Tab E, No. 8(b)

NOAA Technical Memorandum NMFS-SEFSC-692

STATUS REVIEW OF BRYDE'S WHALES (*BALAENOPTERA EDENI*) IN THE GULF OF MEXICO UNDER THE ENDANGERED SPECIES ACT

Patricia E. Rosel, Peter Corkeron, Laura Engleby, Deborah Epperson, Keith D. Mullin, Melissa S. Soldevilla, Barbara L. Taylor

U.S. DEPARTMENT OF COMMERCE
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December 2016

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NOTICE

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Photo credit: Bryde's whale surfacing in the northern Gulf of Mexico. NOAA NMFS taken under MMPA permit 779-1633 to the NMFS SEFSC.

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EXECUTIVE SUMMARY

On September 18, 2014 the National Marine Fisheries Service (NMFS) received a petition from the Natural Resources Defense Council requesting that the Gulf of Mexico population of Bryde's whales, *Balaenoptera edeni*, be listed as an endangered distinct population segment (DPS) under the Endangered Species Act (ESA) and that NMFS designate critical habitat for these whales. NMFS reviewed the petition, concluded that the petition presented substantial scientific information indicating that an ESA listing may be warranted, and committed to conducting an ESA status review of Gulf of Mexico Bryde's whales. NMFS formed a Status Review Team (SRT or 'Team') of scientists with diverse backgrounds to review the best available scientific information on Bryde's whales in the Gulf of Mexico and assess their extinction risk. The Team considered a variety of scientific and technical information. This document reports the results of its comprehensive ESA status review of Bryde's whales in the Gulf of Mexico. The SRT did not make any listing recommendations regarding status under the ESA. Those listing determinations will be made separately by a NMFS management team.

The Bryde's whale is a large baleen whale found in tropical and subtropical waters worldwide. Currently two subspecies of Bryde's whales are recognized: a smaller form, *B. e. edeni*, found in the Indian and western Pacific oceans, primarily in coastal waters, and a larger, more pelagic form, *B. e. brydei*, found worldwide. Bryde's whale distribution in the Gulf of Mexico is currently restricted to a small area in the northeastern Gulf near De Soto Canyon in waters between 100 and 400 m depth along the continental shelf break, although information on their potential occurrence in the southern Gulf of Mexico is sparse. This population exhibits very low levels of genetic diversity and significant genetic divergence from other Bryde's whales, with 24–26 fixed nucleotide differences in the mitochondrial DNA control region between the Gulf of Mexico population and *B. e. edeni* and *B. e. brydei* sampled worldwide. This level of divergence indicates that Bryde's whales in the Gulf of Mexico represent a unique evolutionary lineage and that they are genetically as different from the currently recognized subspecies as the subspecies are from one another, and that the whales in the Gulf of Mexico should receive equivalent taxonomic standing.

The Team considered this level of genetic divergence to be significant and asked the Society for Marine Mammalogy's Committee on Taxonomy (an independent group of experts on cetacean taxonomy) to provide their expert opinion on the level of taxonomic distinctiveness of this population based on the best available science, similar to what was done for the humpback whale ESA status review. The Committee stated that it is "'highly likely' that the Gulf of Mexico Bryde's whales comprise at least an undescribed subspecies" of what is currently recognized as *B. edeni*. The Team concurred with the Committee's conclusion and therefore conducted this status review at the level of subspecies.

While all recent confirmed sightings of Bryde's whales have been in the northeastern Gulf of Mexico, Reeves et al. (2011), suggested, based on whaling records, that historically Bryde's whales had a broader distribution that included waters in the north-central and southern GOMx. In addition to having a very small geographic range, the abundance of these whales is very low. The most recent abundance estimate obtained using standard visual line-transect methods during a 2009 large-vessel survey of the U.S. waters of the Gulf of Mexico is 33 (coefficient of variation (CV) = 1.07). A 2nd estimate, obtained by incorporating visual survey data collected between1992 and 2009 to create density habitat models (and corrected for availability bias) is 44 (CV = 0.27). The Team unanimously agreed that even allowing for the uncertainty about the presence of Bryde's whales in non-U.S. waters of the Gulf of Mexico, given the best available science, there are fewer than 250 mature individuals, and more than likely the population contains fewer than 100 individuals, with 50 or fewer being mature. Therefore, the Gulf of Mexico Bryde's whale population is currently a dangerously small population. The Team also agreed that it is likely that this group is at or below the near-extinction population level.

The small population size and restricted distribution alone place Gulf of Mexico Bryde's whales at high risk of extinction. The Team also evaluated the ESA Section 4(a)(1) factors and qualitatively assessed the current and future severity and level of certainty for the potential impact of 27 individual threats to Gulf of Mexico Bryde's whales. The factors thought to pose the greatest threat to Gulf of Mexico Bryde's whales include habitat destruction, modification or curtailment of habitat range during energy exploration and development, and oil spills, vessel collisions, anthropogenic noise during seismic surveys, and small population effects, particularly demographic stochasticity, genetics (inbreeding depression, loss of potentially adaptive genetic diversity and accumulation of deleterious mutations), and stochastic and catastrophic events. Fishery interactions may also pose a threat, but more research is necessary to determine the level of impact from this threat. The extensive evaluation of threats should help to guide future conservation and management actions.

The Team unanimously agreed that Gulf of Mexico Bryde's whales are at high risk of extinction as a result of their small population size and the suite of anthropogenic threats posed primarily by energy exploration, development and production, and vessel collisions. Small-scale incremental impacts over time or a single catastrophic event could result in extinction.

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LIST OF ABBREVIATIONS AND ACRONYMS

The following are standard abbreviations for acronyms and terms found throughout this document

BIA	Biologically Important Area
CI	Confidence Interval
CPA	Central Planning Area
CV	Coefficient of Variation
dB	decibel
DNA	Deoxyribonucleic Acid
DPS	Distinct Population Segment
DWH	*Deepwater Horizon*
EEZ	Exclusive Economic Zone
EPA	Eastern Planning Area
ESA	Endangered Species Act
fm	fathom
GOMx	Gulf of Mexico
HAB	Harmful Algal Bloom
HARP	High-frequency Acoustic Recording Package
Hz	Hertz
kg	kilogram
km	kilometer
lb(s)	pound(s)
m	meter
MARU	Marine Acoustic Recording Unit
mi	mile
MMHSRP	marine Mammal Health and Stranding Response Program
MMPA	Marine Mammal Protection Act
MPA	Marine Protected Area
mtDNA	mitochondrial Deoxyribonucleic Acid (DNA)
NEFSC	Northeast Fisheries Science Center
NMFS	National Marine Fisheries Service
nmi	nautical mile
PLL	Pelagic Longlines
POP	Persistent Organic Pollutant
s	second
SE	Standard Error
SEFSC	Southeast Fisheries Science Center
SRT	Status Review Team
WPA	Western Planning Area
yr(s)	year(s)
µPa	microPascal

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INTRODUCTION

Scope and Intent of the Present Document

This status review responds to a September 18, 2014 petition from the Natural Resources Defense Council to list the Gulf of Mexico (GOMx) population of Bryde's whale, *Balaenoptera edeni*, as an endangered distinct population segment (DPS) under the Endangered Species Act (ESA) and to designate critical habitat. Under the ESA, if a petition is found to present substantial scientific or commercial information indicating that the petitioned action may be warranted, a status review shall be commenced (16 U.S.C 1533 (b)(3)(A)). The National Marine Fisheries Service (NMFS) determined that the petition contained substantial scientific or commercial information indicating that the petitioned action may be warranted (80 FR 18343 2015), April 6, 2015). NMFS then requested from the public information on Bryde's whales in the GOMx including: (1) historical and current distribution, abundance, and population trends; (2) life history and biological information including adaptations to ecological settings, genetic information to assess paternal contribution and population connectivity, and movement patterns to determine population mixing; (3) management measures and regulatory mechanisms designed to protect the population; (4) any current or planned activities that may adversely impact them; and (5) ongoing or planned efforts to protect and restore the population and its habitat. The ESA stipulates listing determinations should be made on the basis of the best scientific and commercial information available. The agency convened a Status Review Team (SRT) comprised of experts in the fields of marine mammal biology and ecology, conservation biology, taxonomy, population dynamics, acoustics, and marine policy and GOMx management. The SRT reviewed all the available information, including that provided by the public, and then conducted a comprehensive evaluation of the Gulf of Mexico population of Bryde's whales that determines (1) whether the Gulf of Mexico population qualifies as a DPS, subspecies, or species; (2) summarizes the available information on the biology and threats to the population; (3) evaluates potentially significant threats to the population; and (4) assesses the extinction risk. This report describes the SRT's deliberations and conclusions. The draft status review was submitted to independent peer reviewers and comments and information received from them were addressed and incorporated as appropriate before finalizing the report.

Key Questions in the ESA Evaluation

In determining whether a listing under the ESA is warranted for Bryde's whales in the Gulf of Mexico, two key questions must be addressed:

1. Is the entity in question a "species" as defined by the ESA? "Species" eligible for listing also include subspecies and, for vertebrates, DPSs.
2. If so, is the species threatened or endangered?

The ESA (section 3) defines the term "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range." The term "threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." NMFS considers a variety of information in evaluating the level of extinction risk faced by a species and in deciding whether the species is threatened or endangered. Important considerations included (1) the absolute number of animals and their spatial and temporal distribution; (2) the current abundance in relation to historical abundance and carrying capacity of the habitat; (3) threats; and (4) recent events (e.g., change in management or catastrophic events) that have predictable consequences for the species. Additional demographic risk factors, such as abundance, spatial distribution, growth rate and productivity, and genetic diversity are also considered in evaluating a species' extinction risk.

NMFS is required by law (ESA Sec. (4)(1)) to determine whether a recognized species is endangered or threatened based on one or more of the following risk factors:

A. The present or threatened destruction, modification, or curtailment of its habitat or range;
B. Over use for commercial, recreational, scientific or educational purposes;
C. Disease or predation;
D. The inadequacy of existing regulatory mechanisms; and
E. Other natural or man-made factors affecting its continued existence.

According to the ESA, this determination must be made on the basis of the best scientific and commercial information available regarding the species' current status, including existing measures to conserve the species.

Summary of the Bryde's Whale Listing Petition

On September 18, 2014, NMFS received the petition from the Natural Resources Defense Council to list the Gulf of Mexico population of Bryde's whale, *B. edeni*, as an endangered DPS under the ESA and designate critical habitat for the population. The petition argues that the population meets the Services' requirements for identifying a DPS eligible for listing. The petition also asserts that the population meets three of the five listing factors: (1) the present or threatened destruction, modification, or curtailment of its habitat or range; (2) the inadequacy of existing regulatory mechanisms; and (3) other natural or manmade factors affecting its continued existence. The petition cites the following as primary threats to the population: vessel collision (ship strike), acoustic impacts from intensive oil and gas exploration and commercial shipping, bioaccumulation of persistent organic pollutants, and the long-term effects of the *Deepwater Horizon* oil spill. The petition also states that the small size of the Gulf of Mexico Bryde's whale population puts it at greater risk from all these threats, as well as demographic and environmental stochasticity. The petition concludes that the Gulf of Mexico Bryde's whale must be listed as endangered due to small population size and the cumulative effects from the threats listed above.

BACKGROUND INFORMATION ON BRYDE'S WHALES

Taxonomy of Bryde's Whales

The term Bryde's whale refers to a group of medium-sized baleen whales in the Family Balaenopteridae. The Society for Marine Mammalogy's Committee on Taxonomy provisionally recognizes a single species, *Balaenoptera edeni* Anderson 1879 that comprises two recognized subspecies, Eden's whales, *B. edeni edeni* Anderson 1879, and Bryde's whales, *B. edeni brydei* Olsen 1913 (Committee on Taxonomy 2014). Historically there has been considerable disagreement as to whether the two currently recognized subspecies actually should be considered two different species, and at times they have been so recognized. Thus, the identity and number of species in the "Bryde's Whale complex" is still under study. Omura's whale, *B. omurai* was once also considered a member of this complex of whales (Wada et al. 2003). In a morphological comparison of *B. omurai* with other members of the Bryde's whale complex, Wada et al. (2003) suggested that *B. omurai* and the two *B. edeni* subspecies have diagnostic features in the shape of the maxilla and frontal bones and that all three should be considered distinct species: *B. omurai*, *B. edeni*, and *B. brydei*. Genetic analysis supported the morphological findings, indicating that Omura's whale is a distinct species that has long been on a separate evolutionary pathway (Sasaki et al. 2006). As stated above, the Committee on Taxonomy currently recognizes a single species, *B. edeni*, pending further analysis of type specimens for the two subspecies. For this document, we follow the Committee's taxonomy. Throughout this document the term 'Bryde's whale' refers to both recognized subspecies together. When discussion is specific for one of the subspecies, the Latin name is provided.

In a genetic analysis of Bryde's whale samples from the Gulf of Mexico (GOMx) using mitochondrial DNA (mtDNA) control region sequences, Rosel & Wilcox (2014) discovered that this population was genetically distinct from all other Bryde's whales worldwide. Phylogenetic analyses placed these whales on a strongly supported lineage separated from *B. e. edeni* and *B. e. brydei* sampled in the Atlantic, Pacific, and Indian Oceans. Within the first 375 base pairs of the mitochondrial DNA control region, 25−26 fixed nucleotide differences separated the GOMx whales from sei whales, *B. borealis*, and the 2 recognized Bryde's whale subspecies (Table 1). Fixed differences were also identified in two other mitochondrial DNA genes, cytochrome *b* (*cytb*) and cytochrome oxidase I (*cox1*). The level and pattern of mtDNA differentiation indicates that GOMx Bryde's whales are as genetically differentiated from other Bryde's whales worldwide as those Bryde's whales are differentiated from their most closely-related species, the sei whale. Rosel & Wilcox (2014) concluded that the level of divergence suggests a unique evolutionary trajectory for the GOMX Bryde's whales, worthy of its own taxonomic standing. Furthermore, the GOMx Bryde's whales were genetically most closely related to *B. e. edeni*, which, to date, have only been identified in the Pacific and Indian Oceans but not the Atlantic. To date, morphological and genetic analyses indicate that only whales of the subspecies *B. e. brydei* have been recorded in the Atlantic Ocean (outside the GOMx) (Luksenburg 2013, Rosel & Wilcox 2014, Luksenburg et al. 2015, Pastene et al. 2015).

Table 1. Genetic divergence estimates for Bryde's, sei and Omura's whales. (a) Net between group divergence (d_A, Nei 1987) corrected using the T3P model in 375bp of the mitochondrial DNA control region below diagonal and within group divergence is along diagonal. Number fixed differences (number of indels) between taxa in the 375bp control region alignment is above the diagonal. (b) number of fixed differences in 653bp of *cox1* (below diagonal) and 421bp of *cytb* (above diagonal). N, number of individuals. From Rosel & Wilcox (2014).

(a)	N	*B. edeni* GOMx	*B. e. edeni*	*B. e. brydei*	*B. borealis*	*B. omurai*
B. edeni GOMx	23	*0.00*	25	25	26(1)	52(8)
B. e. edeni	19	0.096	*0.004*	20(1)	20(1)	42(8)
B. e. brydei	22	0.130	0.099	*0.014*	16(1)	40(5)
B. borealis	4	0.112	0.093	0.079	*0.017*	43(9)
B. omurai	11	0.272	0.204	0.222	0.226	*0.0025*

(b)	N	*B. edeni* GOMx	*B. e. edeni*	*B. e. brydei*	*B. borealis*	*B. omurai*
B. edeni GOMx	5	-	7	19	12	37
B. e. edeni	3	13	-	17	9	39
B. e. brydei	2	23	25	-	16	41
B. borealis	1	24	18	26	-	38
B. omurai	2	49	45	54	45	-

Rosel & Wilcox (2014) also sequenced 4,801 base pairs across portions of nine nuclear genes for several *Balaenoptera* species. Inter-species variability was extremely low. In some cases, nuclear alleles were shared across species. For example, in 6 of the 9 nuclear loci, 2 or more recognized species shared sequences. Bryde's whales from the GOMx shared alleles with the sei whale at three loci and with fin whales at one locus, while sei and fin whales shared alleles at one locus. Overall, these nuclear loci were uninformative across this group of species. Future taxonomic research is warranted using a broader set of informative nuclear markers.

Life History and Ecology

This section summarizes available information on life history and ecology separately for the two recognized subspecies of *B. edeni*, the smaller Eden's whale, *B. e. edeni,* Anderson, 1879, and then the "ordinary" or large-type Bryde's whales *B. e. brydei* Olsen, 1913. Equivalent information for the GOMx population of Bryde's whale is provided in the following section.

Eden's Whale (*B. e. edeni*)

Physical description
Eden's whales are medium-sized and slender balaenopterids, with adults reaching approximately 11.5m in length. They are smaller than Bryde's whales, *B. e. brydei,* (Rice 1998). Eden's whales appear to be generally grayish on their dorsal surface and white ventrally. This simple color pattern distinguishes them from some other *Balaenoptera* species found in the tropics and subtropics (e.g., Omura's whales, (Cerchio et al. 2015), dwarf minke whales, *B. acutorostrata* subsp., (Arnold et al. 2005)) that have more complex color patterns. All Bryde's whale subspecies, including the GOMx group, are identifiable in the field because of three dorsal head ridges that are not present on Omura's or dwarf minke whales.

Global range/distribution and habitat use

Eden's whales occur in the Indian and western Pacific oceans (Rice 1998). The western limit of their range extends at least as far as the Indian Ocean coast of the Arabian Peninsula (Priddel & Wheeler 1998, Sasaki et al. 2006, Kershaw et al. 2013, Rosel & Wilcox 2014). They are known to occur around the northern rim of the Indian Ocean including off the coasts of India and Bangladesh. The eastern limit of their range extends north to include southern Japan (where it is recognized by the International Whaling Commission as the "East China Sea stock" of Bryde's whale, see below), and southeast at least as far as the central coast of New South Wales, Australia (Priddel & Wheeler 1998, Sasaki et al. 2006, Kershaw et al. 2013, Rosel & Wilcox 2014). The subpopulation of Eden's whales occurring in the northern Indian Ocean (Oman and Bangladesh) was identified as genetically distinct from the subpopulation occurring in the waters off southeastern Japan (Kershaw et al. 2013). Based on genetic analyses, there are no verified records of Eden's whales from the Atlantic Ocean, nor from the eastern Pacific Ocean (Kershaw et al. 2013, Rosel & Wilcox 2014).

There are also no quantitative studies of Eden's whales' habitat use. They have been observed close inshore (Smith et al. 1997, Thongsukdee et al. 2014) and in coastal and continental shelf waters, but apparently not offshore (Rice 1998, Kershaw et al. 2013). They do not appear to undertake long latitudinal (north-south) migrations.

Population status

Cherdsukjai et al. (2015) estimated the population size of Eden's whales in the northern Gulf of Thailand at 63±9 individuals, using a capture-recapture estimator of photo-identified whales. The SRT is unaware of any other abundance estimates specifically for Eden's whales anywhere in their Indo-Pacific range. Further, the Team did not find information on quantitative trends in abundance of Eden's whales throughout their range.

Either Eden's whales or Omura's whales (or both) were hunted at a few sites in the Philippines, with possible evidence of localized depletion from at least one site (Acebes 2014). At least some of the whales killed in this hunt were Omura's whales (Sasaki et al. 2006). Whaling was made illegal under Philippine law in 1997, although illegal hunting may continue on a small scale (Acebes 2014). In Indonesia, hunters from one whaling village (Motonwutun, Lamakera) preferentially hunted baleen whales. These are described as "small" *Balaenoptera*, generally less than approximately 10 m, and could be Eden's, Omura's, Antarctic minke, *B. bonaerensis*, or dwarf minke whales. Interview surveys with whale hunters at Lamakera in the early 2000s suggested whale hunting was at a fairly low level, with less than 5 whales killed per year (Mustika 2006). There are no estimates of abundance for Eden's whales in the areas where these hunts occurred.

Foraging ecology

Little is known of the foraging ecology of Eden's whales. Observations of Eden's whales feeding report consumption of small schooling fish at the surface (Smith et al. 1997, Priddel & Wheeler 1998, Thongsukdee et al. 2014). *B. e. brydei* appear to forage at depth in some instances (Alves et al. 2010), and to feed on krill at depth (Murase et al. 2007). Eden's whales may also forage at depth, but, to date, no tags have been placed on Eden's whales. Thus, observations of Eden's whales foraging at the surface may not reflect the full extent of their foraging behavior.

Reproduction and growth
The SRT is unaware of any studies on the reproductive biology and growth of Eden's whales. Given the basic biology of *Balaenoptera*, females are likely to give birth to a single calf about every second year. Eden's whales probably mature at around 10 years of age, and likely live to at least 40 to 50 years of age, and perhaps much older. Taylor et al. (2007) estimated several reproductive parameters for cetaceans, including *B. e. brydei* (see reproduction and growth section below) and those estimates may be similar for *B. e. edeni*.

Bryde's Whale (*B. e. brydei*)

Physical description
Bryde's whales of the subspecies *B. e. brydei*, are also medium-sized and slender, but larger than whales of the *B. e. edeni* subspecies; adults reach approximately 14.6 m (males) and 15.6 m (females) in length (Rice 1998). *B. e. brydei* whales appear to be generally grayish on their dorsal surface and white ventrally.

Global range/distribution and habitat use
B. e. brydei whales occur in tropical and warm temperate waters of all the world's oceans (Rice 1998, Rosel & Wilcox 2014). Their range approximates the equatorial range hiatus of fin whales, *B. physalus*, in waters south of 20°N and north of 20°S (Edwards et al. 2015).

The current (2014) International Whaling Commission's Schedule[1] identifies stocks of Bryde's whales in the North Pacific and Southern Hemisphere. In the North Pacific, the Schedule identifies three stocks of Bryde's whales: the East China Sea stock (west of the Ryukyu Islands, and likely *B. e. edeni* whales, not *B. e. brydei* whales), the Eastern North Pacific stock, east of 160°W (not including the Peruvian stock) and the Western North Pacific stock west of 160°W (not including the East China Sea stock). The latter two stocks are *B. e. brydei*. In the Southern Hemisphere, the Schedule identifies seven stocks: the Southern Indian Ocean, Solomon Islands, Peruvian, Eastern South Pacific, Western South Pacific, South Atlantic, and South African Inshore stocks. At least some of these stocks' areas (e.g., Solomon Islands, western South Pacific) include places where both *B. e. brydei* and *B. e. edeni* likely occur.

In the eastern Atlantic Ocean, Bryde's whales have been reported from inshore waters and offshore waters of the southern African coast (Best 2001), the Cape Verdes islands (Hazevoet & Wenzel 2000), Madeira (Alves et al. 2010), and the Azores (Steiner et al. 2008). The whales from all these areas, except the Azores (which have not been tested), have been genetically ascribed to Bryde's, *B. e. brydei*, whales (Rosel & Wilcox 2014, Luksenburg et al. 2015).

In the western Atlantic Ocean, Bryde's whales are known to occur off the coast of South America from Brazil (de Moura & Siciliano 2012, Lodi et al. 2015), Suriname (de Boer 2015) and north to at least Venezuela (Romero et al. 2001, Smultea et al. 2013), and into the Caribbean to at least Bonaire (Debrot et al. 1998), Aruba (Luksenburg et al. 2015) and Curacao (Debrot et al. 1998). The Aruba specimens have been identified genetically as *B. e. brydei*, not Eden's whales, and are genetically closest to the whales sampled off Madeira (Luksenburg et al. 2015). Whales stranded in Brazil have also been identified as *B. e. brydei* (Pastene et al. 2015), and (Rice 1998) attributes all records of Bryde's whales in the Atlantic Ocean to *B. e. brydei*. Interestingly, Debrot et al.

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[1] https://iwc.int/private/downloads/ulNGgq2skV5w-o1kzAMmQw/Schedule-September%202014.pdf

(2013) compiled cetacean records for the Dutch Windward Islands (Saba, St. Eustatius, St. Maarten, and the Saba Bank) and noted a surprising lack of records of any Bryde's whales and suggested they may be absent from the northeastern Caribbean. A ship-board survey for cetaceans in 2000 covered waters from Puerto Rico to Venezuela (excluding Antigua and Barbuda, Dominica, and St Vincent and the Grenadines) and recorded five Bryde's whale sightings, all in the southeastern Caribbean (Swartz & Burks 2000), but which subspecies was seen is unknown. Similarly, Yoshida et al. (2010) surveyed from St. Kitts and Nevis south to Grenada and observed six Bryde's whales (subspecies unknown), all in the southern survey area. One sighting was made in shallow waters northeast of Grenada while the remaining sightings were made in deep waters (2000 m) of the Grenada and the Tobago basins. Additional surveys in the northern Caribbean have not recorded any subspecies of Bryde's whales (Roden & Mullin 2000, Swartz et al. 2002), although Mignucci-Giannoni et al. (1999) did report a stranded Bryde's whale (subspecies unknown) in Puerto Rico. Whitt et al. (2011) reviewed records of marine mammals in Cuban waters and indicated one confirmed record of a Bryde's whale from the southeastern coast of Cuba, but which subspecies it belonged to is unknown. This animal was initially identified as a juvenile sei whale by Varona (1965). Mead (1977) re-classified it as a Bryde's whale as the bristles of the baleen were considered too fine to be from a sei whale, although reports indicated no ridges on the rostrum. Varona (1973), as reported in Whitt et al. (2011), suggested that sei whales were historically found off southeastern Cuba in the 1800s but it is possible these were misidentifications of Bryde's whales (Whitt et al. 2011).

B. e. brydei occurs in inshore and offshore waters. Some populations occurring in offshore waters are known to migrate, although these migrations appear to be relatively short for baleen whales (e.g., 20 to 30 degrees of latitude, (Best 2001)). Best (2001) provides a thorough review of habitat-use patterns by *B. e. brydei* off southern Africa. Off the west coast (i.e., in the eastern South Atlantic Ocean), Best (2001) identified a non-migratory stock inshore of the 200 m isobath and a more migratory stock offshore of the 400 m isobath. Individual whales of the inshore stock were smaller than those offshore. Best (2001) also identified a separate pelagic stock off the east coast (in the southwest Indian Ocean) south of Madagascar. Inshore-form whales occur off the east coast as well, where observations of Bryde's whales at one site (Plettenberg Bay) peaked during the austral summer and fall (Penry et al. 2011).

In other areas where Bryde's whales, *B. e. brydei*, occur relatively close to shore, they can be observed over multiple months, for example off Brazil (Lodi et al. 2015) and off Madeira, Portugal (Alves et al. 2010), or year-round for example in and just outside Hauraki Gulf, New Zealand (McDonald 2006, Wiseman et al. 2011), off Oman (Corkeron et al. 2011), and in the Gulf of California (Tershy et al. 1990, Urbán & Flores 1996). Photo-identification studies suggest that the same individuals can re-use areas over weeks (Lodi et al. 2015) or years (Alves et al. 2010). One comparison of photo-identification catalogs from two studies separated by approximately 150 km found some matched individuals (Lodi et al. 2015).

There are indications that Bryde's whales are increasing their use of the southern California Bight (eastern North Pacific Ocean) in recent years, perhaps in response to changes in prey distributions, that, in turn, may be caused by environmental changes (Kerosky et al. 2012, Smultea 2012).

Population status
There are few current estimates of world-wide abundance of Bryde's whales, *B. e. brydei*. There are a variety of estimates of population size for different populations (or stocks) over several decades. However, the spatio-temporal distribution of such population-specific estimates is such that it is impossible to derive an overall estimate of abundance of *B. e. brydei* for any particular time. Additionally, estimates in some places maybe confounded by the inclusion of sympatric Eden's or Omura's whales.

Using a variety of sources, the IWC agreed to estimates of abundance of Bryde's whales in the Southern Hemisphere in 1980 as: southern Indian Ocean: 13,854, western South Pacific: 16,585, and eastern South Pacific (including Peru): 23,181 (IWC 1981). These estimates are based on techniques that are no longer accepted, and should be treated with caution.

Of relevance for the GOMx whales is the biology of some populations of Bryde's whales, *B. e. brydei*, that occur in relatively confined areas. These include the South African inshore population, the Gulf of California population and the Hawaiian Islands stock. These populations can number in the hundreds, rather than the thousands. For example, the stock that occurs in the waters around Hawai'i is estimated at approximately 800 individuals (coefficient of variation (CV) = 0.28) from shipboard line transect surveys, with no trend information available (Carretta et al. 2015). In 1983, the South African inshore population of *B. e. brydei* was estimated at 582 individuals (CV = 0.32) based on a vessel-based line transect survey (Best et al. 1984). Between 1950 and 1967, 808 Bryde's whales were killed by whaling in the coastal waters of the Cape Province of South Africa. Most catches were of the inshore population, which appears to have been depleted by the hunt (IWC 1980). For the Gulf of California, Urbán & Flores (1996) provided estimates ranging from approximately 450 animals in 1984 – 1986 to about 300 animals in 1993. As the methods used were not comparable, this cannot be interpreted as a trend. A mark-recapture estimate conducted at one site in the Gulf of California from 1989 to 1991 resulted in an estimate of 235 ± 62 whales (Urbán & Flores 1996). Between 1913 and 1935, commercial whalers in the Gulf of California killed 121 whales that were most likely Bryde's whales (Urbán & Flores 1996).

Prior to 1972, statistics compiled by the International Whaling Commission (IWC) likely included a mix of *B. e. brydei*, *B. e. edeni*, and *B. omurai,* and those records were not distinguished from sei whale. The IWC records indicate that since the 1986 moratorium on commercial whaling, a total of 1,320 Bryde's whales have been killed by whaling[2]. Of these, 682 were taken under special permit ("scientific whaling")[3] and 634 taken under commercial quota[4] (under objection to the moratorium, prior to 1988). Of the other four catches, two were taken by aboriginal subsistence whaling in St Vincent and the Grenadines, one was taken "by accident" by Japanese whalers, and one was taken in an infraction by Korea[2].

Foraging ecology
Stomach content analyses of whales killed by commercial whaling and whaling under special permit indicate that they feed on small schooling fish and euphausiids (krill) (e.g., Omura 1966, Best 2001, Murase et al. 2007). Observational studies (e.g., Tershy 1992, Urbán & Flores 1996,

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2 https://iwc.int/total-catches
3 https://iwc.int/table_permit
4 https://iwc.int/table_objection

Best 2001, Baker & Madon 2007, Penry et al. 2011) support these findings, as do stable isotope analyses of baleen plates (Niño-Torres et al. 2013). Suction-cup tagging using time-depth recorders of two Bryde's whales, *B. e. brydei*, off Madeira, demonstrated that individual whales dove to over 200 m and fed at depth (Alves et al. 2010), and therefore these whales are not limited to surface foraging.

Reproduction and growth
Information on reproductive biology for *B. e. brydei* comes from whaling data, primarily that summarized in Best (2001). Observations of neonates suggest that calves are approximately 3.8 to 4 m in length at birth. Inshore-form males off South Africa mature at 12.2 to 12.5 m length, and offshore-form males at 12.8 to 13.7 m. Inshore-form females off South Africa mature at 11.9 to 12.5 m, and offshore-form females at 12.8 to 13.1 m.

Off South Africa, breeding behavior of *B. e. brydei* (both inshore and offshore forms) appears seasonal (Best 2001). Best (2001) also reanalyzed data for the Arabian Sea population of Bryde's whales, and found seasonality, with conceptions occurring primarily over three months (December – February). Any seasonality in their reproductive behavior may depend on local productivity and (or) food availability that, among other things, could lead to variation in ovulation rates. Whaling data indicate that the inshore-form of *B. e. brydei* off South Africa ovulates more frequently than does the offshore-form. Offshore-form whales' ovulation rate (0.42/year) suggests a two-year, or sometimes three-year, calving cycle while inshore-form whales' ovulation rate (2.35/year) suggests multiple unsuccessful ovulations, and is difficult to transform into a calving cycle (Best 2001).

Taylor et al. (2007) estimated generation length for cetaceans using only a few parameters: oldest age (or an estimate based on length), calf survival, adult survival, age at maturity, gestation length, and interbirth interval. The estimated generation length for all Bryde's whales, *B. edeni*, was 18.4 yr using the following estimated parameters: maximum age = 58 yr (based on length from Best (1977)), age at first reproduction = 9 yr based on gestation length (Lockyer 1984) and age of sexual maturity (IWC 1997), interbirth interval = 2.5 yr (Lockyer 1984), calf survival rate = 0.840 and non-calf survival rate = 0.925 (IWC 1997). The estimates from the literature are most likely made from data collected from the *B. e. brydei* subspecies as the majority of the samples used to estimate the parameters came from Japanese whaling data from the 'typical' or pelagic form of Bryde's whale in the North Pacific and from South Africa.

Gulf of Mexico Bryde's Whale

Physical description
There is no formal description of GOMx Bryde's whales. Based on the individuals sighted in the northern GOMx (NMFS, unpublished), the whales in the GOMx have a streamlined and sleek body shape, a somewhat pointed, flat rostrum with three prominent ridges (i.e., a large center ridge, and smaller left and right lateral ridges), a large falcate dorsal fin, and a counter-shaded color that is fairly uniformally-dark dorsally and light to pinkish ventrally, similar to *B. e. edeni and B. e. brydei* elsewhere in the world (Jefferson et al. 2015). While the appearance of dorsal color varies depending on light, in most GOMx photographs it is dark brown. Prominent white blazes and chevrons common to fin whales and Omura's whales are not seen in the GOMx Bryde's whales. Baleen from GOMx Bryde's whales has not been thoroughly characterized but

the baleen plates from one stranding are dark gray to black with white bristles. This is consistent with the description by Mead (1977) who also indicated that the bristles of Bryde's whales are coarser than those seen in sei whales.

Rosel & Wilcox (2014) summarized body length information from 14 GOMx strandings and concluded that GOMx whales may have a size range intermediate to the currently recognized subspecies; the largest GOMx whale was a lactating female that was 12.65 m and the next four largest ranged between 11.2 and 11.6 m. Following Rice (1998), adult *B. e. edeni* rarely exceed 11.5 m total length and adult *B. e. brydei* reach approximately 14 to15 m.

Current distribution and habitat use
Bryde's whale is the only baleen whale species known to inhabit the GOMx year-round. Stranding records from the Southeast U.S. (SEUS) stranding network, the Smithsonian Institution, and the literature (Mead 1977, Schmidly 1981, Jefferson 1995) reveal 22 *B. edeni* strandings in the Gulf of Mexico from 1954 to 2012, although three of these remain of uncertain species identification (Figure 1). Most strandings occurred in eastern Louisiana through west central Florida. Two strandings were recorded in western Louisiana. There are no documented Bryde's whale strandings in Texas, although other baleen whale strandings (fin, sei, minke) have been documented.

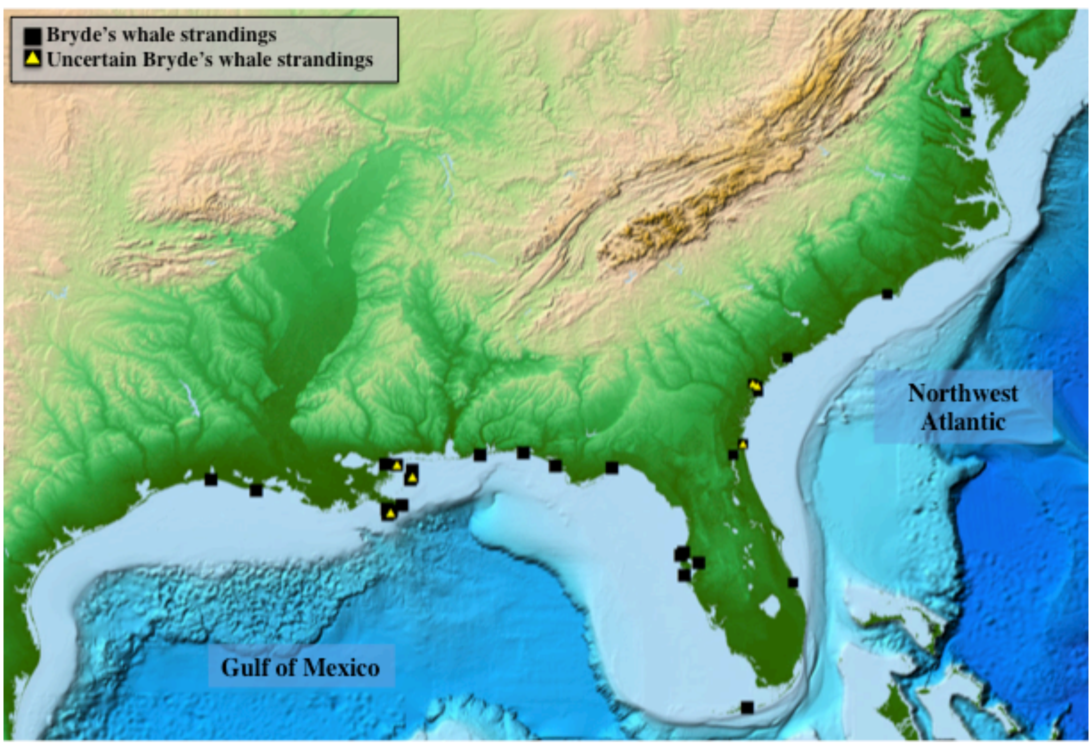


Figure 1. Recorded Bryde's whale strandings in U.S. waters of the GOMx and western North Atlantic. Uncertain strandings are those for which it has not been possible to verify the species identification made in the field. Basemap from NOAA National Centers for Environmental Information (NCEI).

In U.S. waters of the Caribbean, Mignucci-Giannoni et al. (1999) report a single stranding of a 'Bryde's whale' in Puerto Rico and there is a single stranding record from the U.S. Virgin Islands in the Southeast U.S. (SEUS) Historical Stranding Database. It is unknown which subspecies each of these strandings involved. Bryde's whale occurrence in the southeast U.S.

Atlantic is not well understood. NMFS has defined a Northern GOMx Bryde's Whale Stock but has not defined one for the U.S. Atlantic or U.S. Caribbean as there are few or no sightings (Waring et al. 2013) (see Abundance section below).

A similar search of stranding records in the U.S. Atlantic returned 9 records of *B. edeni*, three of which could not be verified as *B. edeni* (Figure 1). The oldest stranding dates to 1923, while the most recent verified *B. edeni* stranding is from North Carolina in 2003. The latter record involved a whale that was entangled in black polypropylene line and extremely emaciated. All but one of the Bryde's whales stranded in the Atlantic were less than 10 m in length and four were under 8 m. Mead (1977) suggested that strandings on the Atlantic coast may represent strays from the GOMx, although they could also be strays from the southern Caribbean *B. e. brydei* population, or from a small and unknown portion of the GOMx *B. edeni* population that may venture into U.S. Atlantic waters. Two of the U.S. Atlantic stranded animals exhibited the same mitochondrial DNA sequence found in whales from the GOMx (Rosel & Wilcox 2014). It is not possible to determine whether the remaining strandings had the same genetic composition as those of the GOMx, or represented the more pelagic form *B. e. brydei*. Extralimital strandings of baleen whales do occur. For example, several individuals of multiple baleen whale species have stranded in the GOMx, but these are all considered accidental as the species are not routinely seen there (Jefferson & Schiro 1997). Movement of sick or dead whales from the northeastern GOMx to the Atlantic is plausible as animals could get caught in the Loop Current which flows out of the eastern GOMx past peninsular Florida and joins the Gulf Stream flowing northward along the southeast U.S. coast. The hypothesis that some *B. edeni* occupy the U.S. Atlantic cannot be rejected, but has limited support. NMFS visual surveys in the western North Atlantic from 1992 to 2009 have recorded a small number of sightings that could be Bryde's or sei whales (Figure 2). Acoustic surveys off Onslow Bay, NC, between 2007 and 2011, have not detected the long-moan calls (see Acoustics section below) associated with the GOMx Bryde's whales (Lynne Williams Hodge, Duke University, pers. comm.) nor have these whales been heard on acoustic buoy deployments in coastal and continental shelf waters from Maine to Florida (C. Clark, Cornell University, pers. comm.), although those acoustic data should be further searched for Bryde's whale calls. Further, call types can vary geographically in balaenopterids (e.g., humpback whale, *Megaptera novaeangliae*, song), which could confound attempts to recognize Bryde's whales based solely on a single call type.

<u>*Gulf of Mexico*</u>
Initial efforts to survey cetaceans in the GOMx in the late 1970s and early 1980s were primarily limited to common bottlenose dolphins, *Tursiops truncatus*, in bays, sounds and estuaries (Scott 1990, Waring et al. 2013). Würsig et al. (2000) reviewed cetacean survey efforts from 1979 to 1997 in continental shelf and oceanic waters. Early aerial surveys focused on continental shelf and some oceanic waters (i.e., > 200 m depth) (Fritts et al. 1983) but there were no sightings of baleen whales. The first surveys dedicated to oceanic waters were conducted by NMFS in 1989 and 1990 in north-central Gulf continental slope waters between De Soto and Mississippi canyons (Mullin et al. 1994). Two baleen whales were sighted at separate times on the eastern side of De Soto Canyon. One whale was identified as a Bryde's whale and the other was incorrectly identified as a fin whale and was later identified as a Bryde's/sei (i.e., it wasn't possible to distinguish between a Bryde's whale or a sei whale) whale based on a photograph (P. Corkeron, NMFS, pers. comm.).

In 1991, NMFS began continental shelf (ship and aerial) and oceanic (ship) surveys that continue to the present and are summarized in Waring et al. (2015). The 1991 survey covered U.S. oceanic waters from the 200 m isobath out to the U.S. exclusive economic zone (EEZ). From 1992 to1994, "GulfCet I" surveys (Davis & Fargion 1996) focused on continental slope waters in the western GOMx from De Soto Canyon to the Texas-Mexico border. From 1996 to1998, the "GulfCet II" program (Davis et al. 2000) surveyed the eastern GOMx continental slope from De Soto Canyon to Tampa Bay.

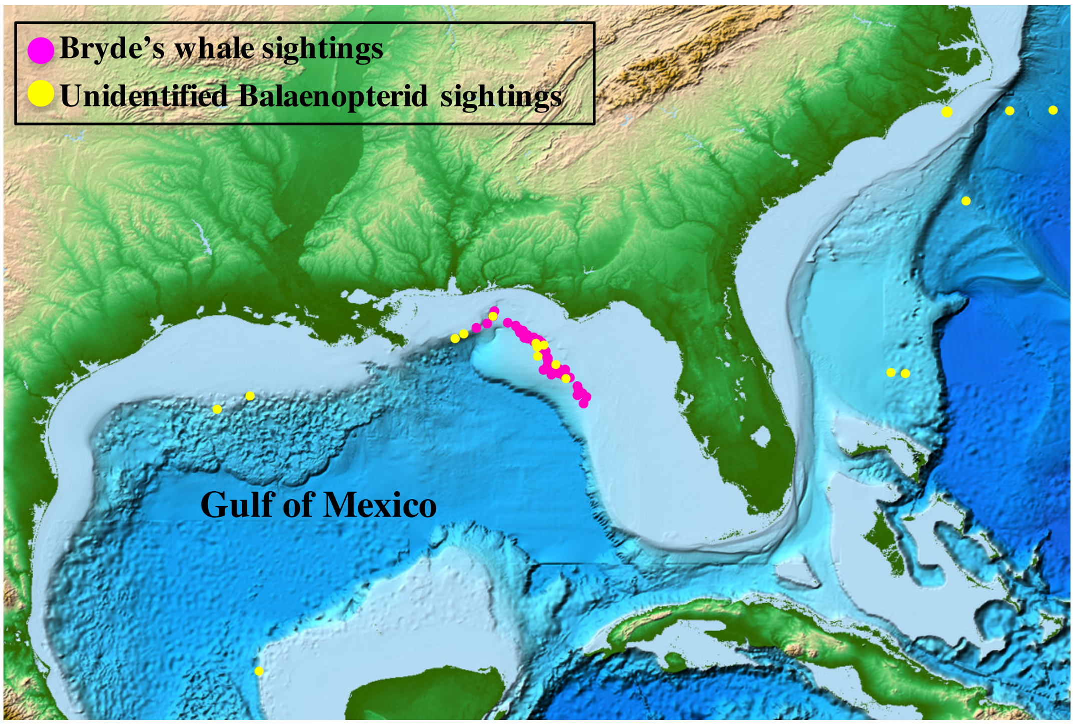


Figure 2. Sightings of Bryde's whales and unidentified balaenopterid whales during NMFS shipboard and aerial surveys between 1989 and 2015 in the northern GOMx and western North Atlantic, and one sighting in the southwestern GOMx from Ortega-Ortiz (2002). Basemap from NOAA National Centers for Environmental Information (NCEI).

