Silber 2013), so measures targeted specifically to these vessel classes and activities may have the most success at reducing overall strike risk. For example, vessel speed restriction recommendations and observer recommendations are in place for some vessel types (i.e., ferries, cargo ships) in the Canary Islands to reduce vessel strikes to Bryde's whales (Ferreira et al. 2021). In areas where busy shipping lanes overlap with high concentrations of large whale species, measures such as posting visual lookouts, vessel re-routing measures, and establishing areas to be avoided may also mitigate strike risk for Bryde's whales and other large whale species (Nanayakkara and Herath 2017;

Flynn and Calambokidis 2019; Redfern et al. 2024). Additionally, public awareness (e.g., voluntary speed reduction efforts) and enforcement efforts may increase compliance rates (van der Hoop et al. 2015). Slowing vessels down can also result in lower underwater noise levels, offering additional benefit to large whale species (Findlay et al. 2023). However, exposure to vessel noise increases with transit time.

Ebdon et al. (2020) evaluated the efficacy of mitigation measures specific to Bryde's whale strike risk in the Hauraki Gulf (New Zealand) and found that 10-knot vessel speed restrictions reduced the probability of lethal strikes by half. Redfern et al. (2024) analyzed management strategies that aim to reduce vessel strike risk to whales along the U.S. East Coast. Using vessel speed, transit distance, and whale density and distribution data, the authors found that a 10 knots speed restriction effectively reduces risk and benefits multiple large whale species. Modeling exercises also indicate that vessel speed restrictions in critical areas (i.e., areas of overlap between high vessel activity and large whale distributions) reduces vessel strike risk (Rockwood et al. 2021). However, the actual effectiveness of these measures depends on the level of compliance by the shipping industry; low compliance levels with voluntary speed restriction measures limits the observed effectiveness of these interventions in reducing whale mortality (Rockwood et al. 2021).

As part of the Biological Opinion on the Federally Regulated Oil and Gas Program Activities in the Gulf (NOAA NMFS 2020), BOEM and the Bureau of Safety and Environmental Enforcement (BSEE) consulted with NMFS to develop a Reasonable and Prudent Alternative (RPA) with measures designed specifically to reduce vessel strike risk to Rice's whales. These measures are summarized below:

- All vessels of all sizes to observe a 10-knot vessel speed restriction within the "mitigation area"[2] during daylight hours year-round (except when necessary for vessel or crew safety).
- No transits permitted in the mitigation area during nighttime (unless necessary for vessel or crew safety).
- Visual observers to monitor the vessel strike avoidance zone (500 meters [1,640 feet]).
- All vessels of all sizes to maintain a minimum 500 meters (1,640 feet) separation distance from Rice's whales or unidentified large whale.
- Report transits within the mitigation area.
- All vessels greater than 19.8 meters (65 feet) in length to transmit AIS at all times.

Implementation of the RPA measures, specifically the 10-knot daytime speed restriction and the nighttime restriction of all transits in the mitigation area, was determined by NMFS to effectively avoid lethal vessel strikes resulting from oil and gas vessel activities in the Gulf (NOAA NMFS 2020).

[2] This area is referred to as the "Bryde's whale area" in NOAA NMFS (2020) and is roughly equitable to the Rice's whale core distribution area (**Figure 2**). To avoid confusion, this will be referred to as the "mitigation area" hereafter.

5 Existing Vessel Strike Risk Analyses

The Gulf is a busy maritime region with significant commercial shipping traffic (**Section 4.3**). The constant movement of large vessels through Rice's whales' habitat increases the risk of collisions. As of August 2024, two analyses directly assess vessel strike risk for Rice's whales in the Gulf (Best 2023[3]; NOAA NMFS 2020), presented below. An additional BOEM-funded study models vessel strike risk for large whales and sea turtles in the Atlantic OCS, but does not include Rice's (or Bryde's) whales or the Gulf (Barkaszi et al. 2021); its relevance to overall strike risk is discussed below, as well. Finally, Rockwood et al. (2021) modeled vessel strike of large whales to evaluate mortality across different management scenarios. Similarly, this study does not include Rice's (or Bryde's) whales or the Gulf, but its relevance to modeling strike risk is presented below. Results of the literature synthesis, including subject/topic review and summaries for each primary and secondary data source, are provided in **Appendix A**.

5.1 The Biological Opinion on the Federally Regulated Oil and Gas Program Activities in the Gulf of Mexico (NOAA NMFS 2020):

Section 8.4 of NOAA NMFS (2020) outlines the evaluation of vessel traffic data concerning the potential impact on ESA-listed species using BOEM-estimated data (vessel trips based on port calls) and AIS (2014 to 2018) data. Use of AIS provides finer resolution regarding vessel routes, distances traveled, and speeds, allowing for more realistic estimates of ESA-listed species exposure to vessel traffic. The proposed action considered in NOAA NMFS (2020) was estimated to involve a maximum of 173,002 vessel trips annually, constituting approximately 20 percent (19.77 percent) of the total vessel trips in the GOM.

To estimate the number of vessel strikes to Rice's and sperm whales that will result from the Oil and Gas Program, they combined information on vessel traffic from the aforementioned AIS dataset with data on Rice's and sperm whale distribution and density as described in NOAA NMFS (2020) Section 8.1.2 in order to quantify the co-occurrence of whales and vessels, hereafter referred to as vessel strike risk. Focus was on vessels traveling >10 knots. It was recognized that there are likely other factors at play that determine the probability of an actual vessel strike occurring, such as whale and vessel size, whale diving behavior, among others. However, consideration of these factors was seen to not invalidate estimates below of the relative risk associated with oil and gas vessel traffic since it was anticipated that these other factor(s) would equally affect the probability of vessel strikes from oil and gas vessel traffic compared to all vessel traffic.

Oil and gas related vessel traffic analyzed in NOAA NMFS (2020) without the application of mitigation measures is likely to result in a total of 23 vessel strikes of Rice's whales, with 17 of these strikes expected to result in serious injury or mortality and six strikes expected to result in minor or no injuries. However, NOAA NMFS (2020) further considered that 35 percent of oil and gas traffic occurs within the mitigation area, which would be limited to a 10-knot speed restriction and no nighttime transits. If a 10-knot speed restriction within the mitigation area results in a 90 percent reduction in the number of vessel strikes, then the overall reduction of vessel strike risk to Rice's whales due to oil and gas vessel traffic of all speeds would be approximately 31 percent; oil and gas vessel activity over 50 years would therefore result in 12 vessel strikes with serious injury or mortality and four with no or minor injuries. Strike risk here is equivalent to the default conditions of BOEM's ship-strike model (Barkaszi et al. 2021; see

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[3] Best PB. 2023. Spatial analysis of ship strike risk for Rice's whales in the Gulf of Mexico. Unpublished Report: https://ecoquants.com/ricei.

Section 5.3) where an intersection or encounter without any mitigating factors (e.g., vessel draft, time of day, aversion [particularly vessel aversion], etc.) represents the highest level of encounter probability. Thus, "relative strike risk" is actually "relative encounter probability"[4].

5.1.1 Assumptions and Limitations

A major assumption in NOAA NMFS (2020) was that a reduction in vessel speed to ≤10 knots is likely to lead to a 90 percent reduction in the number of all vessel strikes, regardless of severity. Furthermore, in using a 10-knot cut off, it was assumed that 100 percent of vessel strikes occurring at speeds of 10 knots or greater would likely result in serious injury or mortality, despite known incidents of vessel strikes of large whales at speeds greater than 10 knots that did not result in serious injury or mortality (e.g., see Figure 2 in Vanderlaan and Taggart [2007]). This analysis also considered stranded animals with characteristic injuries to indeed be from strikes that resulted in mortality or serious injury, though this might not necessarily be the case. In addition, it was also assumed that effects would be equal among different vessel categories, which would only be true if vessel characteristics were equal among both oil and gas and non-oil and gas vessels. A major limitation of NOAA NMFS (2020) was that behavioral factors that affect strike availability, such as diving and/or surface presence or aversion, were not included in the analysis.

5.2 Spatial Analysis of Ship-strike Risk for Rice's Whales in the Gulf of Mexico (Unpublished Report) (Best 2023)

The unpublished Best (2023) report replicates the ship-strike analysis in NOAA NMFS (2020) using an updated whale density model (Litz et al. 2022[5]) and AIS vessel data from 2015 to 2018, extending the analysis Gulf-wide in U.S. EEZ waters. This report uses the updated Rice's whale SDM from Litz et al. (2022), which is based on habitat suitability estimates from Gulf ship-based and aerial surveys conducted from 2003 to 2019 and oceanographic variables from 2015 to 2019. The SDMs from Litz et al. (2022) are extrapolated to predict high-density areas beyond U.S. waters in the Gulf based primarily on habitat suitability (in lieu of sighting events), so these predictions should be interpreted cautiously.

Using these data, Best (2023) suggests a new "whale area" (hereafter called the extended area) in the Gulf based on location (25.5º N and higher) and depth (100 to 400 meters [328 to 1,312 feet]). Application of 10-knot restrictions in all of the Rice's whale core area and extended area resulted in risk reduction regardless of vessel type (oil and gas or all vessels) and speeds (>10 knots and all speeds). For example, when considering all vessel types and all vessel speeds, implementing mitigation measures for oil and gas traffic from NOAA NMFS (2020) reduced strike risk by 93 percent for the extended area compared to only 12 percent in the core area.

Best (2023) replicated NOAA NMFS (2020) methodology (i.e., use of AIS data, grid cell size, risk [number of whales multiplied by vessel traffic in distance traveled per grid cell]) but extended the geography under consideration and applied updated whale density information. Statistical analyses mentioned are previously developed spatial summarization tools. Notably, Best (2023) generalizes to all oil and gas vessels only by speed, but not vessel type, and inherently assumes accurate whale density data. Additionally, strike risk is coarse-grain rank based on vessel and whale abundance and speed but does not

[4] The probability of an encounter is not identical to strike risk, unless the encounter would result in animal exposure within the strike zone of the vessel (e.g., draft).

[5] The metadata associated with this dataset was recently updated (April 1, 2024). However, this report will refer to Litz et al. (2022) as cited in Best (2023) and in accordance with its publication date (July 29, 2022).

appear to consider aversion or any mitigation measures in the assessment (other than as related to the 10-knot vessel speed recommendation).

Use of the Litz et al. (2022) data is a significant extension of the risk map throughout the U.S. EEZ and notably includes the western Gulf. Risk is shown to be much higher in the areas off Louisiana and east Texas than that seen in the original geographic area defined by NOAA NMFS (2020), providing a more comprehensive assessment of Gulf-wide Rice's whale strike risk. Best (2023) used higher resolution animal density data (40 km^2 vs. previous 100 km^2) so the risk basis is at a 2.5-times greater animal resolution than most modeling efforts. This was re-projected to fit 100 km^2 square cells to be consistent with the Biological Opinion (NOAA NMFS 2020) and done in a manner to preserve to some degree the finer grain geometric densities of the animal data. However, the re-projection of the data was scaled to provide a total of 51.3 animals to match published abundance estimates, rather than attempt spatial extrapolation of whale density, which would require many assumptions. If those estimates under-represent the population abundance of Rice's whale, then the strike risk values derived in the paper are an underestimate of strike risk. The analytical approach appears robust, but the findings are ultimately driven by the spatial organization of the new animal density data provided by Litz et al. (2022) and the decision to cap the total number of animals at 51.3. Vessel traffic data were the same date range as in the NOAA NMFS (2020) Biological Opinion and analyzed similarly, minimizing any influence of the vessel component to differences in risk values produced here vs. that of NOAA NMFS (2020).

The risk methodology followed that of NOAA NMFS (2020). However, by capping the number of animals at 51.3 and expanding the geographic extent of the critical habitat, this could have an effect of substantially diminishing animal density and consequently, strike risk, as seen in Table 3 of Best (2023). The strike risk reduction presented is driven by application of the 10-knot slowdown and nighttime closure but also to some unknown degree by a potential dilution of the animal density. However, the computation of risk reduction arising from the slowdown and closure is not described and therefore the accuracy cannot be determined independently.

The efficacy of this result may also turn on the population estimate and agreement as to whether the population number needs to be revised and/or revisited because of a larger geographic extent of detection or whether the population is accurately represented at 51.3 individuals. An increase in the population size will increase the strike risk and Best (2023) would have to be revised accordingly.

5.2.1 Assumptions and Limitations

Since Best (2023) followed the same methodology employed by NOAA NMFS (2020), the main assumptions and limitations outlined in **Section 5.1.1** for the Biological Opinion are also applicable here. In addition, Best (2023) limited the analysis to a population total of 51.3 animals and expanded the geographic extent of the Rice's whales core distribution. In doing this, an artificially low strike risk may be presented if population size and habitat selection differ substantially from the key assumptions. In addition, if the Rice's whale is not actually found in the north-central Gulf (e.g., off Louisiana, east Texas), the expanded geographic extent is indicating risk in an area where there is effectively none at this time.

5.3 Risk Assessment to Model Encounter Rates between Large Whales and Vessel Traffic from Offshore Wind Energy on the Atlantic OCS (Barkaszi et al. 2021)

This study aimed to evaluate the risk of vessel strikes on large whales and sea turtles in Atlantic offshore wind energy areas, considering various vessel types. The research comprised four stages: characterizing baseline vessel traffic and wind farm operations, developing an analytical framework to calculate encounter numbers, creating a quantitative model for strike risk assessment, and building a graphical user interface (GUI) for scenario creation and result visualization. The GUI enables users to simulate potential encounters between vessels and marine animals, allowing manipulation of vessel activity and animal behavioral responses, with capacity for aggregating results from multiple scenarios. The model is limited to the Atlantic OCS and does not assess strike risk for the Rice's whale. However, the basis of the model uses surface density layers, dive and/or surface behaviors, and animal size and/or swim speed for each species to calculate vessel strike risk based on vessel data characteristic of offshore wind energy development and project-specific vessel routes, transit numbers, speed, etc. as entered by the user.

The model provides a risk assessment framework to compute the number of potential encounters among mammals and turtles with various classes of vessels, at varying speeds along transit routes at given times of year. The vessel route is divided into 1-kilometer (0.62-mile) segments, and interactions are modeled for each segment. The total encounters along the route are then summed. Parameters (e.g., vessel speed, animal density) are assumed constant within each 1-kilometer (0.62-mile) block but can vary across different segments based on broader environmental factors. This approach allows for a scalable, consistent framework to assess encounter risks while incorporating adjustable aversion factors to better simulate real-world conditions.

When used as a planning tool, BOEM’s vessel strike model represents a user-friendly, spatial and temporally articulated geographic information system (GIS)-based model with outputs predicting potential vessel-animal encounters under a wide range of tunable variables. BOEM is currently expanding this model to include all U.S. OCS waters (except Alaska) and to lessen some of the limitations identified above. The updated risk assessment tool may be used Gulf-wide for project-specific applications. Strike risk is calculated based on the user-defined vessel activity scenario and availability of an animal for strike, which includes habitat-based predictive density and dive and/or surface behaviors that will be updated for Rice’s whales in the Gulf. BOEM expects to release the updated vessel strike model by 2026.

5.3.1 Assumptions and Limitations

Several assumptions are considered in this vessel strike model. Probabilistic modeling of strike risk is conceptualized as being directly proportional to the expected number of animal encounters a given vessel will accrue while transiting to its destination. The mathematical equations were derived solely from geometric relationships that result from various simplifying assumptions from both the animal’s perspective (i.e., generalizing spatial and temporal behaviors for entire species) and the vessels (i.e., pre-defined vessel classes only transit along previously identified routes). In addition, the geometric model incorporates vessel length to calculate strike risk, such that as length increases, strike risk also increases. However, it is not well established in the literature that this proportional relationship is that simple, as other factors secondary to vessel length (i.e., maneuverability, turning radius, crash stop distance, gross tonnage) also contribute to a vessel’s ability to avoid collision. Finally, aversion probability can be input and manipulated by the user, which can lead to inaccurate and non-realistic results.

5.4 Modeling Whale Deaths from Vessel Strikes to Reduce the Risk of Fatality to Endangered Whales (Rockwood et al. 2021)

Rockwood et al. (2021) outline a comprehensive approach to estimate whale mortality due to vessel strikes in the Southern California region. The study focused on the area from Point Conception to San Diego, California extending 100 kilometers (62 miles) offshore, covering a total area of 39,889 km^2. This region includes the Santa Barbara and San Pedro Channels, known for high productivity and consistent feeding aggregations of large whales. A spatial grid of approximately 1 km^2 cells (47,955 in total) was created for the study area. Modeled whale density data (Becker et al. 2016, 2017), which used environmental predictors and whale sightings from systematic boat-based surveys to develop predictive densities, and AIS vessel data from 2012 to 2018 were used, with specific criteria for excluding erroneous records (e.g., speeds less than 2 knots or greater than 40 knots).

The core of the methodology of Rockwood et al. (2021) is an encounter probability model, adapted from Martin et al. (2016) and previous works by Rockwood et al. (2017, 2020), which calculates vessel-whale encounter rates within each grid cell, considering whale and vessel size, velocity, and distance traveled. Whale time-at-depth data from multi-sensor tags were used to assess the risk of being in the vertical strike zone. Encounter rates were then converted to mortality estimates by incorporating probabilities of collision avoidance and mortality given a collision. Several improvements were made to the model to enhance accuracy. For example, mortality estimates were calculated independently for each vessel track and summed within each grid cell, addressing biases from non-linear relationships between ship parameters and strike mortality. The study also explored various vessel speed reduction scenarios, including different speed limits and compliance levels, to assess potential changes in whale mortality.

This study uses a detailed and systematic approach to estimate whale mortality from vessel strikes, integrating spatial grid analysis, whale density modeling, and an encounter probability framework. The results provide valuable insights into the effectiveness of speed management strategies and potential improvements for reducing whale fatalities in the region.