From 1999 to 2015, NMFS conducted six ship-based assessment surveys that covered northern GOMx oceanic waters (e.g., Mullin & Fulling 2004, Mullin 2007) and five that covered continental shelf waters (e.g., Fulling et al. 2003) in the northern GOMx. Aerial assessment surveys of continental shelf waters were conducted in the eastern GOMx in 2007 and of all GOMx from the U.S.-Mexico border to Key West, Florida in 2011 and 2012 (DWH MMIQT 2015). The survey effort for all cetacean surveys including NMFS surveys in the GOMx and Atlantic through 2009 is plotted in Figure 3. (See the population status section below for abundance estimates obtained from these surveys).

During surveys in 1991, Bryde's whales were sighted in the northeastern GOMx along the continental shelf break. In subsequent surveys, Bryde's whales or whales identified as Bryde's/sei whales were sighted in this same region of the northeastern GOMx (Figure 2). Each balaenopterid whale sighted during NMFS surveys had a large, falcate dorsal fin similar to that of Bryde's and sei whales. When observers clearly saw the dorsal surface of the rostrum of at least one whale in a sighting (11 of 17 sightings), three ridges were present, a diagnostic characteristic of Bryde's whales (Maze-Foley & Mullin 2006). As a result, the Bryde's whale was the only balaenopterid whale thought to have been sighted during NMFS GOMx surveys and sightings identified as Bryde's whales, Bryde's/sei whales and *Balaenoptera* sp. were combined and treated as Bryde's whales for abundance estimation. With three exceptions, no Bryde's whale or any other baleen whale has been sighted outside this region in the northeastern GOMx during NMFS assessment surveys. The exceptions are a fin whale that was identified during an aerial survey in 1992 off Texas, and single sightings in 1992 and 1994 along the shelf break in the western GOMx during GulfCet I surveys that could only be identified to Bryde's/sei whale.

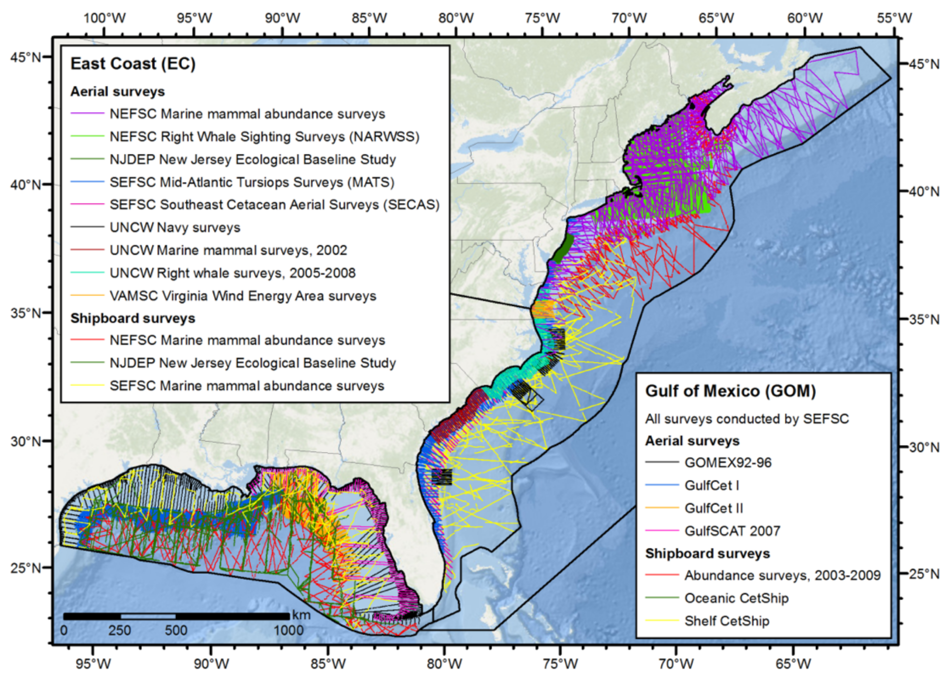


Figure 3. Locations of line-transect survey effort in the U.S. GOMx (1992–2009) and U.S. Atlantic Ocean. NMFS surveys denoted as Southeast Fisheries Science Center (SEFSC) and Northeast Fisheries Science Center (NEFSC). Figure from Roberts et al. (2016).

In summary, within the GOMx, Bryde's whales have been consistently located in a very narrow depth corridor along the shelf break in the northeastern GOMx for the past 25 years and few have been sighted elsewhere despite a large amount of dedicated cetacean survey effort that covered both continental shelf and oceanic waters of the northern GOMx. Sightings have occurred in all seasons in the northeastern GOMx (Mullin & Hoggard 2000, Maze-Foley & Mullin 2006, Mullin 2007, DWH MMIQT 2015). Maze-Foley & Mullin (2006) report the mean sea surface temperature for GOMx Bryde's whale sightings as 23.3˚ C (SE = 0.50, range 21.5 – 25.9, n = 14) and mean water depth as 226 m (standard error (SE) = 7.9, range 199 – 302, n = 14).

LaBrecque et al. (2015) designated an area of the northeastern GOMx a Biologically Important Area (BIA) (Figure 4) on the basis that it is home to a small resident population of Bryde's whales. The area covers waters between 100 m and 300 m deep from approximately Pensacola, Fla.to just south of Tampa, Fla. However, given that there have been sightings at 302 and 309 m depth in this region and west of Pensacola, Fla. (NMFS unpublished data and Figure 4), the BIA area is probably better defined out to the 400 m depth contour and to Mobile Bay, Ala., to provide some buffer around the deeper water sightings and to include all sighting locations in the northeastern GOMx, respectively. All indications are that the whales inhabit this area year round and are a resident population, but residency has not been established based on records of individual whales over an extended time. Rosel & Wilcox (2014) reported that the same whale was biopsied in both 2007 and 2010 in the BIA. In 2010, a satellite-linked tagged whale remained in the BIA for 38 days, the entire time the tag reported (NMFS, unpublished).

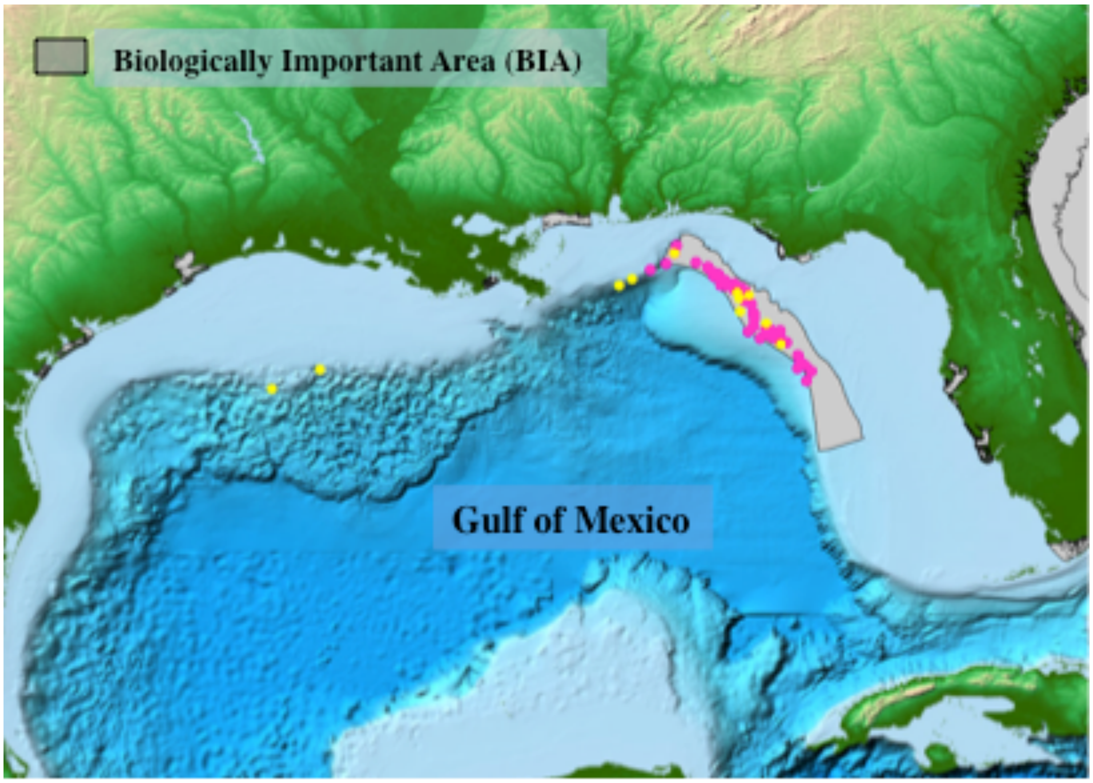


Figure 4. Bryde's whale shipboard and aerial survey sightings (as in Figure 2) with respect to the Biologically Important Area (BIA) defined by LaBrecque et al. (2015). Basemap from NOAA National Centers for Environmental Information (NCEI).

Despite the lack of recent sightings of Bryde's whales outside the BIA, questions remain about their current and former distribution both in U.S. and southern (i.e., Mexico and Cuba) GOMx waters. As part of the mitigation measures for seismic exploration in the U.S. GOMx, protected species observers (PSO) search for and record sightings of cetaceans. From 2010 to 2014, five records of 'baleen whales' have been recorded west of the BIA to the longitude of western Louisiana in water depths similar to those in the BIA (Bureau of Safety and Environmental Enforcement (BSEE), unpublished). Two of those records were south of western Louisiana and included photographs that were clearly of baleen whales. However, the information collected during those surveys is insufficient to verify the sightings to species. Additionally, in 2015, a citizen sighted and photographed what most experts think was a Bryde's whale in the western GOMx south of the Louisiana – Texas border (NMFS, unpublished). It is possible that a small number of whales occur outside the De Soto Canyon area, given the small number of baleen whale sightings by the protected species observers in the north-central and western GOMx from

2010 to 2014 and the 2015 citizen-reported sighting. Given the paucity of sightings, however, these occasional sightings in the north-central and western GOMx are difficult to interpret.

Although fewer systematic surveys have been conducted in Mexican waters of the southern GOMx, opportunistic marine mammal surveys were conducted between June 1997 and June 1999 during six oceanographic surveys conducted from the 50-m *B/O Justo Sierra* in the southern GOMx and the Yucatán Channel (Ortega-Ortiz 2002). In general, during daylight, searches for cetaceans were conducted from the ship's flying bridge by one observer using 25 x 150 mm binoculars for 10 minutes of each half-hour and with unaided eye and 7 x 50 mm binoculars during the remaining 20 minutes. During the six cruises, nearly 4000 km of survey effort were achieved (Figure 5). Much of this effort occurred in the extreme southern Bay of Campeche, an area where Reeves et al. (2011) reported numerous sightings of baleen whales from whaling logbooks (see Figure 6).

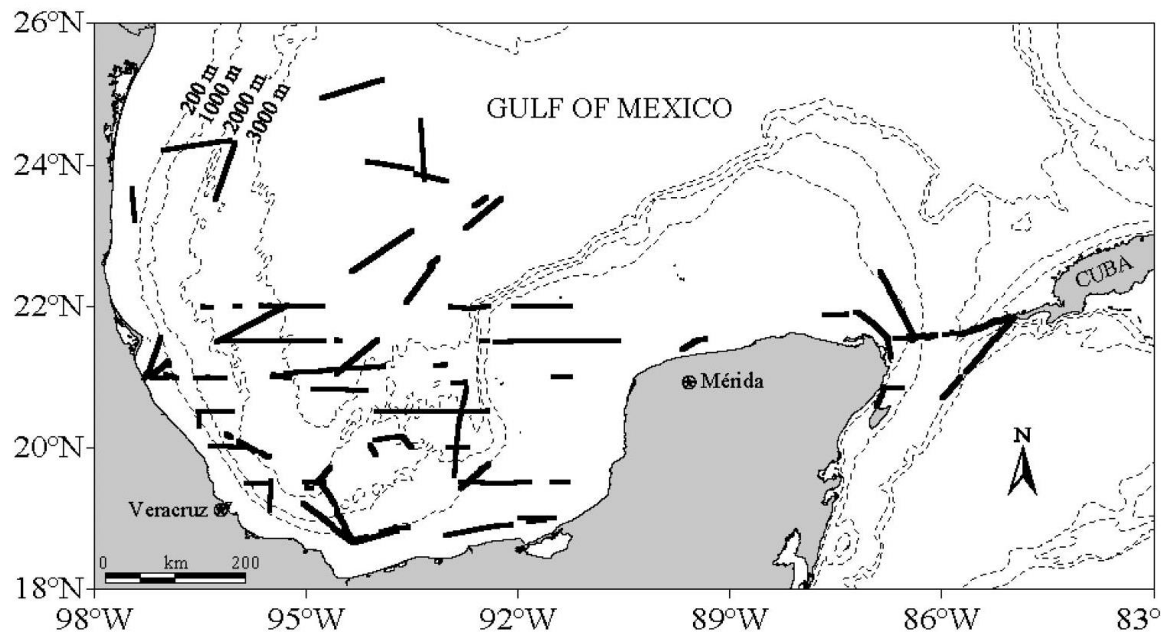


Figure 5. Cetacean survey effort (≈ 4000 km) in the southern GOMx and Yucatán Channel completed opportunistically during oceanographic surveys from 1997–1999. Figure from Ortega-Ortiz (2002).

A total of 58 cetacean sightings were recorded; only 1 baleen whale was seen and it was identified as a fin whale (Figure 2) (Ortega-Ortiz 2002). Subsequent discussion with the author suggested it should have been recorded as an unidentified balaenopterid (J. Ortega-Ortiz, pers. comm.). The sighting was at approximately 1400 m distance, not close enough to see the distinctive ridges of a Bryde's whale or the distinctive color pattern of a fin whale. A compilation of all available records of cetacean sightings, strandings and captures in Mexican waters of the southern GOMx identified no Bryde's whales, although there were two records of common minke whale, *B. acutorostrata*, and one record each for sei, blue, fin and humpback whales (Ortega-Ortiz 2002).

<u>*U.S. Atlantic*</u>

Similar to the GOMx, NMFS aerial- and ship-based cetacean assessment surveys have been conducted in the southeast U.S. Atlantic since the early 1980s to present that cover both continental shelf and oceanic waters (Figure 3). Three Bryde's/sei whales and two unidentified balaenopterids were sighted in January1992 during shipboard surveys broadly covering U.S. waters of the western North Atlantic south of Cape Hatteras (Figure 2). An aerial survey in 1995 recorded one Bryde's/sei whale and one unidentified balaenopterid off the coast of North Carolina. Based on assessment surveys, it does not appear that Bryde's whales consistently inhabit the southeast U.S. Atlantic.

Historical distribution in the Gulf of Mexico

Reeves et al. (2011) reviewed whaling logbooks of "Yankee whalers" and plotted daily locations of ships from 1788 to 1877 as a proxy for effort (Figure 6A) and locations of species takes and sightings in the GOMx. "Finback" whales were reported taken and Reeves et al. (2011) concluded they were "most likely" Bryde's whales based on known distribution and recent records of baleen whale species in the GOMx (see section on whaling for more detail). These data indicate the historical distribution of Bryde's whales in the U.S. GOMx was much broader than it is currently and included the north-central and southern GOMx (Figure 6B). Many of these locations are in waters much deeper (e.g., >1000 m) than recent sighting locations, although it should be highlighted that the primary target was sperm whales, *Physeter macrocephalus*, so most of the effort (Figure 5A) was in deeper waters.

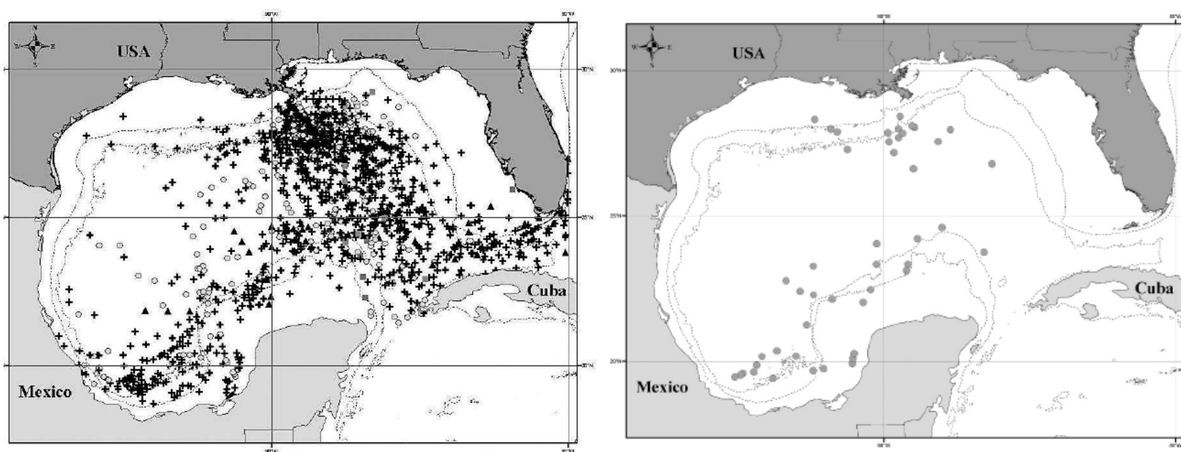


Figure 6. (A-left) All daily positions of whalers in the GOMx identified by Reeves et al. (2011). Contours are 100 m and 1000 m. Note a lack of sightings in the northeastern GOMx is due, in part, to the fact that whalers did not venture into the shallower waters of the northeastern GOMx. (B-right) Daily positions of whalers when 'finback' whales were caught or sighted. From Reeves et al. (2011).

Population status

<u>*Current abundance*</u>

The current abundance estimate (see below) used for management of the Northern GOMx Bryde's Whale Stock in U.S. waters is 33 whales (CV = 1.07) (Waring et al. 2013).

<u>*Past abundance estimates*</u>

All of the abundance estimates for U.S. waters of the northern GOMx are based on aerial- or ship-based line-transect surveys (Buckland et al. 2005). Surveys conducted between 1991 and 2012 indicate Bryde's whale abundance for the entire U.S. GOMx ranges from 15 to 44 whales (Table 2). Most of the estimates are imprecise with CVs over 0.40. With one exception, none of the surveys were designed specifically for Bryde's whales but rather were broad-scale multispecies line-transect cetacean surveys. An abundance estimate generated for the *Deepwater Horizon* marine mammal damage assessment included a line-transect survey designed to focus on the BIA in the northeastern GOMx (DWH MMIQT 2015).

GulfCet surveys were regional. GulfCet I surveyed the western continental slope and consisted of eight aerial surveys with 50,000 km of total effort, one each season for two years (Mullin et al. 2004), and seasonal ship surveys with 21,000 km effort over four seasons (spring – 63% of the effort, summer – 10%, fall – 6%, winter 21%) (Hansen et al. 1996). One "Bryde's/sei" whale was observed in winter during aerial surveys and one in spring during ship surveys. GulfCet II surveyed the eastern continental slope with two winter and two summer aerial surveys (19,000 km of total effort) and two spring ship surveys (2500 km total effort). The GulfCet II area overlapped the BIA and abundances from ship and aerial surveys were similar to those from the U.S. Gulf-wide oceanic surveys (Table 2).

NMFS Bryde's whale abundance estimates subsequent to GulfCet were based on northern GOMx-wide oceanic ship surveys (Table 2). Most of these surveys were conducted in spring or summer, and abundances were based on 6,000 to 12,000 km of survey effort (Mullin & Fulling 2004, Mullin 2007, Waring et al. 2015). An abundance estimate generated for the *Deepwater Horizon* damage assessment was based on survey effort conducted in the BIA during spring, summer and fall ship surveys (DWH MMIQT 2015).

Recently, Roberts et al. (2016) integrated 23 years (1992 – 2014) of aerial and shipboard line-transect surveys for cetaceans in the U.S. Atlantic and U.S. GOMx (Figure 3) that totaled 1,090,000 linear km of effort. This effort was linked to physiographic, physical oceanographic, and biological covariates obtained from remote sensing and ocean models to develop spatially-explicit descriptions of cetacean species density (individuals km^{-2}) in the U.S. Atlantic and U.S. GOMx. For the U.S. GOMx, Roberts et al. (2015a) reported a Bryde's whale abundance estimate of 44 whales (CV = 0.27, Figure 7).

The Roberts et al. (2016) model includes partial correction for g(0) whereas the other estimates in Table 2 are not g(0)-corrected. The primary assumption of unbiased line-transect estimates is that animals directly in front of the ship are always seen (a parameter called g(0) that is assumed to equal 1). This assumption is almost always violated, however, due to perception bias and availability bias (Marsh & Sinclair 1989) and these violations have the potential to cause a negative bias in line-transect abundance estimates. Perception bias occurs when animals are missed for any reason such as weather (e.g., rough seas) or observer error. Availability bias refers to the fact that cetaceans spend a significant amount time underwater and are missed by observers because they are not "available" to be seen at the surface. Whenever perception or availability biases occur, g(0) is less than 1.0; this is typically the case, and abundance estimates will be negatively biased if not corrected. The g(0) correction factor multiplies the abundance estimate, so that a g(0) of 0.5 means that half the whales were seen and consequently the 'raw' abundance would be doubled. For Bryde's whales, Roberts et al. (2015a, 2015b) used g(0) estimates of 0.90 for ship surveys (perception bias only) and, for aerial survey, 0.53 for groups of 1 – 5 whales and 1.0 for groups >5 whales. (These are proxy estimates of g(0) based on other species because estimates are not available specifically for Bryde's whales.) Given that abundance estimates are based primarily on ship survey data, the correction is a ≈10% increase over uncorrected estimates.

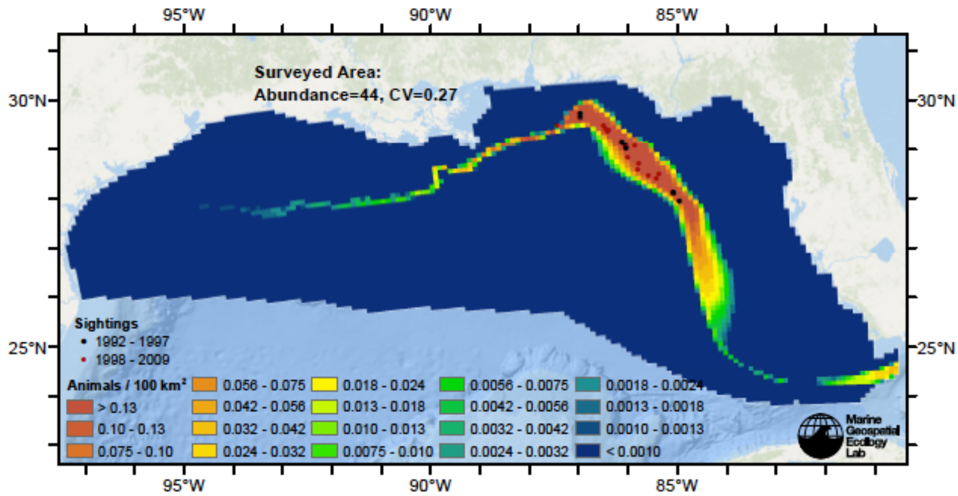


Figure 7. Bryde's whale density models for the GOMx. Individual sightings indicated by black and red circles. Pixels are 10x10 km. Abundance was estimated by summing densities across the region. Figure from Roberts et al. (2015a).

An analysis has not been conducted to evaluate trends in U.S. GOMx Bryde's whale abundance. Four point estimates have been made based on data from line-transect surveys during the period 1991 to 2009 (Table 2). The estimates vary by a factor of nearly three, but the precision of each estimate is very poor. Nearly all of the small number of Bryde's whale sightings from each survey occurred in the BIA during surveys that uniformly sampled the entire oceanic northern Gulf. Because the population size is small, other methods (e.g., capture-recapture, acoustic monitoring) and surveys dedicated to Bryde's whales are necessary to monitor trends.

Table 2. Estimates of Bryde's whale abundance in the U.S. GOMx and the southeast U.S. Atlantic (N = number of whales, CV = coefficient of variation). All data were collected using visual line-transect methods.

Basin/Source	Area Covered	Type	Season	Survey Years	N	CV
U.S. Gulf of Mexico						
Hansen et al. (1995)	Oceanic[1]	Ship	Spring	1991–1994	35	1.10
Mullin & Fulling (2004)	Oceanic[1]	Ship	Spring	1996–2001	40	0.61
Mullin (2007)	Oceanic[1]	Ship	Spring,	2003–2004	15	1.98
Waring et al. (2015)	Oceanic[1]	Ship	Summer	2009	33	1.07
Mullin et al. (2004)	Western slope[2]	Aerial	Spring	1992–1994	2	1.08
Hansen et al. (1996)	Western slope	Ship	All	1992–1994	3	0.81
Mullin & Hoggard (2000)	Eastern slope[3]	Aerial	Summer,	1996–1998	25	1.06
Mullin & Hoggard (2000)	Eastern slope	Ship	Spring,	1996–1997	29	1.05
Fulling et al. (2003)	Shelf	Ship	Fall	1998–2001	0	
Roberts et al. (2015a)[5]	Shelf[4], oceanic[1]	Aerial, ship	Spring,	1994–2009	44	0.27
DWH MMIQT (2015)	Oceanic[1]	Ship	Summer, fall	2007–2012	26	0.40
U.S. Atlantic						
Roberts et al. (2015b)[5]	Shelf[4], oceanic[1]	Aerial, ship	All	1992–2009	7	0.58

1 - Oceanic: 100 m or 200 m isobath to the U.S. EEZ throughout U.S. GOMx
2 - GulfCet I: Western Continental Slope: 100 m isobath to 1000 m or 2000 m isobath from the eastern edge of De Soto Canyon to the Texas-Mexico border
3 - GulfCet II: Eastern Slope: 100 m isobath to 2000 m isobaths from De Soto Canyon to Tampa Bay
4 - Continental shelf: aerial surveys, shoreline to 200 m isobath, ship surveys, 20 m to 200 m isobath throughout U.S. GOMx
5 - These estimates come from a compilation of most survey years and are g(0) corrected

In the U.S. Atlantic, there were four sightings of Bryde's/sei whales between 1992 and 1995. As a precautionary measure to inform management, Roberts et al. (2016) estimated the potential abundance of Bryde's whales in the U.S. Atlantic south of Cape Hatteras. The authors assumed that these four sightings were Bryde's whales but acknowledged that given the sightings occurred in winter, some or all could have, in fact, been sei whales. Roberts et al. (2015b) found these data insufficient for modeling using environmental covariates, and instead modeled their density uniformly across geographic strata delineated according to the known ecology of Bryde's whales; their results indicated an abundance of 7 Bryde's whales (CV = 0.58) in the U.S. Atlantic south of Cape Hatteras (Figure 8) (Roberts et al. 2015b). Bryde's whales or Bryde's/sei whales have not been subsequently identified in the U.S. Atlantic during assessment surveys conducted between 1998 and 2015 (e.g., Mullin & Fulling 2003, Garrison et al. 2011).

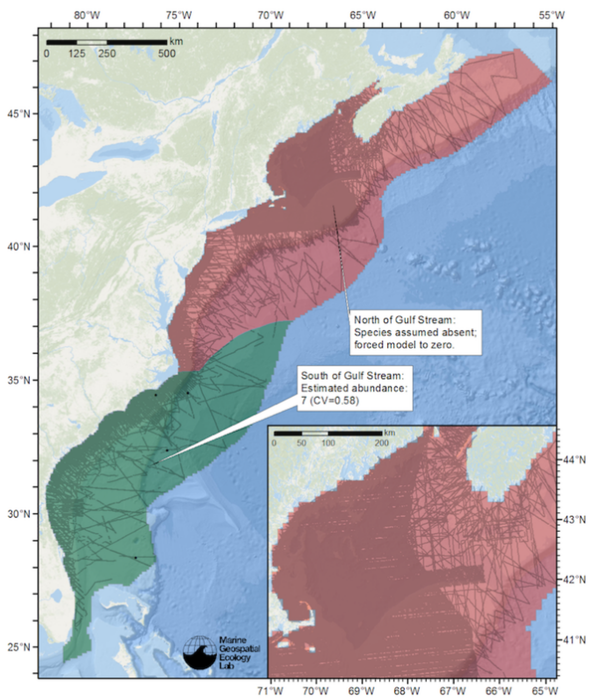


Figure 8. Bryde's whale density model for the western North Atlantic Ocean. Sightings indicated by black circles. See Roberts et al. (2015b) for details.

In summary, in U.S. waters of the GOMx, Bryde's whales are found almost exclusively in the northeastern GOMx in the productive waters of De Soto Canyon, although conclusions are difficult to make for the southern GOMx where there has not been a similarly high level of cetacean survey. The whales are concentrated in a small area focused on waters minimally between 199 and 309 m deep (mean water depth 226 m (Standard error (SE) = 7.9) along the continental slope. Historical whaling records indicate their distribution was broader and encompassed more waters in the north-central and southern GOMx but dedicated cetacean surveys conducted by NMFS have not confirmed Bryde's whales in the north-central or western GOMx since 1992 – 1993 when two baleen whales were sighted and identified as either Bryde's or sei whales. Estimates of Bryde's whale abundance in the GOMx from the early 1990s to present range from 15 – 44 whales (Table 2) and the population size is most likely less than100 whales.

Behavior

There is very little information on the behavior of the GOMx Bryde's whale. The mean group size, 2.0 whales (SE = 0.33, range 1 – 5, n = 14) (Maze-Foley & Mullin 2006), is similar to group sizes observed elsewhere (Wade & Gerrodette 1993). They are also periodically "curious" about ships and approach them in the GOMx (NMFS, unpublished) as has been observed elsewhere (Leatherwood et al. 1976, Cummings 1985). In September 2015 a female GOMx Bryde's whale was tagged with an acoustic and kinematic data-logging, suction-cup tag in the De Soto Canyon (NMFS, unpublished data). A nearly 3-day tagging period logged dive patterns for this whale. The animal exhibited a stereotypical diel dive pattern with deep dives throughout the daytime and shallow dives at night. This whale spent 47% and 88% of its time within 15 m of the surface during daylight hours and nighttime hours, respectively. This behavior of remaining near the surface at night could place the whales at risk of ship strike in areas where their distribution overlaps with shipping traffic.

Foraging ecology

There is little information on foraging available for GOMx Bryde's whales. Based on behavior observed during assessment surveys, they do not appear to forage at or very near the surface (NMFS, unpublished). In general, Bryde's whales are thought to feed primarily on schooling fish such as anchovy, sardine, mackerel and herring as well as small crustaceans (Kato 2002). These prey types occur in the GOMx and in the BIA (Grace et al. 2010). The acoustic and kinematic data-logging, suction-cup tag applied to a whale in September 2015 (described above) indicated that during the daytime, the tagged animal dove to depths as great as 271 m with foraging lunges apparent at the deepest parts of dives. This behavior indicates that the animal was likely foraging at the bottom, or just above the bottom (NMFS, unpublished data) during daylight hours, likely when diel-vertical-migrating schooling fish form tight aggregations at the bottom.

Reproduction and growth

There is little information on reproduction and growth of the GOMx Bryde's whale. The largest stranded individual in the GOMx was a lactating female (12.65 m) (Rosel & Wilcox 2014). No calf/neonate Bryde's whales have been sighted during NMFS assessment surveys. However, a 4.7 m calf stranded in the Florida Panhandle in 2006 (SEUS Historical Stranding Database) and 6.9 m juvenile stranded north of Tampa in 1988 (Edds et al. 1993).

Acoustics

Balaenopterids produce a variety of low-frequency tonal and broadband calls for communicating an animal's position, identity, and territorial or reproductive status as well as the presence of danger, food, or other animals, and these calls are often highly stereotyped (Richardson et al. 1995). Many balaenopterid species produce sequences of stereotyped calls, referred to as song, that are thought to function in a reproductive or territorial context. Similar to other balaenopterids, Bryde's whales produce calls or songs that are distinctive among geographic regions and may be useful for delineating subspecies or populations (Oleson et al. 2003, Širović et al. 2014). In the GOMx, one call type has been definitively identified to free-ranging GOMx Bryde's whales (Širović et al. 2014), four additional call types have been proposed as likely candidates (Rice et al. 2014a, Širović et al. 2014), and two call types have been described from a captive juvenile during rehabilitation (Edds et al. 1993). Širović et al. (2014) reported call types composed of downsweeps and downsweep sequences and localized the downsweep calls to Bryde's whales. Rice et al. (2014a) detected these sequences as well as two stereotyped tonal call types, a long-moan and a tonal sequence, on autonomous instruments in the GOMx and proposed the tonal calls originated from Bryde's whales based on their balaenopterid-like features, movement patterns of tracked calls, and the known distribution of Bryde's whales. The source of the long-moan and downsweep sequences has been preliminarily validated from paired directional sonobuoy call localizations that matched Bryde's whale sighting locations (NMFS, unpublished data). The long-moan is quite distinctive among all balaenopterid calls for its extended duration (20 – 45 s), similar only to blue whale, *B. musculus*, calls (McDonald et al. 1995) and North Atlantic minke whale pulse trains (Mellinger et al. 2000).

Genetics

As described earlier, analysis of mitochondrial DNA (mtDNA) control region sequence data indicates that the GOMx population of Bryde's whales is evolutionarily distinct and likely represents a distinct subspecies or species of the Bryde's whale complex (Rosel & Wilcox 2014). In addition, genetic analysis of the mtDNA data as well as data from 42 nuclear microsatellite data revealed that the genetic diversity of the population is exceedingly low (Rosel & Wilcox 2014). Only 2 mtDNA control region haplotypes were found in the first 375 base pairs of the control region across 21 sampled whales and no variability was seen in mtDNA cytochrome *b* (*cytb)* or cytochrome oxidase I (*cox1*) genes. For comparison, North Atlantic right whales, *Eubalaena glacialis*, exhibit 5 haplotypes across approximately the same control region sequence, while fin whales and minke whales in the North Atlantic exhibit 51 and 26 haplotypes, respectively (Bérubé et al. 1998, Pastene et al. 2007). Across the 42 nuclear microsatellite loci, 25 (60%) were monomorphic (i.e., no genetic variability was seen for the 21 whales) and the remaining loci had only 2 – 4 alleles, with an average of 2.6 alleles per locus when excluding all the monomorphic loci. Observed and expected heterozygosities were quite low, with means ± standard deviation over the 17 polymorphic loci of 0.256 ± 0.201and 0.241 ± 0.187, respectively. Other studies of microsatellite variation in Bryde's whales elsewhere have found significantly higher levels of variability. For example, Kanda et al. (2007), Wiseman (2008), and Penry (2010) found averages of 9.3, 5.5, and 3.6 alleles per locus, respectively, in their studies of *B. e. brydei* populations, and all had higher observed heterozygosities. The level of genetic diversity seen in the GOMx Bryde's whales is lower than that seen in the isolated and endangered population of humpback whales in the Arabian Sea where the number of alleles per locus was approximately 7 and observed heterozygosity was 0.7 (Pomilla et al. 2014). The severely reduced genetic variability seen in the GOMx Bryde's whale is of concern as it places these whales at risk from decreased fitness and evolutionary potential, and from demographic stochasticity (Rosel & Reeves 2000).

DPS DETERMINATION

In the process of determining whether the GOMx Bryde's whale is eligible for listing as endangered under the ESA, it must be determined whether the petitioned "species" meets the ESA definition of species, which includes taxonomic status as a species, a subspecies, or for vertebrates, a Distinct Population Segment (DPS). Taxonomic uncertainty was problematic for an earlier petition for southern resident killer whales (Krahn et al. 2002) and in the status review for potential listing changes in humpback whales (Bettridge et al. 2015). Therefore, to consider the petition to list the GOMX Bryde's whales as a DPS, the SRT first considered whether these whales could be at least a subspecies and therefore not require further consideration as to whether they were a DPS. Genetic analysis of divergence levels among Bryde's whales worldwide revealed that Bryde's whales in the GOMx are significantly differentiated from all other Bryde's whales examined to date (Rosel & Wilcox 2014). The level of divergence was as high as that found between the two recognized Bryde's whale subspecies and indicated they are a distinct lineage on a unique evolutionary pathway (Rosel & Wilcox 2014). The SRT considered this level of genetic divergence to be significant and asked the Society for Marine Mammalogy's Committee on Taxonomy (an independent group of experts on cetacean taxonomy) to provide their expert opinion on the level of taxonomic distinctiveness of this population, similar to what was done for the humpback whale ESA status review (Bettridge et al. 2015). The Committee was provided a background summary (Appendix 1) and was asked: "Are Bryde's whales in the Gulf of Mexico likely to belong to at least an undescribed subspecies of what is currently recognized as *Balaenoptera edeni*? Based on your expert opinion, please rate the likelihood of sub-specific status as high or low." Responses were received from 9 of the 15 members of the committee and "all voted it 'highly likely' that the Gulf of Mexico Bryde's whales comprise at least an undescribed subspecies" of what is currently recognized as *Balaenoptera edeni* (W. F. Perrin, Committee Chairman). This result constituted the opinion of the Committee, which decides its position on such issues based on majority vote. With this expert opinion provided, the Team determined that GOMx Bryde's whales should be treated as a 'species' under the ESA since they should be classified as at least a subspecies according to the best available scientific evidence evaluated by taxonomists. Therefore, the Team proceeded with the status review at the subspecies level. The Team did note, however, that the GOMx Bryde's whales would meet the discreetness criterion of a DPS because they share no haplotypes with named Bryde's whale subspecies, appear to exhibit a unique acoustic call, and have a distributional hiatus from other nearest *B. e. brydei* and *B. e. edeni*. They would also meet the significance criterion as the 24 to 26 fixed base-pair differences between the GOMx population and other Bryde's whales worldwide indicate they have a different evolutionary pattern from other closely related taxa.

ANALYSIS OF THE ESA SECTION 4(A)(1) FACTORS

Section 4(a)(1) of the ESA requires the agency to determine whether a species is endangered or threatened because of any of the following factors (or threats):

- Present or threatened destruction, modification, or curtailment of habitat or range;
- Overutilization for commercial, recreational, scientific, or educational purposes;
- Disease or predation;
- Inadequacy of existing regulatory mechanisms; or
- Other natural or human factors affecting its continued existence.

Incorporating the best available information on the above threats, the Team then evaluated the demographic risks facing the population in the following categories: abundance, spatial distribution, productivity, and diversity and evaluated the extinction risk as recommended by McElhany et al. (2000) and now recommended in the NMFS guidelines for conducting status reviews[5].

The following provides information on each of the above five listing factors as they relate to the Bryde's whale population in the GOMx.

Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

Energy Exploration and Development

The GOMx is one of the world's major oil and gas producing areas and has proven a steady and reliable source of crude oil and natural gas for more than 50 years. The first hydrocarbon well in GOMx waters was drilled in 1937. The first "out of sight of land" well was drilled about 12 mi (19.3 km) offshore Louisiana in 14 ft (4.3 m) water depth in 1947, and gradually oil exploration and development has moved into deeper waters (Austin et al. 2008). The amount of oil and gas activity in the GOMx is significant. There are approximately 2,300 platforms in Federal outer continental shelf (OCS) waters[6] (Figure 9). In 2001, the Minerals Management Service reported that there were approximately 27,569 mi (44,218 km) of pipeline on the seafloor of the GOMx (Cranswick 2001).

[5] NMFS 2015. Guidance on Responding to Petitions and Conducting Status Reviews under the Endangered Species Act.
[6] http://www.data.bsee.gov/homepg/data_center/leasing/WaterDepth/WaterDepth.asp

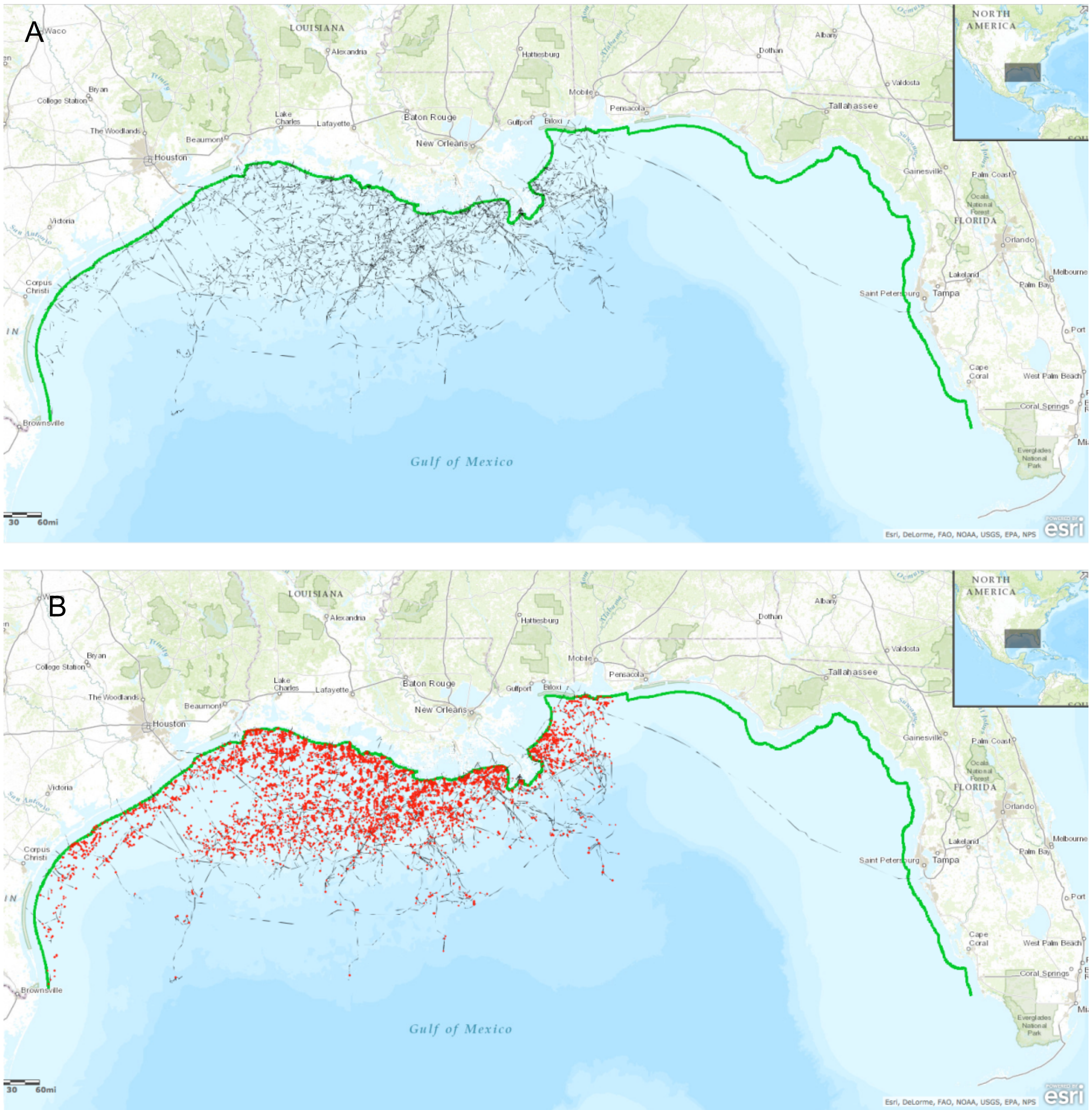


Figure 9. (A) Pipeline in the northern GOMx and (B) Pipeline and oil and gas platforms in the northern GOMx as of September 2014. From: http://www.arcgis.com/home/item.html?id=7aa4535ca4364efe86da66e0cbc376ab. Accessed 9 February 2016.

The Department of Interior's Bureau of Ocean Energy Management (BOEM) and Bureau of Safety and Environmental Enforcement (BSEE) regulate energy activities on the OCS, which is defined by BOEM as the submerged lands, subsoil, and seabed, lying between the seaward extent of the States' jurisdiction and the seaward extent of federal jurisdiction[7]. BOEM plans oil and gas leasing programs on a 5-year cycle. The current program is the 2012 – 2017 program and planning is underway for the 2017 – 2022 draft proposed program (DPP). For planning and administrative purposes, BOEM divides the GOMx into three planning areas: Western, Central and Eastern (Figure 10).