5.4.1 Assumptions and Limitations

Rockwood et al. (2021) acknowledge several limitations that impact the accuracy and applicability of their findings. The study relies on whale density models which are based on past sightings and environmental conditions. These models may not accurately reflect current whale distributions, especially considering potential shifts due to changing oceanographic conditions. Additionally, vessel traffic data, sourced from the AIS, might have inaccuracies, including errors in recorded speeds and locations. Additionally, not all vessels are required to carry AIS transponders, which inherently underestimates the volume of vessel traffic within any given region. Rockwood et al (2021) further filtered AIS data to only include those greater than 19 meters (62 feet) in length and with a draft of 2 meters (6.6 feet) or greater; the authors did not conduct separate analyses of different vessel categories. The encounter probability model makes several assumptions, including whale behavior and the probability of whales avoiding vessels, which may not hold true in all scenarios; the model's predictions depend heavily on the accuracy of whale density data and the assumption that past behavior and distributions are indicative of future patterns. The spatial resolution of the grid cells (1 km^2) and temporal resolution of the data (2012–2018) might not capture finer-scale variations in whale density and vessel traffic, which could lead to underestimations or overestimations of risk in certain areas or times. Finally, broader ecological changes, such as shifts in prey availability or long-term climatic changes, are not fully accounted for in the models; these factors could significantly influence whale distributions and the risk of vessel strikes.

6 Recommendations

The review of primary and secondary source documents spanned examination of both Rice's and Bryde's whale complex distribution, abundance, behavior, feeding, and risk factors. From this, recommendations for additional study to inform a statistically meaningful vessel strike risk assessment methodology that BOEM could realistically implement and that could be peer-reviewed for validating a future assessment were developed. Key emergent information from these papers fell into two categories of recommended additional study, (1) improvements in animal density and distribution data and (2) improvements in understanding of animal behavior.

One emergent question is whether small sample sizes of Rice's whale attributes (distribution, behavior, acoustic signature, diet) as seen throughout the reviewed studies should be utilized to inform ship-strike modeling. Given the very small population size (<100 and perhaps as few as 51), even a sample from one animal represents a comparatively large sub-sample of a population. While individual behavior may skew the utilization of information (e.g., dive times, surface resting times, etc.) from numerically small samples, it is also possible that many aspects of observed behaviors are indeed characteristic of the species. Moreover, the urgency of need for actionable data suggests that its use would be appropriate to generalize to the species. Further, the behaviors noted for other Bryde's subspecies generally do not contradict what has been found in the limited Rice's whale observations, further suggesting the appropriateness of their use.

6.1 Improving Rice's Whale Density and Distribution Data

Central to both range determination and in particular, ship-strike modeling, is accurate animal density data in space and time. Data are often coarse (e.g., animal density averaged at 100 km^2 resolution), inherently mismatching spatial resolution of vessels precisely tracked with AIS data versus that of whales, thereby limiting spatial and temporal predictions of strike risk. Therefore, emphasis on refining the spatial and seasonal abundance of Rice's whale may represent one of the most valuable management data sets. In particular, understanding Rice's whale occurrence patterns and behaviors in the northern Gulf and identifying if there is any east-west migration between the northwest and western Gulf are critical to informing strike risk in these areas.

It is recommended that localized Rice's whale vocalizations (Soldevilla et al. 2022a, 2022b, 2024) are merged with modeling efforts that currently predict Rice's whale occurrence patterns based on habitat suitability and, to a lesser extent, visual detections made from systematic vessel and aerial survey data (Litz et al. 2022; Rappucci et al. 2023; Garrison et al. 2023, 2024). This action, which likely would require additional long-term passive acoustic monitoring (PAM) buoy deployments (especially in the western and central GOM, and potentially deployments outside of U.S. waters), would compile a more comprehensive assessment of Rice's whale distribution and seasonal occurrence patterns in a cost--effective way. However, to use acoustic methods, additional resolution of Rice's whale call signatures is prudent (e.g., Soldevilla et al. 2022a) to ensure that acoustic detection is unambiguous. Short-term studies involving multi-platform approaches (e.g., Izadi et al. 2022) to identify and acoustically fingerprint individuals would be appropriate. Being able to defend identification of Rice's whale acoustically will be critical for use of recording devices on a broad geographic extent to quantify range extent and frequency of use.

Extracting spatial and temporal detection data (e.g. metadata analysis and recovery) from protected species observer (PSO) data (e.g., Barkaszi and Kelly 2024) and oil and gas vessel operator reports would be a cost-effective strategy to supplement animal distribution and density data layers. It is strongly recommended that a central digital repository of these data be created and maintained so that it may be effectively mined for past and ongoing Rice's whale detections.

Anecdotal sightings, if confirmed (i.e., through supporting photo or video documentation), would also contribute to our overall understanding of Rice's whale occurrences. Conducting outreach to boat operators and fishermen to provide awareness of Rice's whales and to request sightings information (i.e., through a simplified sightings sheet and/or website) would be a reasonable approach. It is acknowledged that reception from local communities around the Gulf to outreach and data requests from BOEM may prove challenging. However, partnering with universities or ongoing "citizen science" efforts for other marine species (i.e., whale sharks [*Rhincodon typus*]) may provide a valuable mechanism for compiling sighting events.

Assembly of PSO and even anecdotal data would create an up-to-date and authoritative reference base for understanding distribution and abundance but also would be useful for detecting spatial and temporal gaps in data and to direct additional studies. However, an understanding of the caveats associated with these data sources must be cautioned. PSO and vessel operator data are not equivalent to systematic visual surveys and only represent presence-absence data. Additionally, detections may be confounded by the use of airgun arrays and therefore may not fully represent Rice's whale distribution patterns. Further, anecdotal data can at best represent presence data, but little more than that. Despite these data limitations, an expansion of sightings throughout the GOM still represents valuable insight to Rice's whale occurrences. However, one cannot develop a statistical design without a thorough understanding of the available data structure, including its resolution and extent in both space and time. Consequently, any determination of the appropriate statistical approach (if any) must await data acquisition and structural review.

If evident from gap analysis of existing data, a plan of study for utilization of acoustic buoy deployment to capture Rice's whale spatial and seasonal distribution, including possible east–west migrations, would be a logical build-out from the extant data. Together with the existing data (and consideration of any ongoing studies and surveys), this effort would provide defensible data for designation of critical habitat.

6.2 Improvements in Understanding of Animal Behavior

Several papers review Bryde's whale diving and feeding behavior (e.g., Kershaw et al. 2013; Sirović et al. 2014; Dong et al. 2022; Izadi et al. 2022) but few in the GOM and far fewer specifically targeted Rice's whale (e.g., Soldevilla et al. 2017; Kiszka et al. 2023; Kok et al. 2023). The "common" understanding is that Rice's whales may spend a lot of time at the surface, especially at night, making them vulnerable to ship strike. However, the data supporting this are quite limited (although even a few suction-cup tags on individuals out of a population of 51 individuals would be substantial and worthwhile upon which to build generalizations in ship-strike models). Meanwhile, in the face of data paucity, extrapolating from Bryde's whale data is appropriate, though potentially misleading given the different habitat characteristics of better-studied populations (see **Section 4.2**). Therefore, a strong recommendation is to improve the specific understanding of Rice's whale behavior that includes time spent feeding, moving, and resting.

This field work, requiring tagging and monitoring efforts, would require suitable geographic replication and importantly, stratification of sampling by water depths (foraging and diving behavior must be strongly water depth dependent). Priority focus should be given to localizing individuals outside the Rice's whale core area (i.e., in the northern and western Gulf) and deploying satellite telemetry tags to track long-term movements and multisensory suction-cup tags for higher resolution tracking of dive and foraging behaviors, similar to the methodology described by Soldevilla et al. (2017). At minimum, it is recommended a target of at least five satellite tags and five multi-sensor tags be deployed (each representing approximately 10 percent of the known population). So that our understanding of Rice's whale behavior and habitat selection is not limited to only the northwestern Gulf, it is recommended that the majority of tags are deployed on individuals outside the core area, with at least one of each on individuals inside of the core area. Further, tagging individuals (specifically, with the multi-sensor suction-cup tags) in different depth strata may reveal different behavior or use patterns not currently evident in available data.

Though our recommendation sets a target of sampling 10 percent of the known population, it is acknowledged that this may not be achievable is a realistic timeframe, especially when targeting individuals outside of the core area. A power analysis would be hard to perform because one must have an estimation of variance, which likely does not exist for many variables associated with behavior (i.e., tagged and/or tracked limited numbers) and would be extremely challenging to develop. As a result, it is recommended that any tagging data be acquired urgently, and suggest that whatever proportion can be sampled be taken as representative of the population until proven differently.

Amplification and refinement of previous studies where remote sensing data was used to include identification of cues driving aggregation (i.e., food supply) is also needed to build forecasts of spatial distribution and density models necessary for accurate ship-strike probabilistic modeling. This effort may be combined with those recommended in **Section 6.1** to compile and extract observed behavioral records along with occurrence data.

6.3 Other Considerations

In keeping with BOEM's attention to realistic implementation, consideration was given to utilization of environmental DNA (eDNA). A cursory Google Scholar search shows a relatively recent report (Martinez et al. 2024) where biopsy subsamples and eDNA water samples were collected as part of a preliminary attempt to utilize this technology to ascertain presence of the species. With establishment of an eDNA library for Rice's whale and understanding of eDNA persistence in nature, this method may represent a useful tool for rapid assessment of habitat utilization and buttressing of more expensive derivation of distribution information (see review by Suarez-Bregua et al. [2022]). While not a recommended substitute for direct observation, tagging, and monitoring, these data, if acceptable across agencies, could provide a rapid and comparatively inexpensive means of detecting the regional presence of the species.

Compilation of environmental data to associate with Rice's whale distribution bears consideration. Environmental data such as *chlorophyll-a*, sea surface temperature, sea surface height anomalies, and depth already exist or can be obtained remotely and synoptically and used as predictors from other studies of Bryde's whales to further refine core habitat preferences both spatially and temporally. This would reduce costs but would need to be paired with sightings data to build confidence in the forecasted habitat.

Improvements in vessel tracking and vessel data are necessary to better our understanding and refining the assessment of vessel strike risk for the Rice's whale. Specifically, better documentation of vessel activity in offshore regions where AIS coverage is more limited is especially necessary to quantify vessel strike risk across industries and vessel categories. However, shore-based AIS receivers are limited in their coverage for offshore regions and positions may only sporadically be received. For example, port-based

AIS receivers have a maximum receiving rage of approximately 37 kilometers (23 miles) (USCG n.d.). While repeater stations may be used to improve and extend coverage (USCG n.d.), AIS coverage in offshore regions of the Gulf remains limited. Use of satellite-derived AIS data can serve to fill this data gap and improve our understanding of offshore vessel activity in the Gulf (i.e., Metcalfe et al. 2017). Efforts to ensure compliance with AIS usage, where required, and the accuracy of vessel data input are likely ongoing and must be continued. Analysis of improved offshore data must be conducted using a multi-year timeframe and rooted in a multivariate analysis of vessel movement patterns (i.e., >10 knots and ≤10 knots; daytime and nighttime) relative to Rice's whale core area and proposed critical habitat for different vessel categories and industries. Finally, predictive modeling (i.e., Kaiser 2015) should be conducted to forecast vessel activity and offer an outlook perspective for future vessel traffic in the Gulf.

Adaptations to BOEM's vessel strike model (**Section 5.3**) that incorporate improved animal density, animal behavior, and ship traffic data should be considered a priority for assessing strike risk. Since the underlying framework for the mathematical model and risk assessment tool are already built and tested, modifying its application to industries beyond offshore wind would be a relatively straightforward and cost-effective approach to modeling Rice's whale strike risk in the Gulf. Further, the model should be used to assess the effectiveness of different mitigation strategies, with results that serve as the baseline for recommended or required strike avoidance plans.

Finally, it is recommended that BOEM consider incentives for vessel operators to voluntarily reduce vessel speeds, to implement technology onboard designed to automatically detect large whales in the strike zone so that evasive actions may be taken, and to detect collisions that have occurred. The latter would serve to improve our understanding of cryptic mortality and constitute a database of directly relevant strike risk in the Gulf. Technology, specifically that which can monitor in low visibility conditions (i.e., during nighttime) such as thermal and infrared cameras, has been rapidly developing in recent years and offers a cost-effective way to monitor for marine mammals (Verfuss et al. 2018; Baille and Zitterbart 2022; Paoletti et al. 2023; Richter et al. 2023). Incentives, whether financial, regulatory, or other, can entice companies and vessel operators to implement additional protective measures that ultimately serve to mitigate strike risk for Rice's whales. Voluntary compliance programs have had limited success elsewhere (Redfern et al. 2019; Rockwood et al. 2021; Morten et al. 2022), so consideration of regulatory requirements for large vessels (i.e., over 80 meters [262 feet]) traveling above 10 knots through Rice's whale core area (and critical habitat, if implemented) to use alternative monitoring technologies at nighttime may be warranted. In addition, future recommendations for any vessel speed restrictions should consider vessel class and gross tonnage as these factors may be a better indicator of lethality related to vessel strike then length alone. Importantly, these recommendations are geared specifically toward improving detection capabilities and reducing vessel strikes resulting in injury or mortality for Rice's whales and are not likely to fully eliminate anthropogenic impacts to the species or to the key habitat attributes as identified in the critical habitat proposed rule (**Section 4.1**).

7 Conclusions

Rice's whales are especially vulnerable to vessel strike due to their surface behaviors, especially during the night when they spend up to 88 percent of their time at the surface, and their habitat selection, which overlaps with high levels of vessel traffic in the Gulf. Their very small population size is a confounding risk factor such that any serious injuries or mortalities experienced by individuals could lead to population-level effects. A comprehensive literature review and synthesis was conducted to better understand and assess this risk, which highlighted important data gaps and recommendations for future analyses. Most data gaps center around our understanding of the behavior and ecology of the Rice's whale. As a result, two categories of recommended additional study were developed, including improvements in animal density and distribution data and improvements in understanding the species' behavioral ecology. Additional recommendations were considered that improve our assessment of vessel activity within the Gulf and potential mechanisms that could be implemented to provide an overall reduction in strike risk in the Gulf.

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Appendix A: Literature Review and Synthesis Matrix

Table A-1. Classification matrix and summary table for primary and secondary data sources.

Citation	Rice's Whale (incl. GOM Bryde's Whale)	Bryde's, Omura's, or Eden's Whales	Vessel Strike / Strike Risk	Mitigation Review	Presence / Occurrence Data	Acoustic Data	Dive / Surface Behavior	Habitat Selection / Preference / Suitability	Foraging Behavior / Prey Selection	Models Habitat Use / Suitability	Models Vessel Strike Risk	Summary
Alves et al. (2010)	--	●	--	--	--	--	●	--	●	--	-	This study, the first to use time depth recorders (TDRs) on Bryde's whales (*Balaenoptera edeni*), revealed two distinct dive types and highlighted a significant amount of synchronized deep dive behavior and social association between two individuals tagged off Madeira Island, providing new insights into their foraging patterns and social structures. Mean dive duration was 5.0 ± 1.2 minutes, n =50; maximum 9.4 minutes. **Tag data indicate that feeding occurs at depth and mainly at the bottom of a deep dive, with deeper dive at night than during the day, likely correlated with zooplankton diel migration. From early afternoon through early morning, the majority of the tagged individuals' time was at the surface, likely engaged in resting and respiration rather than traveling or feeding.**
Athayde et al. (2023)	--	●	●	--	●	--	--	--	--	--	--	Vessel collisions are a significant threat to cetaceans, notably larger species like Bryde's whales, which are frequently affected globally. **Long-term research off the northern coast of São Paulo, Brazil, identified 67 Bryde's whales between 2004 and 2022, with 4 percent (n=3) showing scars (sub-lethal) from vessel propellers, indicating vessel collisions, though all individuals appeared to have fully recovered. It is likely that underreporting of Bryde's whale vessel strikes contributes to underestimates of strike risk for the species globally.**

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Barkaszi et al. (2021)*	--	--	●	--	--	--	--	--	--	--	●	This study aimed to evaluate the risk of vessel strikes on large whales and sea turtles in Atlantic offshore wind energy areas, considering various vessel types. The research comprised four stages: characterizing baseline vessel traffic and wind farm operations, developing an analytical framework to calculate encounter numbers, creating a quantitative model for strike risk assessment, and building a geographic user interface (GUI) for scenario creation and result visualization. The GUI enables users to simulate potential encounters between vessels and marine animals, allowing manipulation of vessel activity and animal behavioral responses, with capacity for aggregating results from multiple scenarios. **The model is limited to the Atlantic outer continental shelf (OCS) and does not assess strike risk for the Rice's whale (*B. ricei*).** However, the basis of the model uses surface density layers, dive/surface behaviors, and animal size/swim speed for each species to calculate vessel strike risk based on vessel data characteristic of offshore wind energy development and project-specific vessel routes, transit numbers, speed, etc. as entered by the user.
Best (2023)*	●	--	●	--	--	--	--	●	--	--	●	Since the release of the Biological Opinion on oil and gas activities in the Gulf of Mexico (GOM) in 2020, which used a density surface model to describe the distribution of the critically endangered Rice's whale, a new model has become available. This new model extends the whale's known habitat from the Eastern GOM to the West. This report replicates the ship-strike analysis using the updated distribution model and suggests a new whale area that is able to reduce ship-strike risk, based on location (25.5º N and higher) and depth (100 to 400 meters). Risk reduction was seen regardless of vessel type (oil and gas or all vessels) and speeds (>10 knots and all speeds), using 2015 to 2018 Automatic Identification System (AIS) data. For example, **when considering all vessel types and all vessel speeds, implementing reasonable and prudent measures (RPMs) from the National Marine Fisheries Service (NMFS) 2020 Biological Opinion reduce strike risk by 93 percent for the extended area compared to only 12 percent in the core area.**
Constantine et al. (2015)*	--	●	●	●	--	--	●	--	--	--	--	Collisions between vessels and wildlife, particularly in areas with high vessel traffic like the Hauraki Gulf, New Zealand, pose significant threats to whale populations, as evidenced by a high mortality rate among Bryde's whales due to vessel strikes. **In this study, 85 percent of mortalities with a known cause of death had injuries consistent with vessel strike. Tag data indicated that individuals spent 91 percent of their time at depths within the maximum draft of vessels transiting the region.** Despite challenges in monitoring and mitigating this threat (i.e., re-routing is ineffective because whales are widely dispersed; visual monitoring at night when whales are more likely at the surface is ineffective; passive acoustic monitoring (PAM) is limited to vocalizing individuals and subject to masking), collaborative efforts between scientists and stakeholders have led to the development of a Transit Protocol for Shipping, which **includes voluntary speed restrictions and monitoring plans** to reduce lethal vessel strikes and promote conservation in the region.