[7] http://www.boem.gov/Outer-Continental-Shelf/

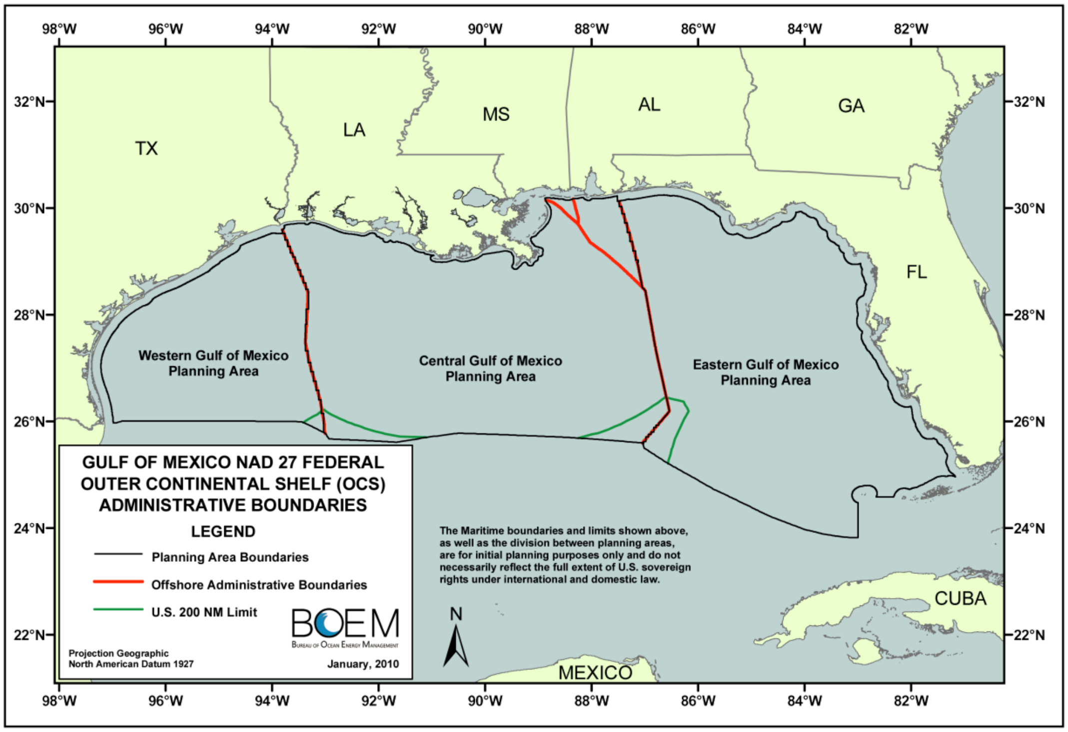


Figure 10. Bureau of Ocean Energy Management GOMx Administrative Planning Area Map. From http://www.boem.gov/Administrative-Boundaries/. Accessed 9 February 2016.

The Western Planning Area (WPA) covers approximately 28.58 million acres (115.7 thousand km^2) and is located 10.4 mi (16.7 km) offshore Texas and extends seaward to the limits of the U.S. EEZ. It is bounded on the west and north by the federal-state boundary offshore Texas and on the south by the maritime boundary with Mexico. The eastern boundary begins at the offshore boundary between Texas and Louisiana and proceeds southeasterly. There are approximately 907 (as of January 4, 2016) active leases in this area (Figure 11), however only 90 are producing any oil and gas[8]. In the GOMx, a typical lease block is 9 mi^2 (23.2 km^2) and an active lease is a lease that has been executed by the Lessor and the Lessee(s), has an effective date and has not been relinquished, expired, or terminated. In the WPA, more than 7,800 wells have been drilled through March 2014. The most recent sale was held in 2015 and one sale remains on the current 2012–2017 Program schedule in 2016. The State of Texas administers a robust oil and gas program in state waters adjacent to this area[9].

The Central Planning Area (CPA) covers approximately 66.45 million acres (268.9 thousand km^2) and is located 3.5 mi (5.5 km) offshore Louisiana, Mississippi, and Alabama and extends seaward to the limits of the EEZ. There are approximately 3,505 (as of January 4, 2016) active leases in this area (Figure 11), however only 810 of those are producing any oil or gas. More than 43,400 wells have been drilled through March 2014. The most recent lease sale was held in 2015 and two sales remain on the current 2012–2017 Program schedule, one each in 2016 and

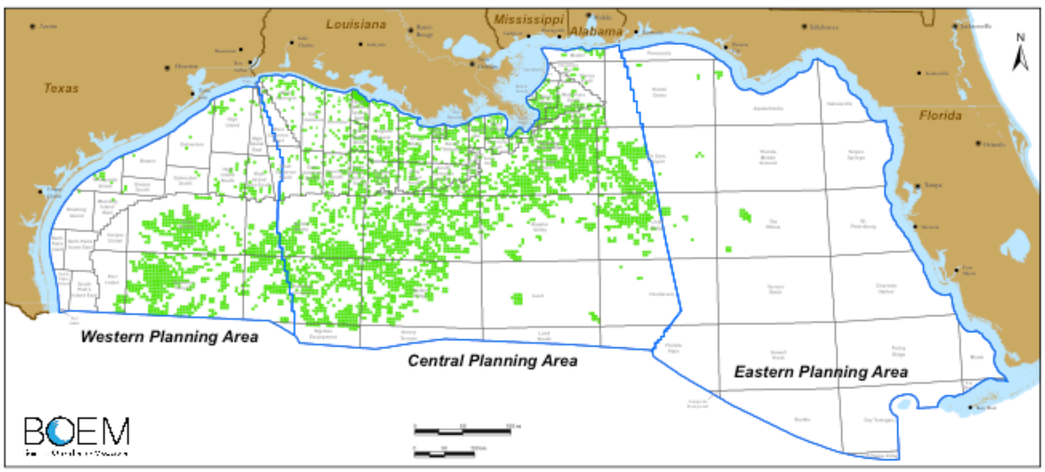
[8] http://www.boem.gov/Combined-Leasing-Report-January-2016/

[9] http://www.rrc.state.tx.us/oil-gas/research-and-statistics/production-data/offshore-production

2017. The States of Louisiana and Alabama administer robust oil and gas programs in state waters adjacent to this area. There are no leases in Mississippi state waters.

The Eastern Planning Area (EPA) covers approximately 64.56 million acres (261.3 thousand km^2) and is located 10 miles (16 km) offshore Florida. There are 48 (as of January 4, 2016) active leases (Figure 11) in this area. Thirteen sales have been held in this planning area and 105 wells drilled, with significant discoveries of natural gas. However, there has been no production from the wells in this planning area.

BOEM Gulf of Mexico OCS Region
Blocks and Active Leases by Planning Area
January 4, 2016



Planning Areas	Total Blocks	Total Acres	Number of Leases	Acres Leased
Western	5,240	28,576,813	907	5,143,073
Central	12,409	66,446,351	3,505	18,574,590
Eastern	11,537	64,357,859	48	264,030
Sub-Totals	29,186	159,381,023	4,460	23,981,693
CPA / EPA Shared Blocks*	(86)		(3)	
Totals	**29,100**	**159,381,023**	**4,457**	**23,981,693**

Active Leases
Planning Area Boundary

* CPA and EPA contain 86 shared blocks of which 3 are leased. These blocks are given both a CPA and EPA designation in the data which accounts for a higher block total.

Figure 11. Bureau of Ocean Energy Management GOMx Leasing Map. From: www.boem.gov/Gulf-of-Mexico-Region-Leasing-Information/. Accessed 9 February 2016.

On December 20, 2006, President Bush signed into law the Gulf of Mexico Energy Security Act of 2006 (Gulf of Mexico ESA), which made available new areas for leasing in the EPA and placed a moratorium on other areas in the GOMx until 2022. The areas not available for leasing under the moratorium include all of the EPA within 125 mi (201.2 km) of Florida, all areas in the GOMx east of the Military Mission Line (86° 41' west longitude), and the area within the CPA that is within 100 mi (161 km) of Florida. The most recent EPA sale was held in 2014 and no bids were received. One sale remains on the current 2012–2017 Program schedule for 2016.

Bryde’s whales are found in the EPA as identified in Waring et al. (2013). Currently there is no production activity in the EPA and most of the area within the EPA falls under the moratorium, at least until 2022. However, Congress has the option of opening more areas of the EPA for oil and gas activity.

Threats to the GOMx Bryde's whale from oil and gas activities include marine debris, operational discharge, oil spill and spill response, vessel collision, disturbance, and noise. Noise can be associated with vessels, aircraft, drilling rigs, production platforms or from geological and geophysical activities (seismic surveys). A 36-inch diameter natural gas pipeline traverses a portion of the Bryde's whale BIA[10]. Table 3 projects activities associated with oil and gas activities in the EPA through 2051. Table 4 projects those activities for the GOMx as a whole. Discussion of marine debris, vessel strike and noise are considered separately below under the 'plastics and marine debris,' "vessel collisions,' and 'anthropogenic noise' sections, respectively.

Table 3. Projected activity levels in the EPA from 2012 to 2051. Table 3-6 from http://www.boem.gov/BOEM-2015-033/. All activities in the EPA are expected to be in waters more than 800 m deep.

	Total EPA
Wells Drilled	
Exploration and Delineation Wells	10-27
Development and Production Wells	0-40
Producing Oil Wells	0-25
Producing Gas Wells	0-10
Production Structures	
Installed	0-2
Removed Using Explosives	0
Total Removed	0-2
Method of Transportation	
Percent Piped	>99.9%
Percent Barged	<0.01%
Percent Tankered	<0.01%
Length of Installed Pipelines (km)[1]	0-233
Service-Vessel Trips (1,000's round trips)	0.48- 35
Helicopter Operations (1,000's operations)	0-0.054

[1]Projected length of pipelines does not include length in State waters.

[10] http://wp.gulfstreamgas.com/

Table 4. Summary of total projected OCS oil and gas activity levels in the GOMx 2012- 2051. From Table 3-4 in http://www.boem.gov/BOEM-2013-200-v2/.

	Offshore Subareas (based on water depth)						
	0-60 m	60-200 m	200-800 m	800-1,600 m	1,600-2,400 m	>2,400 m	Total OCS
Wells Drilled							
Exploration and Delineation Wells	2,730 – 3,900	990-1,390	920-1,350	700-960	770-1,030	790-1,170	6,910-9,827
Development and Production Wells	3,380-4,820	1240-1,730	1130-1670	860-1,190	950-1,280	970-1,450	8,530-12,180
Producing Oil Wells	520-701	215-278	704-1030	574-783	663-873	620-915	3,296-4,605
Producing Gas Wells	2,510-3,629	885-1272	306-470	196-287	187-267	250-385	4,334-6,320
Production Structures							
Installed	1,210-1,720	110-160	26-40	25-30	32-33	32-38	1,435-2,026
Removed Using Explosives	796-1,139	69-104	3-4	0	0	0	868-1,247
Total Removed	1,090-1,560	100-150	24-34	20-28	23-30	22-33	1,279-1,837
Method of Transportation[1]							
Percent Piped	>99%	>99%	>99%	>99%	87->99%		92->99%
Percent Barged	<1%	0%	0%	0%	0%		<1%
Percent Tankered[2]	0%	0%	0%	0%	0-13%		0-7%
Length of Installed Pipelines (km)[3]	10,482-21,121	NA	NA	NA	NA	NA	30,428-69,749
Service-Vessel Trips (1,000's round trips)	1,366-1,942	196-280	111-162	466-619	584-626	587-719	3,310-4,382
Helicopter Operations (1,000's operations)	24,221-47,322	2,297-4,444	595-1,174	574-1,111	676-1,287	888-1,738	28,710-55,605

[1]100% of gas is assumed to be piped.
[2]Tankering is forecasted to occur only in water depths >1,600 m.
[3]Projected length of pipelines does not include length in State waters.
NA= not available.

Persistent Organic Pollutants

Persistent organic pollutants (POPs) are extremely stable, lipophilic and biomagnifying compounds resistant to degradation, creating a ubiquitous threat to the marine environment (Kucklick et al. 2011). Sources of POPs include pesticides, household and industrial items, and flame retardants. POPs may enter the food web through several mechanisms, including agricultural runoff, oceanic and atmospheric circulation, and combustion, and then bio-accumulate in higher trophic levels (Elfes et al. 2010). Once consumed, POPs may depress immune system function (increasing the risk of disease), impair growth, reproduction, and ontogenetic development, and cause lesions/disease of various organ systems (e.g., adrenal glands) (Aguilar et al. 2002, Schwacke et al. 2002).

POP concentrations are typically lower in mysticetes than odontocetes for many compound classes (O'Shea & Brownell 1994, Balmer et al. 2011, Kucklick et al. 2011, Bachman et al. 2014, Waugh et al. 2014, Balmer et al. 2015). Mysticetes forage on species such as krill and small schooling fish lower in the food chain, while odontocetes generally accumulate greater levels of POPs due to their higher position in the food chain (Waugh et al. 2014, Wise et al. 2014b). POPs and their transfer to offspring have been documented in mysticetes, such as humpback whales and blue whales (Metcalfe et al. 2004). Metcalfe et al. (2004) discovered that polychlorinated biphenyls (PCB) congeners and organochlorine compounds in the blubber of blue and humpback whale calves were similar in concentration and proportion to the blubber of adult females, indicating the transfer of contaminants either across the placental barrier, or via maternal milk, or both. Transplacental and lactational transfer have also been documented in odontocetes (Wells et al. 2005). Prior to sexual maturity, male and female common bottlenose dolphins exhibited similar concentrations of PCBs. However, whereas males continue to accumulate higher concentrations throughout their lives, females begin to depurate with their first calf, reaching a POP balance between intake and loss through transplacental and lactational transfer (Wells et al. 2005). The transfer of pollutants also varies among species depending on reproductive biology. In general, mysticetes have shorter lactational periods compared to odontocetes. As a result, the relative proportion of organochlorine load transferred to offspring has been assumed to be lower in mysticetes than in odontocetes (reviewed in Aguilar et al. (1999)).

POP concentrations have not been investigated in Bryde's whales. Overall, the threat of serious health effects from bioaccumulation of POPs in Bryde's whales appears to be lower because they feed on lower trophic levels subject to less bio-accumulation. However, for mysticete species, threshold levels for adverse effects, lethal and sub-lethal, are generally unknown (Steiger & Calambokidis 2000).

Harmful Algal Blooms

Harmful algal blooms (HABs) can affect the environment by producing toxins, depleting oxygen in the water, clogging fish gills, and shading seagrass. Largely due to human activities, HABs are increasing in frequency, duration and intensity throughout the world (Van Dolah 2000). There are more than 50 HAB species that occur in the GOMx, however, the most common HAB species is *Karenia brevis*, also known as the red tide organism (Florida Fish and Wildlife Conservation Commission 2015). *K. brevis* blooms occur throughout the Gulf, from Florida to Mexico, with most blooms occurring off the coast of Florida. Many forms of red tide are common in coastal zones that are most immediately affected by nutrification from agricultural and urban runoff. *K. brevis*, blooms can develop as far as 10 to 40 miles offshore, away from man-made nutrient sources (Florida Fish and Wildlife Conservation Commission 2015).

K. brevis produces neurotoxins (i.e., brevetoxins) that affect the nervous system by blocking the entry of sodium ions to nerve and muscle cells (Geraci et al. 1989). Brevetoxins can accumulate in primary consumers through direct contact with toxins in the water, ingestion, or inhalation. Once they have entered the food web, they can then be transferred through the food web to apex predators (Fire et al. 2009). HABs are known to negatively affect marine mammal populations through acute and chronic detrimental health effects, including reproductive failure (reviewed in Fire et al. (2009)). HABs are sometimes known or suspected to cause marine mammal unusual mortality events (UME). There have been three dolphin UMEs associated with brevetoxicosis in the Florida Panhandle between 1999 and 2006 (Litz et al. 2014). Biotoxins are also documented to affect mysticetes. In 1987 and 1988, fourteen humpback whales in the western North Atlantic were fatally poisoned after consuming mackerel containing saxitoxin, a dinoflagellate neurotoxin (Geraci et al. 1989). In 2003, a UME event occurred in Maine killing 16 humpbacks, 1 fin, 1 minke, 1 pilot whale, and 2 unknown species. While the cause and vector for exposure is unknown, saxitoxin and domoic acid (a type of neurotoxin) were detected in 2 and 3 of the humpback whales, respectively (Gulland 2006). Domoic acid can cause shellfish poisoning in humans as well as widespread mortality of seabirds and marine mammals. Between 1997 and 2008, 87% of fecal samples collected from pygmy sperm whales (*Kogia breviceps*) and dwarf sperm whales (*K. sima*) that stranded along the southeastern and mid-Atlantic U.S. coast tested positive for domoic acid (Fire et al. 2009). Domoic acid blooms are not considered common along the southeast U.S. coast and the vector for domoic acid exposure remains to be determined for these cryptic, deep-diving species. It is possible HABs resulting in domoic acid exposure occur in offshore areas that are not currently monitored (Fire et al. 2009). During a health assessment of common bottlenose dolphins in St. Joseph Bay, Fla., in the GOMx, Schwacke et al. (2010) documented chronic, low-level exposure to domoic acid.

While the majority of effects from HABs in the northern GOMx are seen in common bottlenose dolphins, Bryde's whales may also be exposed to adverse effects from HABs in this area, particularly since HABS are increasing in frequency, duration and intensity in the GOMx (Van Dolah 2000).

Oil Spill and Spill Response

From 2011 to 2013, there were 46 oil spills of < 1,000 barrels associated with oil and gas related activities in the Gulf of Mexico (Bureau of Ocean Energy Management & Gulf of Mexico OCS Region 2015). The majority of these spills were attributed to platforms and rigs while others were attributed to vessels and oil and gas pipelines (Bureau of Ocean Energy Management & Gulf of Mexico OCS Region 2015). On April 20, 2010, an explosion on the *Deepwater Horizon* (DWH) Macondo oil well drilling platform started the largest marine oil spill in U.S. history, releasing nearly five million barrels of oil into the GOMx (National Oceanic Atmospheric Administration 2011b).

Oil spills can cause acute or chronic impacts with lethal or sub-lethal effects depending on such things as the size and duration of the spill and the species affected. Dispersants used during oil spill response may also be toxic and affect wildlife including marine mammals (Wise et al. 2014a). Oil and other chemicals on the skin and body of marine mammals may result in irritation, burns to mucous membranes of eyes and mouth, and increased susceptibility to infection (DWH Trustees 2016). For large whales, oil can foul the baleen they use to filter-feed, thereby potentially decreasing their ability to eat (Geraci et al. 1989). For all marine mammal species, additional impacts may include (1) inhalation of volatile petroleum compounds or dispersants that irritate or injure the respiratory tract leading to inflammation or pneumonia (Schwacke et al. 2014); (2) ingestion of petroleum compounds that cause injury to the gastrointestinal tract, affecting the animals' ability to absorb or digest foods (Geraci et al. 1989); and (3) absorption of petroleum compounds or dispersants that may damage liver or kidney function (Schwacke et al. 2014). Even when oil spill effects are not lethal, they may impair animal health and reproduction, and increase susceptibility to other diseases (Harvey & Dahlheim 1994). After oil spills are stopped, marine mammals may experience continued effects through persistent exposure to oil in the environment, reduction or contamination of prey, direct ingestion of contaminated prey, or displacement from preferred habitat (Schwacke et al. 2014, Bureau of Ocean Energy Management & Gulf of Mexico OCS Region 2015, DWH Trustees 2016).

To investigate potential adverse effects of the DWH oil spill, several inshore dolphin health assessment studies were conducted as part of the Natural Resources Damage Assessment, with an emphasis on Barataria Bay, Louisiana, an area of significant and sustained oiling. Dolphins in Barataria Bay exhibited significant health issues including hypoadrenocorticism and moderate to severe lung disease (Schwacke et al. 2014) and the authors concluded that those health effects would likely lead to reduced survival and reproduction. Dead stranded dolphins in the northern GOMx following the DWH oil spill also exhibited chronic adrenal gland and lung diseases consistent with exposure to oil (Venn-Watson et al. 2015). Both these studies provided evidence that dolphins in heavily oiled areas may exhibit lesions and injuries consistent with those observed in mammals exposed to petroleum products in laboratory studies (Venn-Watson et al. 2015). Although Bryde's whales in the GOMx are found east of the majority of oil and gas exploration and production, the DWH oil footprint included 48% of the Bryde's whale habitat in the northeastern GOMx. The damage assessment also estimated that 17% (95% Confidence Interval (CI) 7% – 24%) of the population was killed, 22% (95% CI 10% – 31%) of reproductive females experienced reproductive failure due to the spill and 18% (95% CI 7% – 28%) of the population likely suffered adverse health effects due to the spill (DWH Trustees 2016). This unprecedented oil spill impacted cetacean populations far from the source of the spill.

<u>Discharge from Oil and Gas Activities</u>

The primary operational waste discharges generated during offshore oil and gas exploration and development are drilling fluids, drill cuttings, produced water, deck drainage, sanitary wastes, and domestic wastes. During production activities, additional waste streams include produced sand and well treatment, workover, and completion fluids. Minor additional discharges occur from numerous sources. These discharges may include desalination unit discharges, blowout preventer fluids, boiler blowdown discharges, excess cement slurry, and uncontaminated freshwater and saltwater (Bureau of Ocean Energy Management & Gulf of Mexico OCS Region 2012). Discharges are regulated by the U.S. Environmental Protection Agency's NPDES permits. Due to the lack of drilling activity and platforms in the eastern GOMx, threats to Bryde's whales from operational discharge are minimal.

Heavy Metals

Little is known about the effects of heavy metals on offshore cetacean populations. Heavy metals can accumulate in whale tissue and cause toxicity (Sanpera et al. 1996, Hernández et al. 2000, Wise et al. 2009). However, tissue concentrations vary based on physiological and ecological factors such as geographic location, diet, age, sex, tissue, and metabolic rate (Das et al. 2003). In addition, the trophic levels where marine mammals feed are often indicative of the amount of bioaccumulation. Species that feed higher on the food chain, such as odontocetes, are more likely to have higher accumulations of contaminants (e.g., POPS, metals) than species that feed lower on the food chain. For example, Tilbury et al. (2002) found that mercury levels in mysticetes tend to be lower than odontocetes. Immediately following the DWH oil spill, Wise et al. (2014b) identified oil-associated metal concentrations of nickel and chromium in one sampled Bryde's whale and 40 sampled sperm whales in the GOMx after the DWH oil spill, and compared them to levels measured in whales in other parts of the world. Concentrations for both metals were higher than that found in sperm whales sampled elsewhere. In the absence of baseline data for the GOMx, it is difficult to put these results in context. Although heavy metals are pervasive in the marine environment and documented in various marine mammal species, their impact on Bryde's whale health and survivorship is not known.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Historical Whaling

Although not considered prime whaling grounds, commercial whaling did take place in the GOMx. Yankee whalers began whaling in the GOMx as early as the mid-1700s and continued until the late1800s, with a peak in the mid-1800s (Reeves et al. 2011). The primary target was sperm whales, but other species from pilot whales, *Globicephala macrorhynchus*, to baleen whales were taken. Many whaling logbooks noted the presence of and occasional attempts to take "finback" whales and Reeves et al. (2011) reported at least 46 geographic locations noted in logbooks where "finbacks" were sighted or caught in the GOMx. Reeves et al. (2011) indicated that these were most likely Bryde's whales, a species northern whalers would be less familiar with, as all baleen whale species except for Bryde's whales are considered extralimital in the GOMx (Jefferson & Schiro 1997, Rosel & Wilcox 2014). Most whaling effort took place in waters greater than 100 m deep, but vessel positions in waters between 100 and 1000 m in the northeastern GOMx were recorded, although no sightings of "finback" whales were recorded in that area (Figure 6A, B).

Scientific Research

Scientific biopsy sampling

The primary goal of biopsy sampling is to collect data to support stock differentiation, to evaluate genetic variation, and to investigate health, reproduction and pollutant loads (Brown et al. 1994). Because biopsy sampling has the potential to disturb (Level B harassment) and/or injure marine mammals (Level A harassment), researchers must obtain a letter of authorization or permit under the ESA and/or Marine Mammal Protection Act of 1972 (MMPA) for biopsy sampling.

As of March 7, 2016, there is one active scientific permit authorizing take of Bryde's whales only in the GOMx and four scientific research permits authorizing take of Bryde's whales worldwide, including the GOMx. All five permits authorize Level B harassment for activities such as vessel or aerial surveys, photo-identification, behavioral observation, collection of sloughed skin, or passive acoustics. Four of these permits also authorize Level A harassment for activities such as dart biopsies and/or tagging. The total number of takes authorized for all Bryde's whales throughout their global range is 1,658 Level B authorized takes and 335 Level A authorized takes. It is unclear how range-wide takes might be allocated for Bryde's whales in the GOMx (NMFS APPS permits database, queried on March 7, 2016).

There are no documented negative impacts on Bryde's whales from biopsy sampling in the GOMx. However, there have been several studies examining the short-term reactions of other baleen whales to biopsy sampling in other geographic areas (Weinrich et al. 1992, Clapham & Mattila 1993, Brown et al. 1994, Gauthier & Sears 1999). Evidence suggests that the general response among six different whale species was minimal (Weinrich et al. 1992). The most commonly observed short-term behavioral responses included increased swim speed, avoidance behavior, diving, and flinching. In all cases, animals resumed normal behavioral patterns within 10 minutes (Brown et al. 1994). Biopsy sampling has also been found to have no effect on reproduction and calf survival rates for southern right whales, *Eubalaena australis* (Best et al. 2005).

Disease, Parasites, and Predation

<u>Disease and Parasites</u>

There are few data available on disease or parasitism of any Bryde's whales, including those within the GOMx, in the refereed literature. Reviews of conservation issues for baleen whales have tended to see disease as a relatively inconsequential threat (Clapham et al. 1999).

Diseases and parasitism known to occur in Bryde's whales (reported as *B. edeni)*, include spondylitis deformans, recorded in an apparently mature individual that stranded in subtropical Australia (Paterson 1984), and parasitism of the gut by an acanthocephalan, *Bolbosoma capitatum* (Pinto et al. 2004) from a whale stranded in subtropical Brazil. Hematology and blood chemistry values from a Bryde's whale entrapped in a subtropical estuary for 100 days, are available (Priddel & Wheeler 1998), but the individual was emaciated, stressed, and had alkaline phosphatase levels that suggested high levels of protein catabolism, so these values cannot be considered "normal" or baseline.

Cetacean morbillivirus has caused epizootics resulting in serious population declines in delphinids (Van Bressem et al. 2014) and has been detected in *Balaenoptera*, both fin whales in the eastern Atlantic Ocean (Jauniaux et al. 2000) and the Mediterranean Sea (Mazzariol et al. 2012) and common minke whales in the Mediterranean Sea (Di Guardo et al. 1995). The 2013 to 2015 common bottlenose dolphin unusual mortality event along the U.S. east coast from New York to Florida was caused by cetacean morbillivirus and killed hundreds of dolphins. Several balaenopterid species have also tested positive for morbillivirus during this event (D. Fauquier, NMFS, pers. comm.). If morbillivirus were to infect the GOMx Bryde's whale population, the consequences could be catastrophic. Historically, there have been morbillivirus or suspected morbillivirus outbreaks causing cetacean mortalities in the northern GOMx (Litz et al. 2014). These include an event in 1990 in which morbillivirus was the suspected cause of 344 cetacean mortalities across the northern GOMx, and an event in 1992 confined to the central Texas coast in which 119 cetacean mortalities were recorded. In 1994, morbillivirus was the confirmed cause of a mortality event in Texas in which 240 cetacean deaths were recorded (Litz et al. 2014). Most mortalities during these events were of common bottlenose dolphins. There are no confirmed morbillivirus-related deaths of Bryde's whales in the Gulf of Mexico.

Predation

Outside the GOMx, killer whales, *Orcinus orca*, are known to prey on Bryde's whales, *B. edeni* (Silber & Newcomer 1990, Alava et al. 2013), and are their only known predator. There are no published records of killer whale predation on GOMx Bryde's whales, but killer whales have been observed harassing sperm whales and attacking pantropical spotted dolphins, *Stenella attenuata*, and a dwarf/pygmy sperm whale, *Kogia* sp., in the GOMx (Pitman et al. 2001, Whitt et al. 2015, NMFS SEFSC, unpublished). Killer whales also occur in Caribbean waters, to at least Cuba in the northern Caribbean (Bolaños-Jiménez et al. 2014). Scarring on a Bryde's whale stranded in Venezuela indicates it previously had been attacked by killer whales (Bolaños-Jiménez et al. 2014).

Although large sharks (e.g., white sharks, *Carcharodon carcharias*, and tiger sharks, *Galaecerdo cuvier*) are known to scavenge Bryde's whale carcasses elsewhere in the world (Dudley et al. 2000), there are no published reports of direct predation on healthy individuals. However, white sharks appear to prey on the calves of North Atlantic right whales on their calving grounds in the Atlantic off Florida and Georgia (Taylor et al. 2013). Similarly, white sharks could target calves of GOMx Bryde's whales, although there is no evidence to date that this happens.

Migration has been suggested as an anti-predator adaptation in baleen whales (Corkeron & Connor 1999) although this is debated (Clapham 2001). A non-migratory species such as the GOMx Bryde's whale clearly lacks this adaptation. *Balaenoptera* use a flight strategy (Ford & Reeves 2008) when attacked by killer whales, which would be less effective with a young calf. Field observations of killer whales conducting multiple successful predatory attacks on neonatal humpback whales (Pitman et al. 2015) demonstrate that killer whales can efficiently dispatch a small baleen whale calf in minutes to hours. The small numbers of GOMx Bryde's whales would produce only a few calves each year. Few kills of calves or mothers would be needed to drive this population into a predator pit (that is, mortality due to predation is sufficient to keep the population from increasing). The likelihood of detecting these predation events, if they are occurring, is extremely low.

Inadequacy of Existing Regulatory Mechanisms

The ESA requires an evaluation of existing regulatory mechanisms to determine whether they may be inadequate at addressing threats to GOMx Bryde's whales. These regulatory mechanisms include federal, state, and international regulations. Below is a summary and evaluation of current regulations that affect the conservation of Bryde's whales in the GOMx.

Federal Regulations

Marine Mammal Protection Act of 1972, as amended

In U.S. waters, Bryde's whales are protected by the Marine Mammal Protection Act (MMPA) (16 U.S.C. 1361 *et seq*.). The MMPA sets forth a national policy to prevent marine mammal species or population stocks from diminishing to the point where they are no longer a significant functioning element of their ecosystem. The Secretaries of Commerce and the Interior have primary responsibility for implementing the MMPA. The Department of Commerce, through NMFS, has authority with respect to whales, dolphins, porpoises, seals, and sea lions. Both agencies are responsible for promulgating regulations, issuing permits, conducting scientific research, and enforcement, as necessary, to carry out the purposes of the MMPA.

The MMPA includes a general moratorium on the 'taking' and importing of marine mammals, which is subject to a number of exceptions. Some of these exceptions include 'take' for scientific purposes, public display, subsistence use by Alaska Natives, and unintentional incidental take coincident with conducting lawful activities. Take is defined in the MMPA to include the "harassment" of marine mammals where "harassment" includes any act of pursuit, torment, or annoyance which "has the potential to injure a marine mammal or marine mammal stock in the wild" (Level A harassment), or "has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering" (Level B harassment).

U.S. citizens who engage in a specified activity other than commercial fishing (which is specifically and separately addressed under the MMPA) within a specified geographical region may petition the Secretaries to authorize the incidental, but not intentional, taking of small numbers of marine mammals within that region for a period of not more than five consecutive years (16 U.S.C. 1371(a)(5)(A)). Similar to these incidental take authorizations, the MMPA also authorizes U.S. citizens to apply for an authorization to incidentally take small numbers of marine mammals when the take is limited to harassment. These "incidental harassment authorizations" or IHAs are limited to one-year and similar to the incidental take authorizations, the Secretary must find that the total of such taking during the period will have a negligible impact on such species or stock and will not have "an unmitigable adverse impact on the availability of such species or stock for taking for subsistence uses…."

The MMPA also provides mechanisms for researchers to "take" marine mammals for the purposes of bona fide scientific research (see Section 104 of the MMPA). Takes of Bryde's whales for bona fide scientific research are currently authorized on a global scale and typically do not specify a geographic area. This has the potential to result in multiple takes of the same animals in the GOMx. However, in these situations, NMFS takes a proactive role and coordinates with researchers to minimize any potential negative effects to a small population.

Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA)

The Magnuson-Stevens Fishery Conservation and Management Act, 16 U.S.C. §§ 1801-1884, is the primary law governing marine fisheries management in U.S. federal waters. The Act specifically covers the fish along the coast of the U.S., the highly migratory species of the high seas, the species which dwell on or in the continental shelf out to 200 nautical miles from shore, and anadromous species which spawn in U.S. rivers or estuaries. First passed in 1976, this Act fosters long-term biological and economic sustainability of U.S. marine fisheries in waters. The key objectives of the Act are to prevent overfishing, rebuild overfished stocks, increase long-term economic and social benefits, and ensure a safe and sustainable supply of seafood. The 1976 law established eight regional fishery management councils (Councils) with representation from the coastal states and fishery stakeholders. The Councils' primary responsibility is development of fishery management plans (FMPs). These FMPs must comply with a number of conservation and management requirements and principles that promote sustainable fisheries management. These implemented plans and regulations are reviewed periodically and may be updated or modified after public review to accommodate changing conditions and needs. FMPs managed by the Gulf of Mexico Fishery Management Council include: reef fish, aquaculture (50 C.F.R. § 622 2014), essential fish habitat, shrimp, spiny lobster, corals, migratory pelagic species, and red drum. In addition, any future emerging fisheries in Federal waters would similarly be managed under this Act.

Outer Continental Shelf Lands Act (OCSLA)
The Outer Continental Shelf Lands Act (OCSLA) establishes federal jurisdiction over submerged lands on the outer continental shelf (OCS) seaward of coastal state boundaries in order to explore and develop oil and gas resources on the OCS. Implementation, regulation, and granting of leases for exploration and development on the OCS are delegated to BOEM and BOEM is responsible for managing development of the Nation's offshore resources in an environmentally and economically responsible way. The functions of BOEM include leasing, exploration and development, plan administration, environmental studies, NEPA analysis, resource evaluation, economic analysis, and the renewable energy program. The BSEE is responsible for enforcing safety and environmental regulations.

OCSLA mandates that orderly development of OCS energy resources be balanced with protection of human, marine and coastal environments. It is the stated objective of the OCSLA "to prevent or minimize the likelihood of blowouts, loss of well control, fires, spillages… or other occurrences which may cause damage to the environment or to property, or endanger life or health" (43 U.S.C. § 1332(6)). The OCSLA further requires the study of the environmental impacts of oil and gas leases on the continental shelf, including an assessment of effects on marine biota (43 U.S.C. § 1346).

OCSLA, as amended, requires the Secretary of the Interior (Secretary), through BOEM and BSEE, to manage the exploration and development of OCS oil, gas, and marine minerals (e.g., sand and gravel) and the siting of renewable energy facilities. The Energy Policy Act (EPAct) of 2005, Public Law (P.L.) 109-58, added Section 8(p)(1)(C) to the OCSLA, which grants the Secretary of Interior the authority to issue leases, easements, or rights-of-way on the OCS for the purpose of renewable energy development (43 U.S.C. § 1337(p)(1)(C)). The Secretary delegated this authority to BOEM (30 C.F.R. § 585 2011) who now regulates activities within federal waters.

The Oil Pollution Act (OPA)
The Oil Pollution Act (OPA) of 1990 (33 U.S.C. 2701-2761) is the principal statute governing oil spills in the nation's waterways. This Act was passed in the wake of the Exxon Valdez oil spill in March of 1989. After this spill, the U.S. identified two major issues (1) it lacked adequate resources, particularly federal funds, to respond to oil spills; and (2) the scope of damages to those impacted by a spill that are compensable under federal law was fairly narrow (National Pollution Funds Center 2016). The OPA was designed to address both of these

deficiencies through the establishment of new requirements for oil transportation, for oil spill response capabilities of the federal government and industry, and for cleanup (Kenney 2010). In addition, the process established by OPA makes the owner or operator of a facility that discharges oil liable for the cost associated with cleanup of the spill and damages cause by the spill.

The OPA authorizes Trustees (representatives of federal, state, and local government entities, and Tribes with jurisdiction over the natural resources in question) to determine the type and amount of restoration needed to compensate the public for the environmental impacts of the spill. This assessment is described in a "Final Programmatic Damage Assessment and Restoration Plan (PDARP)." In the PDARP associated with the 2010 *Deepwater Horizon* oil spill in the GOMx, Bryde's whales were found to be the most impacted offshore cetacean. Forty-eight percent of the population was affected, resulting in an estimated 22% maximum decline in population size (DWH Trustees 2016). The PDARP allocates fifty-five million dollars over the next 15 years for restoration of oceanic marine mammals, including Bryde's whales. The PDARP does not identify specific projects, but lays out a framework for planning future restoration projects that will contribute to the restoration of Bryde's whales.

National Environmental Policy Act (NEPA)

The National Environment Policy Act (NEPA) was signed into law on January 1, 1970 and provides a framework for environmental planning and decision making by federal agencies. NEPA directs federal agencies to assess and consider potential impacts on the environment as well as socio- economic effects of actions for which federal permits are required. When federal agencies plan projects or issue permits for projects in the GOMx, marine mammals, including Bryde's whales, are considered in the NEPA analyses.

State Regulations

The states of Alabama, Louisiana, and Mississippi have primary jurisdiction out to 3 nautical miles (5.6 km) from shore, and Texas and Florida have primary jurisdiction out to 9 nautical miles (16.7 km) from shore in the GOMx. Beyond these boundaries, the federal government has primary jurisdiction. As previously discussed, Bryde's whale sightings from vessel surveys are concentrated offshore, beyond nine nautical miles (16.7 m) and the jurisdiction of state laws in the GOMx.

International Regulations

In 2013, Mexico instituted constitutional reforms related to the country's oil and gas sector. These reforms were followed with laws implemented in 2014 that officially opened Mexico's oil, natural gas, and energy sectors to private investment. As a result, Mexico's *Petroleos Mexicanos* (Pemex) can now partner with international companies that have the experience and capital required for exploring Mexico's vast deep water and shale resources. Mexico held its first shallow water lease sale in 2015 with few blocks being awarded.

In January of 2015, Mexico issued rules for seismic exploration[11] and, while new leasing has had a slow start following the constitutional reforms, geophysical companies are moving forward

[11] http://cnh.gob.mx/ares_i.aspx

aggressively to acquire data in Mexican waters of the GOMx[12]. To date, more than nine companies have permits either pending or approved and 2D and 3D seismic data collection has begun. Many of these companies have permits from BOEM for U.S. waters as well.

In 2013, the U.S. Congress approved the U.S.-Mexico Transboundary Hydrocarbons Agreement, which aims to facilitate joint development of oil and natural gas in part of the GOMx. This agreement, coupled with recent reforms in Mexico, could transform Mexican GOMx waters into a more developed oil and gas landscape including infrastructure development and cross-border pipelines. The potential for increased oil and gas activities in Mexican waters of the GOMx is high.

International Convention for the Regulation of Whaling (ICRW)
The International Whaling Commission (IWC) was set up under the International Convention for the Regulation of Whaling, signed in 1946. Part of the IWC's function is to set catch limits for commercial whaling and under the commercial whaling moratorium, limits have been set at zero since 1985. The IWC's regulations provide a process by which countries may object to specific provisions, and Norway and Iceland currently allow commercial whaling based on these objections. The ICRW also allows for signatory nations to harvest whales for scientific purposes through their own national permit process, and Japan uses this process for scientific whaling and Bryde's whales in the North Pacific Ocean are taken by Japan. However, no whaling for Bryde's whales occurs in the GOMx.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)
CITES is aimed at protecting species at risk from unregulated international trade and regulates international trade in animals and plants by listing species in one of its three appendices. Appendix I includes species that are threatened with extinction and may be affected by trade; trade of Appendix I species is only allowed in exceptional circumstances. Appendix II includes species not necessarily threatened with extinction presently, but for which trade must be regulated to avoid use incompatible with their survival. Appendix III includes species that are subject to regulation in at least one country, and for which that country has asked other CITES Party countries for assistance in controlling and monitoring international trade in that species. All Bryde's whales, *B. edeni,* are currently listed in Appendix I under CITES.

International Maritime Organization (IMO)
The International Maritime Organization (IMO), a branch of the United Nations, is the international authority on shipping, pollution, and safety at sea. It also has adopted guidelines to reduce shipping noise. The IMO's Marine Environment Protection Committee occasionally designates "Particularly Sensitive Sea Areas" (PSSA), "Areas to be avoided" (ATBA), routing schemes, or "Traffic Separation Schemes" (TSS) for various ecological, economic, or scientific reasons. For example, some of these types of areas or routing schemes have been endorsed by the IMO to help recover endangered right whales and humpback whales. However, there are no IMO protected areas or routing schemes designed to benefit Bryde's whales in the GOMx.

[12] http://www.aapg.org/publications/news/explorer/details/articleid/16355/mexico-invites-seismic-exploration

Other Natural and Manmade Factors Affecting Continued Existence

Small Population Effects

Small populations are subject to a number of inherent risks that may increase the potential for decline and extinction. These risks typically include Allee or other depensation effects that are tied to survival and reproduction via three mechanisms: ecological (e.g., mate limitation, cooperative defense, cooperative feeding, and environmental conditioning), genetic (e.g., inbreeding and genetic drift), and demographic stochasticity (i.e., individual variability in survival and recruitment) (Berec et al. 2007). The actual number at which a population would be considered critically small and at heightened risk from such effects depends on the species and the mechanism(s) involved.

Allee effects
If a population is critically small in size, individuals may have difficulty finding a mate. However, the probability of finding a mate depends largely on density (i.e., abundance per area) rather than absolute abundance alone. The U.S. portion of the GOMx has been extensively surveyed and Bryde's whales are found in only a small portion of this area. Noise from ships and industrial oil activities, including seismic exploration, are known to be generally high in the GOMx. Therefore, high noise levels could mask mating calls and contribute to reduced fecundity. Other factors may affect reproduction, including the potential that there are very low numbers of one or the other sex. Recent biopsies have shown nearly equal numbers of males and females (Rosel & Wilcox 2014), so a skewed sex ratio does not currently appear to be a problem for this group.

Demographic stochasticity
If a population is critically small in size, chance variations in the annual number of births, sex ratio at birth, and deaths (by gender) can put the population at added risk of extinction. Demographic stochasticity refers to the variability of annual population change arising from random birth and death events at the individual level. When populations are very small (e.g., < 100 individuals), they are more vulnerable to demographic stochasticity. The mean population growth rate can be reduced by inter-annual variance in growth rates and this variance steadily increases as population size decreases (Goodman 1987). Demographic stochasticity is more problematic for slowly reproducing species than for rapidly reproducing species for a given population size. Species that have multiple young per birth, a mouse for example, have a lower chance of having skewed sex ratios because females have more offspring and are less likely to give birth to all males or all females. Under normal conditions, Bryde's whales are likely to calf every two to three years and have a higher probability of getting more of one sex than another by chance alone. Because of the low abundance of the GOMx Bryde's whale population, it is clearly vulnerable to adverse effects from demographic stochasticity.

Genetics
Genetic stochasticity results from three separate factors: inbreeding depression, loss of potentially adaptive genetic diversity and mutation accumulation (Frankham 2005, Reed 2005). If a population is critically small in size, genetic drift can elevate the frequency of deleterious or lethal alleles or decrease the frequency of beneficial alleles. An isolated population with a small number of mature individuals (which appears to be the case for the GOMx Bryde's whales) will likely already be experiencing inbreeding (mating with related individuals). This may lower the

population's fitness by reducing adaptive potential and increasing the accumulation of deleterious alleles. For many years, conservation genetics has employed genetic theory coupled with empirical observations to support the 50/500 rule as a threshold population size below which short-term fitness is lost (Soulé 1980, Shaffer 1981). The rule-of-thumb of an effective population size (see below) of 50 was based on Soulé's theoretical estimate of the minimum short-term effective population size required to avoid extremely deleterious effects of inbreeding through immediate loss of genetic diversity (Soulé 1980). It was based, in part, on observations of levels that could be tolerated in domesticated animal populations and is also the number below which some species of birds have been known to go extinct rapidly (Soulé et al. 1988). Numerous recent publications have confirmed that inbreeding depression has resulted in reduced survival and fecundity that lead to substantial increases in the risk of extinction (O'Grady et al. 2006). The 500 value was meant to reflect an effective size for which a rough balance might be achieved between loss of diversity through drift and gain of diversity through mutation. Both values are only meant as rough guides.

Frankham et al. (2014) suggested that 50 was too low because newer studies have shown the effects of inbreeding depression to be greater in wild populations than for domestic populations, which formed the basis for the earlier estimate of 50 to avoid inbreeding depression in the short term. They suggested revising the number needed to prevent inbreeding depression over 5 generations in the wild to an effective population size of 100 individuals. This suggested change from 50 to 100 is still being debated in the conservation genetics community.

Effective population size (N_e) is a theoretical construct used by geneticists to estimate the effects of mutations and genetic drift on an idealized population where every individual has an equal chance of mating with every other individual and all contribute equally to the next generation. The relation of N_e to the census population size (N_c) depends on the violations of the assumption made for the idealized population and generally relates to life history of the organism, but N_e is usually less than N_c. The assumption for mammals is that N_e is close to the number of mature individuals because the sex ratio is at parity and there is little variance in the reproductive output of females. Even though this assumption apparently forms the basis for the IUCN abundance thresholds (Mace & Lande 1991, Mace et al. 2008), recent research has shown that the N_e/N_c ratio (or the ratio of N_e to the annual number of breeding individuals, N_b) is quite variable (Palstra & Fraser 2012, Waples et al. 2013). For baleen whales, there is also no apparent mating strategy that would allow high variance in male success (as there would be in a species like elephant seals).