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Ebdon et al. (2020)	--	●	●	●	--	--	--	--	--	--	--	The study investigates the effectiveness of voluntary ship-strike mitigation measures introduced in 2013 to protect Bryde's whales in New Zealand's Hauraki Gulf. It contrasts the quicker implementation of voluntary agreements with the uncertain efficacy due to reliance on stakeholder awareness and cooperation. Using AIS and whale sighting data from 2014 to 2016, researchers mapped whale and shipping routes, finding a significant reduction in the risk of lethal ship strikes (from 51 to 26 percent) attributed to ships adhering to a voluntary speed limit of 10 knots. Despite low reporting rates of whale sightings to Harbor Control and minimal ship course diversions based on reports, the study underscores the potential of effective voluntary actions in mitigating threats to marine wildlife. **The efficacy of mitigation measures specific to Bryde's whale strike risk in the Hauraki Gulf (New Zealand) were evaluated and show a 10-knot vessel speed restriction reduced the probability of lethal strikes by half.**
Farmer et al. (2022)*	●	--	--	--	●	--	--	●	--	●	--	Marine Spatial Planning (MSP) uses spatial data and models to evaluate trade-offs when locating ocean industries, with a focus on minimizing conflicts with protected species habitats. In the U.S. GOM, a method was developed to identify suitable aquaculture areas with minimal impact on endangered species, integrating a multi-criteria decision-making framework to optimize site selection and mitigate risks to marine wildlife. This paper highlights the importance of recognizing broader distinct habitat regions for the Rice's whales (i.e., the core area and the extended area) as a conservative measure when assessing risk until more is known about the species' distribution and density. **The Rice's whale core area features seasonal advection of low salinity, high productivity surface waters, and persistent upwelling driven by winds and Loop Current intrusions. The confluence of these features leads to a mixing area with intermediate *chlorophyll-a* (*Chl-a*) concentrations, temperatures, and high salinity bottom water, which is where Rice's whales are most commonly observed (i.e., in the mixing zone). While other regions in the Gulf have similar bottom temperatures, lower surface productivity and higher shipping activity and noise may explain the less frequent observations of Rice's whales in those areas.**
Ferreira et al. (2021)	--	●	●	●	●	--	--	●	--	--	--	The study on Bryde's whales in Macaronesia utilized a 14-year photographic database to assess site fidelity and movement patterns, identifying 59 individuals in Madeira **with both short-term and long-term site fidelity evident**, and some individuals moving between Madeira and the Canaries. The findings highlight the ecological importance of this region for Bryde's whales, emphasizing the need for coordinated conservation efforts among countries and the value of open-access photographic data for research. **Fast ferries in the Canary Islands pose one of the biggest ship-strike risk for large whales including Bryde's whales. Vessel speed restriction recommendations and observer recommendations are in place for some vessel types (i.e., ferries, cargo ships) in the Canary Islands to reduce vessel strikes.**

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Garrison et al. (2020)*	●	--	--	--	●	--	--	--	--	--	--	The report uses visual line-transect survey data (conducted by the NMFS Southeast Fisheries Science Center in the GOM during the summers of 2017 and 2018, as part of the GOM Marine Assessment Program for Protected Species [GoMMAPPS]) to report on abundance, habitats, and spatial distribution of cetaceans to support marine mammal stock assessments under the Marine Mammal Protection Act (MMPA). The findings contribute to the Stock Assessment Reports (SARs) which update the status and management of marine mammal stocks in the GOM. **Abundance from 2017 to 2018 is estimated at 51 individuals (coefficient of variation [CV] 0.53; confidence interval [CI] 20, 130; based on line-transect surveys conducted during 2017 and 2018 [Garrison et al. 2020]).**
Garrison et al. (2023)* *and* Rappucci et al. (2023)*	●	--	--	--	●	--	--	●	--	●	--	From 2003 to 2019, **vessel surveys primarily observed Rice's whales near the 220-meter isobath off the coast of Florida**. One confirmed sighting was in the western GOM near Texas. Additional sightings from other surveys were included to improve detection models. The species distribution model incorporated factors such as depth, *chl-a* concentration, bottom temperature, bottom salinity, and geostrophic velocity components. The model indicated that Rice's whale density is highest in shallow waters with bottom temperatures between 10 and 19°C and intermediate *Chl-a* levels. This habitat mainly occurs in the northeastern GOM, with a similar environment along the shelf break in the western GOM. Although surveys are limited to the northern GOM, it is possible that Rice's whales also inhabit the southern GOM. However, **projections of the SDM beyond the northern GOM should be treated cautiously, as it assumes consistent species-habitat relationships**. Potential high-density areas include regions with similar bathymetric and current characteristics to the core area, particularly near the Campeche Bank.
Garrison et al. (2024)*	●	--	--	--	--	--	--	●	--	●	--	The study focuses on the newly identified Rice's whale, one of the most endangered large whale species, primarily found near the continental shelf break in the northeastern GOM. By analyzing visual line-transect survey data collected from 2003 to 2019, researchers developed spatially explicitly surface density maps to understand the whale's habitat preferences. **The authors found that water depth, surface chlorophyll concentration, bottom temperature, and bottom salinity are crucial factors defining the whale's habitat, influenced by oceanographic features like upwelling and circulation patterns**. This research aids in designating critical habitat under the Endangered Species Act (ESA) and informs MSP to mitigate anthropogenic impacts like wind energy and aquaculture development on Rice's whales.

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Gonçalves et al. (2016)	--	●	--	--	●	--	●	●	--	--	--	This paper presents findings from investigations into Bryde's whales along the São Paulo coast, contributing to our understanding of their occurrence and behavior, particularly in the context of conservation. Sighting surveys conducted from 2003 to 2005 revealed higher rates of sightings and individuals in coastal areas during the summer season, with notable social interactions observed at the 1,200-meter isobath; a total of 71 individuals were observed, with all sightings between the isobaths of 20 and 3000 meters. **Sighting rates were higher in coastal areas during the summer season, suggesting potential feeding in coastal areas and breeding offshore. Dive duration was typically shorter during foraging dives (maximum = 7 minutes) and longer for traveling individuals (maximum = 17 minutes).** The behavioral patterns revealed by this study could have implications for marine protected areas and conservation efforts in Brazil.
Hayes et al. (2023)*	●	--	●	--	●	--	--	--	--	--	--	Rice's whales, closely related to Bryde's and sei whales, were recognized as a distinct species in 2021 and are critically endangered with fewer than 100 individuals remaining. They are primarily found in the northern GOM near De Soto Canyon, with some evidence suggesting occasional sightings along the southeastern U.S. Atlantic coast. Historical records indicate a broader past range, potentially extending to the southern GOM. Recent abundance estimates suggest a population size of around 51 individuals, showing no significant trend over recent survey years. The species faces threats from anthropogenic activities such as oil spills, fishing gear entanglements, and vessel strikes, and their small population size and limited genetic diversity make them highly vulnerable to environmental and demographic stochasticity. **Abundance from 2017 to 2018 is estimated at 51 individuals (CV: 0.53; CI: 20, 130, based on line-transect surveys conducted during 2017 and 2018 [see *Garrison et al. 2020*]).**
Helble et al. (2024)	--	●	--	--	●	●	●	--	--	--	--	This study examines the acoustic and swimming behaviors of Bryde's whales in the central North Pacific, leveraging data from acoustically derived tracks spanning 2011 to 2022 at the U.S. Pacific Missile Range Facility in Kaua'i, Hawai'i. Findings reveal distinct kinematic states and seasonal patterns in movement and calling behavior, providing valuable insights into the behavior of this understudied whale species. **Bryde's whales were tracked with faster swim speeds than other mysticetes (1.7 m/s), and appeared to have more directional travel during daytime than at night, and more between May and August then the remainder of the year.**
Henry et al. (2022)	●	--	●	--	--	--	--	--	--	--	--	Opportunistic reports from 2015 to 2019 were used to calculate human-caused serious injury and mortality rates for baleen whale stocks along the GOM, U.S. East Coast, and Atlantic Canadian provinces. The average annual rates detected were 7.65 for North Atlantic right whales, 16.25 for Gulf of Maine humpback whales, 1.85 for western North Atlantic fin whales, 10.35 for Canadian East Coast minke whales, 0.6 for Nova Scotian sei whales, 0 for western North Atlantic blue whales, and 0 for northern GOM Bryde's whales, with actual levels potentially being much higher due to unreported cases. **The Bryde's whale human-caused mortality/serious injury (M/SI) value remains 0 for the 2015 to 2019 time period; there were no reported injuries and 1 mortality from natural causes for this time period.**

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Izadi et al. (2022)	--	●	--	--	--	--	●	--	●	--	--	Baleen whales, despite being the largest predators, primarily consume plankton and small fish. Unlike many other baleen whales that migrate to polar regions for abundant zooplankton prey, Bryde's whales in warm-temperate waters off New Zealand adapt to variable prey availability, targeting both fish and zooplankton. Through multi-sensor tags and visual observations, it was found that Bryde's whales use specialized feeding tactics depending on the prey type: they use head-slaps to aggregate zooplankton and perform side-lunges, or swim in circles and perform multiple lunges when targeting plankton patches. **Their diet plasticity and dynamic feeding behaviors are believed crucial for adapting to changes in prey availability, which is characteristic of warm-temperate waters that have limited prey resources and are less productive. As cited in Izadi et al. (2022), Izadi (2018) (doctoral dissertation) documented tagged individuals feeding only during the day and resting most of the night, which may save energy resources; daytime foraging may be sufficient for this species, which does not undergo seasonal migrations like most other large whale species.**
Kiszka et al. (2023)*	●	--	--	--	--	--	--	--	●	--	--	Understanding prey selection drivers in marine predators is essential for investigating ecosystem structure and function. For the critically endangered Rice's whale in the GOM, research using Bayesian stable isotope mixing models indicated a preference for high-energy schooling fish, particularly *Ariomma bondi* (a small schooling fish found in demersal habitats over muddy bottoms at depths of 50 to 500 meters), suggesting that energy content, rather than prey abundance, primarily drives prey selection. Prey availability (by use of trawl data) and prey selection (by use of stable carbon and nitrogen isotope mixing models) were assessed for Rice's whales in the core area. Ten skin and blubber biopsy samples were collected in 2010 (n=1) and 2018 to 2019. **The data indicate that Rice's whales in the northeastern GOM primarily prey on high-energy content species, particularly *A. bondi*, while other abundant species like *M. weitzmani* are less significant in their diet. These results suggest selective prey selection driven mainly by prey energy content as opposed to abundance.** The authors also note that deep dives are energetically expensive and therefore requires high quality prey to meet their energetic requirements.
Kok et al. (2023)*	●	--	●	--	--	--	●	--	●	--	--	Rorqual foraging behavior is highly variable and critical to Rice's whale fitness, influenced by species, prey type, and foraging conditions. The endangered Rice's whales, with a population of fewer than 100 individuals, were studied using suction-cup tags on two individuals to reveal their predominantly bottom-focused lunge-feeding behavior. The whales exhibited unique patterns, including circling before lunging and a lower lunge rate compared to other lunge-feeding baleen whales, potentially reflecting their preference for fish or different foraging conditions. **Lunge-feeding behaviors were recorded most commonly near the sea bottom during 6 to 10 minute foraging dives. Extended periods of time were spent at the surface during the night.**
LaBrecque et al. (2015)	●	--	--	--	--	--	--	●	--	--	--	This review identifies and supports the delineation of 12 biologically important areas (BIAs) in U.S. waters of the GOM. For the Bryde's whale, **observations in the GOM are mainly limited to the 100 to 300-meter isobaths in the eastern Gulf**, which denotes the year-round BIA for the species.

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Laist et al. (2001)*	--	●	●	●	--	--	--	--	--	--	--	Ship strikes with great whales have been a concern since the late 1800s, becoming more frequent from the 1950s to the 1970s due to increased ship numbers and speeds. Among the 11 species affected, fin whales are struck most often, followed by right whales, humpback whales, sperm whales, and gray whales. Collisions often result in severe injuries, particularly when involving ships over 80 meters long traveling at speeds of 14 knots or faster, posing a significant threat to vulnerable whale populations like the northern right whales in the western North Atlantic. **Records of collisions with Bryde's whales are rare, although strikes may be underrepresented for small mysticetes due to their size.** Implementing measures to reduce vessel speeds below 14 knots in areas prone to ship strikes could help mitigate this issue.
Litz et al. (2022)*	●	--	--	--	●	--	--	--	--	--	--	The National Oceanic and Atmospheric Administration (NOAA) Southeast Fisheries Science Center (SEFSC) created spatial density models (SDMs) for cetaceans and sea turtles in the GOM, using data from ship-based and aerial surveys conducted from 2003 to 2019. These models, based on generalized additive modeling (GAM), analyze the relationship between species abundance and environmental variables (oceanographic conditions from 2015 to 2019). The models were extrapolated to predict high-density areas beyond U.S. waters in the GOM, though these predictions should be interpreted cautiously. The dataset includes 19 shapefiles for the SDMs of each species or species group. **Rice's whale dataset is used and referenced in Best (2023).**
Maze-Foley and Mullin (2006)*	●	--	--	--	●	--	--	--	--	--	--	The paper provides a comprehensive overview of cetacean distribution and behavior in the oceanic northern GOM. It highlights the impacts of the MMPA and concerns over oil and gas industry activities on cetacean research in the region. The study conducted nine ship surveys over 11 years, covering 45,462 kilometers in the continental shelf-edge and oceanic waters (>100 meters depth), identifying 18 cetacean species from 1,868 sightings. Key findings include detailed descriptions of species distribution, group sizes, and associations with sea surface temperature, water depth, birds, and fish. Bryde's whales were the only balaenopterid whale sighted during these surveys (n=15) and were likely not sei whales according to the authors (based on morphological features); **all balaenopterid/Bryde's whale sightings occurred within the core area and in a very narrow depth range (199 to 302 meters) and in small group sizes (<3).**
Mullin (2007)*	●	--	--	--	●	--	--	--	--	--	--	In the GOM, ship-based surveys conducted during 2003 and 2004 in oceanic waters over 200 meters deep revealed a diverse cetacean community with at least 17 species sighted across 10,933 kilometers of survey effort. The most commonly sighted species included pantropical spotted dolphins, sperm whales, and bottlenose dolphins, with some species showing regional distributions. Abundance estimates varied, with notable differences from previous surveys, particularly for pantropical spotted dolphins and sperm whales, reflecting improved counting methodologies. **All Bryde's whale detections occurred in the core area.**

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Mullin and Fulling (2004)*	●	--	--	--	●	--	--	--	--	--	--	Ship-based, line-transect surveys conducted in oceanic waters (>200 meters deep) of the northern GOM within U.S. waters from 1996 to 1997 and 1999 to 2001 provided data on the abundance of cetaceans. The surveys covered an area of 380,432 km^2 and yielded minimum abundance estimates based on 12,162 kilometers of effort and 512 sightings of at least 19 species. Pantropical spotted dolphins, sperm whales, and dwarf/pygmy sperm whales were among the most commonly sighted species, with variations in abundance and distribution observed among different species in the region. **All Bryde's whale sightings (n=40; mean group size=2) occurred in the Northeast Slope region of the GOM.**
Mullin and Hoggard (2000)*	●	--	--	--	●	--	--	--	--	--	--	The GulfCet I study provided seasonal abundance and distribution data for 19 cetacean species in continental shelf and slope waters of the north-central and northwestern GOM. Species such as pantropical spotted dolphins, bottlenose dolphins, striped dolphins, and others were widely distributed across different water depth ranges. The GulfCet II program extended these surveys to the northeastern GOM, focusing on seasonal patterns and comparing abundance estimates with previous studies to establish baselines for monitoring trends over time. **Bryde's whales were detected three times during vessel-based surveys and two times during aerial visual surveys; all Bryde's whale detections occurred in the core area near the 100-meter isobath.**
NOAA NMFS (2020)*	●	--	●	●	--	--	--	--	--	--	●	**Section 8.4:** This section outlines the evaluation of vessel traffic data concerning the potential impact on ESA-listed species, considering data provided by BOEM and supplemented by AIS data for a more detailed representation. While Bureau of Ocean Energy Management (BOEM) data measures vessel trips based on port calls, AIS data provides finer resolution regarding vessel routes, distances traveled, and speeds, allowing for more realistic estimates of ESA-listed species exposure to vessel traffic. AIS data reveals that Oil and Gas Program vessel traffic comprises approximately 43 percent of total traffic in the GOM (measures by distance traveled), differing significantly from the 9.23 percent estimated by BOEM. The proposed action is estimated to involve a maximum of 173,002 vessel trips annually, constituting approximately 20 percent (19.77 percent) of the total vessel trips in the GOM. **Section 8.4.2.1:** BOEM-proposed vessel strike mitigation is likely to result in a total of 23 vessel strikes of Bryde's whales, with 17 of these strikes expected to result in serious injury or mortality and six strikes expected to result in minor or no injuries. *Assumptions: a reduction in vessel speed to ten knots and below is likely to lead to a 90 percent reduction in the number of all vessel strikes, regardless of severity, and 35 percent of oil and gas traffic occurs within the mitigation area, which would be limited to a 10-knot speed restriction*. If a 10-knot speed restriction results in a 90 percent reduction in the number of vessel strikes, then the overall reduction of vessel strike risk to Bryde's whales due to oil and gas vessel traffic of all speeds is approximately 31 percent. **The proposed speed restriction RPAs for oil and gas vessel activity over 50 years would result in 12 vessel strikes with serious injury or mortality and the remaining four with no or minor injuries.**