There are no data on the number of mature GOMx Bryde's whales or, of those, the number that are capable of reproduction. The Team inferred this number by using data from closely related species and making assumptions about the age and sex composition for the purpose of equating the numbers needed to avoid short-term fitness loss. Taylor et al. (2007) provided an estimate of 0.51 for the proportion of a Bryde's whale (as *B. edeni*) population that is mature. The Team assumed that all mature whales are capable of reproducing and thus our estimates can only be on the high side. Even so, it is likely that N_e/N_c is less than 0.51 because there is likely to be some variation in reproductive output. For example, Hawaiian false killer whales were estimated to have 151 individuals (Baird 2009) and the genetic estimate of N_e was 46 (Chivers et al. 2010) resulting in an N_e/N_c ratio of 0.30. False killer whales are known to have strong social structure that is likely to reduce this ratio more than would be expected for the less social baleen whales like Bryde's whales.

The estimated total abundance for Bryde's whales in the northern GOMx is 33 (CV = 1.07) (Waring et al. 2015). The Team agreed by consensus that even allowing for the uncertainty about presence of Bryde's whales in non-U.S. waters of the GOMx, given the best available science, there are fewer than 250 mature individuals, and more likely that a value of 100 or fewer is plausible. Regardless of any theoretical discussions of the ratio of N_e/N_c for GOMx Bryde's whales, a census population size of less than 100 individuals would put these whales at immediate recognized risks for genetic factors given that, if we assume a stable age distribution, there would be at most 50 mature individuals (using a proportion mature of 0.51 estimated by Taylor et al. (2007)). Using the abundance estimate of 33 whales would result in an estimate of 16 mature individuals. Even with a 50-50 sex ratio, 8 males and 8 females would certainly meet any genetic risk threshold for both decreased population growth due to inbreeding depression and potential loss of adaptive genetic diversity. Using the higher abundance estimate of 44 (Roberts et al. 2015a) negligibly increases these numbers to 11 males and 11 females.

K-selected life history parameters
Whales are k-selected species due to their life history characteristics. K-selected species (i.e., those with slower population growth rates) generally tolerate a lower level of additive mortality than r-selected species (i.e., those with higher population growth rates). Populations can be reduced by added anthropogenic deaths at rates much higher than maximum growth rates. A slower ability to recover from small population size increases the time at vulnerable, small population sizes and thereby increases the chance that multiple risks will act synergistically, a phenomenon called the 'extinction-vortex' (Gilpin & Soulé 1986). For example, a population that numbers 35 individuals growing at 4%/year (the assumed maximum growth rate for cetaceans under the MMPA) would take 68 years (from 2015 to 2083) to reach 500 individuals (250 mature individuals). During this period, the population is more vulnerable to catastrophic events.

Stochastic and catastrophic events
Animals that are highly mobile with a large range are less susceptible to stochastic and catastrophic events (such as oil spills) than those that occur in concentrated areas across life history stages. Catastrophic events are a serious risk given the small current distribution known for GOMx Bryde's whales, which is in close proximity to oil extraction developments, extreme weather events and toxic algae blooms.

Anthropogenic Noise

Human activities (e.g., oil and gas exploration and production, military activities, navigation and transportation (shipping), offshore construction, and research) intentionally and unintentionally introduce sound into the marine environment. Anthropogenic sound has increased in all oceans over the last 50 years with an estimated doubling each decade (Wenz 1962, Croll et al. 2001, McDonald et al. 2006). Hildebrand (2005) evaluated total energy output per year (in joules) to compare various noise sources. The results indicate that the highest energy output is from singular, relatively infrequent events (e.g., from nuclear explosions and ship-shock trials (2.1×10^{15} J)). After those sources, the next highest sources of energy are seismic airgun surveys (3.9 x

10^{13} J), military sonars (2.6 x 10^{13} J), supertankers, merchant vessels, and fishing vessels (sum = 3.8 x 10^{12} J), and navigational and research sonars (sum = 3.6 x 10^{10} J) (Hildebrand 2005).

Marine mammals rely heavily on acoustic sensory capabilities to detect and interpret acoustic communication and environmental cues to select mates, find food, maintain group structure and relationships, avoid predators, navigate, and perform other critical life functions. Rising noise levels impact marine animals and ecosystems in complex ways, including through acute, chronic, and cumulative effects (Francis & Barber 2013). These impacts include a variety of direct and indirect adverse physical and behavioral effects such as death, hearing loss or impairment, stress, behavioral changes, physiological effects, reduced foraging success, reduced reproductive success, masking of communication and environmental cues, and habitat displacement (Richardson et al. 1995, Southall et al. 2007, Francis & Barber 2013). Many studies have shown these impacts are relevant both for marine mammals (e.g., Croll et al. 2001, Aguilar Soto et al. 2006, Cox et al. 2006, Nowacek et al. 2007, Weilgart 2007a, Tyack et al. 2011, Hatch et al. 2012, Rolland et al. 2012, Azzara et al. 2013, Rossi-Santos 2014) as well as their prey sources (e.g., Popper et al. 2003, Mooney et al. 2012, Radford et al. 2014). The physiological and behavioral effects of a given noise source are dependent on the sound source characteristics (including source levels, sound frequency and bandwidth, directionality, rise time, duration and duty cycle), the environmental sound propagation conditions, distance between the animal and the source, the animal's behavioral and physiological state (e.g., hearing sensitivity, behavioral context, age, sex, previous experience), and time of day or season (Southall et al. 2007, Ellison et al. 2012).

To understand the potential effects of anthropogenic noise on marine mammals one needs to know the radius within which acoustic affects may occur. Severity of impacts generally decreases with decreasing received sound levels, and received levels decrease with increasing distance from a sound source. Four common acoustic-effect criteria can be visualized as four concentric zones with decreasing size and increasing intensity of the signal. The zone of audibility is the largest and occurs out to the lowest received levels. The zones of responsiveness, masking, and injury each occur at consecutively higher received levels and over smaller areas. The received sound levels at which each effect may occur vary with the conditions described previously, but some general values are used for management purposes. To evaluate applications for incidental take authorizations, NOAA uses a threshold of 180 dB re 1uPa (rms) for determining Level A takes, which include serious injuries, such as hearing loss, and deaths. NOAA uses a threshold of 120 dB re 1uPa (rms) for non-impulsive sound sources and a threshold of 160 dB re 1uPa (rms) for impulsive sound sources for determining Level B behavioral harassment. Behavioral harassment may include such things as ceasing feeding or reproductive behavior, exhibiting antipredator responses, avoiding an area, mothers separating from dependent offspring, panic, flight, stampede, aggression, or stranding. Masking of biologically important sounds occurs when human-caused sounds are so loud that a whale cannot hear or interpret natural sounds that it otherwise depends on for social, foraging, predator avoidance, or other purposes. As masking increases, the area in which a whale can hear those essential natural sounds decreases, which is often referred to as a decrease in its hearing of communication space.

Many anthropogenic sources have considerable energy at low frequencies. Low-frequency noise travels farther underwater and therefore can have significant adverse effects over a larger geographic are. For example, naval Low Frequency Active (LFA) sonar and distant shipping may sometimes be heard over millions of square kilometers of ocean at levels high enough to cause possible disturbance in marine mammals (Hildebrand 2009). Seismic survey noise has been documented as the loudest component of underwater ambient noise at distances up to 3000 – 4000 km away (Nieukirk et al. 2004, Nieukirk et al. 2012). These surveys can raise the background noise levels by 20 dB over 300,000 km^2 continuously for days (IWC 2005, Weilgart 2007a). Baleen whales produce calls that span a similar low frequency range (20 Hz – 30 kHz) and presumably their best hearing abilities fall in this range as well and they would therefore be most impacted by low-frequency sounds (Richardson et al. 1995, Ketten 1997, Ketten et al. 2013, Cranford & Krysl 2015). In contrast, odontocetes produce calls and hear best at mid to high frequencies (Richardson et al. 1995) and therefore appear to be less vulnerable to low-frequency sound sources than mysticetes.

Energy exploration and extraction, military activities, and shipping are pervasive in the GOMx. The acute, chronic, and cumulative impacts of these anthropogenic noise sources on most marine mammal species in this region are not well studied or well characterized.

Acute impacts of noise producing activities
Acute impacts of noise producing activities have been studied for many marine mammal species, though no information is available for GOMx Bryde's whales. The SRT evaluated the nature of activities, characteristics of the sound sources, and the documented injuries or behavioral impacts to marine mammals for noise-producing activities associated with oil and gas activities, military activities, commercial fishing and scientific research, and shipping traffic. Similar acute impacts may be expected for GOMx Bryde's whales.

<u>Aircraft and vessel noise associated with oil and gas activities</u>
Aircraft and vessel operations (service vessels, etc.) support the OCS oil and gas activities in the GOMx (See Table 4). Aircraft noise is generally short in duration and transient in nature, although it may ensonify large areas. Helicopter sounds contain dominant tones (resulting from rotors) generally below 500 Hz (Richardson et al. 1995). Helicopters, while flying offshore, generally maintain altitudes above 213 m during transit between shore and platforms and about 152 m between platforms. Routine overflights may elicit a startle response from and interrupt marine mammals nearby (depending on the activity of the animals) (Richardson et al. 1995). This temporary disturbance may occur as helicopters approach or depart OCS facilities if marine mammals are near the facility. Due to the lack of oil and gas activities currently in the eastern GOMx and Bryde's whale habitats, the threat from service aircraft and vessel noise would be minimal.

<u>Drilling and production noise associated with oil and gas activities</u>
Drilling and production activities associated with the energy industry produce low-frequency underwater sounds that are detectable by marine mammals. Drilling noise from conventional metal-legged structures and semisubmersibles is not particularly intense and is strongest at low frequencies, averaging 5 Hz (119 – 127 dB re 1 μPa near field) and 10 – 500 Hz (154 dB re 1 μPa-m), respectively (Richardson et al. 1995). Drill ships produce higher levels of underwater noise than other types of platforms, with broadband source levels up to 10,000 Hz and 191 dB re 1 μPa during drilling operations. There are currently no wells being drilled in the eastern GOMx

and no production platforms in place, however BOEM is leasing areas in the EPA so this could change in the future.

Seismic survey noise associated with oil and gas activities
The northern GOMx is an area of high seismic survey activity. Seismic surveys are typically conducted 24 hours a day, 365-days a year. These surveys support leasing, exploration, drilling and production activities. BOEM and NMFS are currently working on a Programmatic Environmental Impact Statement for Geological and Geophysical activities in the GOMx (see for more details: http://www.boem.gov/Gulf-of-Mexico-Geological-and-Geophysical-Activities-Programmatic-EIS/). Airguns used in seismic surveys are a source of primarily low-frequency sound (Sodal 1999). Airguns produce broadband impulsive signals from a single airgun or an array of typically 12 to 48 airguns (Hildebrand 2005). Airgun source characteristics, including source levels, frequency range, signal durations, and pulse rates are highly variable depending on survey instrumentation, number of airguns in an array, and survey design. Airgun sources typically produce sounds with peak pressure in the 5-300 Hz frequency range and energy up to 3 kHz (Hildebrand 2009), with source levels as high as 260 dB peak re 1 µPa at 1 m output pressure (Hildebrand 2009), and pulse rates are typically 1 per 10 – 20 s (Hildebrand 2009). Seismic survey airgun arrays are typically towed at 5 knots (Hildebrand 2005). Seismic surveys occur year round in the GOMx and the number of vessels active in any given period can vary.

Cetaceans may experience permanent hearing loss when received sound levels are 230 dB re: 1 μPa (peak) or higher (Southall et al. 2007). Sound levels diminish rapidly near the source (10-20 dB with each 10-fold increase in distance) (Richardson et al. 1995). Therefore, seismic surveys with source levels of 260 dB re 1 uPa @ 1 m have the potential to cause serious injury to animals within 100 m to 1 km of the airguns. To minimize these impacts, seismic survey vessels carry protected species observers and have a protocol to shut down operations if cetaceans are seen within 500 km of the survey vessel and array (e.g., Barkaszi et al. 2012).

Blackwell et al. (2015) documented behavioral changes in bowhead whale, *Balaena mysticetus*, calling rates in the Arctic associated with nearby seismic surveys. Specifically, calling rates appeared to increase until a threshold for received sound was reached, and then calling ceased altogether. That observation indicates that received sounds may cause significant behavioral changes that, in turn, may influence important functions and, possibly, vital rates. Subtle effects on surfacing, respiration, and dive cycles have been noted (Richardson et al. 1995). The probability and strength of such responses appear to diminish gradually with increasing distance and decreasing sound level (Richardson et al. 1995). Bowhead and gray, *Eschrichtius robustus*, whales often show strong avoidance within 6 – 8 km (4 – 5 mi) of an airgun array (Malme et al. 1984, Gordon et al. 2001). Humpback whales off western Australia were found to change course at 3 – 6 km (2 – 4 mi) from an operating seismic survey vessel, with most animals keeping a standoff range of 3 – 4 km (2 – 2.5 mi) (McCauley et al. 1998).

Although reactions of Bryde's whales to seismic activities have not been studied, the auditory abilities of all mysticete species are considered to be broadly similar, based upon vocalization frequencies and ear anatomy (Ketten 1998). As described earlier, low-frequency sounds can travel substantial distances and airgun sounds have been recorded many hundreds of miles away from the survey locations (Nieukirk et al. 2004). Currently, there are few seismic surveys occurring in the eastern GOMx, however seismic sounds from surveys nearby may be impacting Bryde's whales.

Noise associated with military training and exercises

Military training and exercises use active sonar sources and explosives as part of their operations and each of these sources have the potential to impact marine mammals. Military explosives are used for several purposes including ship shock trials and may include the detonation of mines, bombs, torpedoes and shells. Explosions create a pressure impulse with a sharp rise time and spectral content that is broadband in frequency, including low frequencies. Explosions generally have high source levels, although spectral content and amplitude vary with the weight of the charge and the depth of the detonation (Hildebrand 2009). Explosive sources include both a shock wave and an acoustic wave, and close proximity to a blast wave may expose animals to physiological injury, including death, organ damage, and the rupture of gas-filled cavities such as lungs, sinuses and ears (Ketten 1995, Weilgart 2007b). Explosive blasts with charge weights between 1700 and 5000 kg were implicated in the death of two humpback whales that suffered severe ear bone injuries (Ketten et al. 1993, Ketten 1995). Explosive sounds are typically detectable on regional scales, but in some conditions they can be detected over several ocean basins (e.g., Munk et al. 1988, Munk & Forbes 1989).

The Navy uses low-frequency active (LFA) sonars for broad-scale military surveillance to detect submarines over scales of 100s of kilometers. These systems produce constant or frequency-modulated low-frequency tonal signals (30 Hz bandwidth) in the 100 – 500 Hz range, with signal durations of 6 – 100s, signal intervals of 6 – 15 min, duty cycles of 10%, and array source levels of 235 dB re 1 μPa @ 1 m or higher (Anonymous 2001, Hildebrand 2009). Operations in a given location typically last for days or weeks, and the U.S. Navy was scheduled to have four operating LFA source ships by 2011 (Hildebrand 2009). To date, there are no LFA activities in the Gulf of Mexico[13] Low-frequency naval sonar is a concern for baleen whales, and documented impacts include changes in calling behavior of humpback whales (Miller et al. 2000, Fristrup et al. 2003), avoidance/displacement in gray whales (Malme et al. 1988, Moore & Clarke 2002), and cessation or reduction of vocalizations by sperm whales (Watkins et al. 1985, Miller et al. 2009). The potential area over which cetaceans may be impacted (at which received levels are $\geq$ 120 dB) by the U.S. Navy's LFA sonar is estimated at 3.9 million km^2 (Johnson 2001) and it is likely to be detectable over a much larger area (Weilgart 2007b).

The navy uses mid-frequency active (MFA) sonars for detecting submarines at ranges less than 10 km. These systems produce frequency-modulated pulses in the 1 – 5 kHz band (up to 10 kHz for NATO sources (Cox et al. 2006)), with signal durations of 1 – 2 s, 40^o vertical beam width, and source levels of 235 dB re 1 μPa @ 1 m or higher (these characteristics are specific to AN/SQS-53C sonar) (Hildebrand 2009). The sonars are incorporated into the hulls of naval surface vessels, including destroyers, cruisers, and frigates, and there were about 300 MFA sonar ships in use globally in 2003 (Watts 2003, per Hildebrand, 2009). Tactical mid-frequency naval sonar has been implicated in strandings of beaked whales and other deep diving odontocetes (Cox et al. 2006, Southall et al. 2006), and although baleen whales are not generally thought to

[13] http://www.navfac.navy.mil/content/dam/navfac/Environmental/PDFs/NEPA/AFAST_EIS.pdf

be impacted by tactical mid-frequency sonars, minke whales have also stranded during some beaked whale mass strandings thought to be related to naval sonar (Weilgart 2007b).

Noise associated with commercial fisheries and scientific acoustics

Commercial and scientific vessels employ active sonars for detection, localization, and classification of underwater targets, including the seafloor, plankton, fish, and human divers (Hildebrand 2009). Source frequencies typically range from 10s to 100s of kHz. Commercial and scientific sonar sources include multibeam sonars for seafloor mapping (12 kHz or 70 – 100 kHz, source levels to 245 dB re 1 μPa @ 1m, 1° x 120° beams), sub-bottom profilers (3 – 7 kHz, 230 dB re 1 μPa @ 1m), hydroacoustic sonars (20 – 1000 kHz), and scanning sonars and synthetic aperture sonars (85 – 100 kHz) (Hildebrand 2009). Source frequencies of many of these sonars are likely above the frequency range that Bryde's whales hear (Watkins 1986, Au et al. 2006, Tubelli et al. 2012). Commercial and scientific sonars have lower source levels than military sonars, and many source types are highly directional, such as seafloor mapping and echo-sounding sonars that are directed toward the ocean bottom. However, commercial and scientific sonars are more ubiquitous, for example, most large and small vessels are equipped with commercial sonars for water depth sounding that are operated continuously for aid in navigation (National Research Council 2003).

Acoustic telemetry is becoming more common and is used for underwater communications, remote vehicle command and control, diver communications, underwater monitoring and data logging, trawl net monitoring, and other applications. Acoustic modems operate over distances up to 10 km and use signals with frequencies ranging from 7 to 45 kHz and source levels up to 190 dB re 1 μPa @ 1m (Hildebrand 2009).

Recent technological advances in ecosystem-wide (i.e., 100 km diameter areas) acoustic imaging of fish shoals are resulting in more common scientific research usage of low-frequency acoustic sources, such as the Ocean Acoustic Waveguide Remote Sensing (OAWRS) system, that have the potential to impact baleen whale behavior (Risch et al. 2012). This OAWRS system was shown to affect humpback whale vocal behavior at a location 200 km away from the source (Risch et al. 2012). OAWRS is unlikely to be used in U.S. waters in the foreseeable future, so is unlikely to pose any risk to GOMx Bryde's whales.

Noise associated with vessels and shipping traffic

Shipping activity produces noise as an unintended byproduct and contributes significantly to low-frequency noise in the marine environment, with main energy in the 5 – 300 Hz frequency range. Source levels ranging from about 140 to195 dB re 1 μPa @ 1 m (National Research Council 2003, Hildebrand 2009), depending on factors such as ship type, load, and speed, and ship hull and propeller design; levels typically increase with increasing speed and vessel size (Allen et al. 2012, McKenna et al. 2012b, Rudd et al. 2015). Propeller cavitation is the dominant source of radiated underwater noise from ships and vessels at frequencies less than 200 Hz (Ross 1976), with other sources (e.g., rotational machinery and reciprocating machines) also contributing (McKenna et al. 2012b). Although shipping noise is characterized by mainly low frequencies, energy is detectable at much higher frequencies (up to 160 kHz) at close ranges (Hermannsen et al. 2014). While vessel-specific source levels are generally lower than those of many other anthropogenic noise sources, the large number of ships and the fact that they occur throughout much of the world's oceans make ship noise a major component of chronic rising ambient noise levels (Hildebrand 2005, Hatch et al. 2012). Approximately 50% of U.S. merchant vessel traffic (as measured by port calls or tonnage for merchant vessels over 1000 gross tons) occurs at U.S. GOMx ports indicating shipping activity is a significant source of noise in this region[14]. Shipping noise in the northeast U.S. was predicted to reduce communication space of humpback whales, right whales, and fin whales by 8%, 77%, and 20%, respectively (Clark et al. 2009). The comparatively large loss in communication space of calling right whales is because their call frequencies overlap more with the frequencies of shipping noise, and their calls are at lower source levels compared to fin and humpback whales. GOMx Bryde's whale call source levels (155 dB re 1μPa) and frequency ranges (78 – 110 Hz, Širović et al. (2014)) are most similar to those of right whales (Clark et al. 2009) and therefore Bryde's whales may be similarly impacted. Documented impacts of shipping and boat noise on cetaceans include habitat displacement (gray whales, Bryant et al. (1984)), changes in dive behavior and creak production thought to relate to foraging attempts (Cuvier's beaked whales, Aguilar Soto et al. (2006)), changes in vocal behavior including call durations, source levels, frequency shifts, and call rates (beluga whales and killer whales, Lesage et al. (1999), Foote et al. (2004), Scheifele et al. (2005)), cessation of vocalizations (fin whales, Watkins (1986)), and changes in stress hormone levels (North Atlantic right whales, Rolland et al. (2012)). In northeastern and southwestern U.S. waters, nearby shipping appears to increase background noise levels in the 71 – 224 Hz range by 10 – 13 dB (Hatch et al. 2012, McKenna et al. 2012a, Rolland et al. 2012).

Chronic impacts of noise producing activities

The chronic impacts of noise-producing activities occur as average ambient noise levels in a region increase above historic, natural levels and include impacts such as decreased listening and communication space, increased stress and similar impacts described above. Theoretical and empirical studies are just beginning to evaluate ambient noise levels throughout the GOMx through spatial modeling of average annual noise levels across the GOMx and through long-term measurements at specific sites within the GOMx. The SRT evaluated the total modeled anthropogenic noise levels in the GOMx, the ambient noise levels measured over time at specific GOMx sites, and the expected biological impacts of these noise levels on communication space for GOMx Bryde's whales.

Total modeled anthropogenic noise levels in the Gulf of Mexico

NOAA recently convened the Cetaceans and Sound Mapping (CetSound) working group to evaluate the impacts of anthropogenic noise on cetacean species and develop geospatial tools to understand wide-ranging, long-term underwater noise contributions from multiple human activities throughout U.S. waters[15]. This project has led to the development of regional noise maps for major anthropogenic noise sources and BIAs. CetSound modeled the average contribution to overall low-frequency ambient noise levels for each sound source (commercial vessels, passenger vessels, service vessels, seismic surveys) in the GOMx during 2011 based on geospatial distributions and densities of vessels, seismic surveys, vessel noise source characteristics, airgun noise source characteristics and environmental descriptors for sound propagation modeling. Data used to develop distributions and densities of vessel traffic and seismic surveys include (1) 2004 – 2005 large commercial ship tracks (specifically cargo ships

[14] http://www.navigationdatacenter.us/data/datappor.htm

[15] http://cetsound.noaa.gov

and tankers >500 gross tons) from the World Meteorological Organization Voluntary Observing Ships Scheme (VOS) data (Halpern et al. 2008); (2) 2008 – 2010 passenger vessel tracks from VOS and Automatic Identification System (AIS) data; (3) 2007 – 2012 oil and gas service vessel traffic models; and (4) the geospatial distribution and density of 16 2D to 4D-coil seismic surveys operating during 2009. These noise level estimates are subject to a number of caveats and assumptions particularly with respect to the data on vessel distributions and densities[16]. Two caveats are especially important for interpreting CetSound noise maps. First, the dataset used for commercial shipping and passenger shipping noise modeling does not represent coastal waters, (e.g., traffic lanes) well, and noise estimates in those waters are likely underestimates. Second, the spatial distribution of seismic survey activity in the GOMx varies inter-annually, and the specific spatial distribution of noise levels mapped by CetSound is only representative of 2009 survey activity, which was higher in the EPA than is typical.

Throughout the GOMx, the predicted noise level contributions from all shipping sources modeled by CetSound ranged from 7.2 to 100.4 dB re 1 μPa (Figure 12, Table 5). Ninety-five percent of the GOMx was predicted to to have total annual average vessel-related noise levels of 59.7 dB, over 50% of the GOMx was predicted to have shipping noise contributions of at least 73.6 dB re 1 μPa, and 5% of the GOMx was predicted to have shipping noise contributions greater than 89.7 dB re 1 μPa, (Table 5). In the GOMx, the BIA identified for Bryde's whales has an area of 23,559 km^2 (Ferguson et al. 2015, LaBrecque et al. 2015). By extracting modeled noise levels from within this BIA, the SRT attempted to determine the range of noise levels that GOMx Bryde's whales may be experiencing throughout their current known distribution range. For 1/3-octave band noise levels centered on 100 Hz (the frequency at which Gulf of Mexico Byrde's whale calls are centered, Širović et al. 2014), and a receiver at 15 m water depth, the annual average modeled noise levels from vessels (combined commercial shipping vessels, passenger vessels, and oil and gas service vessels) range from 58.3 to 89.1 dB re 1 μPa throughout the BIA area. Ninety-five percent of the BIA area was predicted to have shipping noise levels of 73.2 dB or higher, 50% of the area was predicted to have shipping noise levels of 82.2 dB re 1 μPa or higher, and 5% of the area was predicted to have shipping noise levels of at least 87.6 dB re 1 µPa, (Figure 12, Table 5). These modeling results indicate the noise contribution from shipping may be higher in the BIA than throughout the rest of the GOMx. This seems reasonable when comparisons are made between the BIA and GOMx areas where there is little shipping traffic, but is surprising when comparisons are made between the BIA and the western GOMx where shipping traffic patterns indicate higher densities of vessels. Sound in

[16] Data and modeling caveats associated with CetSound sound maps include the facts that (1) tracks of individual passenger vessels certainly differ from the average distributions represented here, (2) AIS data are limited in the geographic area covered (and were only used for large passenger vessels, mainly cruise ships), (3) VOS is a voluntary reporting system, (4) data from the given time periods were reasonable approximations of annual averages of spatial distribution patterns that could be extrapolated across years with density corrections applied based on changes in the total global fleet of large ships and passenger vessels, (5) support vessels visit one rig per trip, (6) support vessels begin and end trips at closest port, and (7) acoustic characteristics of rig supply vessels from other locations can be used to describe acoustic source characteristics of the GOMx supply vessel traffic (see http://cetsound.noaa.gov). Caveats and assumptions for noise modeling of GOMx seismic surveys include (1) both 2D and 3D surveys are uniform in patterns of source activation, (2) a nominal source level based on a typical array volume and configuration may be used to represent all surveys, (3) vessel navigation during surveys is exclusively for the purposes of deep-focused seismic and (4) only full-scale, deep-focus seismic surveys in offshore exploration areas with information reported to BOEM are represented (smaller scale surveys, some on-lease deep and high resolution seismic surveys that are unpermitted; or seismic surveys for scientific research or those conducted in state waters are not represented.

open areas may be refracting to deeper waters, but the east-west differences between noise levels and shipping densities along the shelf and shelf break are surprising. These apparent inconsistencies highlight the need to validate modeled noise predictions with *in situ* measures to determine if the model predictions are accurate or biased.

CetSound also modeled the annual average contribution to overall low-frequency ambient noise levels for seismic surveys and modeled annual average ambient noise levels of combined shipping traffic and seismic surveys throughout the GOMx. While the contribution of seismic surveys only to noise levels was modeled, there can be high interannual variability in seismic survey distribution and the noise levels for seismic survey activities were modeled using 2009 data for which seismic survey activities were higher in the EPA than they have been in subsequent years. Therefore, these modeled seismic-survey-only noise levels in the EPA are likely not representative of what Bryde's whales are experiencing today and are not discussed further. However, it is informative to consider both total shipping noise only (see above) and combined shipping and seismic survey noise levels to understand the range of noise levels that may be found in different years. Throughout the GOMx, the predicted noise level contributions from combined shipping and seismic surveys ranged from 23.54 to 107.8 dB re 1 μPa in the 1/3 octave band centered at 100 Hz at 15 m depth (Table 5). Ninety-five percent of the GOMx was predicted to have annual average combined shipping traffic and seismic survey noise levels of at least 60.4 dB, over 50% of the GOMx was predicted to have annual average combined shipping traffic and seismic survey noise levels of at least 76.2 dB re 1 μPa, and 5% of the GOMx was predicted to have combined shipping noise and seismic contributions greater than 97.0 dB re 1 μPa, (Figure 13, Table 5). The statistics of spatial variance for total summed noise levels from vessel noise and seismic surveys combined can be extracted for the GOMx Bryde's whale BIA, to provide an estimate of levels in years with activity similar to the 2009 modeled year. For 1/3-octave band noise levels centered on 100 Hz and a receiver at 15 m water depth, the predicted noise level contributions from all shipping and seismic surveys ranged from 82.8 to 101.0 dB re 1 μPa. Ninety-five percent the BIA was predicted have levels over 88.8 dB, over 50% of the BIA was predicted to have annual average combined shipping traffic and seismic survey noise levels of at least 94.7 dB re 1 μPa, and 5% of the GOMx was predicted to have combined shipping noise and seismic contributions greater than 99.0 dB re 1 μPa, (Figure 13, Table 5). Because the seismic survey noise levels were modeled on 2009 data for which seismic survey activities were higher in the EPA than they have been in recent years, it is anticipated that CetSound models of total shipping noise only are a closer approximation to current noise conditions in the EPA than those of combined shipping and seismic survey noise. CetSound models of combined shipping and seismic survey noise are likely a closer approximation of current noise conditions in the CPA and WPA. However, the modeled seismic survey noise levels from 2009 are informative for exploring how noise could be if the EPA were opened to seismic surveys. Projected seismic survey activity for 2017 – 2022 is expected to be higher in the CPA and WPA than in the EPA (D. Epperson, BSEE, pers. comm.)

Table 5. Descriptive statistics of the spatial variance of CetSound modeled annual average ambient noise levels (dB re 1 µPa) in the 1/3 octave band centered at 100 Hz for a receiver at 15 m depth. The values represent the spatial variance of predicted annual average noise levels in 0.1° x 0.1° grid cells for each individual anthropogenic sound source, for all vessel sources combined (Total Shipping), and for vessels and seismic surveys combined (Total Shipping and Seismic). These are presented for all modeled locations in the GOMx (Total GOMx), and for those locations encompassed by the GOMx Bryde's whale Biologically Important Area (BIA Only). Values in bold indicate noise levels expected to match measured noise levels since 2010, due to differences in seismic survey distribution in the year 2009.

	Total Shipping	Seismic Surveys	Total Shipping and Seismic
Total GOMx			
min	7.2	23.5	**23.5**
5th%ile	59.7	23.54	**60.4**
median	73.6	23.5	**76.2**
95%ile	89.7	96.3	**97.0**
max	100.4	107.8	**107.8**
BIA Only			
min	**58.3**	82.0	82.8
5th%ile	**73.2**	87.8	88.8
median	**82.2**	94.3	94.7
95%ile	**87.7**	98.7	99.0
max	**89.1**	101.0	101.0

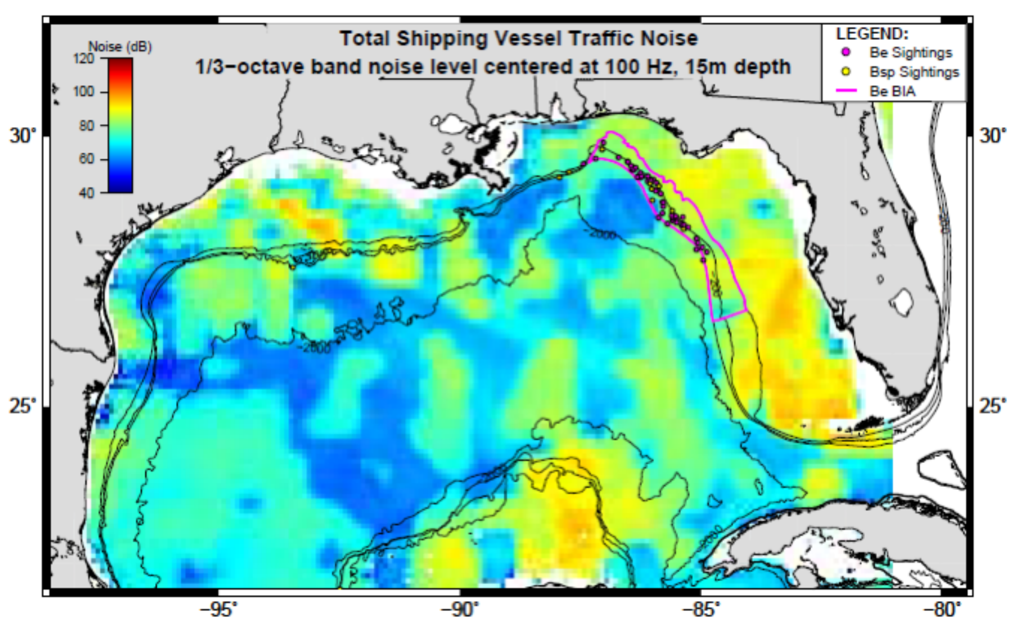


Figure 12. Total contribution of shipping traffic to modeled annual average noise levels for 2010 – 2011 including large commercial vessels, passenger vessels, and oil and gas service vessels in 1/3 octave band centered at 100 Hz for a receiver located at 15 m depth (data provided by CetSound project cetsound.noaa.gov). Spatial resolution is 0.1° x 0.1°. Bryde's whale sightings and BIA boundaries (pink outline) are overlaid, and the 100, 200, 300, and 2000 m isobaths are included.

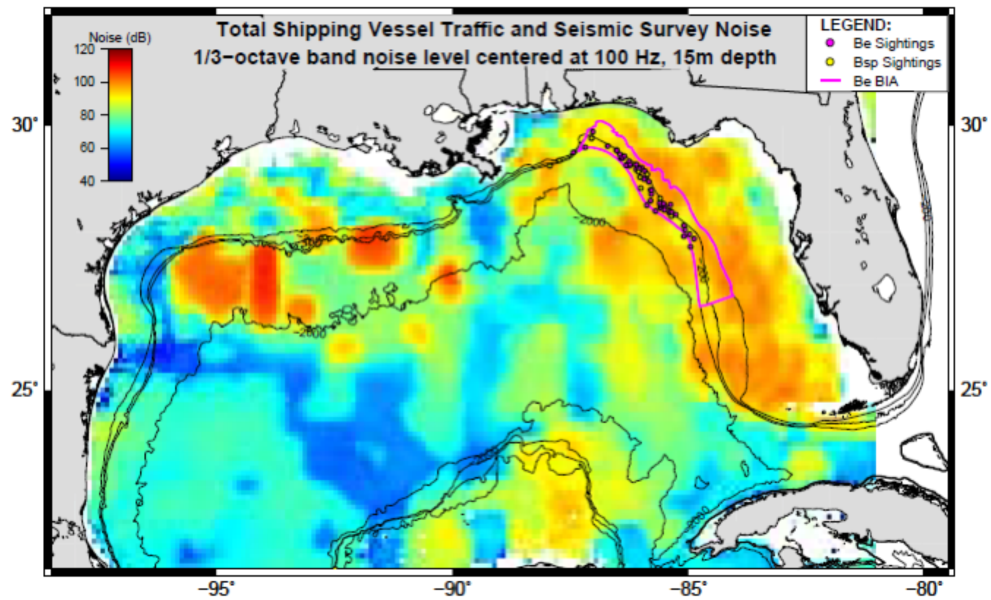


Figure 13. Modeled annual average ambient noise levels from combined global shipping, passenger vessels, oil and gas service vessels, and seismic airgun surveys in 1/3 octave band centered at 100 Hz for a receiver located at 15 m depth (data provided by CetSound project cetsound.noaa.gov). Seismic survey data are based on the geospatial distribution and density of 16 2D to 4D-coil seismic surveys operating during 2009. The spatial distribution of surveying activity in the GOMx varies inter-annually, and projected survey activity (2017 – 2022) is expected to be higher in the CPA and WPA than in the EPA (D. Epperson, BSEE, pers. comm.). Spatial resolution is 0.1^{o} x 0.1^{o}. Bryde's whale sightings and BIA boundaries are overlaid, and the 100, 200, 300, and 2000 m isobaths are included.

Ambient noise levels measured in the Gulf of Mexico

The waters of the GOMx are highly industrialized for oil and gas energy exploration and production, and for shipping transportation. Predicted noise levels in the GOMx, described in detail above, are expected to be higher in the GOMx than for most other regions managed by NOAA because seismic surveys and shipping traffic are the main contributors to low-frequency noise and their densities are higher in the GOMx than in other regions. Vessel-traffic noise contributes substantially to low-frequency noise and the U.S. Department of Transportation Maritime Administration estimates that large vessel traffic (based on number and tonnage of vessels) is higher in the GOMx than in other U.S. waters (MARAD 2015, 2013 vessel port call statistics http://www.marad.dot.gov/resources/data-statistics/). That observation indicates that noise may pose a significant, chronic threat to Bryde's whales in the GOMx. The modeling results described above are consistent with that concern, although those results should be validated with in-situ ocean noise measurements over broad spatial and temporal scales.

In situ noise measurements of ambient noise levels have been made throughout the GOMx at five sites using High Frequency Acoustic Recording Packages (HARPs) from May 2010 to October 2013[17] and at six sites throughout the GOMx using Marine Autonomous Recording

[17] Wiggins SM, Hall J, Thayre BJ, Hildebrand JA. (in review). Gulf of Mexico low-frequency ocean soundscape dominated by noise from airguns. Journal of the Acoustical Society of America

Units (MARUs) from June 2010 to December 2012 (Rice et al. 2014b). Sound pressure levels in the 1/3 octave band centered at 100 Hz were measured and percentiles of these band levels over time are presented for each site in Table 6. The MARUs and HARPs can be considered as pairs as they were deployed in relatively close proximity (~30 – 100 km) to each other (Figure 14). The instrument pairs have similar median sound pressure levels, but the MARUs have more extreme 1st and 99th percentile levels. This likely reflects the shorter time period over which the percentiles were calculated for the MARUs. The MARU and HARP pair (LF12, DC, Figure 14) in the Bryde's whale BIA had the lowest received noise levels of all GOMx sites. This is the only case where median sound levels differ by more than 2 dB 1 μPa, with the MARU LF12 having higher noise band levels (median 82.5 dB re 1 μPa) than the HARP DC (median 76.5 dB re 1 μPa). Low and high noise band levels at these two sites ranged from 72 to 91 dB re 1 μPa and 71 to 84 dB re 1 μPa, respectively. These two sites are separated by the greatest distance of all the pairs with the MARU closer to shipping channels. Overall, noise levels in the 1/3 octave band at 100 Hz are highest at the deep Mississippi Canyon, Green Canyon and Dry Tortugas and HF17 sites with median noise band levels ranging from 93 to 96 dB re 1 μPa (Table 6). Highest noise band levels (110 and 114 dB re 1 μPa) were measured at MARUs in the north-central GOMx. The high noise levels at the deep sites are likely influenced by site proximity to active seismic survey locations in the north-central and western GOMx and to high densities of shipping traffic in the western GOMx and near the Florida Straits. Noise levels at the deep sites also are high due to common GOMx sound propagation conditions in which sounds are refracted downward.

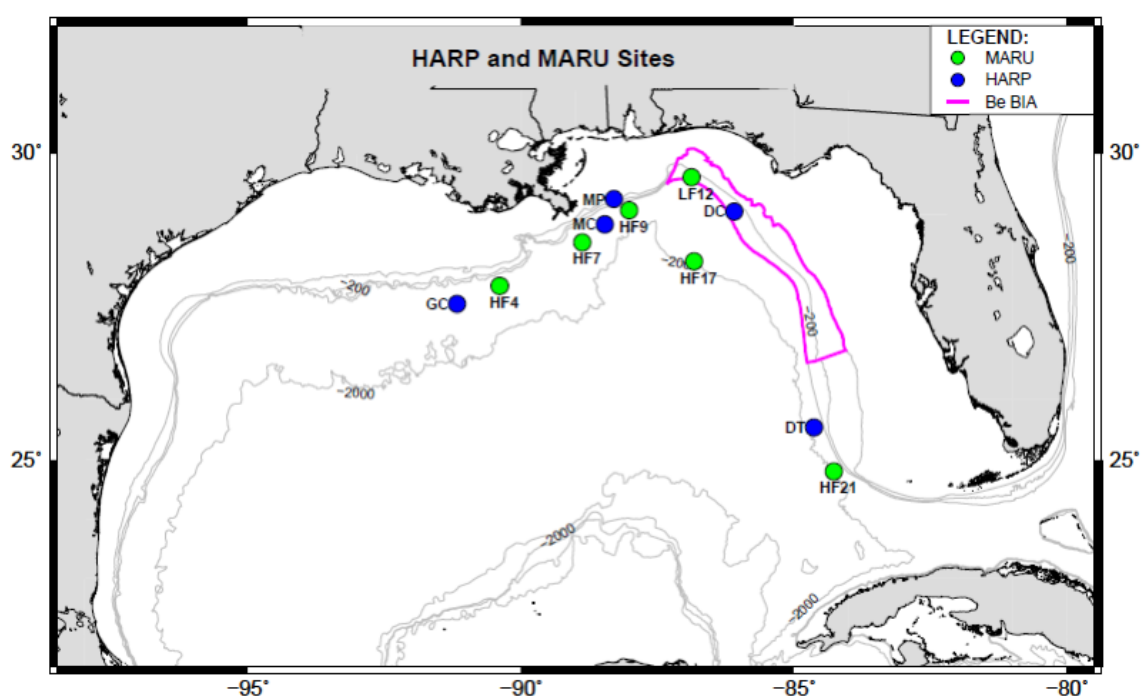


Figure 14. Locations of High Frequency Acoustic Recording Packages (HARPs) deployed from May 2010 to October 2013[18] and Marine Autonomous Recording Units (MARUs) deployed from June 2010 to December 2014

[18] Wiggins SM, Hall J, Thayre BJ, Hildebrand JA. (in review). Gulf of Mexico low-frequency ocean soundscape dominated by noise from airguns. Journal of the Acoustical Society of America

(Rice et al. 2014b). GC: Green Canyon, MC: Mississippi Canyon, MP: Main Pass, DC: De Soto Canyon, DT: Dry Tortugas. HF: High Frequency. LF: Low Frequency.

A comparison of sound levels detected by the HARP and MARU devices and the CetSound predictions indicate that the predictions are a reasonable approximation, considering the differences in spatial and temporal scales of the models and *in situ* measurements. The 5th to 95th percentile noise level ranges in the Bryde's whale BIA are 73 to 81 dB re 1 μPa for HARP measurements, 73 to 90 dB re 1 μPa for MARU measurements, and 73 to 88 dB re 1 μPa for CetSound spatial models of total shipping. This similarity between *in situ* measurements and predictions of only total shipping noise levels confirms our expectation that nearby noise from seismic survey activity appears to currently be limited in its impacts to the Bryde's whale BIA since current survey activity is low in the EPA.

Table 6. In situ noise measurements at five GOMx sites using High Frequency Acoustic Recording Packages (HARPs) from May 2010 to October 2013[19] and at six GOMx sites using Marine Autonomous Recording Units (MARUs) from June 2010 to December 2014 (Rice et al. 2014b). For each HARP and MARU site, we summarize the depth, total number of days of recordings and percentile statistics of the temporal variability in sound pressure levels in the 1/3 octave band centered at 100 Hz (dB re 1μPa). Some temporal gaps occurred at some sites between deployments. Acoustic recorder site locations are presented in Figure 14. MARUs and HARPs that are in close proximity to one another are aligned in the same columns in the table. Site abbreviations as in Figure 14. HARP and MRU sites located in the Bryde's whale BIA are denoted with *.