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NOAA NMFS (2021)*	●	--	●	--	--	--	--	--	--	--	--	The Gulf of Mexico Oil and Gas Program Incidental Take Statement (as amended April 26, 2021) indicated the following incidental take considering the extent of the RPA in NOAA NMFS (2020): • No take of GOM Bryde's whales is expected from pile driving activities. • Take is anticipated for GOM Bryde's whales from seismic survey sound associated with geophysical survey activities. • **Take is anticipated for GOM Bryde's resulting from vessel strike. Since NMFS states "Feasible monitoring techniques for directly detecting the full extent of take (either lethal or nonlethal) of these species resulting from vessel strike do not exist", vessel activity level is used as a proxy for determining anticipated vessel strike take numbers (see Section 8.4 of the NOAA NMFS 2020).** •
NOAA NMFS (2023)*	●	--	●	--	●	--	●	●	●	--	--	The document provides detailed analysis and information necessary for the designation of critical habitat for Rice's whale under the ESA. It covers essential biological and physical features, management considerations, economic impacts, and potential implications for activities in the GOM, along with compliance with regulatory requirements under the ESA and the Regulatory Flexibility Act. **A comprehensive literature review is conducted for: species description and life history; vocalizations and sound; distribution, movement, and habitat use; diet and foraging; and abundance.**
Redfern et al. (2024)*	--	--	●	●	--	--	--	--	--	--	●	The study focuses on evaluating strategies to reduce the risk of vessels striking North Atlantic right, humpback, fin, and sei whales on the US East Coast. Evaluating strategies to reduce vessel strikes on whales requires balancing species protection with economic impacts. Previous simplistic methods lack important elements of vessel strike risk, while complex methods often rely on unestimated parameters. The study introduces a simple metric, Total PLETHd, which incorporates vessel speed, transit distance, and whale distribution to assess risk reductions. **Findings indicate that a 10 knot speed restriction effectively reduces risk and broad area speed restrictions are almost as effective as those applied across all East Coast waters, benefiting multiple whale species. The areas primarily defined to protect right whales also provide protection for humpback, fin, and sei whales.** The study highlights the importance of considering both the whale and vessel metrics used in risk estimation.
Rice et al. (2014)*	●	--	--	--	●	●	--	--	--	--	--	The study deployed marine autonomous recording units (MARUs) in the northeastern GOM from 2010 to 2012 (core area) to study Bryde's whales' acoustic ecology post-*Deepwater Horizon* oil spill, revealing a poorly documented acoustic repertoire for this sub-population. **The recordings captured numerous stereotyped, low-frequency signals, categorized by spectral and temporal properties, suggesting Bryde's whales as the likely source.** These findings potentially unveil previously undocumented calls, which could enhance future PAM efforts to assess the population dynamics and status of Bryde's whales in this region.

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Rockwood et al. (2021)*	--	--	●	●	--	--	--	--	--	--	●	Vessel strikes are a major cause of large whale mortality globally. The Santa Barbara Channel, California, has one of the highest predicted whale mortality rates from vessel strikes in U.S. Pacific waters. Since 2007, the NOAA has requested voluntary vessel speed reductions (VSRs) for ships over 300 gross tonnage (GT) in this area to mitigate whale strikes. A study using whale density data and AIS vessel data estimated whale mortality under different management scenarios. For 2012 to 2018, it was estimated that during summer/fall (June to November), an average of 8.9 blue whales, 4.6 humpback whales, and 9.7 fin whales were killed by ship strikes each year, which is 13 to 26 percent higher than previously estimated. Winter/spring (January to April) humpback whale mortality was assessed for the first time, estimating an average of 5.7 deaths per year. Poor compliance with the VSR resulted in minimal or no reduction in strike mortalities. The study found that if 95 percent compliance with VSRs were achieved in the shipping lanes, whale deaths could be reduced by 22 to 26 percent. Extending VSRs to additional areas with similar compliance could reduce strike mortalities by 30 percent. Overall, with 95 percent compliance in all areas, vessel strike mortalities could decrease by 21 to 29 percent relative to the entire study area. To effectively reduce whale mortalities from vessel strikes in this region, **the study recommends expanding VSR areas and increasing voluntary compliance, or considering mandatory speed limits if high cooperation levels are not otherwise achievable**.
Rosel and Garrison (2019)*	●	--	--	--	●	--	--	●	--	●	--	Map of Rice's Whale **Core Distribution Area** (June 2019) in the northeastern GOM.
Rosel and Wilcox (2014)*	●	--	--	--	--	--	--	--	--	--	--	Bryde's whales are the sole year-round resident baleen whale species in the northern GOM, with a severely restricted range and an estimated population abundance of 33 individuals. Genetic analysis using mitochondrial DNA and nuclear genes revealed **extremely low diversity, with only two mitochondrial haplotypes and limited microsatellite variation**. Phylogenetic reconstruction indicated that GOM Bryde's whales are evolutionarily distinct from other members of the Bryde's whale complex, suggesting a unique evolutionary trajectory deserving of separate taxonomic recognition. The findings highlight conservation concerns due to their small population size and low genetic diversity.

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Rosel et al. (2016)*	●	--	●	--	●	--	●	--	--	--	--	The NMFS received a petition from the Natural Resources Defense Council on September 18, 2014, to list the GOM population of Bryde's whales as an endangered distinct population segment under the ESA, which prompted a comprehensive review. The petition was based on substantial scientific information indicating that an ESA listing may be warranted, given the whales' restricted distribution, low genetic diversity, and susceptibility to numerous threats including habitat modification, oil spills, vessel collisions, and anthropogenic sound. Despite no specific listing recommendation from the Status Review Team, it was unanimously agreed that the GOM Bryde's whales are at high risk of extinction due to their small population size and vulnerability to various anthropogenic impacts, highlighting the urgent need for conservation and management measures. **Vessel traffic in the GOM is highest in the north-central and western regions; comparatively less traffic (based on AIS tracks) is evident within the core area, though several shipping lanes do bisect it. Only one Bryde's whale vessel strike is documented within the GOM, though collisions are likely underreported. Constantine et al. (2015) reports high levels of vessel strike in Hauraki Bay, New Zealand, likely driven by their distributional overlap with shipping lanes and their surface/dive behavior (i.e., individuals spend 91 percent of their time at night in the top 14 meters of the water column). Soldevilla et al. (2017) report GOM Bryde's whales spend 88 percent of their time at night in the top 15 meters of the water column. It is expected that larger and faster ships will increasingly utilize the GOM, posing greater risk to Bryde's whales.**
Rosel et al. (2021)*	●	●	--	--	--	--	--	--	--	--	--	Bryde's-like whales constitute a complex of medium-sized baleen whales found in tropical waters across all major ocean basins. Currently recognized as a single species, *Balaenoptera edeni*, with two subspecies, recent genetic data identified a new, genetically distinct lineage of Bryde's-like whale primarily in the northern GOM. A comprehensive morphological examination of a complete skull from these whales revealed diagnostic features distinguishing them from other medium-sized baleen whale taxa. **Genetic sampling of 36 individuals from the GOM lineage supports the existence of an undescribed species of *Balaenoptera* in this region.**
Sasaki et al. (2013)	--	●	--	--	●	--	--	●	--	●	--	This study investigated habitat differentiation between sei and Bryde's whales in the western North Pacific from May to August 2004 and 2005, focusing on oceanographic features like sea surface temperature (SST), sea surface *Chl-a*, sea surface height anomalies (SSHAs), and depth. **It found that the two whale species utilized habitats with distinct SST, *Chl-a*, and SSHA ranges, and identified the 0.25 mg/m³ *Chl-a* contour as a significant indicator separating their habitats.** Generalized linear models revealed that SST influenced habitat use patterns and varied seasonally, with the boundary between their potential habitats shifting northward.
Sirović et al. (2014)*	●	--	--	--	●	●	--	--	--	--	--	Bryde's whales in the GOM are thought to be a distinct population with a restricted range around DeSoto Canyon. **This study describes the first documented recordings of Bryde's whale calls in the GOM, identifying distinctive pulse pair calls and suggesting their possible residency and small population size in the region.**

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Soldevilla et al. (2017)*	●	--	●	●	--	--	●	●	●	--	--	Bryde's whales are the sole resident baleen whale species in the GOM, where their population is extremely rare and has a restricted distribution, representing a unique evolutionary lineage. This study assessed the overlap of GOM Bryde's whales with commercial shipping and fisheries, highlighting potential threats such as vessel strikes and entanglement in fishing gear, especially given their diel diving behavior and frequent near-surface presence at night. Management strategies to mitigate these threats are crucial for the recovery of this vulnerable population. Using SEFSC survey data (1992 to 2015; 99,652 kilometers shipboard trackline survey), 50 sightings of 112 Bryde's whale detections were made. Sightings: All sightings were in the 100 to 400-meter isobath; 92.9 percent of the detections were inside the BIA, with the remainder just outside. Sat tag, location: One satellite tag was deployed and remained on the individual for 33 days, coving a total track length of 780 kilometer. The majority of time was spent in the De Soto Canyon region (28 days), with one excursion southeast of the canyon and back (5 days). Suction-cup tag: one individual was tagged, with tag lasting 2.7 days on the animal. **The individual exhibited a diel dive pattern as follows: deep (>70 meters) daytime dives; shallow (<30 meters) nighttime dives.** 123 deep dives were recorded (only 3.25 percent occurred at night). Daytime dives: Deepest dive was 271 meters; animal was likely foraging at or near the bottom based on lunge patterns. **The tagged animal spent 47 percent of its time in the top 15 meters of the water column during the daytime. Night dives: During nighttime, the animal remained close to the surface, made shallow dives with occasional deeper dive (deepest three: 125 to 150 meters); whale spent 88 percent of its time in the top 15 meters of the water column.** Vessel activity in the BIA: from October 2009 to 2010, less than one vessel transit was recorded per week in 98.5 percent of the BIA, with the remainder averaging one per week to two per day, though vessel data is likely underrepresented based not he limitations of AIS. Summary: the tag data represent highly consistent diel dive behavior with presumed foraging at/near the bottom over the 2.7 days the tag was attached. The authors indicate that it is reasonable to infer that this behavior is representative of the GOM Bryde's whale population as other tagged baleen whales also display similar stereotypical diel dive behaviors linked to foraging and prey distribution. Strike Risk: Overall, the animal spent 70 percent of its total time within 15 meters of the surface, which overlaps with the draft of deep-draft vessels that transit the region. While only one GOM Bryde's whale strike has been recorded, the incidence of ship strike is likely underreported (i.e., Williams et al. 2011 suggest 98 to 99.6 percent of ship strikes are unrecovered). Mitigation recommendations: vessel speed reduction rules and re-routing measures have been successful at reducing risk for North Atlantic right whales (NARWs); identifying appropriate habitat should be a priority and then these measures could be implemented in the GOM.

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Soldevilla et al. (2022a)*	●				●	●						The study focuses on the acoustic validation and characterization of the recently named Rice's whale, one of the most endangered whales in the world, to improve understanding of its spatiotemporal occurrence patterns crucial for conservation efforts. **Using sonobuoys and passive acoustic tagging (all within the core area), the researchers identified and attributed several call types, including long-moan calls, downsweep sequences, and tonal sequences, to Rice's whales, while ruling out anthropogenic sources.** This validation and characterization of the call repertoire provide foundational knowledge necessary for employing PAM to aid in the conservation of these critically endangered whales.
Soldevilla et al. (2022b)*	●	--	--	--	●	●	--	--	--	--	--	The Rice's whale, an endangered species with fewer than 100 individuals remaining, is the only year-round resident baleen whale in the GOM, primarily found near De Soto Canyon. Recent studies using long-term passive acoustic recordings reveal the presence of 6 new variants of Rice's whale long-moan calls in the northwestern GOM, indicating a broader distribution than previously known, which has implications for conservation efforts and habitat designation. **Rice's whale vocalizations were recorded outside the core area, but detections were sparce compared to the northeastern GOM: fewer calls were detected on fewer days in the western GOM, potentially indicating fewer whales or more sparse occurrences of individuals in the northwestern GOM. However, the data does indicate a persistent presence of Rice's whales in the northwest GOM, which coincides with high levels of anthropogenic activities. It is unknown if Rice's whales occur in the north-central GOM or travel between the northwestern and northeastern areas.**
Soldevilla et al. (2024)*	●	--	--	--	●	●	--	--	--	--	--	Rice's whales, one of the world's most endangered marine mammals, are primarily found in the GOM with an estimated population of 51 individuals concentrated along the northeastern shelf break. Long-term PAM has revealed their presence in waters off Texas and Mexico, highlighting the need for comprehensive transboundary conservation efforts to mitigate threats from industrial activities and climate change. **Rice's whale calls were detected regularly and throughout the year, present on 25 to 33 percent of days (depending on the receiver), indicating the species' regular occurrence in the northwestern GOM. Calls were also detected sporadically in the western GOM in Mexican waters (15 percent of days). These occurrences int he western GOM overlap with high levels of anthropogenic activities.**

Citation	Rice's Whale (incl. GOM Bryde's Whale)	Bryde's, Omura's, or Eden's Whales	Vessel Strike / Strike Risk	Mitigation Review	Presence / Occurrence Data	Acoustic Data	Dive / Surface Behavior	Habitat Selection / Preference / Suitability	Foraging Behavior / Prey Selection	Models Habitat Use / Suitability	Models Vessel Strike Risk	Summary
van der Hoop et al. (2013)*	●	--	●	--	--	--	--	--	--	--	--	This study evaluated the effectiveness of regulatory actions by the U.S. and Canadian governments aimed at reducing whale mortality caused by human activities, such as vessel strikes and entanglement in fishing gear, from 1970 to 2009. The results indicated that human-caused mortalities, primarily due to entanglements and vessel strikes, exceeded sustainable levels for some whale species, and regulatory measures have not significantly reduced these lethal effects on a population-wide basis. At least 1,762 confirmed mortalities comprising 8 large whale species were recorded from 1970 to 2009. Species were identified in 85 percent of cases and cause of death identified in 42.6 percent of mortalities. Of those, 66.9 percent were resultant from human activities. 22.8 percent of mortalities resulted from vessel strikes; one Bryde's whale mortality is attributed to vessel strike. The leading cause of mortalities for fin and right whales were vessel strikes. **Bryde's whales died of non-human causes more frequently than expected**, and sei whales died of vessel strike more than expected. Recorded human-caused mortality for Bryde's whales (and minke, fin, and sperm whales) was lower than their Potential Biological Removal (PBR) level. **Williams et al. (2011) estimated between 0 to 6.2 percent of mortalities in the GOM go undetected. Additionally, coastal species are more likely to be recorded and documented than pelagic-dwelling species.**
Van Waerebeek et al. (2007)*	--	●	●	--	--	--	--	--	--	--	--	Collisions between vessels and large whales in the Northern Hemisphere are well documented, but less attention has been given to similar incidents in the Southern Hemisphere and to small cetaceans globally. A compiled experimental database of 256 incidents (119 large whales, 137 small cetaceans) was created for rapid assessment, revealing confirmed collisions for 25 species and probable collisions for 10 others. Species like southern right, humpback, and Bryde's whales are heavily impacted, with significant mortality observed in southern right whale populations off South Africa and eastern South America. A total of 13 vessel collisions with Bryde's whales (Australia, New Zealand, and Ecuador) were assessed, with 5 confirmed and 8 unconfirmed. **Collisions with Bryde's whales, once considered rare, have been increasingly documented, suggesting underreporting in (sub)tropical regions. Recent cases include specimens found dead with propeller-inflicted traumas in Brazil and New Zealand, indicating a higher frequency of collisions with vessels than previously believed.**
Vanderlaan and Taggart (2007)*	--	--	●	●	--	--	--	--	--	--	●	This study analyzes historical records of vessel strikes on large whales to determine the relationship between vessel speed and the likelihood of causing lethal injuries. **The analysis reveals that the probability of a lethal injury to whales increases significantly with vessel speed, particularly between 8.6 and 15 knots, where the probability rises from 0.21 to 0.79**. The probability of lethal injury drops below 50 percent at speeds under 11.8 knots and approaches near certainty at speeds above 15 knots. The study suggests that implementing vessel speed limits could significantly reduce the lethality of vessel strikes on endangered whale species, especially the North Atlantic right whale. The findings provide a critical basis for policy decisions regarding maritime traffic regulations aimed at protecting large whale populations.

• = applicable; -- = not applicable; * = primary literature; AIS = Automatic Identification System; BIA = biologically important area; BOEM = Bureau of Ocean Energy Management; *Chl-a* = *chlorophyll-a*; CV = coefficient of variation; ESA = Endangered Species Act; GAM = generalized additive modeling; GOM = Gulf of Mexico; GoMMAPPS = Gulf of Mexico Marine Assessment Program for Protected Species; GUI = graphic user interface; GT = gross tonnage; MARU = marine autonomous recording unit; M/SI = mortality/serious injury; MMPA = Marine Mammal Protection Act; MSP = marine spatial planning; NARW = North Atlantic right whale; NMFS = National Marine Fisheries Service; NOAA = National Oceanic and Atmospheric Administration; OCS = outer continental shelf; PBR = Potential Biological Removal; PAM = passive acoustic monitoring; RPM = reasonable and prudent measure; SAR = stock assessment report; SDM = spatial density models; SEFSC = Southeast Fisheries Science Center; SSHA = sea surface height anomaly; SST = sea surface temperature; TDR = time depth recorded; VSR = vessel speed reduction.

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