HARP Sites						
	GC	MC	MP	DC*		DT
Depth	1100	980	90	260		1300
Days	1011	1075	957	818		786
1%	89.5	88.3	83.9	70.8		88.6
5%	91.5	90.4	86.5	73.2		90.3
50%	95.4	95.1	91.2	76.5		93.4
95%	99.0	101.1	101.2	81.5		96.6
99%	103.4	103.8	109.3	84.1		98.9

MARU Sites						
	HF4	HF7	HF9	LF12*	HF17	HF21
Depth	826	864	1092	250	1136	1370
Days	523	502	519	307	508	418
1%	81.2	92.0	81.5	72.4	87.1	78.3
5%	81.9	93.9	81.6	73.6	88.7	81.1
50%	93.0	96.4	91.3	82.5	94.3	92.8
95%	106.3	107.6	98.0	89.7	98.1	101.9
99%	110.3	114.4	101.0	91.2	101.4	107.5

[19] Wiggins SM, Hall J, Thayre BJ, Hildebrand JA (in review) Gulf of Mexico low-frequency ocean soundscape dominated by noise from airguns. Journal of the Acoustical Society of America

Biological impacts of noise on communication space for Bryde's whales in the Gulf of Mexico
Chronic increases in ambient noise levels from anthropogenic noise sources can mask biologically important sounds, i.e., reduce the ability to detect biologically important sounds such as communication calls and the sounds of predators and prey. Acoustic communication is a critical part of Bryde's whale life. While the functions of individual call types are unknown, all baleen whales produce calls during foraging and travelling to remain in contact or coordinate activities with conspecifics. Calls are likely important for predator avoidance (i.e., alarm calls), and most baleen whale species produce calls during behaviors related to reproduction (Richardson et al. 1995).

Communication ranges for cetaceans can be estimated based on signal to noise ratios derived from call source levels, ambient noise levels, and sound propagation loss estimates. Using the methods of Clark et al. (2009), and the empirical sound propagation and single downsweep call characteristics of GOMx Bryde's whales (Širović et al. 2014), the SRT estimated the potential communication distances of GOMx Bryde's whales under different ambient noise conditions. For the average noise band level range of 58 – 89 dB re: 1 μPa described above for CetSound total vessel noise (summed commercial shipping, passenger vessels, and service vessels) across the BIA, GOMx Bryde's whale communication may be detectable between 35 and 4,015 km across the BIA, with average communication ranges of 102 km (Figure 15). If noise levels in the EPA were to rise to 2009 levels, these communication ranges would decrease to 6 to 93 km, with average communication ranges of 15 km. Based on the *in situ* noise band level measurements at the HARP DC site, animals would have communications ranges of at least 217 km on 50% of days, 77 km on 99% of days and 571 km on 1% of days. To put this in context, the maximum dimensions of the Bryde's whale BIA are about 455 km long by 75 km wide. Furthermore, these communication ranges will be smaller if sound propagation conditions are better represented by deep-water spherical spreading losses [i.e., 20log(Range)] (Figure15).

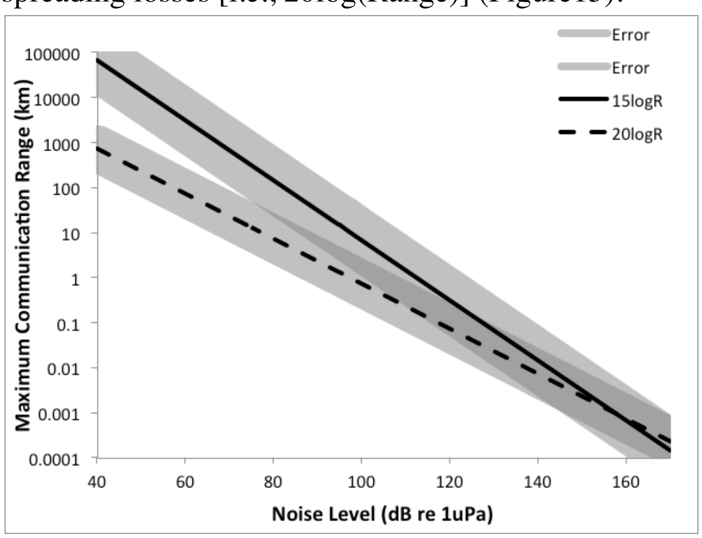


Figure 15. Maximum communication ranges as a function of ambient noise levels, assuming a call source level of 155 ± 14 dB re: 1 μPa at 1 m, call bandwidth of 43 Hz, call duration of 0.4s, directivity index of 0, and detection threshold of 10 under conditions with either simple spherical spreading (20*logR) or empirically derived geometric spreading (15*logR) losses, where R= range. Error encompasses the variability due to source level error estimates.

One way to characterize the effects of GOMx noise levels on Bryde's whales' communication distances is to compare the communication distances with possible geographic distances between animals. If 33 animals occupy the 23,559 km^2 area of the BIA and the whales are uniformly distributed throughout the region, they would need minimum communication distances of 30 km (Figure 16). For the median predicted annual average noise levels summed for all three ship types (82.2 dB re 1 μPa), maximum communication ranges would be102 km and uniformly spaced Bryde's whales would likely be able to hear their nearest neighbors. Similarly, for the measured median noise levels of 76.5 dB re 1 μPa and 82.5 dB re 1 μPa at the HARP and MARU sites, respectively, maximum communication distances would be 245 km and 98 km, such that whales should be able to communicate, but only with a portion of their population. For the median predicted annual average noise levels if there were heavy seismic activity (94.7 dB) in the EPA, such as was seen in 2009 and modeled by CetSound, maximum communication ranges would be 15 km, and Bryde's whales would not be likely to hear even their nearest neighbors. Similarly, if median noise levels in the BIA were similar to measured median noise levels (93.0 to 96.4 dB re 1 μPa) at MARU and HARP sites in the WPA and the CPA which have higher seismic activity levels, maximum communication distances would range between 20 and 12 km, and whales would be unlikely to hear their nearest neighbors. Levels of seismic activity are predicted to be low in the EPA over the next 10 years. However, these values are informative for how noise could impact the habitat if seismic activity were to occur closer to the Bryde's whale BIA. Additionally, while it is unlikely whales would be distributed uniformly, and they are likely moving around the area, which could make them more likely to encounter each other, these results are nonetheless informative about the relationship between animal spacing and the effects of ambient noise levels on communication ranges.

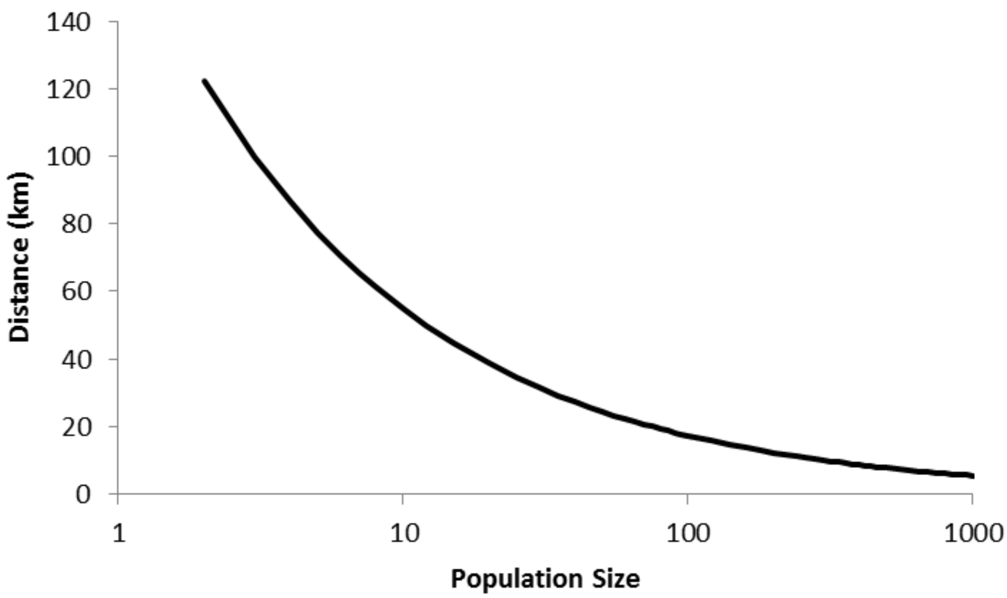


Figure 16. Expected distance between animals as a function of population size, assuming all animals are uniformly distributed throughout the GOMx Bryde's whale BIA with an area of 23,559 km^2. This can be compared to communication distances as they vary with ambient noise levels (Figure 15).

This evaluation of chronic noise impacts on communication spaces, has used measured and predicted ambient noise levels for the 1/3 octave band levels centered at 100 Hz to allow comparisons at the frequencies at which Bryde's whales produce their calls. However, injury, physiological responses, behavioral responses, and impacts to listening spaces can occur at any frequency within Bryde's whale hearing range. While the Bryde's whale hearing range is unknown, it likely extends beyond the 24 Hz band centered at 100 Hz that has been evaluated here. The total sound pressure levels received by whales could increase by 3 dB re 1 μPa with each doubling of bandwidth for sources with equal energy across the frequency band. Total received sound pressure levels may be even higher for sources with higher energy at lower frequencies, as is typical for shipping and seismic airgun noise which have peak energy in the 10 to 100 Hz range. This complicates comparison with NOAA acoustic guidance, but gives some indication of how these levels compare to those expected to cause injury or behavioral reactions. In some regions of the GOMx (e.g., MARU sites HF4 and HF7 in the CPA, Table 6, Figure 14), ambient noise sound pressure levels over a 10-200 Hz bandwidth may exceed NOAA acoustic guidance thresholds for behavioral disturbance during a proportion of the year.

Vessel Collisions

Vessel collisions are an important source of anthropogenic mortality for most large whale species (Laist et al. 2001). Vessel collisions can seriously injury or kill cetaceans either by propeller cuts (the severity of which depends on the species, the individual, the location of the cut, and the depth of penetration) or blunt force trauma from colliding with the hull of the vessel (leading to bone fractures, organ damage, and/or internal hemorrhaging) (Andersen et al. 2008). Stranding records and public reports represent minimum estimates of ship strike occurrence as many go undetected or unreported when they occur in remote areas or when carcasses sink or drift out to sea (Jensen & Silber 2004). Larger ships and faster speeds result in more lethal outcomes (Laist et al. 2001, Jensen & Silber 2004, Vanderlaan & Taggart 2007) and ship speed reduction rules have been effective at reducing North Atlantic right whale deaths (Laist et al. 2014, Van der Hoop et al. 2015). The major factors affecting collision mortality risk are the overlap of whale spatial distribution and shipping lanes, diving behavior, and the severity of the trauma, which increases with larger, faster vessels. Average and maximum ship draughts are 8.5 m and 14 m, respectively (Constantine et al. 2015), and whales that that spend a greater proportion of time near the surface are at greater risk of ship strike. Coastal species (right whale and humpback whales) are the most commonly reported whales struck by ships, but they are likely over-represented in ship strike databases (Jensen & Silber 2004) as species that inhabit nearshore waters have higher carcass recovery rates than those inhabiting offshore waters (e.g., Garshelis 1997, Williams et al. 2011, Wells et al. 2015) and their carcasses are more likely to be fresh enough to determine cause of death. However, shipping traffic is also more concentrated in coastal waters where these whales spend most of their time.

The northern GOMx is an area of considerably high ship traffic, which increases the chances of ship-whale collisions. In 2013, ten U.S. GOMx ports were in the top 15 U.S. principal ports by total tonnage, and cumulatively U.S. GOMx ports make up 48% of total tonnage (~2.5 billion tons) transported to and from the top 150 U.S. principal ports. Two ports, Port of South Louisiana, La. and Port of Houston, Tex., transport 19% of the total tonnage of the top 150 principal ports in the U.S. (U.S. Army Corps of Engineers 2015). At these two ports, respectively, over 4,000 and 8,000 vessel calls were made by merchant vessels larger than 1,000 gross register tons in 2013. From 2002 to 2013, the number of vessel calls at the top 20 U.S. GOMx ports doubled from 17,200 to 34,700 vessel calls[20].

Geospatial density distributions of vessel traffic in the GOMx are available through NOAA's Emergency Response Management Application website, which maps locations of transponder transmissions from the vessel Automatic Information Systems (AIS). These data provide an indication of where low to high densities of vessel traffic occur, but cannot be interpreted as actual vessel counts. Throughout the GOMx, vessel densities are highest in shipping lanes near ports and around oil platforms, and major traffic lanes can be discerned (Fig. 17). Vessel densities tend to be higher in the north-central and western GOMx near the Port of South Louisiana, La. and Port of Houston, Tex. Several shipping lanes cross through the GOMx Bryde's whale BIA, and moderate vessel densities are apparent in some portions of their habitat.

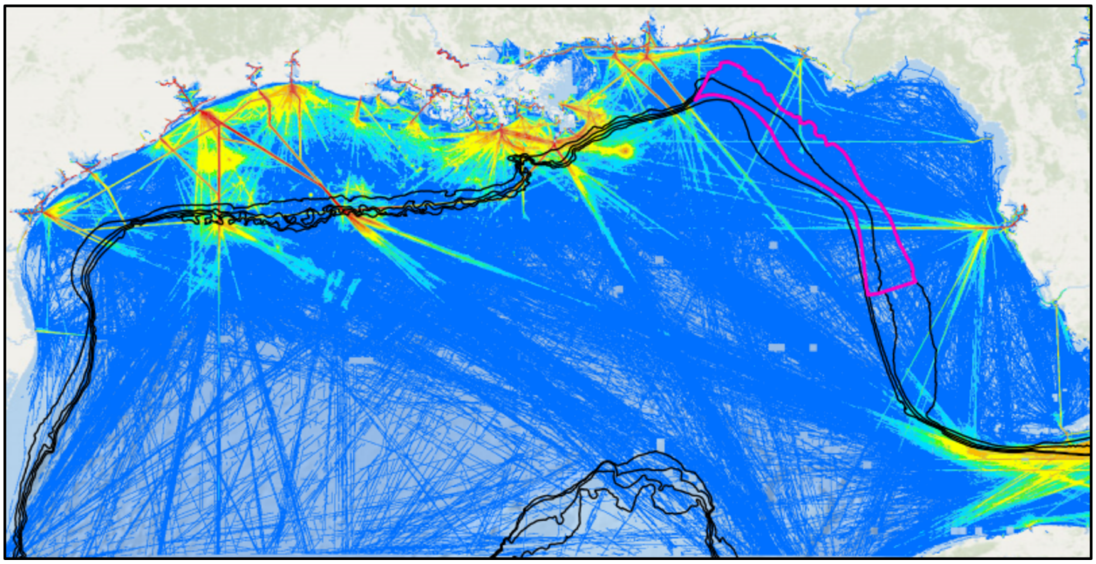


Figure 17. Density of all northern GOMx vessel traffic from October 2009-2010 based on Automated Information Systems (AIS) transponder transmissions mapped in 100 m grid cells. Shipping traffic is not as high in the Bryde's whale BIA (pink polygon) region as it is in the western GOMx and near ports. However, several shipping lanes can be seen cutting through it with moderate vessel densities in some locations. AIS data obtained from marinecadastre.gov. Bryde's whale BIA boundaries are overlaid, and the 100, 200, 300, and 400 m isobaths are included.

Vessel traffic associated with oil and gas activities in the GOMx is considerable (see Table 4). There are thousands of vessel trips annually to support the facilities and infrastructure in the GOMx and support vessel speeds are often high. Currently the amount of vessel traffic associated with OCS oil and gas activities in the eastern GOMx is relatively low as there are no production facilities in place (although this could change in the future). This reduces the potential impacts to Bryde's whales from vessel strikes from oil and gas activities.

Bryde's whales are struck by ships throughout much of the world's oceans. Van Waerebeek et al. (2007) found that Bryde's whales, *B. edeni*, were the third most commonly reported species in the southern hemisphere (after South Atlantic right whales and humpback whales) to be struck by ships. Worldwide, fin whales, humpback whales, and right whales are the most commonly

[20] www.marad.dot.gov/data_statistics

reported species (Van Waerebeek & Leaper 2008). Only one Bryde's whale is known to have been struck by a ship in the GOMx (Waring et al. 2013). However, shipping routes between Tampa, Fla. and both Corpus Christi, and Houston, Tex., cut through the Bryde's whale BIA (Fig. 17) and pose a risk to the whales. Furthermore, the number of reported ship strikes may be underestimated because GOMx offshore cetacean species have low carcass recovery rates. Williams et al. (2011) estimated a pooled-species carcass recovery rate of 0.4% and an average species-specific estimate of 2%. If GOMx Bryde's whale carcass recovery-rates are similar to those of other offshore GOMx cetacean species, the mean annual number of observed strandings might range between 0.00132 and 0.044 carcasses [lowest: 33 population estimate * (1 – 0.99 natural adult survival rate) * 0.4% carcass recovery rate; highest: 44 population estimate * (1 – 0.95 natural adult survival rate) * 2% carcass recovery rate]. These numbers indicate that under the best conditions, the recovery rate for Bryde's whales in the GOMx dying of natural causes would be about one whale every 23 years. So most ship-struck whales would likely go undetected.

Dive behavior is another factor affecting the likelihood of collision, and animals that spend more time at or near the surface are at greater risk. Collisions with vessels are a major source of Bryde's whale mortality in the Hauraki Gulf, New Zealand where the whales' primary habitat overlaps with major shipping lanes and the whales spend 91% of their time within 14 m of the surface (Constantine et al. 2015). At that depth, the whales are within the maximum draught depth of many vessels (Constantine et al. 2015). A GOMx Bryde's whale showed a consistent diel dive pattern over 3 days, spending 88% of its night time hours within 15 m of the surface (NMFS, unpublished data). This behavior will place the population at greater risk of ship strike if other individuals exhibit a similar diving pattern. Similarly, the population may be at greater risk of vessel collisions in the dark when mariners cannot see them and take action to avoid a collision.

Shipping trends indicate that faster, larger ships will traverse the GOMx following expansion of the Panama Canal (post-Panamax). Re-inauguration of the canal is expected in June 2016. The expansion is expected to redistribute some freight transport from Pacific coast ports to southeastern U.S. ports, including those in the GOMx (Institute for Water Resources 2012). By 2030 these large vessels are expected to account for 27% of the world's container fleet by number and 62% by capacity (Institute for Water Resources 2012). Seven GOMx ports are expected to be able to host Panamax vessels, including the ports of Tampa, Fla., Mobile, Ala., New Orleans, La., Corpus Christi, Tex., Beaumont, Tex., Galveston, Tex., and Houston, Tex.

Military Activities

Significant portions of the GOMx are used for military training and testing activities (Figure 18 and 19). The Navy's Atlantic Fleet Training and Testing (AFTT) Study area encompasses the east coast of the U.S. Atlantic Ocean and the GOMx. The Navy conducts training exercises and testing activities in eight functional warfare areas called primary mission areas. Training exercises fall into the following eight "primary mission areas" involving anti-air warfare, strike warfare, anti-submarine warfare, mine warfare, amphibious warfare, anti-surface warfare, electronic warfare, and naval special warfare.

Within the GOMx, Navy training exercises occur within either the Key West Range Complex or the Gulf of Mexico Range Complex (GOMEX). A range complex is a designated set of specifically bounded geographic areas that encompass a water (above and below the surface), airspace, and possibly a land component where training and testing of military platforms, tactics, munitions, explosives, and electronic warfare systems occur. In addition to the two range complexes, the Navy also maintains its Naval Surface Warfare Center, Panama City Division Testing Range, which is responsible for conducting testing activities in the Pensacola and Panama City operating areas, in St. Andrew Bay, and in other designated military warning areas.

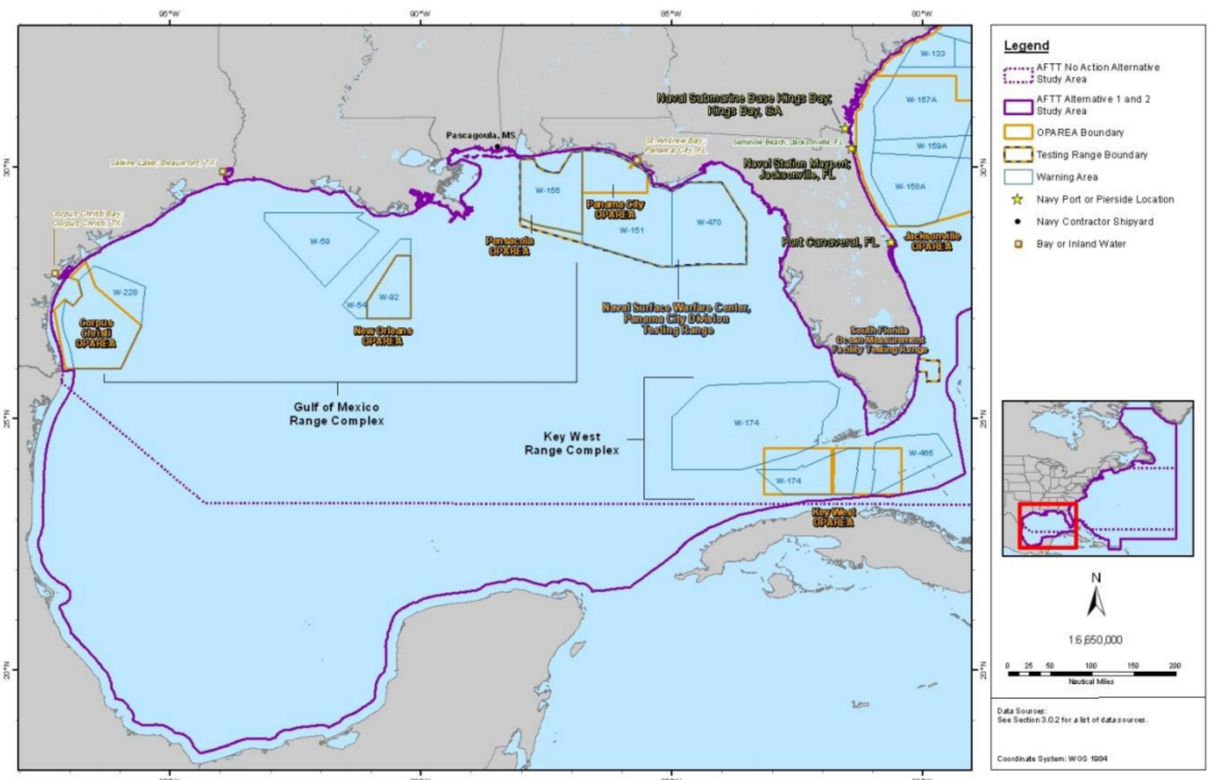


Figure 18. Navy Atlantic Fleet Training and Testing Study Area, GOMx. From: http://www.nmfs.noaa.gov/pr/pdfs/permits/aftt_navy_loa_application_dec2012.pdf.

In the 2013 –2018 AFTT Activities Biological Opinion[21], the Navy and NMFS assessed different stressors to biological resources, including acoustic stressors (i.e., sonar and other active sources, explosives, swimmer defense airguns, weapons firing noise, vessel noise, aircraft noise), energy stressors (i.e., electromagnetic devices, high energy lasers), physical disturbance and strike stressors (i.e., vessels, in-water devices, aircraft and aerial targets, military expended materials, seafloor devices), entanglement stressors (i.e., fiber optic cables and guidance wires, parachutes), ingestion stressors (i.e., military expended materials from munitions, military expended materials from other munitions), and secondary stressors (i.e., sediment, water, and air quality, prey). Because Bryde's whales are not listed under the Endangered Species Act, they were not considered in the biological opinion (although they were considered under MMPA requirements). However, threats to endangered sperm whales were considered. During testing activities, sperm whales could potentially experience up to 1,103 instances of take in the form of behavioral harassment resulting from impulsive (1 instance) and non-impulsive acoustic stressors

[21] http://www.nmfs.noaa.gov/pr/consultation/opinions/biop_aftt_loa_nov142013.pdf

(1,102 instances). The biological opinion estimated no more than 680 sperm whale takes would occur per year in the form of harassment from temporary threshold shifts (TTS) resulting from impulsive (14 instances) and non-impulsive sound stressors (666 instances). No takes are anticipated from permanent threshold shifts (PTS). Up to four sperm whale takes in the form of gastro-intestinal tract or lung injury are predicted to occur from annual or non-annual testing activities and impulsive acoustic stressors. Lastly, no more than one sperm whale death from vessel strike is allowed over the five-year period.

In December 2013, NMFS also published a final rule issuing a Letter of Authorization and regulations under the MMPA to govern the unintentional taking of marine mammals incidental to training and testing activities conducted in the AFTT study area from November 2013 to November 2018. Take was authorized for training and testing activities incidental to impulsive and non-impulsive source effects (78 FR 73009 2013). The final rule authorizes 955 annual (4,755 over 5 years) takes by Level B harassment (activities that have the potential to disturb or harass) of Bryde's whales throughout the Atlantic and Gulf of Mexico for training activities and 64 annual (305 over 5 years) takes by Level B harassment associated with all testing activities. There are no authorized takes by Level A harassment (potential to injure) authorized for Bryde's whales (78 FR 73009 2013). Although taking by Level B harassment is authorized, the Navy determined that very few training or testing activities are likely to occur in the southern half of the Bryde's whale Biologically Important Area (BIA). In addition, the Navy agreed to expand their Planning Awareness Area in the eastern portion of the Gulf of Mexico Range Complex to encompass the Bryde's whale BIA (Figure 19A, (78 FR 73009 2013). Planning Awareness Areas are locations that the Navy has identified to avoid planning major training activities when feasible. They identify these areas on sites of high productivity correlated with high concentrations of marine mammals.

Eglin Air Force Base (AFB) also has training areas in the GOMx (Figure 19B) and holds two active incidental take authorizations for them: they are for (1) Precision Strike Weapons (PSW) and Air-to-Surface (AS) Gunnery Exercises (2014 – 2019 (79 FR 13568 2014)); and (2) Naval Explosive Ordnance Disposal School (NEODS) Training Operations (2012 – 2017, (77 FR 16718 2012)). Eglin AFB also has an incidental harassment authorization for their Maritime Weapon Systems Evaluation Program. PSW and AS gunnery operations expose marine mammals to impulsive noise and pressure waves generated by ordnance detonation at or near the surface of the water. Because these missions take place in relatively shallow continental shelf waters ranging from approximately 35 to 50 m, they may affect common bottlenose dolphins, Atlantic spotted dolphins, *Stenella frontalis*, pantropical spotted dolphins, spinner dolphins, *S. longirostris*, and dwarf/pygmy sperm whales (79 FR 13568 2014). Potential exposure to energy and pressure resulting from detonations could occur at the surface or at any depth below the surface with different consequences. Such exposure could result in non-lethal injury (Level A harassment) and disturbance (Level B harassment). NEODS training operations involve underwater detonations of small, live explosive charges adjacent to inert mines (77 FR 16718 2012). These operations occur up to eight times annually at varying times of the year. The detonations are conducted on the seafloor at a depth of approximately 60 ft (18 m). The marine mammal species that commonly occur near the NEODS training area are the West Indian manatee, *Trichechus manatus*, Atlantic spotted dolphin, and common bottlenose dolphin. Common bottlenose dolphins are the most common species to overlap with training operations and the only species for which an incidental take authorization was requested.

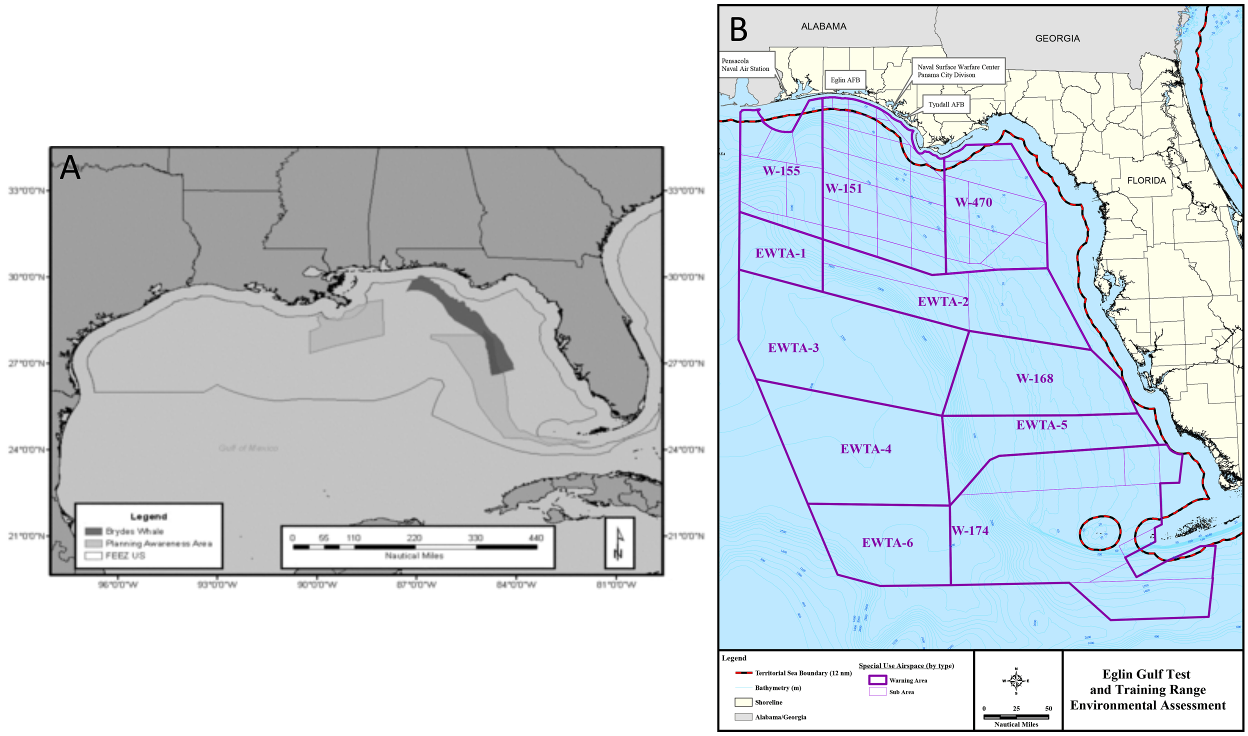


Figure 19. Military areas in the eastern GOMX. A) The Navy's eastern Planning Awareness Area in the GOMx was expanded to encompass an area occupied year-round by a small resident population of Bryde's whales. B) Eglin Air Force Base Gulf Test and Training Range in the eastern Gulf of Mexico. From: http://www.eglin.af.mil/shared/media/document/AFD-150826-021.pdf.

In 2015, Eglin AFB prepared a Range Environmental Assessment (REA) to comply with the National Environmental Policy Act (NEPA) requirement for assessment of activities in the Eglin Gulf Test and Training Range (EGTTR). The EGTTR encompasses 102,000 square nautical miles (349,850 km^2) of GOMx surface waters and the related air space (Figure 19B). Most testing occurs in area W-151, and specifically in sub-area W-151A, 15 – 20mi (28 – 37 km) offshore of Destin, Fla., in water depths of approximately 35 m (81 FR 7307 2016). The 2015 update to the 2002 Programmatic Environmental Assessment[22] proposes new actions that will occur in the EGTTR over the next five years (2015 – 2020) and the major changes involve increases in the level and types of air-to-surface testing and training and include the use of live munitions.

An Incidental Harassment Authorization (IHA) was also issued to Eglin AFB to take two species of marine mammals, the common bottlenose dolphin and the Atlantic spotted dolphin, by harassment, incidental to a Maritime Weapon Systems Evaluation Program (Maritime WSEP). This program would involve activities within the EGTTR from February 4, 2016 through February 3, 2017 (81 FR 7307 2016). The proposed Maritime WSEP training activities include the release of multiple types of inert and live munitions from fighter and bomber aircraft, unmanned aerial vehicles, and gunships to destroy small, static, towed, and remotely-controlled boat targets. Munition types include bombs, missiles, rockets, and gunnery rounds. Activities

[22] http://www.eglin.af.mil/shared/media/document/AFD-150826-021.pdf

involve detonations above the water, near the water surface, and under water within the EGTTR (81 FR 7307 2016).

The Air Force does not anticipate that the above described activities would take Bryde's whales because they are rare in the areas involved. Therefore, it did not request a take authorization for this species (81 FR 7307 2016).

Fishery Gear Entanglement

Many cetacean populations are negatively impacted by direct fishery interactions, including bycatch, in which animals inadvertently become hooked, trapped, or entangled in fishing gear deployed with the intention of catching something else, and leading to injury or mortality (Read 2008, Reeves et al. 2013). Bycatch rates are often underestimated because marine mammals may become entangled in, or hooked by, fishing gear and swim away mortally injured (sometimes with gear still attached), but their injuries and deaths are not observed and accounted for in bycatch statistics (Reeves et al. 2013). High rates of entanglement scarring on living baleen whales indicate that such cryptic incidents may be significant causes of large whale mortality, and that fishery entanglements occur much more frequently than indicated by statistics on known bycatch mortality (Robbins & Mattila 2004, Knowlton et al. 2012). Interactions are documented more frequently for odontocetes (Reeves et al. 2013), but remain a major threat for small populations of baleen whales, which are especially vulnerable to low levels of human-caused mortality (Read et al. 2006).

The degree of risk from direct fishery interactions is a function of whale size and behavior, the likelihood that a specific gear type will cause a serious injury or mortality, and the degree of spatial overlap between fishing effort and whale habitat (Benjamins et al. 2012). Fishery entanglements may lead to acute mortality from drowning or more protracted mortality caused by injury or impaired foraging and subsequent starvation, infection, hemorrhage or debilitation (Cassoff et al. 2011). Entangled whales also may be less able to avoid other mortality sources such vessels or predators (Cassoff et al. 2011). Newer, stronger, longer lasting line material in fishing gear poses a higher threat as animals, particularly smaller animals, are less likely to be able to break free of gear (Knowlton et al. 2015). In general, smaller whales, such as minke whales, Bryde's whales, and Omura's whales, and juveniles and calves, are more likely to suffer serious injury or mortality than larger whales for a given gear type and rope strength (Benjamins et al. 2012, Reeves et al. 2013, Knowlton et al. 2015). More than 95% of fishing effort occurs in continental shelf waters, and baleen whale populations that inhabit and migrate across these waters are at greater risk of encountering and becoming entangled in gear (Cassoff et al. 2011).

Throughout U.S. waters, dozens of large whale entanglements are reported per year, mainly involving minke, humpback, right, and gray whales entangled in gear from trap pot, pelagic longline, sink gillnets, pelagic gillnets, and purse-seine fisheries (Andersen et al. 2008). These species are more common in U.S. waters than are Bryde's whales. From 2007 to 2011 off the U.S. west coast, 62 of 108 large whale strandings with signs of human interaction were caused by fishery entanglements, mainly in trap/pot or gillnet gear (Carretta et al. 2013). The other 46 strandings with signs of human interaction were caused by vessel strikes.

Baleen whales interact with all commercial fishery gear types. Gillnet fisheries, which use set gillnet, fixed gillnet, driftnet, trammel net, or other entangling net gear, are one of the most commonly reported sources of fishery entanglements, with bycatch incidents reported worldwide for 9 of 14 mysticete species between 1990 and 2011 (Reeves et al. 2013). Trap and pot fisheries are the second most commonly reported entanglement source for large whales, with North Atlantic right whales, humpback whales, fin whales, and gray whales especially susceptible because of their feeding behavior and the spatial overlap between their habitat and the trap and pot fisheries. Entanglements frequently occur in the surface buoy line and fisheries that do not use a surface buoy line are thought to pose lower entanglement risk. Purse-seine fisheries have been reported to entangle marine mammals, particularly odontocetes, although humpback whale entanglements are relatively common and entanglements of fin, sei, and gray whales also have been reported (78 FR 73477 2013, Allen & Angliss 2015). Midwater and demersal trawls pose some entanglement and entrapment risk to cetaceans, which also can be entangled in netting or tow lines. Trawls appear to pose more risk to odontocetes, but minke, gray, humpback whale, fin whale, North Atlantic right whale and sperm whales also may interact with trawl nets (Northridge 1991, Fertl & Leatherwood 1997, Cole et al. 2005, Glass et al. 2008, 78 FR 73477 2013, Allen & Angliss 2015). Baleen whales also may become entangled in pelagic or bottom longlines. Whales may break free or be cut free of such lines, but also may swim away with trailing gear (including lines, floats, and weights) (Andersen et al. 2008). Vertical hook and line fisheries are not known to entangle large whales, primarily because they use monofilament line with low test strengths (i.e., breaking strength) and the whales are able to break free from this gear type without serious injury (e.g., Knowlton et al. 2015). Hooking injuries are generally not considered significant unless the whale has ingested the hook or it is lodged in a whale's eye (Andersen et al. 2008).

Bryde's whales, like other large whales, are susceptible to entanglement and entrapment in fishery gear including gillnet, longline, purse-seine, and trap/pot fisheries gear. Mead (1977) documents a Bryde's whale mistakenly identified as a sei whale that stranded on Anclote Key, Fla. (north of Tampa Bay) in 1974 entangled in a length of polypropylene line that led to blindness in one eye and likely interfered with jaw function. But in general, Bryde's whale fishery entanglements are not commonly observed by fishery observer programs in U.S. waters: no takes were observed in the CA/OR/WA gillnet fisheries from 1994 to 2011 (Forney et al. 2000, Carretta et al. 2008, Carretta et al. 2013) or the GOMx pelagic longline fishery between 1998 and 2010 (Waring et al. 2012). Between 1994 and 2009, one Bryde's whale was observed entangled in shallow-set longline gear off Hawaii in 2005, but this entanglement was considered a non-serious injury (Forney et al. 2011). Blaylock et al. (1995) reported a GOMx Bryde's whale entanglement in unidentified fishing line with subsequent live release. Later, the 2003 GOMx Bryde's whale stock assessment report describes the entanglement of a Bryde's whale in a pelagic longline. The line was purportedly removed and the animal released alive (Waring et al. 2004), but the cited references (Yeung 1999, 2001) do not substantiate this statement, nor could any supporting evidence be obtained from the pelagic long-line observer program. Furthermore, this could be the same entanglement described in Blaylock et al. (1995). There also is a well-documented case of a trap/pot entanglement mortality in 2003, in which a severely emaciated male Bryde's whale washed ashore in North Carolina and was determined to have died from impaired foraging and long-term starvation due to severe entanglement of the mouth (Cole et al. 2006, Cassoff et al. 2011, Van Der Hoop et al. 2012, Berkenbusch et al. 2013). Additionally, globally, three Bryde's whales are known to have been entangled in a gillnet, including one in Pakistan in a tuna gillnet (Moazzam & Nawaz 2014), one in Oman between 1990 and 2010 (Reeves et al. 2013), and one in Brazil between 1990 and 2010 (Reeves et al.

2013). In addition, one non-fishery shark net entanglement was documented in South Africa over the time period 1981 – 2009 (Meÿer et al. 2011). One international pot/trap fishery interaction resulted in immobilization and drowning of a Bryde's whale in rock lobster gear in Western Australia over the time period 1982 – 2010 (Groom & Coughran 2012). Four Bryde's whale entrapments were observed in the Western and Central Pacific Fisheries Commission purse-seine fishery between 2007 and 2010, three of those resulted in mortality. Bryde's whale is the only large whale species for which entrapments were known to result in mortality (Western and Central Pacific Fisheries Commission 2012, Berkenbusch et al. 2013). Additionally, two Bryde's whales are known to have been entangled in aquaculture gear and one entanglement in unspecified fishery gear were documented off New Zealand between 1970 and 2013 (Lloyd 2003, Constantine et al. 2015).

Spatial distribution of commercial fisheries in the Gulf of Mexico
Numerous commercial fisheries operate in the U.S. waters of the GOMx, including the 1) Atlantic Ocean, Caribbean, Gulf of Mexico large pelagics longline; 2) Gulf of Mexico gillnet; 3) Gulf of Mexico menhaden purse seine; 4) Florida west coast sardine purse seine; 5) Southeastern U.S. Atlantic, Gulf of Mexico stone crab trap/pot; 6) Florida spiny lobster trap/pot; 7) Gulf of Mexico blue crab trap/pot; 8) Southeastern U.S. Atlantic, Gulf of Mexico golden crab trap/pot; 9) Southeastern U.S. Atlantic, Gulf of Mexico shrimp trawl; 10) Gulf of Mexico butterfish trawl; 11) Southeastern U.S. Atlantic, Gulf of Mexico, and Caribbean snapper-grouper and other reef fish bottom longline/hook-and-line; 12) Southeastern U.S. Atlantic, Gulf of Mexico shark bottom longline/hook-and-line; and 13) Southeastern U.S. Atlantic, Gulf of Mexico, and Caribbean pelagic hook-and-line/harpoon.

The Team evaluated the spatial distribution of effort for each of these 12 fisheries and determined that 6 of them may have effort within or along the edge of the known range of Bryde's whales in the northeastern GOMx and therefore may interact with Bryde's whales (Table 7). Of these 6 fisheries, one exclusively uses gear types that are unlikely to pose a direct entanglement threat to marine mammals (hook and line gear, harpoons). The five remaining fisheries with gear types that may interact directly with whales are described further. In addition, Appendix 2 provides a snapshot of effort for a variety of these fisheries based on Vessel Monitoring System (VMS) data that, where available, indicate where effort occurs for each fishery.

Table 7. Commercial fisheries active in U.S. waters of the GOMx. This table documents the Team's evaluation of the overlap of known fishing effort for each GOMx fishery and the Bryde's whale BIA. The table does not attempt to quantify the risk of interaction or compare the relative risks posed by the different fisheries.

Fishery Name	Target Species	Gear Types	Spatial Distribution	Overlap	Citation
Atlantic Ocean, Caribbean, Gulf of Mexico large pelagics longline	Tuna: bluefin, bigeye, yellowfin, albacore, skipjack, blackfin, Billfish: blue marlin, white marlin, sailfish, longbill spearfish, swordfish, oceanic sharks	Pelagic longline	Mainly in waters deeper than 300m with some effort in 100-300 m depths. Prohibited in De Soto Canyon MPA	Yes	Waring et al. (2014), NMFS unpublished data
Gulf of Mexico gillnet[+]	Black drum, sheepshead, weakfish, mullet, spot, croaker, king mackerel, Spanish mackerel, Florida pompano, flounder, shark, menhaden, bluefish, blue runner, ladyfish, spotted seatrout, croaker, kingfish, and red drum, coastal sharks including blacktip, blacknose, finetooth, bonnethead, and sharpnose sharks	Various gillnets including strike, straight, drift, and bottom gillnets, runaround gillnets prohibited in Florida, Texas, drift gillnets and purse-seine prohibited in federal waters	Most coastal gillnet effort occurs in state waters of Louisiana and Alabama. Coastal migratory pelagic gillnet typically occurs in waters less than 45 m, but may occur out to 200 m	Unlikely	National Marine Fisheries Service (2009), Waring et al. (2014)
Gulf of Mexico menhaden purse seine[*]	Gulf menhaden	Purse-seine	Inshore and nearshore waters of Texas, Louisiana, Alabama, and Mississippi, with most effort occurring off Louisiana (75%) and within state waters (>95%)	No	SEDAR (2013)
Florida West coast sardine purse seine[*+]	Spanish sardine and other schooling baitfish	Purse-seine	Offshore of Florida especially Manatee and Gulf counties. Mainly in waters less than 50 m deep	Unlikely	Addis et al. (2015)

Fishery Name	Target Species	Gear Types	Spatial Distribution	Overlap	Citation
Gulf of Mexico stone crab trap/pot[+]	Florida stone crabs	Baited traps	Primarily in Florida state waters, less than 20 m deep	No	Muller et al. (2006), Waring et al. (2014)
Florida spiny lobster trap/pot[+]	Caribbean spiny lobster, smooth tail spiny lobster, spotted spiny lobster	Wooden traps	Almost exclusively in waters of the Florida Keys, typically less than 30 m, but possibly up to 60 m depths	No	Waring et al. (2014)
Gulf of Mexico blue crab trap/pot[+]	Blue crab	Baited wire traps	Mainly estuarine and nearshore waters throughout the GOMx, especially Louisiana, followed by Florida, waters less than 90m deep	No	Guillory et al. (2001), Waring et al. (2014)
Gulf of Mexico shrimp trawl[*]	Mainly brown shrimp, pink shrimp, and white shrimp. To a lesser extent, rock shrimp, *Trachypenaeus* shrimp, seabobs, and royal red shrimp	Demersal otter trawls, skimmer trawls	Throughout the Gulf with highest effort off Louisiana, Alabama, and Mississippi. Mainly estuarine, coastal and shelf waters less than 120 m deep. Royal red shrimp along deep continental slope 256 to 549 m deep, east of the Mississippi River	Possible for royal red shrimp	Scott-Denton et al. (2012)
Gulf of Mexico butterfish trawl	Gulf butterfish	Demersal trawls	Limited information: northeastern GOMx (Alabama, Florida) in water depths from 50 to 290 m	Possible	Vecchione (1987), Herron et al. (1989)

Fishery Name	Target Species	Gear Types	Spatial Distribution	Overlap	Citation
Gulf of Mexico snapper-grouper and other reef fish bottom longline/hook-and-line	Snappers: queen snapper, mutton snapper, blackfin snapper, red snapper, cubera snapper, gray (mangrove) snapper, lane snapper, silk snapper, yellowtail snapper, wenchman, vermillion snapper, Groupers: speckled hind, Atlantic goliath grouper, red grouper, yellowedge grouper, warsaw grouper, snowy grouper, black grouper, yellowmouth grouper, gag, scamp, yellowfin grouper, Tilefishes: goldface tilefish, blueline tilefish, tilefish, Jacks: greater amberjack, lesser amberjack, almaco jack, banded rudderfish, Triggerfishes: gray triggerfish, Wrasses: hogfish	Bottom longline Vertical hook and line (electric reels, hydraulic reels, bandit reels, hand reels, buoy gear) Fish traps prior to 2007	Mainly in waters less than 100m but bottom longlining for yellowedge grouper, golden tilefish, and blue tilefish occur in deeper waters	Yes	Scott-Denton et al. (2011) Gulf of Mexico Fishery Management Council & South Atlantic Fishery Management Council (2013)
Gulf of Mexico shark bottom longline/hook-and-line	Various shark species	Bottom longline, vertical hook and line (electric reels, hydraulic reels, bandit reels, hand reels, buoy gear)	Florida west coast, waters deeper than 37 m. Louisiana and Alabama landings are from the reef-fish fishery.	Yes	Hale et al. (2010), Scott-Denton et al. (2011)

Fishery Name	Target Species	Gear Types	Spatial Distribution	Overlap	Citation
Gulf of Mexico, and Caribbean pelagic hook-and-line/harpoon	King mackerel, Spanish mackerel, dolphinfish, cobia, cero	Trolling hook and line gear	Typically in waters less than 45 m, but may occur out to 200 m, significant recreational effort	Limited	Cass-Calay & Ortiz (2009) Collette & Russo (1979), McEachran & Finucane (1979), Gulf of Mexico Fishery Management Council & South Atlantic Fishery Management Council (2013)
[+] Direct interactions with gillnets, purse-seines, and trap pots may be unlikely, but indirect interactions, such as entanglement in derelict "ghost fishing" gear may be of concern. See section on Marine Debris. * Direct interactions with purse-seine and shrimp fishery may be unlikely, but indirect effects such as ecosystem wide trophic impacts may be of concern. See section on Trophic Impacts.					

Pelagic longline fisheries

In the GOMx, the only pelagic longline fishery is the Atlantic Ocean, Caribbean, Gulf of Mexico large pelagics longline fishery, which includes the Highly Migratory Species (HMS) pelagic longline fishery. These fisheries operate year-round and operate throughout most of the GOMx (Figure 20A) in waters deeper than 300 m, targeting swordfish, tuna, dolphinfish, wahoo, shortfin mako shark, and a variety of other sharks (Waring et al. 2014). Target fish species are regulated under the Highly Migratory Species Fishery Management Plan and marine mammal species taken as bycatch are protected under the ESA and/or the MMPA. Longline gear consists of a mainline, gangions, baited hooks, high-flyer buoys to monitor gear position while fishing, and may include weights to stabilize line in the water column. The GOMx pelagic longline fishery uses a mainline of > 700 -lb-test (317.5 kg) monofilament, typically ranging from 10 – 45 mi (16 –72 km) long. Bullet-shaped floats are used to suspend the mainline at regular intervals along the mainline, radio beacons are used to mark long sections of gear and 100 – 200 ft (30.5 – 61 m) long gangion lines of 200 – 400-lb-test (91 – 181 kg) monofilament are suspended from the mainline with hooks typically fished at depths between 40 – 120 ft (12 and 36.6 m). Gear typically remains in the water for 10 – 14 hours with gear targeting tuna typically set at dawn and hauled near dusk and gear targeting swordfish typically set at night and hauled in the morning (Waring et al. 2014). Cetacean interactions with pelagic longline gear most commonly involve odontocetes, such as pilot whales, false killer whales, *Pseudorca crassidens*, Risso's dolphins, *Grampus griseus*, and common bottlenose dolphins, becoming entangled or hooked in longline gear leading to injuries (e.g., lacerations, puncture wounds) and in some cases, exhaustion and/or drowning (Andersen et al. 2008). An entangled minke whale was recently observed in the Atlantic pelagic longline fishery (Garrison 2007, Waring et al. 2015) and humpback whales and Bryde's whales have been documented entangled in Hawaii pelagic longline gear (Andersen et al. 2008, Forney et al. 2011). Large whales typically become entangled in mainlines or branchlines and are often released with trailing gear (including lines, floats, and weights).

In the GOMx from 2005 to 2013, the average annual number of pelagic longline sets reported to the pelagic longline logbook program was 3,295 $\pm$ 952 (NMFS, unpublished data). This average includes 2010 and 2011, which had an unusually low number of sets as a result of the *Deepwater Horizon* oil spill. However, the sets are not distributed throughout the GOMx because in 2000, the HMS Atlantic Tunas, Swordfish, and Sharks FMP was amended to close De Soto Canyon to commercial pelagic longline fishing all year (65 FR 47214 2000) (Figure 20A). Approximately 2/3 of the GOMx Bryde's whale's BIA overlaps with this marine protected area (MPA). There is some degree of overlap between pelagic longline fishing and the remaining 1/3 of the BIA (Figure 20B), although the fishery typically operates in waters greater than 300 m. While overall effort since 2005 remained reasonably constant throughout the GOMx (with the exception of 2010 – 2011), some effort appears to be shifting into the region northeast of the MPA in recent years (Figure 21). From 2005 to 2013, a total of 705 sets occurred in the waters northeast of the De Soto Canyon MPA, with an almost 3-fold increase in effort after 2008 and 2009 (excluding 2010 and 2011) (Figure 21, (NMFS unpublished data). During the 2005 to 2008 period, the average annual number of sets was 48 $\pm$ 12 while during 2009, 2012, and 2013 the annual average was 136 $\pm$ 5 sets. Approximately 80 sets occurred in the Bryde's whale BIA over the 9-year period.

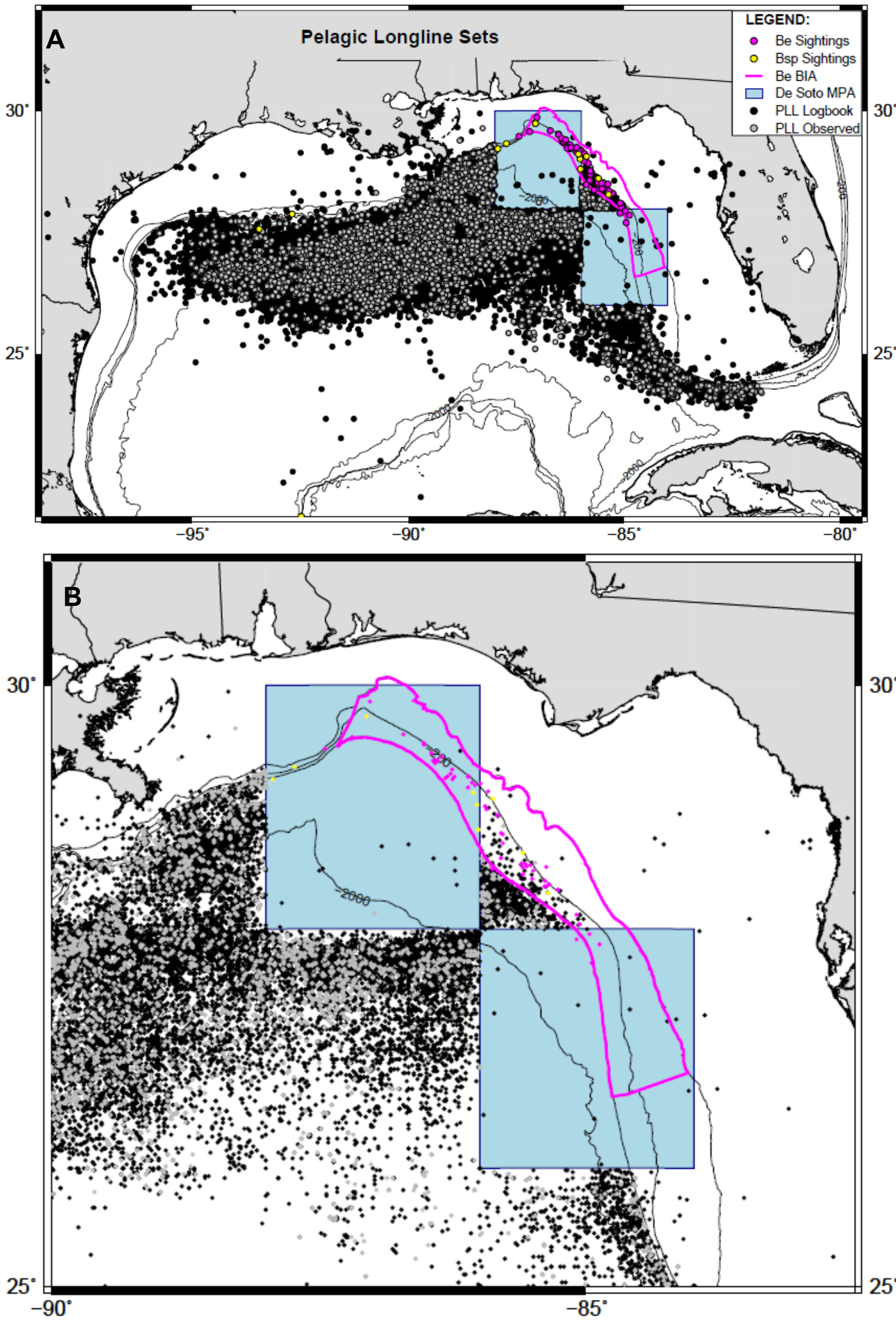


Figure 20. Pelagic longline set locations in the GOMx based on logbook data for 2005 – 2013 and observer program data from 2005 to 2014 for the entire GOMx (A) and the De Soto Canyon region, only (B). The De Soto Canyon MPA (blue boxes) is closed to pelagic longline fishing year-round. This area covers two/thirds of the GOMx Bryde's whale BIA and approximately 50% of Bryde's whale sighting locations are within the De Soto Canyon MPA. The 100, 200, 300, and 2000 m isobaths are shown.

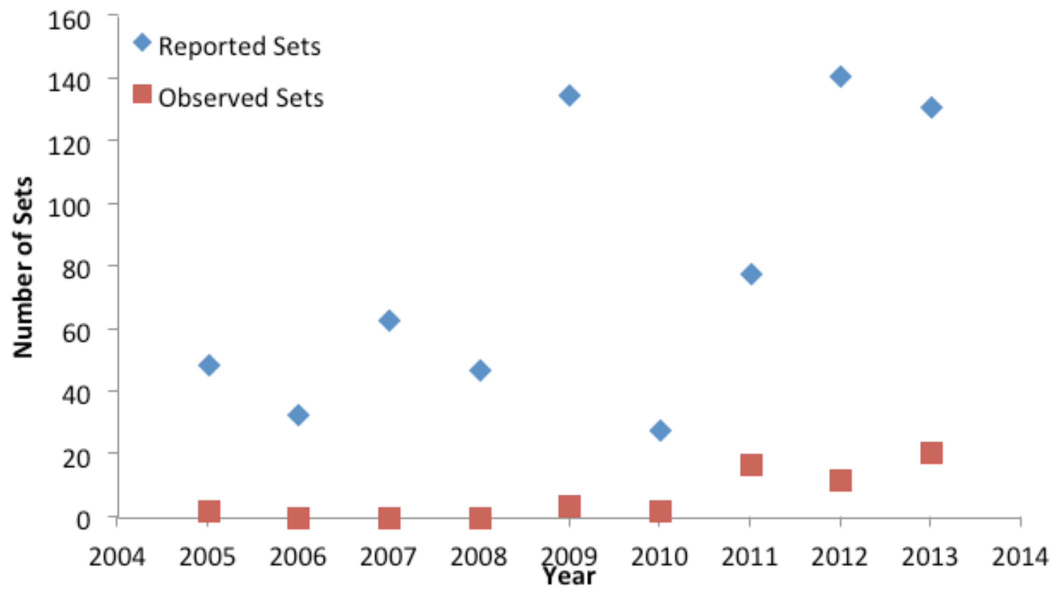


Figure 21. Pelagic longline sets occurring in the region to the northeast of the De Soto Canyon MPA boundaries from both logbook records (reported sets) and observer program (observed sets). The total number of sets has increased 2-3 fold after 2008 (with the exception of 2010 and 2011 when fishing bans were in place during and following the *Deepwater Horizon* spill).

Trawl fisheries

In the GOMx, there are two trawl fisheries: the Gulf of Mexico shrimp trawl fishery and the Gulf of Mexico butterfish trawl fishery. The shrimp trawl fishery mainly targets penaeid shrimp with the highest effort being off Louisiana, Alabama, and Mississippi and mainly in estuarine, coastal and shelf waters less than 120 m deep (Figure 22). There is therefore limited spatial overlap with known Bryde's whale habitat. However, there may be some overlap along the northwestern limits of the Bryde's BIA, and some effort for royal red shrimp in deeper waters along the slope also may have overlap, although this represents a small portion of the total fishery effort (Figure 22). It is unknown whether this is enough effort to increase the potential for interaction to a non-negligible level. In addition, the shrimp trawl fishery removes a significant amount of biomass from the GOMx ecosystem and therefore may have the potential to have a trophic impact on Bryde's whales in the GOMx. See section "Trophic Impacts Due to Commercial Harvest of Prey Items" for further discussion.

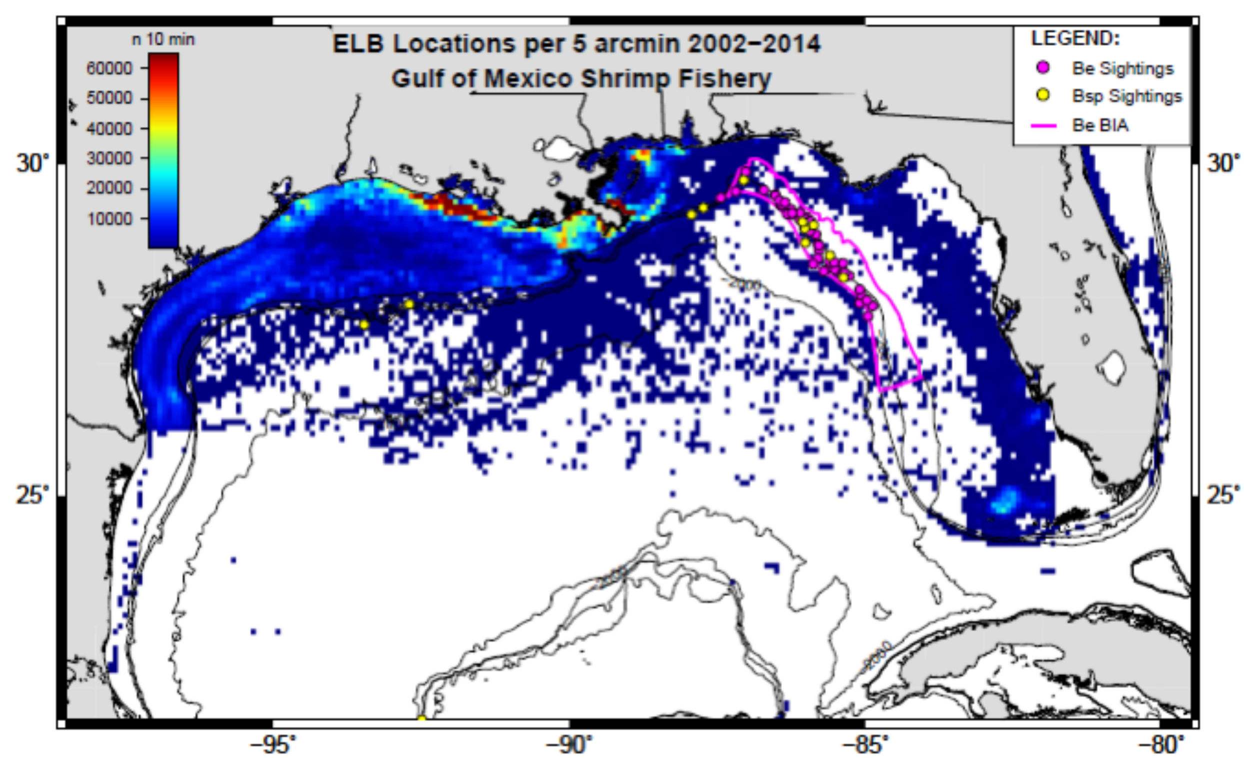


Figure 22. Shrimp trawl active fishing effort from electronic logbook data from 2002 to 2014 and Bryde's whale sightings (pink circles) from SEFSC aerial and vessel surveys from 1992 to 2015. Effort is represented as the total number of 10-min GPS location stamps during active fishing effort per 5-arcmin bins. The 100, 200, 300, and 2000 m isobaths are shown.

The Gulf of Mexico butterfish trawl fishery is a small fishery with only two vessel/persons currently permitted (78 FR 73477 2013). Gulf butterfish are a small schooling demersal fish common to the northeastern GOMx that aggregate in waters of 50 to 290 m deep (Herron et al. 1989). There is limited information available on current fishery effort; a small sample of fishery effort (six trips on two vessels) was evaluated in May and June in the 1980s and Vecchione (1987) recommended that effort be concentrated deeper than 150 m in spring during daylight hours. The fishers landed between 12 and 122 thousand lbs (10 and 55 thousand kg) of butterfish per trip (5-10 days each) setting in waters with depths ranging between 35 and 223 m with most between 129 and185 m. From 2000 to 2014, a total of 11.8 million lbs (5.4 million kg) of butterfish were landed mainly off Alabama and Florida, averaging 786.6 thousand lbs (356.8 thousand kg) per year, with 95% of landings coming from Florida[23].

Bottom longline fisheries
In the GOMx, the reef fish snapper grouper fishery and the Gulf of Mexico shark fishery use bottom longline gear. Bottom longline gear consists of a monofilament mainline up to a mile in length anchored on the seafloor at either end with buoy lines marked by high flyer flags. Up to 1000 baited hooks can be attached to the mainline via leaders (gangions or snoods), and gear can soak anywhere from hours to days. Bottom longline gear generally poses less of an

[23] https://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/annual-landings/index, accessed 2/18/2016

entanglement threat to cetaceans than pelagic longline gear[24] except in cases where cetaceans engage in feeding activity along the bottom that exposes them to risk of entanglement in the mainlines, as may be the case for the GOMx Bryde's whale. Entanglement in the vertical buoy lines may also occur, and could result in anchoring, restricting entanglements, or trailing of gear including line, surface buoys, and/or anchors all of which could result in serious injury or mortality (Andersen et al. 2008).

Commercial fishermen using bottom longline gear off the coast of Florida generally target red grouper, *Epinephelus morio*, in shallow waters and yellowedge grouper *E. flavolimbatus*, tilefish (Malacathidae), and sharks (Carcharhinidae) in deeper waters, including waters between 100 and 300 m in the northeastern GOMx (Figure 23) (Scott-Denton et al. 2011). Observed trip lengths averaged 11.7 days for bottom longlines with average set fishing depths of 51.5 ± 37.8 fm (range 19.3 – 212.0 fm [94.2 ± 69.1 m, range 35.3 – 387.7 m]) (Scott-Denton et al. 2011). Bottom longline gear averaged 5.6 nmi (10.4 km) set lengths, with 5.8 ft (1.8 m) gangions and 991 circle hooks per set-(Scott-Denton et al. 2011). Soak times averaged 5.1 ± 2.9 hr (range 0.9-32.2hr) (Scott-Denton et al. 2011).

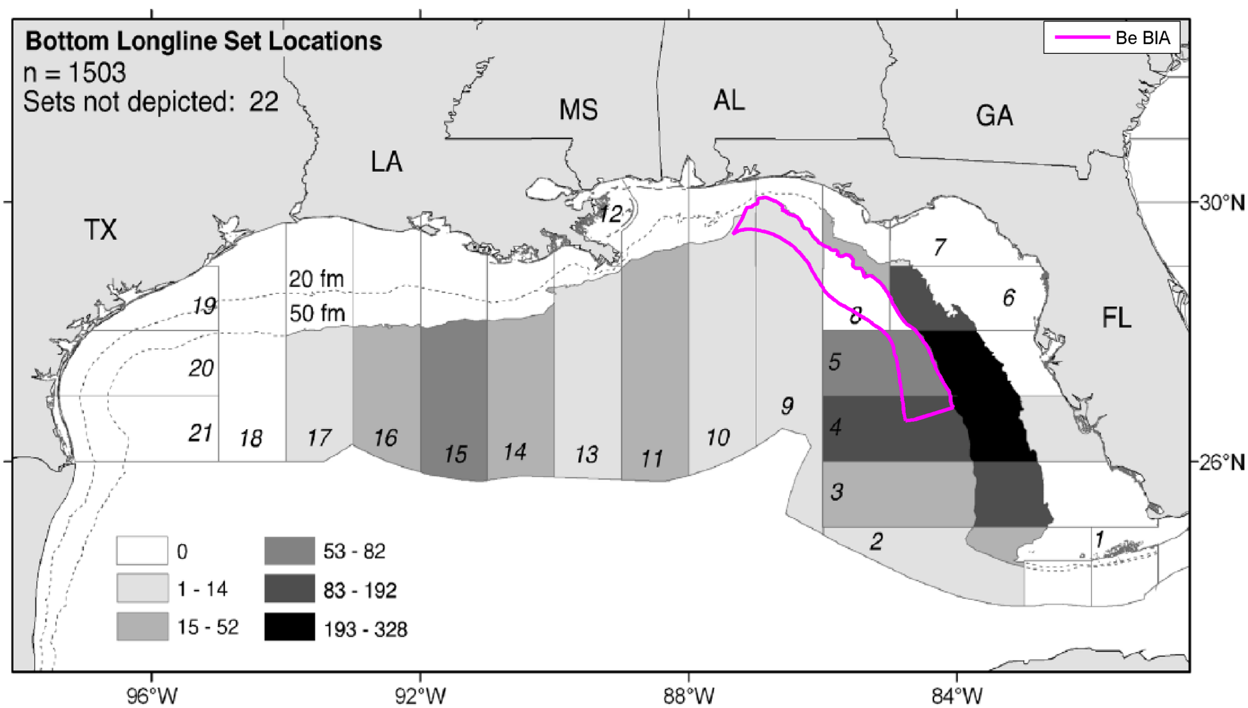


Figure 23. Distribution of total observed sets from 2006 to 2009 in the bottom longline fishery observed by the SEFSC Reef Fish Observer Program, which observes the reef fish snapper/grouper bottom longline and shark bottom longline fisheries. Number of observed sets over the time period are depicted (shading) per shrimp statistical zone (numbered regions) and depth strata, and show potential for spatial overlap with the GOMx Bryde's whale primary habitat. The 50 fathom (fm) isobath (91 m) is approximately the inshore limit (100 m) of the Bryde's whale BIA. Figure reproduced from Scott-Denton et al. (2011).

Throughout the year, bottom longline gear are prohibited for reef fish harvest inshore of 36.6 m off the Florida shelf and inshore of 91.4 m through the rest of the Gulf. From June through

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[24] http://www.nmfs.noaa.gov/pr/interactions/gear/)

August, bottom longline gear are prohibited inshore of 54.3 m in the eastern GOMx (Gulf of Mexico Fishery Management Council & South Atlantic Fishery Management Council 2013). The spatial distribution of bottom longline sets sampled by the SEFSC Reef Fish Observer Program indicates the potential for overlap between the bottom longline fishery and GOMx Bryde's whale habitat (Figure 23). When fishing, fishermen with reef fish permits are required to collect and transmit their positions using a Vessel Monitoring System (VMS) instrumentation while fishing. A VMS density distribution map of reef-fish fishermen with a bottom longline endorsement indicates there is a high degree of spatial overlap with a portion of this fishery and the Bryde's whale BIA (Figure 24). Further investigation into reef-fish occurrence shows that yellowedge grouper and tilefish species have a similar distribution to that of GOMx Bryde's whales and may potentially be the target species of bottom longliners operating in the GOMx Bryde's whale BIA (Figure 25). Additionally, reef fish fishermen who also carry a Shark Directed permit overlap spatially with the Bryde's whale BIA (Figure 26) and may therefore interact directly with the whales. An important caveat regarding the VMS distributions is that fishers may hold multiple permits and the target species being fished during each trip is unknown. Additionally, shark fishermen who do not also have a reef fish permit are not represented in these data.

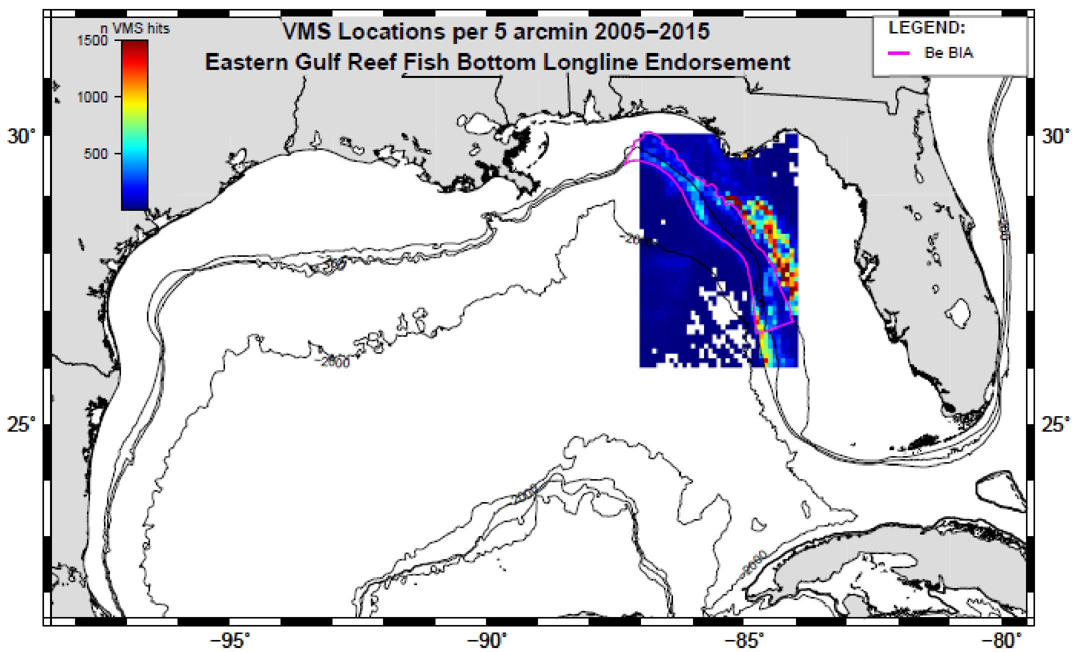

Figure 24. VMS ping locations from vessels carrying a Reef fish permit and an Eastern Gulf Reef Fish Bottom Longline Endorsement (fishers may hold multiple permits and the target species being fished during each trip is unknown). Locations may represent transiting as well as active fishing. VMS data were obtained from Rivero (2015). The 100, 200, 300, and 2000 m isobaths are shown.

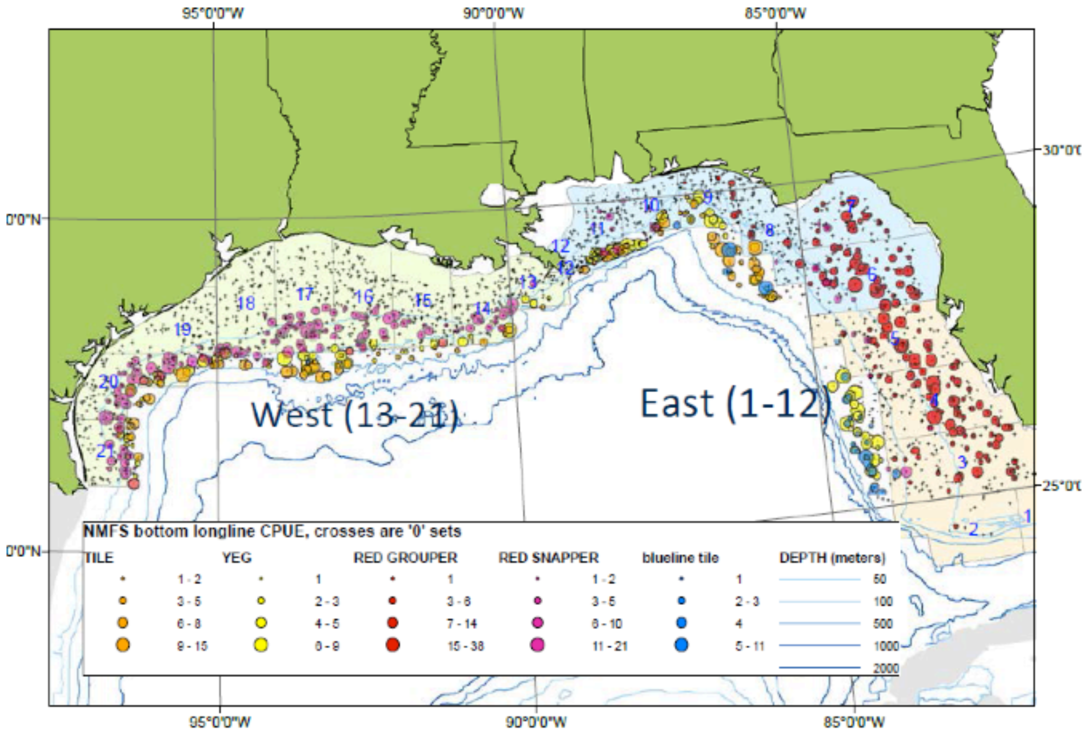

Figure 25. Map of NMFS bottom longline catch rates for five predominant reef fish (Tile: golden tilefish, YEG: yellowedge grouper, red grouper, red snapper, and blueline tilefish). Surveys do not extend beyond 500 m depths. The 100 m isobath represents the inshore limit of the Bryde's whale BIA. Figure reproduced from National Marine Fisheries Service (2011).

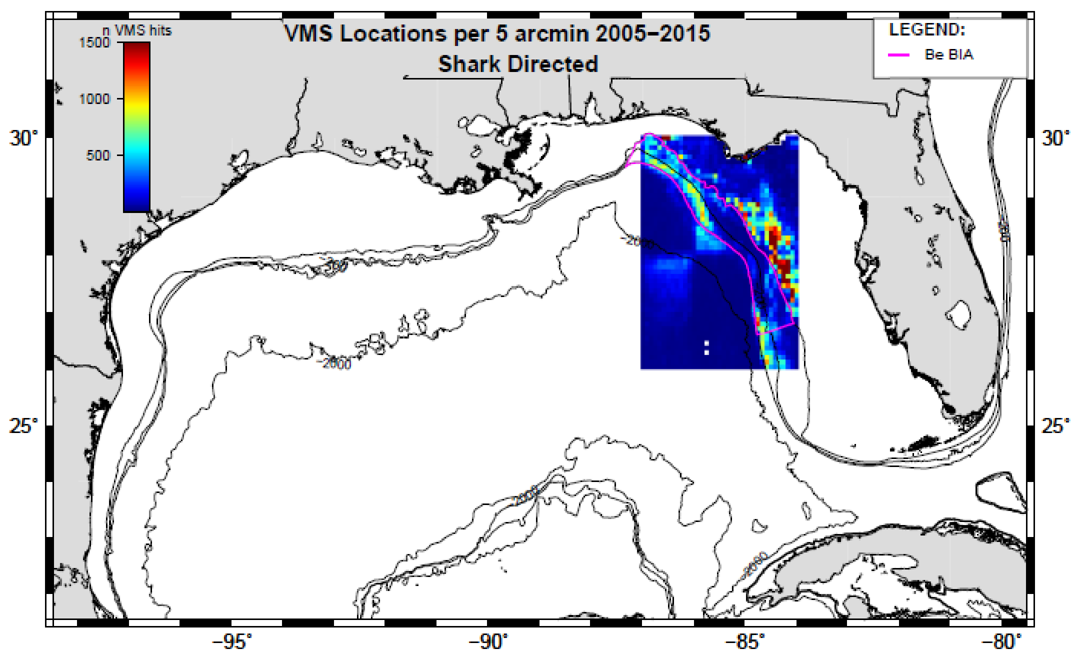

Figure 26. VMS ping locations from vessels carrying a Reef fish permit and Shark directed permit (fishers may hold multiple permits and the target species being fished during each trip is unknown). Locations may represent transiting as well as active fishing. Shark directed permit holders without reef fish or pelagic longline permits are not required to carry VMS and are not represented in this map. VMS data were obtained from Rivero (2015). The 100, 200, 300, and 2000 m isobaths are shown.

Historic trap pot fishery
Historically, the Gulf of Mexico reef fish fishery also used fish trap pots, but these have been prohibited since 2007 (Scott-Denton et al. 2011). Traps and pots are typically made of wire or wood, may be weighted with cement or rebar, and are attached to a surface buoy by a vertical line. They may be deployed singly or in series, called trawls, which are connected by ground lines, and can be set at depths up to 730 m. Cetacean entanglements occur in the vertical line to surface buoys or in floating ground lines and can lead to drowning or to serious injury if whales swim away with gear still attached. It is unknown whether the reef fish fishery fish traps were deployed in similar locations to bottom long-line effort, and whether they represented a fishery entanglement risk prior to 2007. Two GOMx Bryde's whales have been entangled in trap/pot gear (1974 stranding in GOMx and 2003 stranding in NC described above), but the gear from these strandings cannot be assigned to any specific fishery.

Trophic Impacts Due to Commercial Harvest of Prey Items

Direct threats to marine mammals from commercial and recreational fisheries include bycatch mortality, gear entanglements, and injuries (Read et al. 2006). A suite of indirect fishery threats must also be considered. These include habitat damage, direct competition for marine mammal prey targeted by fisheries or non-targeted prey lost as bycatch, and indirect competition through fishery depletion of the species consumed by the prey of marine mammals. Fisheries can also reduce ecosystem productivity and alter food webs by changing species composition and population size structure (Dayton et al. 1995). Upper-level predators tend to be especially sensitive to reduced ecosystem productivity, overfishing, and loss of forage species. In the GOMx, forage species comprise 90% of total commercial fishery landings: 72% menhaden (*Brevoortia patronus*) and 12.7% penaeid shrimp (National Marine Fisheries Service 2014).

Depletion of marine mammal prey by commercial and recreational fisheries could threaten marine mammal food supplies. Bryde's whales, globally, forage on small schooling fish including species in the anchovy, sardine, mackerel, herring, and oceanic lightfish families, and on invertebrates, including euphausiids and pelagic red crabs, with rare instances of squid and copepods (Best 1960, 1967, 1977, Nemoto & Kawamura 1977, Ohsumi 1977, Omura 1977, Tershy 1992, Tershy et al. 1993, Urbán & Flores 1996, Best 2001, Siciliano et al. 2004, Murase et al. 2007, Niño-Torres et al. 2013). Comparisons of stomach contents of the offshore and inshore Bryde's whale, *B. e. brydei*, forms off South Africa indicated euphausiids were the preferred prey of the offshore type of Bryde's whale, while the inshore type rarely preyed on euphausiids (e.g., Best 1977). Tamura et al. (2009) estimated Japanese-caught Bryde's whales ranging from 9,300 to 17,800 kg body mass would need to consume approximately 350 to 970 kg of prey per day.

Reliable data providing evidence of direct competition between fisheries and whales for prey resources is very difficult to obtain due to the complexity of ecosystem interactions and often sparse data on prey availability and spatio-temporal dynamics, whale foraging behavior, and whale spatio-temporal dynamics (e.g., Clapham & Brownell 1996). Several key principles have been proposed to indicate when exploitative interspecific competition may occur between large whales species (Clapham & Brownell 1996), and these same principles also apply to competition between large whales and human fisheries.

Direct competition between GOMx Bryde's whales and commercial or recreational fisheries does not appear to be likely based on the current distribution of Bryde's whales, the distribution of fishery effort, and presumed fish and invertebrate habitat. While Bryde's whale prey in the GOMx are unknown, they likely feed on small schooling fish and invertebrates, similar to other Bryde's whales worldwide, and may prefer small schooling fish similar to coastal forms elsewhere. The two main GOMx commercial fisheries for small schooling fish are the GOMx menhaden purse-seine fishery and the Florida west coast sardine purse-seine fishery. While the GOMx menhaden fishery extracts tremendous quantities of menhaden biomass annually (it is the 2nd largest U.S. fishery by weight), the fishery mainly operates off Louisiana and Mississippi with some effort off Texas and Alabama, with the majority of effort occurring in state waters. GOMx menhaden are generally not found out to the depths preferred by GOMx Bryde's whales, so these seem an unlikely prey item and therefore direct impact to Bryde's whale prey by this fishery appears low (but see below for possible indirect effects). While the main target of the Florida west coast sardine purse-seine fishery is sardines, their catch includes all local schooling baitfish, such as Atlantic thread herring, round scad and Gulf menhaden (Mahmoudi et al. 2002). The fishery is mainly active off Florida's Gulf and Manatee counties, with the majority of effort occurring in 15-150 ft (4.6 to 46 m) waters[25]. Total Florida baitfish annual landings (mainly from purse-seine nets) peaked at 37 million lbs (16.8 million kg) in one year, but are now regulated at 10 million lb s (4.5 million kg) per year, with the majority of commercial effort occurring in waters < 150 ft (46 m) deep[26]. A 1994 Florida constitutional amendment led to regulations to restrict fishing effort and thereby ensure ecosystem health[16]. However, annual Spanish sardine biomass in 1994 was 28 million lbs (12.7 million kg) and dropped to 4 million lbs (1.8 million kg) in 1999 and has not recovered since, although the factors impacting Spanish sardine population abundance are unknown (Mahmoudi et al. 2002). In 2013, total landings in the Florida west coast sardine purse-seine fishery were 662,633 lbs (300,565 kg). The peak 37 million lbs (17 million kg) and current 662,633 lbs (300,565 kg) levels of annual biomass removal are similar to the annual biomass that could be consumed by 92 and 2 Bryde's whales, respectively, assuming a whale consumes 500 kg of prey per day (e.g., Tamura et al. 2009), but it is unknown whether the bait fish targeted on the Florida shelf are part of the prey populations targeted by GOMx Bryde's whales along the shelf break. Lastly, it is unknown whether shrimp are among Bryde's whale invertebrate prey items, but the most heavily fished species in the GOMx are penaeid shrimp including brown, white, and pink shrimp, which are rarely found beyond the 150 m isobaths. Therefore, it appears that the shrimp fishery has, at most, limited overlap with the current extent of known Bryde's whale habitat in the northeastern GOMx. Approximately 2/3 of the total catch by the shrimp fishery are non-target finfish with limited quantities of schooling fish in the bycatch composition (Scott-Denton et al. 2012).

The total biomass removed by fishing in the GOMx and the resulting impact on ecosystem functioning, species composition, and potential trophic pathway alterations may be a threat to Bryde's whales but the impact is unknown. The menhaden fishery is the largest source of biomass and energy removal in the GOMx, with 1.02 billion lbs (463 million kg) of fish landed in 2013, representing 14% of national commercial fisheries landings by weight (National Marine Fisheries Service 2014). This level of biomass removal is similar to the annual biomass that can be consumed by 2,537 Bryde's whales that each consume 500 kg prey per day (e.g., Tamura et

[25] http://myfwc.com/media/195536/spanish_sardine.pdf

[26] FFWCC June 2000 - http://www.islamoradasportfishing.com/pdf/baitfish.pdf

al. 2009). Gulf menhaden is a key link in the food web between primary producers and secondary consumers, is a principal forage food for predatory fishes, sea birds, and marine mammals (Leatherwood 1975, Vaughan et al. 2007), and is a principal food base for larger fishes that become marine mammal prey. Annual menhaden fishery landings averaged 1.1 billion lbs (499 million kg) from 2003 to 2014, and far exceeded the total catch of most other commercial fisheries (only exceeded by landings of walleye pollack in Alaska) (National Marine Fisheries Service 2014). Additionally, while finfish bycatch in the menhaden fishery is only 2.35% (Guillory & Hutton 1982), this yields an average of 26 million tons (23.6 million metric tons) of bycatch of non-target species. The GOMx shrimp trawl fishery also removes substantial biomass from the GOMx ecosystem. In 2013, a total of 205 million lbs (93 million kg) of shrimp were landed in the GOMx (National Marine Fisheries Service 2014). During 2007 – 2010, finfish bycatch [of which the main species composition is grouped finfish (29%), Atlantic croaker (16%), sea trout (6%), and longspine porgy (4%)] averaged approximately two times the total shrimp catch (Scott-Denton et al. 2012), suggesting a total of 410 million lbs (186 million kg) of finfish (i.e., a level of biomass equivalent to the annual biomass 1,020 Bryde's whales can consume) were bycaught in 2013. While most of this bycatch is returned to the sea, the proportion that survives, and the ecosystem fate of the discarded proportion that does not remains unknown. Additionally, the impacts of the high levels of demersal shrimp trawling (mean 179,000 days of active trawling per year from 1997 to 2011 (Soldevilla et al. 2015)) have on the GOMx ecosystem are unknown. However, a global study of the relationship between seabird population declines and availability of forage fish found that fishery-induced reductions of 1/3 maximum prey biomass led to seabird population declines (Cury et al. 2011) and suggested a similar relationship exists for marine mammals.

The total quantity of removals is not the only ecosystem-level threat from commercial fisheries. Marine mammal prey density is often heterogeneous due to schooling and habitat patchiness. Marine mammals tend to target, and may require, high density clusters of prey for successful foraging (e.g., Piatt & Methven 1992). Fisheries also selectively target high concentrations of fish and squid and can alter the food web by reducing the frequency of occurrence of high density clusters and by reducing average prey density, change prey composition, spatial distribution, and size structure (Pauly et al. 2002). In these cases, even if the total quantity of food available is sufficient to support marine mammal populations, marine mammals may have decreased survival and reproductive success if prey density is too low or prey schools are too infrequently encountered (Boyd 1996).

Climate Change

Climate change is widely recognized as a global issue (IPCC 2007). The International Whaling Commission (IWC) held its first workshop on climate change in 1996, and has followed it with additional workshops in 2009 and 2010 (IWC 1997, 2010, 2012). In 2014, the IWC Climate Change Steering group met and concluded that climate change was not being given "appropriate attention." The group recognized that predictive powers for climate models have improved and recent information may allow these models to predict species and ecosystem level responses (IWC 2014a). Recently, NMFS as released a Climate Science Strategy (Link et al. 2015) which mandates that all management-related actions by the Agency consider the likely consequences of climate change.

All cetaceans have undoubtedly lived through considerable variation in climate (including multiple ice ages, and significant warming events) over the course of their evolutionary history. However, the ways in which cetaceans dealt with climate change in the past are not known and may not be sufficient in the current context as the current rate of change far exceeds historical changes in climate.

Climate change may have a variety of impacts on marine environments, including through increases in ocean water temperature and pH, and changes in coastal riverine input (Evans et al. 2010). The potential impacts of climate change on marine mammals include range shifts, habitat degradation or loss, changes to the food web, susceptibility to disease and contaminants, and thermal intolerance (MacLeod 2009, Evans & Bjørge 2013).

Climate change may disproportionately affect species with specialized or restricted habitat requirements. Species that possess little ability to disperse or colonize new habitats may also be particularly vulnerable. The best-known examples include those species dependent on sea ice. For species in more temperate climates, the effects are less clear (MacLeod 2009, Evans et al. 2010). Recent information (Rosel & Wilcox 2014) suggests that Bryde's whales in the GOMx have been isolated for some time from other Bryde's whale populations so their ability to disperse to or colonize new habitats may be limited. Certainly, they will be unable to move further north within the GOMx to avoid warming water temperatures. In addition, GOMx Bryde's whales have a limited distribution and occupy an area that is heavily influenced by the Mississippi River as well as the Loop Current. Freshwater from the Mississippi River mixes with the Loop Current and can be transported great distances along the Florida shelf. Alterations in freshwater discharge from the Mississippi River due to climate change could result in reduced biological productivity in the GOMx (Twilley et al. 2001). Climate change also may influence hurricane frequency and intensity in the GOMx (Twilley et al. 2001), although the impacts on cetaceans are unknown. Finally, changing ocean temperatures have the potential to increase exposure to and susceptibility to pathogens and disease and this would be a serious concern for a very small population (Simmonds & Elliot 2009, Evans & Bjørge 2013).

<u>Plastics and Marine Debris</u>

Marine debris is an ongoing and growing threat to the aquatic environment. An estimated 6.4 million tons (5.8 million metric tons) of marine debris enter the ocean each year (UNEP 2005). This estimate does not account for marine debris than is unintentionally dumped, swept, or blown off ocean-based sources such as fishing vessels, cargo ships, and platforms, or from land-based sources and extreme natural events (National Oceanic Service 2015). Ingestion and entanglement are the primary debris-related causes of direct injury to, or mortality of, marine organisms (UNEP 2005). Sub-lethal effects from entanglement and ingestion can compromise feeding and ingestion leading to malnutrition, disease, and reduced reproductive fitness (reviewed in Baulch & Perry (2014)).

Plastics comprise 60 – 80% of all marine debris (Baulch & Perry 2014) and can persist in the environment from decades to centuries before decomposing (Derraik 2002). Some plastics are made with chemical pollutants such as polychlorinated biphenyls (PCBs) that, even at low levels, can have detrimental effects on marine organisms (Derraik 2002). The second most common form of marine debris is derelict fishing gear, which includes nets, lines, pots, and other recreational and commercial fishing equipment that has been lost, abandoned, or discarded at sea

(National Oceanic Service 2015). Oil and gas exploration and production activities introduce debris into the marine environment, albeit unintentionally. In a study at Padre Island National Seashore in the western GOMx, materials associated with the offshore oil and gas industry composed 13% of all marine debris collected (Miller et al. 1996). Marine debris from oil and gas activities in the GOMx could be a threat to Bryde's whales, although the lack of platforms or production in the eastern GOMx must reduce the risk to an unknown degree.

A recent literature review by Baulch & Perry (2014) determined that ingestion of debris has been documented worldwide in 48 cetacean species, including nine mysticete and 39 odontocete species. Entanglement in marine debris has been documented in fewer species (n=14) with the majority (97%) of entanglement interactions involving derelict fishing gear (Baulch & Perry 2014).

Based on stranding data in the GOMx, four marine mammal species, all odontocetes, were documented either ingesting or entangled in marine debris, with common bottlenose dolphin being the most frequent species documented (78% of cases) and the most common species that stranded (MMHSRP Stranding Database query 2000 – 2014). In some cases, investigators documented stomach contents containing debris such as cigarette butts, bathing suits, and foil. Some stranding cases showed evidence of both marine debris and fishing gear interaction (e.g., plastic in the stomach as well as monofilament entanglement). In general, marine-debris interactions with marine mammals in the GOMx are not frequently documented. From 2000 to 2014, only 0.29% of total marine mammal strandings in U.S. waters of the GOMx showed evidence of entanglement or ingestion of marine debris (MMHSRP Stranding Database query 2000 – 2014). However, those numbers cannot be considered comprehensive since not all strandings are reported, records of reported cases may not be available, not all affected animals are recovered, and some recovered animals are too decomposed to determine cause of death. Concerns regarding the impacts of marine debris on all marine mammal species are increasing because of population and industrial expansion.

Although there are no documented cases of Bryde's whale interactions with marine debris in the GOMx (NOAA Fisheries MMHSRP stranding database), a Bryde's whale carcass was recovered in Cairns, Australia with ingested marine debris (Simmonds 2012). The contents of this animal's stomach contained 30 whole plastic bags and plastic sheeting, that when stretched out, covered an area of six square meters (Simmonds 2012).

Oceanography is also an important consideration when evaluating the risks of debris to Bryde's whales in the GOMx. Marine debris can easily be carried by oceanic currents and atmospheric winds, and become entrapped by oceanic features (National Oceanic Service 2015). In the GOMx, the Loop Current is the dominant circulation feature that travels north from the Yucatan Strait, loops east, and then south out through the Florida Strait, bordering the western edge of the De Soto Canyon (Oey et al. 2005). The location of this current and associated eddies could potentially circulate floating marine debris near known Bryde's whale habitat, possibly increasing the risk of interactions.

Overall, the threat of plastics and marine debris is vast and is not easily evaluated or predicted, but generally considered serious for all marine mammal species in all parts of the world.

Aquaculture

NOAA has a long history of conducting regulatory, research, outreach, and international activities on marine aquaculture issues within the context of its missions of service, science, and stewardship (National Oceanic Atmospheric Administration 2011a). In 2011, NOAA issued a National Aquaculture Policy, pursuant to the National Ocean Policy Implementation Plan (Executive Order 13547). The statutory basis for NOAA's aquaculture activities includes the Magnuson-Stevens Fishery Conservation and Management Act, the Marine Mammal Protection Act, the Endangered Species Act, the Coastal Zone Management Act, the National Marine Sanctuaries Act, and the Fish and Wildlife Coordination Act. Under these laws, in addition to the National Environmental Policy Act, NOAA is responsible for considering and preventing and/or mitigating the potential adverse environmental impacts of planned and existing marine aquaculture facilities through the development of fishery management plans, sanctuary management plans, permit actions, proper siting, and consultations with other regulatory agencies at the federal, state, and local levels. Aquaculture activities are regulated under Fishery Management Plans (FMPs) for fisheries in federal waters. FMPs are developed by regional Fishery Management Councils and implemented by NOAA Fisheries under the authority of the MSCMA (National Oceanic Atmospheric Administration 2011a).

On January 13, 2016, NOAA Fisheries published a final rule (81 FR 1761 2016) for the Gulf of Mexico Fishery Management Council's Fishery Management Plan for Regulating Offshore Marine Aquaculture in the Gulf of Mexico. The rule became effective on February 12, 2016 and establishes a regional permitting process to manage the development of an environmentally-sound and economically-sustainable aquaculture industry in federal waters of the Gulf of Mexico. The FMP specifies that each aquaculture facility must satisfy a list of siting requirements and conditions. An application may be denied if it poses potential risks to essential fish habitat, endangered and threatened species, marine mammals, wild fish and invertebrate stocks, public health, or safety (Gulf of Mexico Fishery Management Council & National Marine Fisheries Service 2009). Aquaculture may be proposed for any GOMx area in federal waters inside the U.S. EEZ (Gulf of Mexico Fishery Management Council & National Marine Fisheries Service 2009), except that they are prohibited in GOMx marine protected areas, marine reserves, habitat areas of particular concern, Special Management Zones, permitted artificial reef areas, and coral areas specified in 50 CFR part 622 (81 FR 1761 2016). Bryde's whale sightings are predominantly documented between 100 m and 400 m, mainly within the De Soto Canyon area (Waring et al. 2013), and depending on aquaculture site selection, whale habitat could overlap with aquaculture operations. To address this concern, each permit application is to be considered on a case-by-case basis taking into account any potential impacts to marine mammals.

Marine mammals, particularly seals, sea lions, cetaceans, and otters, are known to interact with aquaculture facilities (Price & Morris 2013). Marine mammals pose a threat to cultured fish and aquaculture operations may negatively impact marine mammals. The siting of aquaculture cages in the route of marine mammal migratory pathways or within critical feeding and breeding grounds may displace marine mammals from their habitats (Markowitz et al. 2004, Cañadas & Hammond 2008). Entanglement may result from physical interaction with nets, ropes, twine, and anchors lines (reviewed in Price & Morris (2013)). In a five-year study by López (2012), common bottlenose dolphins were observed foraging on wild fish concentrated near an aquaculture farm site in Italy, but also observed depredating on discarded or escaped fish during the harvesting operations. Over the course of the study, annual common bottlenose dolphin mortality was 1.5 per year and five animals were found entangled in nets. An additional survey of fish farms off Italy resulted in more aggressive estimates of one common bottlenose dolphin mortality per month due to entanglement with fish farms (López & Shirai 2007). Measures may be taken to reduce the risk of entanglement in aquaculture facilities. Techniques such as siting farms away from known migration routes, using rigid net materials or secondary rigid anti-predator nets, and keeping anchor and mooring lines taut can aid in reducing serious injury or mortality from entanglement (Price & Morris 2013).

There have been two separate reports of entanglement and death of Bryde's whales in mussel spat-catching lines in New Zealand (Lloyd 2003). However, those interactions involved a longline aquaculture operation that uses two lines of rope stretching up to several kilometers long between two suspended buoys. Such mussel and kelp operations are different from what is proposed under the GOMx Aquaculture Plan.

Additional ecosystem risks associated with the development of aquaculture facilities include hurricanes, other natural or man-made catastrophes, or the spread of disease from farm to wild stocks. The final rule implementing the GOMx Aquaculture Plan includes requirements for permittees that address these issues(81 FR 1761 2016)[27]. Each aquaculture facility must submit an emergency disaster plan detailing how it will prepare the aquaculture systems, equipment, and cultured organisms for a disaster such as a hurricane, tsunami, harmful algal bloom, or chemical or oil spill. Permit holders must also obtain a health certificate by a certified aquatic animal health expert prior to stocking cultured animals in a system, to ensure the animals are free of reportable pathogens (81 FR 1761 2016). Once cultured organisms are stocked in a system, permit holders must report all findings or suspected findings of pathogens to NOAA Fisheries within 24 hours of diagnosis. NOAA Fisheries, in coordination with the USDA, may order the removal of all cultured organisms upon a determination by a certified aquatic animal health expert that a suspected pathogen exists and poses a threat to the health of wild aquatic organisms (81 FR 1761 2016).

[27] http://sero.nmfs.noaa.gov/sustainable_fisheries/gulf_fisheries/aquaculture/documents/pdfs/gulf_aquaculture_fmp_fr.pdf

ASSESSMENT OF EXTINCTION RISK

Upon compiling information regarding the five listing factors set forth in Section 4(a)(1)(A)-(E) factors and threats, the Team evaluated the severity of each specific threat and the Team's level of certainty about each severity score. To promote consistency, the Team used definitions for 'severity of threat' and 'level of certainty' used in many status reviews, including Oleson et al. (2010) and Dewar et al. (2013). For many threats, direct evidence from studies on Bryde's whales is lacking and the Team therefore agreed that published scientific evidence from other similar cetacean species was relevant and necessary to estimate impacts to GOMx Bryde's whales and the risk of the population's extinction. Each threat was evaluated in terms of its current and future risk to the GOMx Bryde's whale population over the next three generations (or 55 years, based on a generation time of 18.4 years, Taylor et al. (2007)). A three generation outlook has been applied in several other marine mammal status reviews (Oleson et al. 2010, Bettridge et al. 2015). The Team also considered the potential historical impacts of the threats but did not score them because so little historical information is available for most of the threats that were considered. Instead, the Team discussed and focused on two historical threats for which some information was available, whaling and energy exploration and development.

Certain threats could reasonably be placed in several of the listing factors. For example, energy exploration and development can physically modify the habitat and it also produces noise and involves significant vessel traffic. In these cases, the Team evaluated the threat explicitly for each listing factor to avoid counting threats multiple times. For example, under the 'present or threatened habitat destruction, modification or curtailment of habitat or range' listing factor, the Team evaluated the physical modification of the environment resulting from oil and gas exploration and production, and evaluated the noise component of this threat in the anthropogenic noise section of the 'other natural or human factors affecting continued existence of the population' listing factor. The Team also recognized the potential for cumulative and synergistic effects of many of the threats that were evaluated. Because so little information is available on how to quantify cumulative effects of threats, the Team chose not to try to do so.

For some species petitioned for listing under the ESA, there may be sufficient available data to conduct a quantitative population viability analysis (PVA) or other quantitative extinction risk assessment. However, for Bryde's whales in the GOMx, there is no trend in abundance information, no information on age and sex composition of the population, and no information on appropriate demographic parameters to use in a model. The data uncertainties are so large, the Team believed an individual-based model to quantify extinction risk was not a useful exercise.

Finally, because each listing factor included multiple types of threats with differing levels of risk, the Team also considered an 'Overall current and future threat ranking' for each of the listing factors, similar to other status review (e.g., Oleson et al. 2010), to provide an idea of which listing factors may to pose the greatest risk to GOMx Bryde's whales.

<u>Definition of Threat</u> – Those specific human or natural events/actions that may affect the present or future status of a species or population. Threats were defined by time frame as follows:

- Current Threats = threats that are occurring now

- Future Threats = threats that are likely to result in a mounting risk to the species in the next 55 years. These threats may or may not be occurring now as well

Each threat was scored for level of severity and level of certainty by each SRT member using a numeric value corresponding to high, medium, and low (as defined below) by each SRT member.

Definition of Severity – Current and future (over the next 55 years). The degree to which this threat is likely to contribute to the decline of the population currently and in the future. Specific rankings for this category are defined as follows:

3 = High: The threat is likely to *eliminate or seriously degrade* the population

2 = Moderate: The threat is likely to *moderately degrade* the population

1 = Low: The threat is likely to *only slightly impair* the population

Level of Certainty – Current and future risk. The level of certainty that the threat is affecting or is likely to affect the GOMx Bryde's whales. Specific rankings for this category are defined as follows:

3 = High: There are *definitive* published and/or unpublished data to support the conclusion that this threat did affect, is affecting, or is likely to affect the population with the severity ascribed

2 = Moderate: There are *some* published and/or unpublished data to support the conclusion that this threat did affect, is affecting, or is likely to affect the population with the severity ascribed

1 = Low: There are *little* published and/or unpublished data to support the conclusion that this threat did affect, is affecting, or is likely to affect the population with the severity ascribed

Individual scores were listed in tabular form together with the the overall mean and standard deviation across the Team. After scores were provided, the Team met by webinar to discuss each score for each specific threat. Team members provided perspectives and rationale for their scores and were given the opportunity to revise scores, if desired, after the discussion. Team members also individually scored the overall threat risk for each of the listing factors (see below). Final individual scores are presented in Appendix 3 along with the mean and standard deviation of the values.

Overall Threat Ranking – The SRT's overall ranking for current and future threat categories are defined as follows:

High: This threat category includes *a high number* of threats that are moderately or very likely to contribute to the decline of the GOMx Bryde's whale, or contains some individual threats identified as very likely to contribute to the decline of the population.

Moderate: This threat category includes *an intermediate number* of threats that are likely to contribute to the decline of the GOMx Bryde's whale, or contains some individual threats identified as moderately likely to contribute to the decline of the population.

Low: This threat category includes *a low number* of threats that are likely to contribute to the decline of the population.

Threat Scoring Narrative Summary:

Present or Threatened Habitat Destruction, Modification or Curtailment of Habitat or Range

Overall, this threat category contained a number of specific threats that were thought to moderately or very likely contribute to the decline of the GOMx Bryde's whale. Habitat modification and destruction due to both energy exploration, development and production (drilling rigs, platforms, cables, pipelines), and oil spills and oil spill response were ranked as high (the threat is likely to eliminate or seriously degrade the population) with relatively high certainty. While there are currently no production platforms in the EPA, which encompasses the current primary Bryde's whale habitat in the GOMx, the fact that this region may be opened up to energy exploration in 2022 raised significant concern, particularly in light of the apparent limited use by Bryde's whales of the north-central and western GOMx where habitat has been significantly modified with the presence of thousands of oil and gas platforms. Furthermore, although the *Deepwater Horizon* oil platform was not located within the EPA, damage to marine mammals, including Bryde's whales, in the EPA as a result of the explosion and oil spill from this platform was documented.

Harmful algal blooms (HABs) were ranked as a moderate risk to the population, but with relatively low certainty. As noted in the Threats description section, HABs are a common event in offshore and coastal waters of the northeastern GOMx where they have been associated with several large-scale mortality events for common bottlenose dolphins and manatees. Although there are no documented cases of Bryde's whale deaths resulting from a HAB in the GOMx, deaths due to HABs have been documented for humpback whales (Geraci et al. 1989) and potentially for fin and minke whales in a 2003 event in Maine (Gulland & Hall 2007). Given the small population size for the GOMx Bryde's whale (Waring et al. 2013), the Team noted that a toxic bloom that killed even a single female GOMx Bryde's whale would significantly degrade the population.

Persistent organic pollutants and heavy metals were scored as low risk by the majority of Team members. One consideration with respect to heavy metals is the presence of significant amounts of drilling muds in the GOMx, which could increase exposure of Bryde's whales to heavy metals. However, there has been limited drilling activity in the eastern GOMx and there is little information available on the potential impacts of heavy metals from drilling muds.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

The Team considered two specific threats under this category: historical whaling and research biopsy sampling. Both threats were given low risk scores with respect to their current and future impact on the population. The Team therefore considered the overall level of threat for this category to be low. Certainty in these scores was moderate.

As described in more detail earlier, available evidence indicates that whalers hunting "finback' whales" in the 18^{th} and 19^{th} centuries in the GOMx were primarily taking Bryde's whales (Reeves et al. 2011). The total number of whales killed, however, has not been quantified. Given that this limited whaling occurred over a century ago (Reeves et al. 2011), and using the default population growth rate for cetaceans of 4%/year (Wade 1998), the population should have recovered from the whaling mortalities sustained more than a century ago. The Team concluded, therefore, that the current low abundance is not related to historical whaling. Currently, there is no whaling in the GOMx and the Team knew of no future plans for whaling. International whaling is regulated by the International Whaling Committee (IWC) and there is a moratorium on all whaling, with exemptions for scientific purposes.

Remote biopsy sampling is a common research tool for studying marine mammal populations and the few studies of wound healing indicate little long-term impact from such sampling (Brown et al. 1994, Best et al. 2005). However, the Team did express concern for regulation under the MMPA of permits for biopsy sampling. Given the extremely small sample size, multiple permits allowing biopsies of even five animals per year could result in individuals in the population being biopsied every year and the potential for individuals to be biopsied more than once a year. Collaboration and coordination among researchers who wish to do research involving Level A and/or Level B harassment of this population seems critical to mitigating the effects of research activities on the population.

Disease, Predation and Parasites

This threat category received an overall low risk score but with relatively low certainty. The Team discussed the specific threat of disease, noting that morbillivirus in the Atlantic Ocean and elsewhere is known to severely impact cetaceans (Rubio-Guerri et al. 2013, Litz et al. 2014). The Team expressed concern that the 2013 – 2015 morbillivirus epidemic that killed more than 1,000 common bottlenose dolphins along the U.S. east coast or a similar event could move into the GOMx. Given that a few individuals of multiple species of baleen whales in the Atlantic tested positive during this outbreak, this disease seems capable of impacting Bryde’s whales. Although there have not been any recent morbillivirus-related cetacean mortality events in the GOMx, there were one confirmed and 2 suspected events in the 1990s (Litz et al. 2014), one of which was thought to have originated in the Atlantic. Similar to the discussion on HABs, given the extremely small population size of Bryde’s whales in the GOMx, even the death of a single breeding female due to disease or predation could significantly affect the population’s persistence.

Inadequacy of Existing Regulatory Mechanisms

The Team evaluated the Inadequacy of Existing Regulatory Mechanisms listing factor, but did not generate severity or certainty scores because the Team unanimously agreed this factor is a high threat to Bryde’s whales in the GOMx. Whaling records indicate the historic range included waters outside of the current primary distribution in the northeastern GOMx (Reeves et al. 2011). Their currently known, limited distribution indicates regulatory mechanisms were not sufficient to maintain the population in the broader GOMx where energy exploration and production started in the 1950s and is now widespread, and where there is a significant amount of shipping traffic. Ship strikes are of concern to the current population, given its extremely small size, and there are no regulatory mechanisms in place in the GOMx to address them. Additionally, future energy exploration in the EPA is of concern. Finally, there is likely to be considerable scientific research effort in the GOMx during restoration efforts following the *Deepwater Horizon* oil spill. The Team expressed the need for permits allowing research activities with the potential to harass or harm Bryde’s whales in the GOMx to be carefully coordinated, similar to what is done for North Atlantic right whales.

Other Natural or Human Factors Affecting Continued Existence of the Population

The Team evaluated a suite of other natural and anthropogenic threats as well as small population concerns, as has been done in other status reviews. Seven anthropogenic and natural threats, five aspects of small population size, and five anthropogenic noise threats (Appendix 3) were evaluated individually. These where then placed into three groups and an overall risk score was produced for Anthropogenic Noise, Small Population Concerns, and Other Natural or Human Factors.

Vessel collision scored high as a threat with high certainty. As described earlier, vessel collisions are a significant source of mortality for a variety of coastal large whale species. Several important commercial shipping lanes travel through primary Bryde's whale habitat in the northeastern GOMx, while in the north-central and western GOMx the sheer number of support and supply vessels for the energy industry creates a high likelihood of interactions with any large whales. Furthermore, there is one documented case of a Bryde's whale ship strike mortality in the GOMx when a commercial vessel brought a dead lactating female Bryde's whale into the Tampa Bay harbor on its bow in 2009. Blunt impact trauma, shredded muscle, blood clots and vertebral separations noted during necropsy confirmed ship strike as the likely cause of death. In the fall of 2015, an Acousonde acoustic and kinematic data-logging, suction-cup tag was placed on a Bryde's whale in the Bryde's whale BIA by the NMFS SEFSC and it revealed that, while the whale spent ~50% of daytime hours deeper than 15 m, at night the whale spent nearly 90% of its time at the surface or within 15 m of the surface (NMFS, unpublished data). Given the location of commercial shipping lanes in the GOMx, the difficulty of sighting a whale at the surface at night, and the low ability of large ships to change course quickly enough to avoid a whale, ship strikes may pose a significant threat to this population, particularly given their very small population size.

Military activities (explosive pressure waves, target training, vessel activities) and trophic impacts due to commercial harvest of prey items were considered of moderate risk and relatively low risk, respectively. Although there are military activities in the GOMx, including the northeastern GOMx, most seem to occur outside the BIA. Activities are not constant and, due to the current scope of military activities, these threats were considered less likely to have a negative impact on the population than other threats evaluated by the Team. However, certainty in the impacts was relatively low and should military activities change location or intensity and approach the Bryde's whale habitat in the northeastern GOMx, this threat may need re-evaluation. Trophic impacts were difficult to evaluate, as indicated by the low certainty score. Two large commercial fisheries operate primarily in the north-central and western GOMx and they remove a significant amount of biomass from the GOMx ecosystem. The Gulf menhaden reduction fishery operates primarily off Louisiana and within state waters. This is the second largest U.S. fishery by weight. The shrimp trawl fishery also operates in the north-central and western GOMx in coastal waters out to ~120 m depth and has considerable non-targeted species bycatch. This fishery is one of the largest and most economically important fisheries in the southeastern U.S. and the level of effort in this fishery dwarfs all other fisheries in the GOMx. The ecosystem and trophic effects of these removals are unknown.

The risk due to commercial fishing gear entanglement scored moderately high with moderately high certainty. As noted earlier, entanglement in commercial fishing gear, including nets, line, and trap pot gear, poses a significant threat to many baleen whales (Cassoff et al. 2011, Robbins et al. 2015). Ship strikes and entanglement in trap pot gear are some of the greatest threats to the endangered North Atlantic right whale in U.S. waters (Knowlton & Kraus 2001). Commercial fishery activity in the primary Bryde's whale habitat in the northeastern GOMx appears to be lower than in other parts of the GOMx. However, the commercial pelagic longline fishery for large pelagic species and the commercial bottom longline fisheries for shark and snapper-grouper are active in the region. Pelagic longline fishery sets occur occasionally in the BIA but higher effort occurs just beyond it at the 300 m isobath. Some whale sightings have been made in waters just over 300 m depth so there may be potential for interaction with this fishery. The kinematic tag placed on a Bryde's whale in this region by the NMFS SEFSC revealed that the whale made repeated dives to near the bottom during the day with foraging lunges apparent at the deepest parts of dives indicating the animal was likely foraging at the bottom, or just above the bottom (NMFS, unpublished data). Pelagic longlines are a known entanglement threat to baleen whales since the majority of mainline gear is in the water column (Andersen et al. 2008). Bottom long-line gear is expected to be an entanglement risk to bottom-foraging whales only, as those whales are more likely to encounter and become entangled in the mainline gear that is on the bottom[28]. The dive behavior of the tagged whale suggests bottom longline gear could pose an entanglement risk to GOMx Bryde's whales as they appear to be foraging at or near the bottom. If bottom or near-bottom feeding is a normal feeding strategy for these whales (since these data are from a single whale more data are needed to establish this) there is potential for interactions given the foraging behavior and the geospatial overlap of bottom longline fishery effort and GOMx Bryde's whale habitat. To date no interactions have been recorded.

The level of effort and biomass removal of the Gulf menhaden and shrimp trawl fisheries in the north-central and western GOMx combined with the overlap of the bottom longline fishery with Bryde's whales in the northeastern GOMx were the primary reasons the threat of fishing gear entanglement received a relatively high threat score.

Plastics and marine debris, aquaculture, and climate change, all scored as low threats to the population, although certainty in the scores was also relatively low. Impacts of marine debris to cetaceans are not well quantified. Marine debris in the form of ghost fishing gear may pose a significant risk to large whales (IWC 2014b). Aquaculture has not yet begun in U.S. waters of the GOMx. However, should aquaculture activities be initiated in or near the Bryde's whale habitat in the northeastern GOMx, potential direct and indirect impacts to the population would be of concern and should be be carefully evaluated and considered. The impacts of climate change on cetaceans are also not easily quantified, although direct and indirect impacts are expected (Evans & Bjørge 2013). In this regard, the restricted distribution of the GOMx Bryde's whale is a concern. As water temperatures rise, many marine species have shifted their distributions northward or in a direction that maintains a near-constant environment (e.g., temperature, prey availability) (Evans et al. 2010). Within the GOMx, Bryde's whales have little room to shift their distribution northward into cooler waters. Furthermore, the predicted changes in freshwater inflow and its effects on productivity may affect the health of the GOMx

[28] http://www.nmfs.noaa.gov/pr/interactions/gear/

ecosystem and should not be ignored. Overall, the Team believed there were more significant and immediate pressures on the population than marine debris, aquaculture and climate change and, accordingly, they scored those threats lower.

The small population concerns of demographic stochasticity, genetics, and stochastic and catastrophic events were considered, with high certainty, to be of high severity (likely to eliminate or seriously degrade the population). Certainties in these scores were some of the highest recorded. Allee effects and k-selected life history parameters were each considered of moderate to moderately high threat, with moderate and with high certainty, respectively. The very small population size means demographic stochasticity and Allee effects pose significant threats to the population. Background noise levels in the GOMx and anticipated increased shipping activities in the future may result in acoustic masking and lead to difficulty in hearing mating calls. Stochastic and catastrophic events that affect the population could significantly degrade the population due to the small population size and limited spatial distribution. Analysis of the impacts of the *Deepwater Horizon* oil spill on cetacean stocks in the GOMx estimated that 48% of the Bryde's whale stock habitat was found within the oil footprint, 17% (95% CI 7 – 24%) of the population was killed, 22% (95% CI 10 – 31%) of reproductive females experienced reproductive failure due to the spill and 18% (95% CI 7 – 28%) of the population likely suffered adverse health effects due to the spill (DWH Trustees 2016).

K-selected life history characteristics in and of themselves are not a problem for baleen whales, but at very small population sizes, the low productivity rate of a k-selected species can increase the time a population remains small such that the probability of experiencing multiple synergistic risks could propel a population into an extinction vortex. Finally, the very small population size and documented low level of genetic diversity (Rosel & Wilcox 2014) place the GOMx Bryde's whale population at risk of inbreeding depression, loss of potentially adaptive genetic diversity and accumulation of deleterious mutations (Frankham 2005, Reed 2005). The small census population size (less than 100 individuals) puts the population at immediate recognized risk for genetic factors given that there would be at most 50 mature individuals (and more likely there are fewer than 25 mature individuals). Even with a 50:50 sex ratio, 12 males and 12 females would certainly meet any genetic risk threshold for both decreased population growth due to inbreeding depression and potential loss of adaptive genetic diversity. The overall threat ranking for the small population concerns category was high.

The GOMx is one of the world's noisiest sites at low frequency (<100 Hz) owing to the presence of airguns (primarily) and shipping (secondarily). The Team evaluated the category of anthropogenic noise, including noise from aircraft and vessels associated with oil and gas activities, oil drilling and production, military training and exercises, shipping traffic and other vessels, and seismic surveys. Noise associated with military activities scored the lowest in this group as it appears to be a small component of the total noise in the GOMx. Oil and gas aircraft and vessel noise and oil drilling and were considered of moderate risk to the population. Given the amount of drilling activity and platforms in the north-central and western GOMx, noise levels are high. The potential opening of the EPA to increased oil and gas exploration and production is of considerable concern. Noise from shipping traffic also scored as a moderate threat while noise from seismic surveys was scored as a high threat. The Team believed there was the most certainty in these two sources of noise being the drivers of chronic impacts. Masking of vocalizations and habitat displacement as a result of seismic surveys have both been documented for other baleen whales (Cerchio et al. 2014, Blackwell et al. 2015, Castellote & Llorens 2016). Here again, the small population size and the restricted range of this population significantly increase the potential for serious impacts from these threats. The overall threat ranking for the anthropogenic noise category was medium-high (2.57 out of 3), driven strongly by impacts of seismic noise and vessel noise derived from shipping, and oil and gas activities.

In summary, the high level of noise in the GOMx, the cumulative threats posed by energy exploration, development and production, and the risk of vessel collisions, in combination with the small population size pose major threats to this population and place it at risk of serious degradation or extinction.

Evaluation of Demographic Factors

A population's or species' continued persistence is directly linked to demographic processes. In particular, demographic risks associated with abundance, population growth rate, spatial structure, and genetic and ecological diversity are particularly useful for evaluating extinction risk (McElhany et al. 2000). These viability criteria, originally developed for Pacific salmon have been used in previous NMFS status reviews to summarize and assess a population's extinction risk due to demographic processes (e.g., Miller et al. 2013, Seminoff et al. 2015) and NMFS has recommended that status reviews consider these four factors[29].

The Team evaluated each of these risk criteria. As described earlier, small populations (i.e., those with low abundance) are at significantly greater risk of extinction than large populations due to a suite of problems associated with low abundance. These include Allee effects, genetic effects, and demographic and environmental stochasticity. The population size of the GOMx Bryde's whales is critically small. In addition, as a k-selected species, the life-history characteristics of these whales will result in a slower recovery from their small population size and hence have a longer time during which a risk factor like a catastrophe could occur.

Related to population size, consideration of the second demographic risk factor, population growth rate, is also critical to understanding extinction risk. A population's natural growth rate should be sufficient to maintain the population abundance above the viable level through time. Populations with unstable or declining population growth rates are clearly not faring well in the current environment and are expected to have poor resiliency to environmental degradation. The small population size may mean that Allee effects are occurring, making it difficult for individual whales to find one another for breeding, thereby reducing the growth rate. High noise levels in the GOMx could mask mating calls and negatively impact reproductive success. Population trend data are not available for GOMx of Bryde's whales, but the fact that the population is so small suggests growth from this small size is problematic.

Spatial distribution plays a significant role in population risk. A population that is broadly distributed across inter-connected habitats should be less vulnerable to catastrophes than a single

[29] NMFS. 2015. Guidance on Conducting Status Reviews under the Endangered Species Act. Available at http://www.nmfs.noaa.gov/pr/laws/esa/policies.htm

isolated population. The best available scientific data indicate that Bryde's whales in the GOMx are now restricted primarily to a small region along the continental shelf break in the De Soto Canyon area of the northeastern GOMx. Survey effort throughout U.S. waters of the GOMx over the past 23 years has not identified any Bryde's whales outside this region. Sightings and stranding reports in the southeastern U.S. waters of the Atlantic suggest Bryde's whales are extremely rare in this area as well. Distribution and abundance of GOMx Bryde's whales in the southern GOMx (i.e., Mexican and Cuban waters) is an important information gap that needs to be addressed. The best available scientific information at the time of this status review suggests that animals are primarily found in De Soto Canyon. Because there has been limited survey effort outside U.S. waters, we cannot make inferences about the presence or abundance of animals in the southern GOMx.

Finally, genetic diversity is a crucial risk factor for demographic stability. As described earlier, low genetic diversity can lead to inbreeding depression, accumulation of deleterious alleles and loss of adaptive potential. Genetic diversity provides the means for populations to respond and adapt to long-term environmental change, such as global climate change, and also allows a population to exploit varied habitats and respond to short-term changes in the environment (McElhany et al. 2000). Bryde's whales in the GOMx exhibit very low genetic diversity both in mitochondrial DNA and nuclear DNA (Rosel & Wilcox 2014). The small population size means that individuals are likely breeding with related individuals and inbreeding depression may be occurring, resulting in loss of genetic diversity that will be difficult to regenerate.

Each Team member assigned a risk score to each of the four demographic criteria (abundance, growth rate/productivity, spatial structure/connectivity, diversity). Risks for each demographic criterion were ranked on a scale of 1 (no or very low risk) to 5 (very high risk). Below are the definitions that the Team used for each ranking:

1 = No or low risk: It is unlikely that this factor contributes significantly to risk of extinction, either by itself or in combination with other factors

2 = Low risk: It is unlikely that this factor contributes significantly to risk of extinction by itself, but some concern that it may contribute, in combination with other factors

3 = Moderate risk: It is likely that this factor in combination with others contributes significantly to risk of extinction

4 = High risk: It is likely that this factor, by itself, contributes significantly to risk of extinction

5 = Very high risk: It is highly likely that this factor, by itself, contributes significantly to risk of extinction

Team members were given a template to fill out and asked to rank the demographic risk currently and in the foreseeable future (see Appendix 3). After scores were provided, the Team discussed the range of perspectives for each of the demographic risks and the supporting data on which they were based, and members were given the opportunity to revise scores if desired after the discussion. The scores were then tallied, reviewed by the Team, and considered in making the overall risk determination.

The Team concluded that all demographic risk factors were is likely to contribute significantly to the risk of extinction of Bryde's whales in the GOMx. Low abundance and restricted spatial distribution were each assessed to be *highly* likely (very high risk) to contribute significantly, by themselves, to the risk of extinction; population growth rate and genetic and ecological diversity each scored as high risk to the population.

Summary of Extinction Risk

NMFS guidelines[30] direct status review teams to synthesize the information they obtained on threats and demographic risks to estimate the risk of extinction. To do so, the teams should evaluate risk of extinction qualitatively using categories of high, moderate, or low. The high risk category is defined as:

> *A species or DPS with a high risk of extinction is at or near a level of abundance, productivity, spatial structure, and/or diversity that places its continued persistence in question. The demographics of a species or DPS at such a high level of risk may be highly uncertain and strongly influenced by stochastic or depensatory processes. Similarly, a species or DPS may be at high risk of extinction if it faces clear and present threats (e.g., confinement to a small geographic area; imminent destruction, modification, or curtailment of its habitat; or disease epidemic) that are likely to create present and substantial demographic risks.*

The above definition from the guidelines is sufficiently general to capture high risk for all species. To clarify the general terms of the definition and be appropriate for GOMx Bryde's whales, the Team examined thresholds for small population sizes used in other ESA status reviews including examples given for small population sizes justifying an endangered listing reviewed in the Ashe Memorandum by the U.S. Fish and Wildlife Service (Ashe 2010)[31]. The Team used this information to define "high risk of extinction" given a specific population size and characteristics of GOMx Bryde's whales and then to classify the extinction risk for GOMx Bryde's whales. Because the Team agreed unanimously that the population was at high risk of extinction, it did not create definitions for moderate and low risk of extinction for these whales.

<u>Choice of thresholds for small population size</u>

The Team considered small population size definitions used in evaluating risk for white sharks (Dewar et al. 2013). These are:

Dangerously small population size is defined as *a population that is sufficiently small that density depensation may occur and that variability in population size resulting from fluctuations in the environment could result in reaching near-extinction.* A dangerously small population is at risk of extinction because of the risks incurred by virtue of being a small population without

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[30] NMFS. 2015. Guidance on Responding to Petitions and Conducting Status Reviews under the Endangered Species Act. Available at http://www.nmfs.noaa.gov/pr/laws/esa/policies.htm

[31] Ashe D.M. (2010) Supplemental explanation for the legal basis of the Department's May 15, 2008 determination of threatened status for polar bears. *Memorandum in re Polar Bear Endangered Species Act Listing and S 4(d) Rule Litigation (DC Dist Ct, Misc No 08-764).*

the need to add the threats that caused the population to become small, although those threats may persist and would only increase the level of risk.

Near-extinction is defined as *a population that has declined to a size at which the probability of extinction in the near future (50 years or the lifespan of the species whichever is the longer) is extremely high.*

The Team considered arguments that had been made for near-extinction in Regan et al. (2009, 2013) and found them to apply to this case:

> *The rule:* Near-extinction is defined as ≤ 50 mature individuals. See definition of mature individuals below.
>
> *The rationale:* It is difficult to argue that any species that has declined to only 50 mature individuals will not be at very high risk of extinction. Using a value of 50 mature individuals for "near-extinction" allows earlier listing of long-lived species where individuals may "linger" for a period of decades. An example would be killer whales that can live to be over 50 years old and can therefore have individuals living for decades past the point when, for example, no males were present and therefore reproduction was not possible. The resulting listing criteria using near-extinction instead of absolute extinction treats taxa more equitably regardless of generation time.

The IUCN Red List defines "mature individuals" as the number of individuals known, estimated or inferred to be capable of reproduction (IUCN Species Survival Commission 2001). The Team concurred with that definition and used that meaning in this document. Although no rationale is given in the IUCN Red List guidelines for the number 50, it corresponds to a number that is known to result in irreversible genetic losses if numbers remain this low for very long (Regan et al. 2009). Because the original proposal for quantitative listing guidelines specified an effective population size of 50 rather than 50 mature individuals (Mace & Lande 1991), it is very likely that this number traces back to Soulé's theoretical estimate of the minimum effective population size required to avoid extremely deleterious effects of inbreeding (Soulé 1980). It is also the number below which some species of birds have been known to go extinct rapidly (Soulé et al. 1988).

The Team then considered what value for a dangerously small population would be appropriate for this case. The Team settled on 250 mature individuals or a population found in a spatial configuration vulnerable to a single catastrophic event that could drive the taxon to near-extinction in a very short time.

The rule: Dangerously small population for GOMx Bryde's whales is defined as a population either having equal to or fewer than 250 mature individuals or a population found in a spatial configuration vulnerable to a single catastrophic event that could drive the taxon to near-extinction (i.e., ≤ 50 mature individuals) in a very short time.

The rationale: Given a default assumption that 50% of the population consists of mature individuals, an abundance of 500 would correspond to 250 mature individuals. Fewer than 250 mature individuals has been suggested as a level where genetic diversity will erode due to genetic drift leaving the species less fit through time and at risk of long-term extinction (Franklin

1980). This 'rule of thumb' has recently been suggested to be revised to a lower limit of 500 mature individuals (Frankham et al. 2014), but this has yet to be widely discussed or adopted. The Team believed that using the older value, but with the added safety net that required a distribution that would mitigate against single catastrophes, would capture the definition for dangerously small population.

The use of 250 mature individuals is also consistent with past ESA listing decisions (Boyd et al. in press). For the 14 case studies used in a retrospective analysis, using a threshold value for small population size of 250 mature individuals resulted in consistent ESA listings (Boyd et al. in press). To assess whether this result was specific to their set of case study species, they used the IUCN Red List database to identify 17 vertebrate species that occur in the U.S. and are listed as Critically Endangered or Endangered under Criterion D1 because they have a population fewer than 250 mature individuals. All are also listed as endangered, including southern resident killer whales, insular false killer whales in Hawaii, and North Atlantic right whale and the North Pacific right whales, *Eubalaena japonica*, under the ESA with the exception of two species currently under review (Boyd et al. in press).

Definition of High Risk of Extinction

Given the above rationales, the Team defined a species to be at high risk of extinction if it was dangerously small by meeting either of these conditions: (1) the number of mature individuals was less than or equal to 250, or 2) the population is found in a distribution that is vulnerable to a single catastrophic event that could drive the taxon to near-extinction (defined as less than or equal to 50 mature individuals) in a very short time.

The status of GOMx Bryde's whales with respect to the definition of high risk of extinction
Recent studies estimate that the total abundance of the GOMx Bryde's whale is less than 100 mature individuals. Although the estimate used in the most recent SARs is 33 (CV = 1.07) total individuals, the Team agreed that the estimate is negatively biased because it was assumed g(0) = 1.0 (i.e., all whales on the trackline were sighted). The final estimate made by Duke University researchers (Roberts et al. 2015a, Roberts et al. 2016) that averages 15 years of survey data and accounts for not meeting the assumption of sighting all whales on the trackline (i.e., the estimate was g(0) corrected), was higher at 44 (CV = 0.27). In addition, Mexican and southern GOMx waters are essentially unsurveyed and are likely to contribute to some unknown level of negative bias given that these whales were found there historically (Reeves et al. 2011). Considering these factors, the Team unanimously agreed that is it not plausible given the best available data that there are 200 GOMx Bryde's whales but that a value of 100 or fewer is plausible. These Bryde's whales have a high chance of having an overall decrease in population growth rates resulting from genetic and/or demographic stochasticity. Taylor et al. (2007) estimated the proportion mature to be 51% (with a generation time of 18.4 years). Thus, it is likely that there are 50 or fewer mature individuals.

The Team unanimously agreed that given the best available science there are fewer than 250 mature individuals, and likely less than 100 mature, and that the current distribution is vulnerable to catastrophe, and therefore the GOMx Bryde's whales are currently a dangerously small population. The Team also agreed that it is likely that this group is at or below the near-extinction population level. Further, surveys in the last decade suggest that most or all of the remaining individuals are concentrated within the De Soto Canyon area. The limited geographical range increases risk as the entire species is vulnerable to a single catastrophic event. Given the slow growth rate of whales, it will take decades to build a sufficient population size that would result in range expansion and alleviate this vulnerable distribution.

The Team unanimously agreed that the Bryde's whale population in the GOMx has a high risk of extinction.

Extinction risk—summary of SRT concerns

The GOMx Bryde's whale population is very small and is restricted to a small habitat area in the De Soto Canyon region of the northeastern GOMx. Their level of genetic divergence from other Bryde's whales worldwide indicates they are reproductively isolated and on a unique evolutionary trajectory. The Society for Marine Mammalogy's Committee on Taxonomy concluded they represent at least an unnamed subspecies of Bryde's whales. Although the historic population size is unknown, whaling data indicate their distribution in the GOMx was once much broader. The Team concluded, therefore, based on thebest available scientific data, that there has been a range contraction such that their primary range is restricted to the northeastern GOMx, although there are limited data from outside U.S. waters. The north-central and western GOMx contains some of the most industrialized marine waters in the U.S. due to expansive energy exploration and production, and also experiences significant commercial shipping traffic and commercial fishing activity. The area in the northeastern GOMx, where all verified sightings of Bryde's whales have been recorded during cetacean surveys, has experienced the least amount of energy exploration, due in part to a moratorium put in place in 2006. However, this moratorium expires in 2022 and the eastern GOMx could be exposed to increased energy activities. Commercial fishing and vessel traffic also could affect the whales in the eastern GOMx.

The Team concluded that the small population size alone put the GOMx Bryde's whale at high risk of extinction. The small size of this population makes it vulnerable to inbreeding depression, demographic stochasticity, and stochastic and catastrophic events. The combination of small size plus risk factors that may have affected the population in the past and may affect it in the future, further increase the extinction risk. These factors include, in particular, impacts due to energy exploration (e.g., habitat modification, noise from seismic surveys, and shipping) and energy production (e.g., oil spills), and vessel collisions. The Team's concern for this group of whales is further increased by uncertainty regarding the cause(s) of its small population size, its limited distribution, current and future threats, and the long-term viability of the population.

CONSERVATION EFFORTS

There are several upcoming conservation, restoration and research efforts in the GOMx that have the potential to benefit Bryde's whales. In addition, the International Union for the Conservation of Nature and Natural Resources (IUCN) lists Bryde's whales on their International Red List although their global status is listed as data deficient.

Deepwater Horizon Final Programmatic Damage Assessment and Restoration Plan (PDARP)

On April 20, 2010, the *Deepwater Horizon* oil rig exploded and released millions gallons of oil into the Gulf of Mexico. Since that time, the natural resource trustees have worked to assess the impacts of the oil and dispersants on natural resources, including marine mammals. In February 2016, the United States, the five Gulf states (Trustees), and BP proposed a settlement for natural resource injuries from the *Deepwater Horizon* oil spill. The Trustees determined that the best method for addressing the injuries is comprehensive, integrated, ecosystem restoration and published the *Deepwater Horizon* Oil Spill Final Programmatic Damage Assessment and Restoration Plan (DWH Trustees 2016). The plan allocates up to $8.8 billion for restoration and identifies five goals intended to restore wildlife, habitat, water quality, and recreational activities in the Gulf. To achieve these goals, funds are allocated to 13 different restoration types, including a category type for marine mammals.

The plan does not identify specific restoration projects, but lays out a framework for planning future restoration projects. The plan also describes how restoration funding will be allocated across different geographic areas and restoration types. A total of $144M is allocated for marine mammals, with $55M of those funds dedicated to restoring open ocean marine mammal species. These funds will be allocated annually, starting in calendar year 2017 over approximately 15 years. Thus, funds available to support restoration of marine mammals in offshore waters of the GOMx are approximately $3.7M per year. Restoration for marine mammals, including offshore species like Bryde's whales, will be focused on activities that support population resilience, reduce further harm or impacts, and complement existing management priorities. Among other things, restoration activities could include decreasing and mitigating interactions with commercial and recreational fishing gear, characterizing and reducing impacts from noise, reducing harm from industrial activities, reducing harassment, and increasing understanding of causes of marine mammal illness and death. The restoration portfolio also could include robust monitoring and scientific support for an adaptive management approach to ecosystem restoration.

Bryde's whales were the most impacted offshore cetacean by the oil spill. Forty-eight percent of the population was affected, resulting in an estimated 22 percent maximum decline in population size (DWH Trustees 2016). Many of the proposed restoration activities in the PDARP should benefit Bryde's whales, particularly those activities that improve understanding and management of the effects of anthropogenic noise on marine mammals and activities that reduce injury and mortality from vessel collisions.

Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS)

GoMMAPPS is led by the BOEM Environmental Studies Program and involves collaboration among BOEM, NOAA, U.S. Fish and Wildlife Service, U.S. Geological Survey, and the U.S. Navy. The purpose of this program is to improve information about abundance, distribution, habitat use, and behavior of living marine resources (e.g., marine mammals, sea turtles, sea birds) in the GOMx, as well as mitigate and monitor potential impacts of human activities. The study is modeled after the successful Atlantic Marine Assessment Program for Protected Species (AMAPPS), now in its 2nd phase (AMAPPS-II). GoMMAPPS will promote collaboration via data sharing with other efforts in the GOMx, including the potential for expanded use of passive acoustic monitoring (PAM) in the GOMx and potential coordination of science with Mexico. Results from GoMMAPPS will provide tools for decision makers about possible adverse impacts to marine mammals from offshore energy development or other activities such as military readiness exercises. Given the scope of this program, studies are likely to increase scientific understanding about Bryde's whales and their habitat.

Future Needs to a Better Understanding of GOMx Bryde's Whales and Threats to Their Survival

Table 8. List of research needs to improve understanding of the distribution, abundance, biology, and ecology of, and threats to, Bryde's wales in the GOMx. Needs are prioritized High (H), Medium (M), and Low (L) and are also associated with which Topic areas of management they may address: 1= critical habitat designation, 2 = improve metrics for restoration and recovery goals, 3=address jeopardy determinations, 4=stock assessment.

Priority	Topic	Needs
H	1	*Describe the Bryde's whale habitat in the northeastern GOMx
	1	- Identify favored physiographic habitat – e.g., depth, slope, bottom type
	1	- Define physical oceanography that defines the habitat – e.g., sea surface temperature, salinity, and fronts
	1	- Identify the biological oceanography that defines this habitat – e.g., productivity, potential prey abundance and distribution (see below)
	1, 2, 3	- Medium-term (<50 days) LIMPET satellite tags for movement patterns (to quantify whether/ how often whales visit north-central and western GOMx
	1, 2, 3	- Short-term acoustic and kinematic tags for calling and diving behavior, energy budgets
H	1, 2, 3, 4	*Establish calibrated long-term passive acoustic monitoring units in potential habitats to examine temporal and spatial variation in occurrence concurrent with noise measurement.
H	2, 3, 4	*Monitor abundance and distribution in the northeastern GOMx
	2, 3, 4	- Conduct seasonal and then consistent (genetic or photo-identification) capture-recapture studies (every 2-3 years)
	2, 3, 4	- Establish and maintain a photo-identification catalog
H	1, 2, 3, 4	*Investigate whether there is a broader distribution through fine-scale visual and/or acoustic surveys of habitat similar to the northeastern GOMx coupled with biopsy sampling. Investigate whether there is seasonal variability in distribution
	1, 2, 3, 4	- North-central and western Gulf of Mexico
	1, 2, 3, 4	- Southern Gulf of Mexico
(M)	1, 2, 3, 4	- Southeast U.S. Atlantic Ocean

Priority	Topic	Needs
	1, 2, 3, 4	- Northern Caribbean
(M)	1, 2, 3, 4	- Compile and maintain non-research sightings (Protected Species Observer sightings and effort from energy activities, records from the public)
M	1, 2, 3	*Describe and quantify what is known about potential prey
	1, 2, 3	- Analyze current NMFS trawl data for Gulf-wide prey distribution
	1, 2, 3	- Analyze existing EK60 data collected within the Bryde's whale habitat in the northeastern GOMx
	1, 2, 3	- Conduct additional trawling and targeted sampling of bottom associated fish aggregations based on EK60 signatures in northeastern GOMx
(L)	1, 2, 3	- Perform stable isotope analysis of potential prey to pair with isotope analysis of the whales to identify trophic level and prey preference
M	2, 3	*Improve understanding of life history and population dynamics
	2, 3	- Characterize demographic structure of the population (e.g., adults, juveniles, sex ratios, age structure, survival rates, etc.)
	2, 3	- Develop a well parameterized stage-structured population model for the species/stock
	2, 3	- Conduct visual health assessment based upon photographic data
M	3	*Improve assessment of population health through collection and analysis of biopsy samples
(H)	3	- Estimate pregnancy rates
	3	- Evaluate stress hormones
	3	- Measure contaminant loads
	3	- Measure mercury levels
H	3, 4	*Improve understanding of threats to the population in the northeastern GOMx habitat; expand to other habitats as necessary
	3, 4	- Measure ambient noise related to vessel traffic and energy exploration and production
	3, 4	- Characterize vessel traffic

Priority	Topic	Needs
	3, 4	- Characterize fishing activities
	3, 4	- Characterize risk of exposure to oil spills throughout the GOMx
H	2, 3	*Ensure enhanced data collection from any stranded animals (e.g., full necropsy, stomach contents, tissue sampling, cause of death, etc.)
L	2	*Further investigate taxonomic relationships of Bryde's whales worldwide

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Appendix 1. Document sent to Society for Marine Mammalogy's Committee on Taxonomy

Question: Are Bryde's whales in the Gulf of Mexico likely to belong to at least an undescribed subspecies of what is currently recognized as *Balaenoptera edeni*? Based on your expert opinion, please rate the likelihood of sub-specific status as high or low.

Background

In October 2014, the U.S. National Marine Fisheries Service (NMFS) received a petition from the Natural Resources Defense Council to list the Gulf of Mexico (GOMx) population of Bryde's whale as Endangered under the U.S. Endangered Species Act (ESA). A biological review team (BRT) has now been convened by NMFS to assess the status of Bryde's whales in the Gulf of Mexico under the U.S. Endangered Species Act as a result of this petition. The BRT must evaluate the status of the population relative to the broader taxonomic group to which is belongs. If this population is likely to be recognized as a subspecies, but this has not yet been achieved or nomenclature has not yet been resolved, the BRT can take this into consideration in their status review. Taxonomy is therefore an important component in managing species under the ESA. Subspecies taxonomy in cetaceans has lagged behind that of other taxa (Reeves et al. 2004). However, the BRT is obligated to make their designations based on "best available science". Recent genetic and acoustic evidence have been acquired that suggest this population of Bryde's whales represents a unique evolutionary lineage. We ask the Committee on Taxonomy to provide their expert opinion on whether this population is likely to warrant status at least as an undescribed subspecies of what is currently recognized as *Balaenoptera edeni*.

Evidence

Bryde's whales are the only baleen whale species resident in the Gulf of Mexico. In U.S. waters, the species is seen only in the northeastern Gulf of Mexico along the continental slope (Fig.1) despite significant survey effort throughout U.S. waters of the Gulf (Fig. 2). The best population size estimate is 33 (CV=1.07) based on a 2009 shipboard survey (Waring et al. 2014). Although fewer systematic surveys have been conducted in Mexican waters of the Gulf of Mexico, opportunistic surveys were conducted between June 1997 and June 1999 during 6 cruises in the southern GOMx and the Yucatan Channel in Mexico (Figure 3). A total of 58 cetacean sightings were recorded; only 1 baleen whale was seen and it was identified as a fin whale (Ortega-Ortiz 2002). A compilation of all available records of cetacean sightings, strandings and captures in the southern GOMx identified no Bryde's whales, although there were 2 records of common minke whale, and 1 record each for sei, blue, fin and humpback whale (Ortega-Ortiz 2002).

Despite a lack of sightings of Bryde's whales outside the continental slope in the northeastern Gulf of Mexico, they may historically have been more wide spread. Reeves et al. (2011) examined Yankee whaling records in the Gulf of Mexico for 1788-1858. While primarily targeting sperm whales, 'finback' whales were recorded (Fig. 4). Given that all other baleen whale species are extralimital in the GOMx, Reeves et al. (2011) concluded that most of these finback whale records were likely Bryde's whales, suggesting the species was more broadly distributed in the GOMx in the 18th and 19th centuries.

Genetic distinctiveness: Rosel & Wilcox (2014) examined mtDNA control region sequence data for 21 Bryde's whales from the Gulf of Mexico and 2 strandings from the southeast U.S. Atlantic coast and compared these data to published control region sequences collected from Bryde's whales worldwide. The GOMx haplotypes and the two strandings from the Atlantic coast were not found anywhere else and phylogenetic reconstruction revealed that these haplotypes are evolutionarily distinct from other members of the Bryde's whale complex examined to date. Although the 2 Atlantic strandings exhibited the same haplotype as the whales sampled in the Gulf of Mexico, they were considered extralimital because 1) no Bryde's whales have ever been sighted during NMFS shipboard surveys in Atlantic U.S. waters and 2) Mead (1977) has previously suggested Bryde's whale strandings on the U.S. Atlantic coast are strays from the Gulf of Mexico.

Within the first 375 base pairs of the control region, 25–26 fixed differences were found among GOMx haplotypes and those from sei whales and the 2 currently recognized Bryde's whale subspecies. Similarly, there were 13-24 fixed differences at the *cox1* gene and 7-19 at the *cytb* gene between the GOMx haplotypes and haplotypes of the other Bryde's whale subspecies and the sei whale. Genetic diversity was also extremely low in the population with only two mtDNA control region haplotypes found. Twenty-five microsatellite loci known to be polymorphic in other baleen whales, include Bryde's whales, were monomorphic, while 17 polymorphic loci exhibited only 2 to 4 alleles.

Acoustics: Rice et al. (2014) analyzed acoustic recordings collected from 4 bottom-mounted MARUs (marine autonomous recording units) placed in the northeastern Gulf Mexico where Bryde's whales are most often encountered. Recordings picked up regular occurrence of 'potential, low-frequency biological sounds with baleen whale like features', including 'down-sweep sequences,' 'long-moans,' and 'tonal-sequences.' Bryde's whales are the only baleen whale species to regularly occur in the Gulf of Mexico. The characteristics of these recorded signals, when compared to other baleen whale species that rarely occur in the Gulf found general overlap but nothing similar enough to conclude the sounds came from another species of baleen whale. Furthermore, while the signals shared some characteristics with other Bryde's whales, overall they were not similar to those reported for Bryde's whales elsewhere.

Life history (anecdotal): Although a very small sample size, Rosel & Wilcox (2014) reported that the length of Bryde's whales from the GOMx seems to be intermediate to that reported for *B. edeni edeni* and *B. edeni brydei* by Rice (1998) as 9-11.5 m for *B. e. edeni* and 11.2 (for males) and 11.7m (for females) to > 14.6m (males and 15.6 (females) for *B. e brydei*. Of 14 verified stranding records in the GOMx, the largest whale was a 12.65m lactating female, and there were 4 additional whales with lengths between 11.2 and 11.6 m, although physical maturity was unknown for these whales. Since only *B. e brydei* has been genetically identified in the Atlantic Ocean, the GOMx whales seem to be considerably smaller than the other subspecies present in the ocean basin.

Summary

An often cited criterion for separation of subspecies is the ability to differentiate 75% of individuals found in one region from > 95% of individuals from another region. Based on this criterion, mtDNA sequence data can be used to distinguish 100% of GOMx Bryde's whales as there are > 20 fixed differences between control region sequences from this population and other Bryde's whale subspecies sampled worldwide. In addition, a characteristic attributes (CAs) diagnosis (Davis & Nixon 1992) applied to a 305 bp alignment of control region sequences identified multiple diagnostic nucleotide positions for the two Bryde's whale subspecies, Omura's whale and the Gulf of Mexico Bryde's whale: *B. e. edeni* (n = 2 diagnostic sites), *B. e. brydei* (n = 4), *B. omurai* (n = 13), and GOMx Bryde's whales (n = 7).

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Reeves, R. R., J. N. Lund, T. D. Smith and E. A. Josephson. 2011. Insights from whaling logbooks on whales, dolphins, and whaling in the Gulf of Mexico. Gulf of Mexico Science 29:41-67.

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Waring, G. T., E. Josephson, K. Maze-Foley and P. E. Rosel. 2014. U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments -- 2013. NOAA Technical Memorandum NMFS-NE-228. 463 pp.

Figure 1. From Waring et al. (2009): Distribution of Bryde's whale sightings from NMFS Southeast Fisheries Science Center vessel surveys during spring 1996-2001, summer 2003 and spring 2004, and summer 2009. Solid lines indicate the 100m and 1,000m isobaths and the offshore extent of the U.S. EEZ.

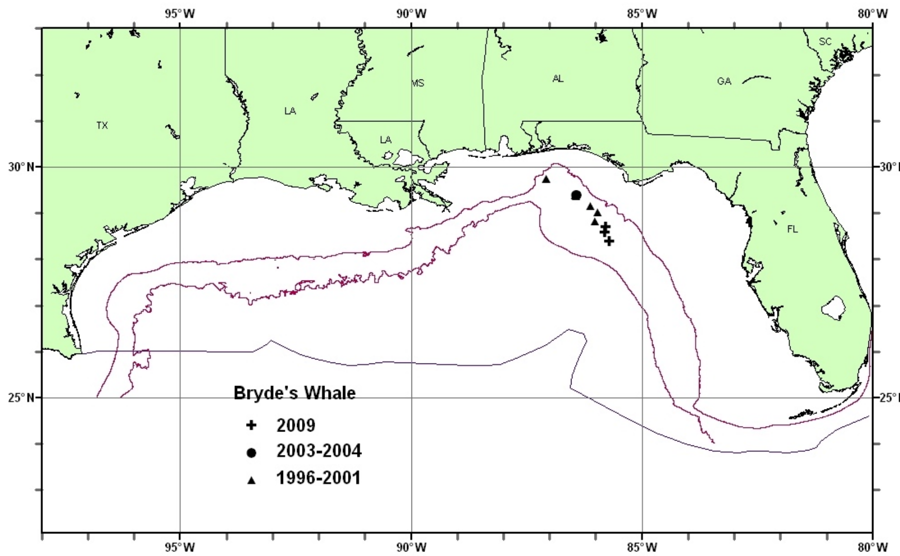


Figure 2. From Vollmer & Rosel (2013): Tracklines (pink lines) showing ship-based survey effort conducted in the shelf and offshore waters of U.S. waters of the Gulf of Mexico from 1992 – 2009. Solid gray lines indicate the 20m and 200m isobaths and the offshore extent of the U.S. EEZ.

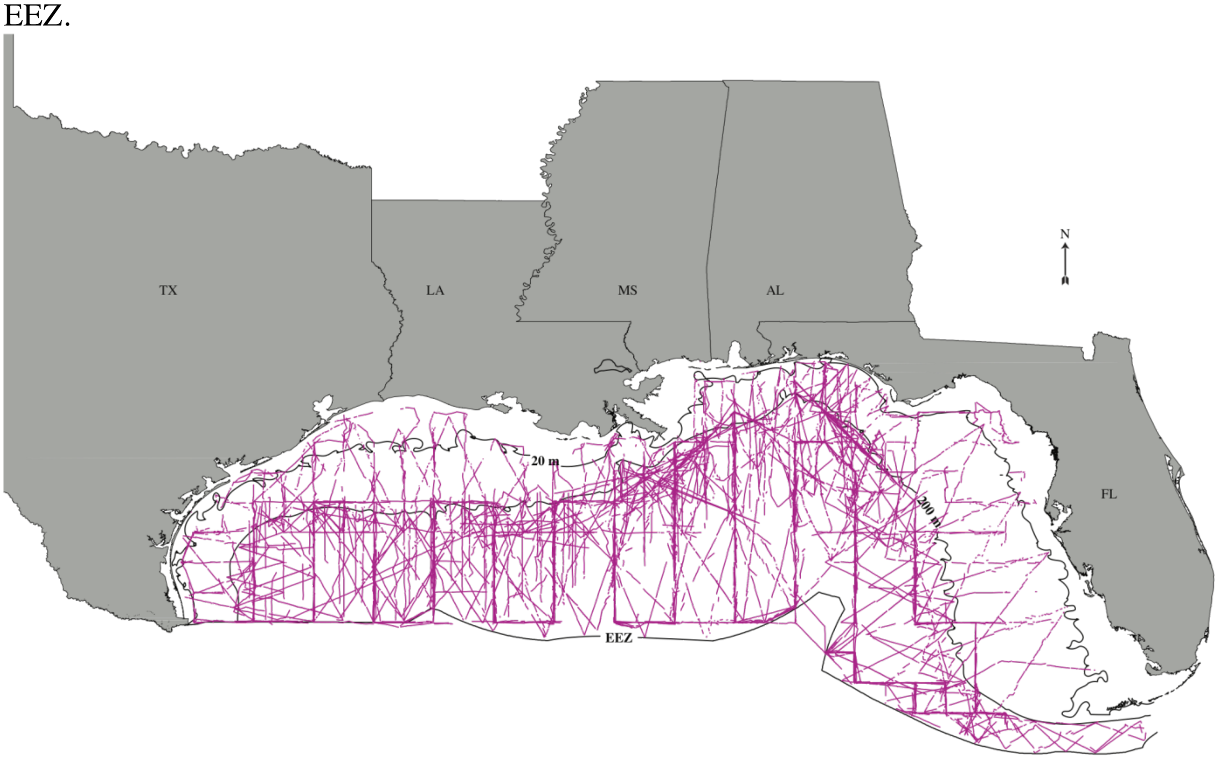


Figure 3. From Reeves et al. (2011): Records of locations when 'finback whales' were caught or sighted during whaling effort in the Gulf of Mexico between 1788 and 1877. Reeves et al. (2011) suggested that most of these sightings were probably of Bryde's whales. Dotted lines indicate the 100m and 1,000m isobaths.

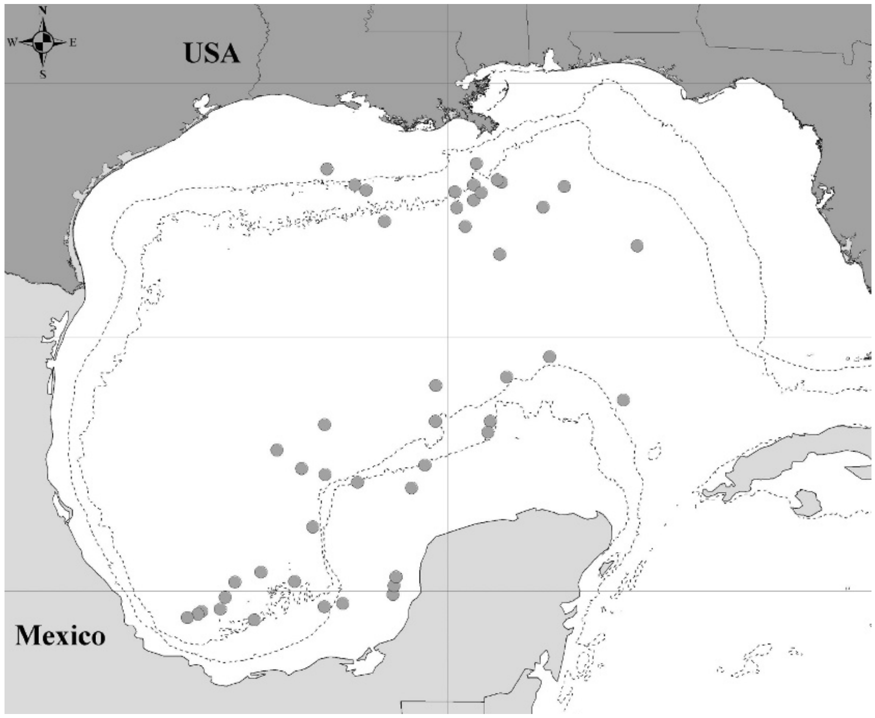
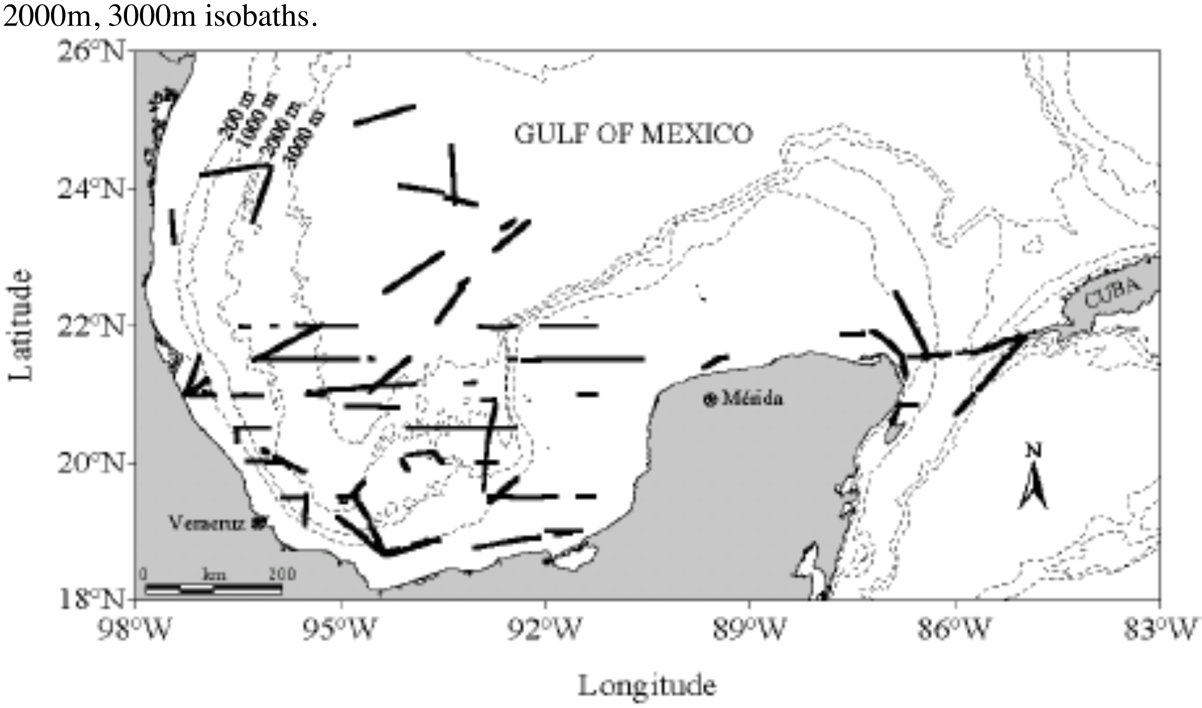


Figure 4. From Ortega-Ortiz (2002): Survey effort for cetacean surveys in the southern Gulf of Mexico and Yucatan Channel between June 1997 and June 1999. Only 1 balaenopterid was recorded- a fin whale on the Campeche escarpment. Dotted lines indicate the 20m, 1000m, 2000m, 3000m isobaths.



Email Response from Chair of SMM Committee on Taxonomy

-------- Forwarded Message --------
Subject: Gulf of Mexico Bryde's whales
Date: Mon, 15 Jun 2015 10:07:05 -0700
From: William Perrin - NOAA Affiliate <william.perrin@noaa.gov>
To: Patricia Rosel - NOAA Federal <Patricia.Rosel@noaa.gov>, Barbara Taylor - NOAA Federal <barbara.taylor@noaa.gov>

BRT for Gulf of Mexico Bryde's whales:

The attached was circulated to the members of the Committee on Taxonomy of the Society for Marine Mammalogy. Nine members responded (of 15); all voted it "highly likely" that the Gulf of Mexico Bryde's whales comprise at least an undescribed subspecies. This result constitutes the opinion of the Committee, which decides its position on such issues based on majority vote.

Bill Perrin
Chair, SMM Committee on Taxonomy

Appendix 2 Vessel Monitoring System and Fishery Effort Geospatial Density Distributions

Several fisheries require the use of Vessel Monitoring System (VMS) instrumentation as part of their management plans, and the collected data can provide information regarding the geospatial distribution of fishery effort. In the Gulf of Mexico, both the reef fish and pelagic longline fisheries are mandated to carry and transmit VMS instrumentation while fishing. Reef fish and pelagic longline permit holders often carry multiple permits and VMS data therefore is incidentally collected for additional fisheries. However, it is unknown what the target catch of a given fishery is based on VMS data alone, so a VMS transmission associated with a given permit may actually be fishing for a target species from another permit. Maps are presented of VMS locations, which also are not indicative of whether a vessel is actively fishing or not. Vessels which are transiting more slowly while actively engaged in fishing will result in more VMS hits during active fishing than non-fishing activity. So these maps give a general indication of fishing effort by permit type, but may not be representative in some cases of multiple permits. It is very important to use caution in interpreting any VMS maps as 1) the vessel may be carrying that permit but targeting a different species, and 2) fishers carrying that permit but not a reef fish or pelagic long line permit are not represented. Maps will not include effort happening on vessels with only that fishery's permit and it is unknown how substantial that level of effort may be, and whether the geospatial distribution would be biased. Additional data exist outside the mapped regions, but databases are very large and queries were focused to the area near the Bryde's whale primary habitat.

Several permitting and VMS requirements may influence interpretation of maps. Pelagic longline and Reef-fish fisheries are required to carry VMS. Pelagic longline fishers must also have a shark (directed or incidental) and a swordfish (directed or incidental) permit, and most longline fishers also opportunistically participate in snapper/grouper fisheries, shark fisheries, and shrimp fishery. Additionally, reef-fish fishers using bottom-longline gear in waters east of Cape San Blas, Fla. must carry a Bottom long-line endorsement, but are not required to carry an endorsement west of 85º 30', and effort may be under-represented to the west.

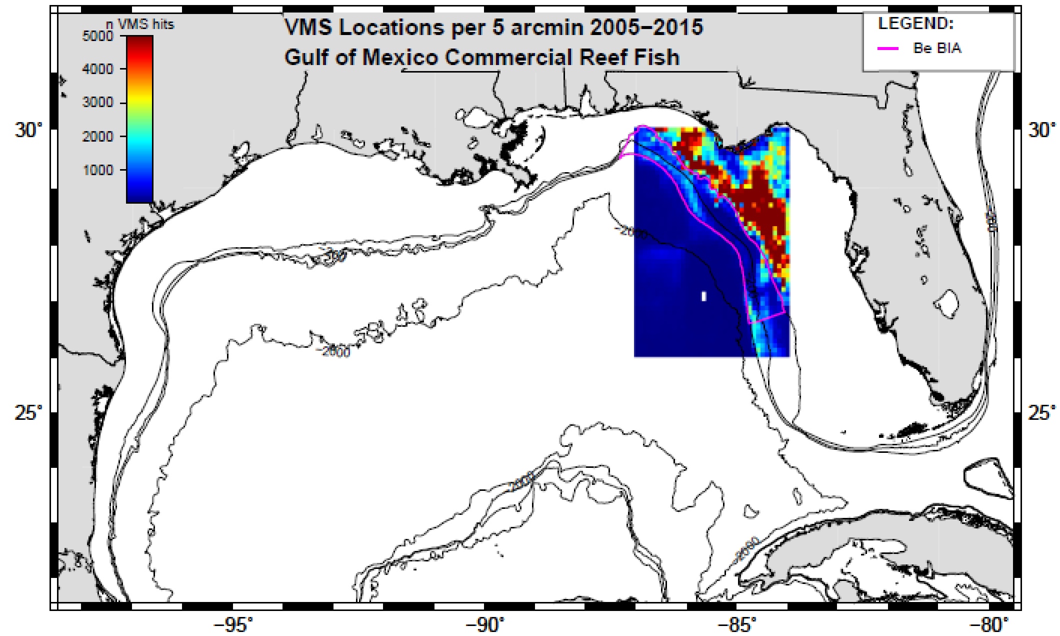


Figure 1. VMS ping locations from vessels with Gulf of Mexico Commercial Reef Fish permits (fishers may hold multiple permits and the target species being fished during each trip is unknown). Locations may represent transiting as well as active fishing. VMS data were obtained from Rivero (2015)

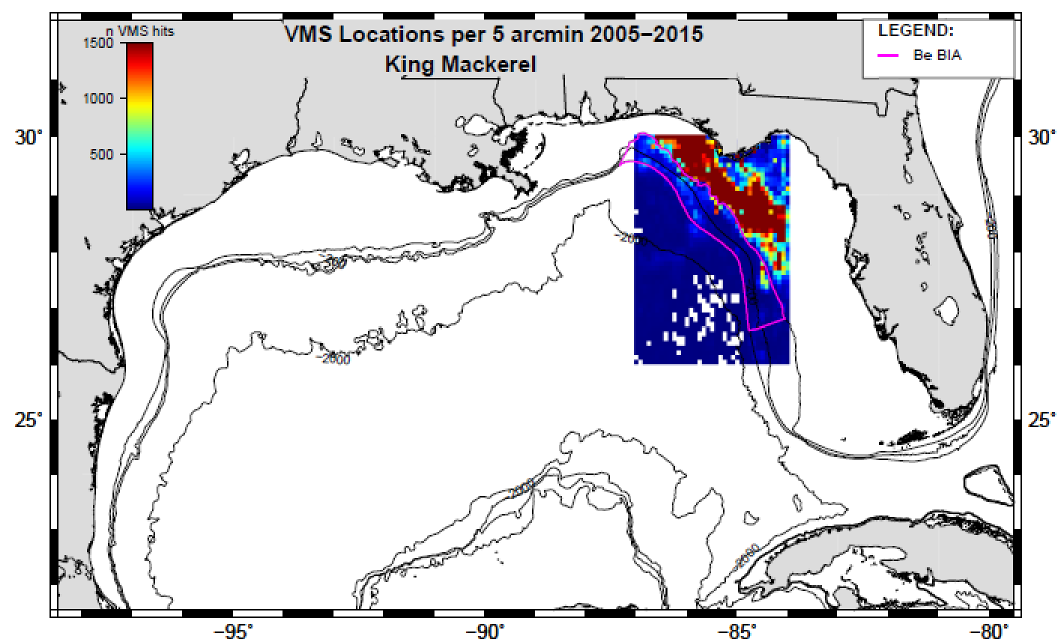


Figure 2. VMS ping locations from vessels with king mackerel permits (fishers may hold multiple permits and the target species being fished during each trip is unknown). Locations may represent transiting as well as active fishing. King mackerel permit holders without reef fish or pelagic longline permits are not required to carry VMS and will not be represented in these maps. VMS data were obtained from Rivero (2015)

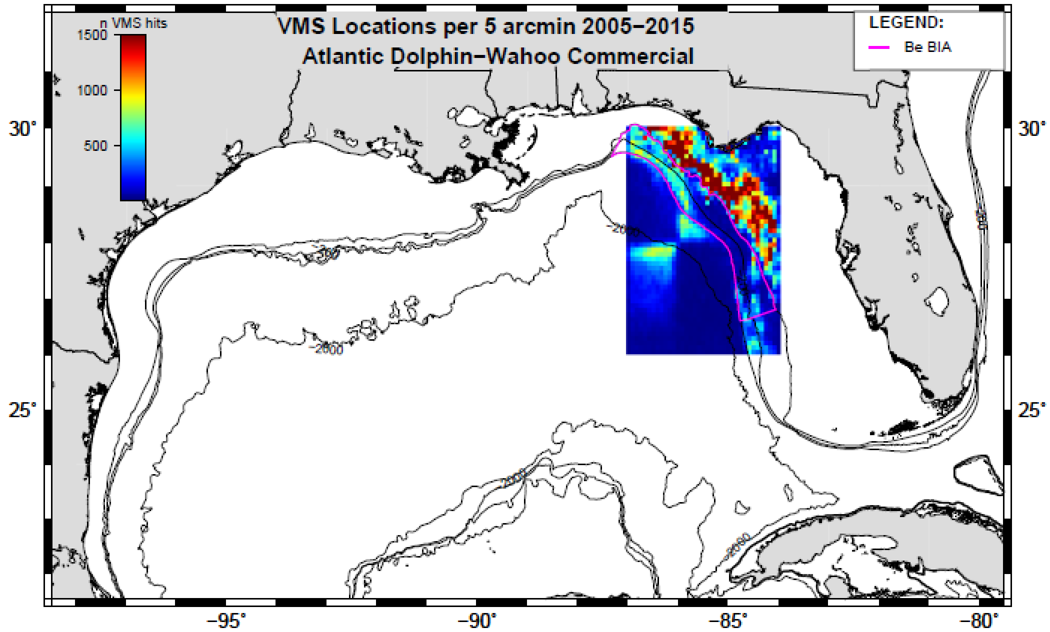


Figure 3. VMS ping locations from vessels with Atlantic Dolphin Wahoo Commercial permits (fishers may hold multiple permits and the target species being fished during each trip is unknown). Locations may represent transiting as well as active fishing. Atlantic Dolphin Wahoo Commercial permit holders without reef fish or pelagic longline permits are not required to carry VMS and will not be represented in these maps. VMS data were obtained from Rivero (2015)

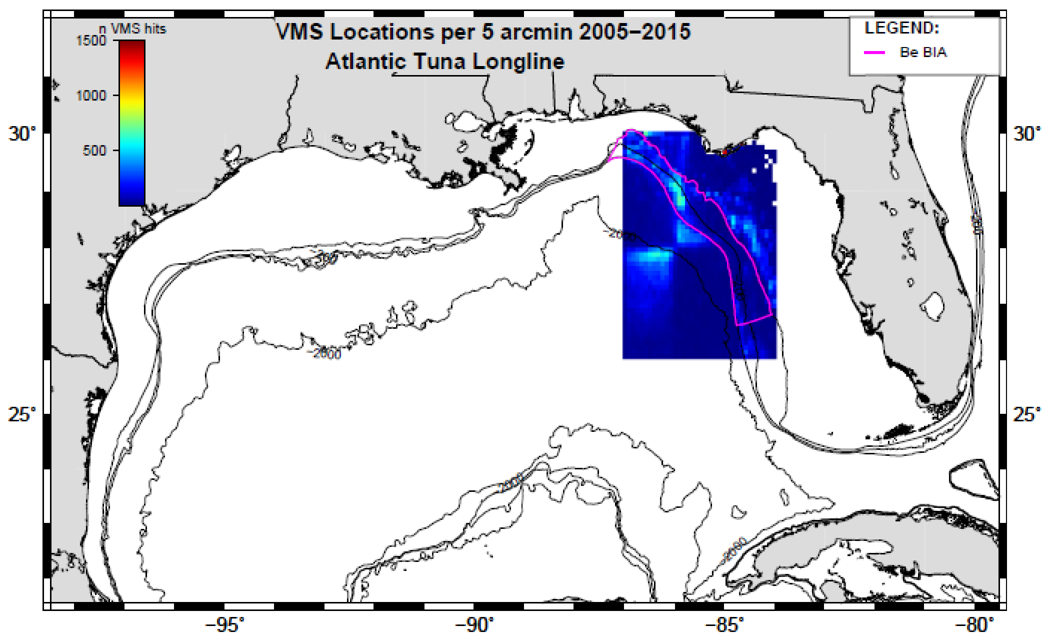


Figure 4. VMS ping locations from vessels with Atlantic Tuna Longline permits (fishers may hold multiple permits and the target species being fished during each trip is unknown). Locations may represent transiting as well as active fishing. VMS data were obtained from Rivero (2015)

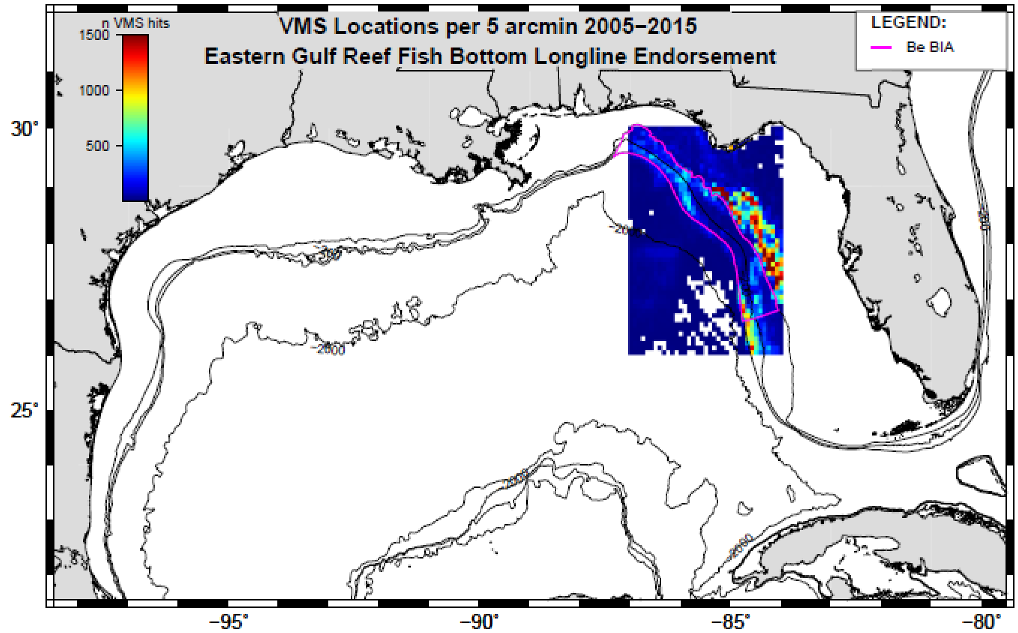


Figure 5. VMS ping locations from vessels Reef fish permits and an Eastern Gulf Reef Fish Bottom Longline Endorsement (fishers may hold multiple permits and the target species being fished during each trip is unknown). Locations may represent transiting as well as active fishing. Eastern Gulf Reef Fish Bottom Longline Endorsement is only required east of Cape San Blas and bottom longliners who may be operating to the west without this endorsement will not be represented in these maps. VMS data were obtained from Rivero (2015)

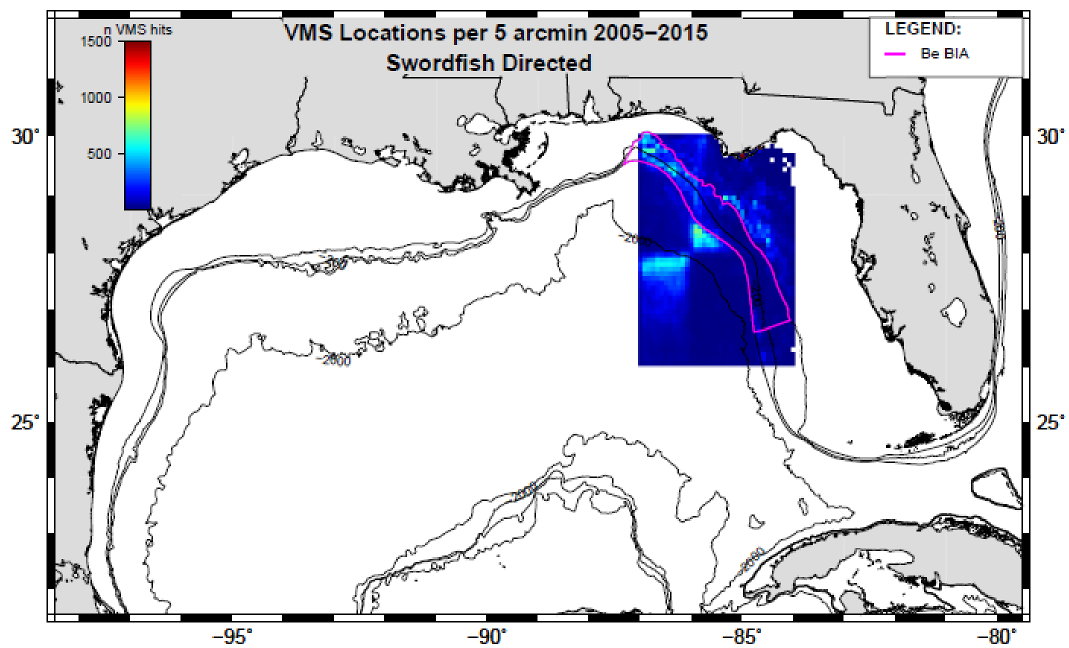


Figure 6. VMS ping locations from vessels with Swordfish Directed permits (fishers may hold multiple permits and the target species being fished during each trip is unknown). Locations may represent transiting as well as active fishing. Swordfish Directed permit holders without reef fish or pelagic longline permits are not required to carry VMS and will not be represented in these maps. VMS data were obtained from Rivero (2015)

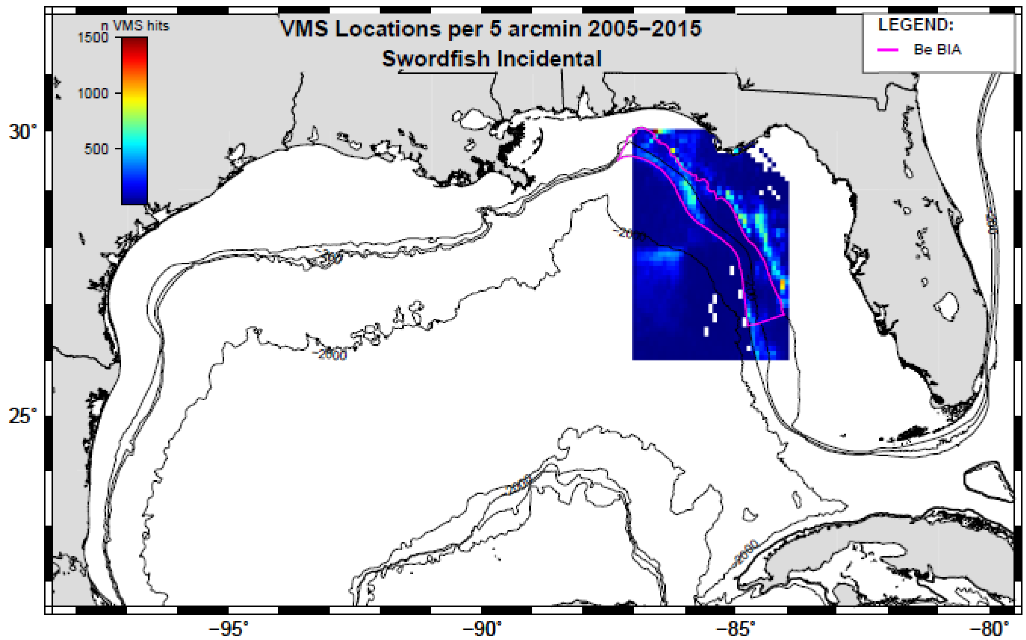


Figure 7. VMS ping locations from vessels with Swordfish Incidental permits (fishers may hold multiple permits and the target species being fished during each trip is unknown). Locations may represent transiting as well as active fishing. Swordfish Incidental permit holders without reef fish or pelagic longline permits are not required to carry VMS and will not be represented in these maps. VMS data were obtained from Rivero (2015)

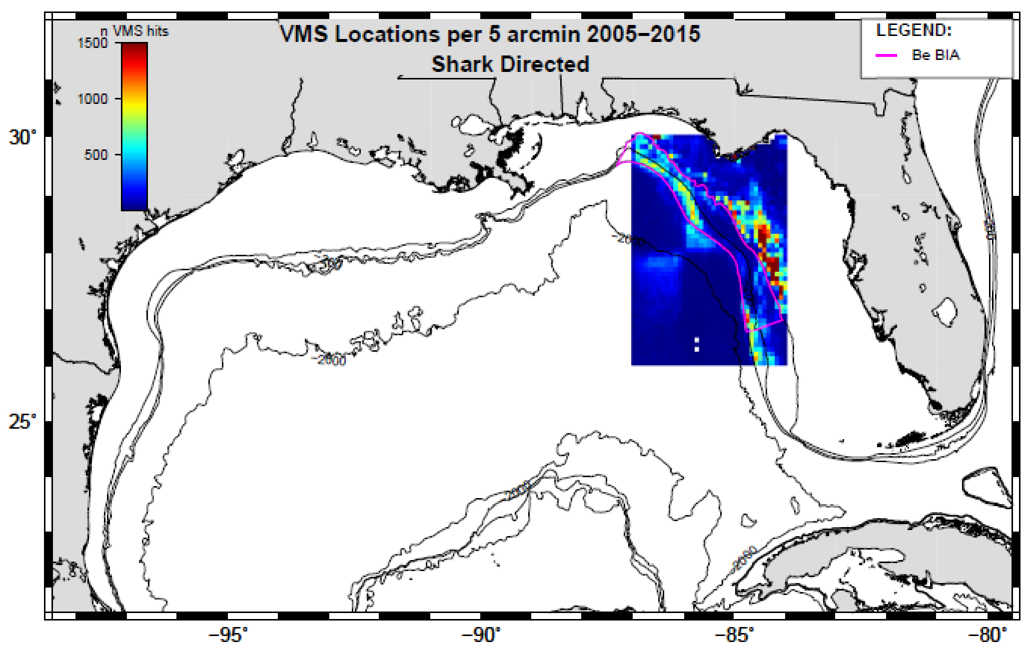


Figure 8. VMS ping locations from vessels with Swordfish Incidental permits (fishers may hold multiple permits and the target species being fished during each trip is unknown). Locations may represent transiting as well as active fishing. Shark directed permit holders without reef fish or pelagic longline permits are not required to carry VMS and will not be represented in these maps. VMS data were obtained from Rivero (2015)

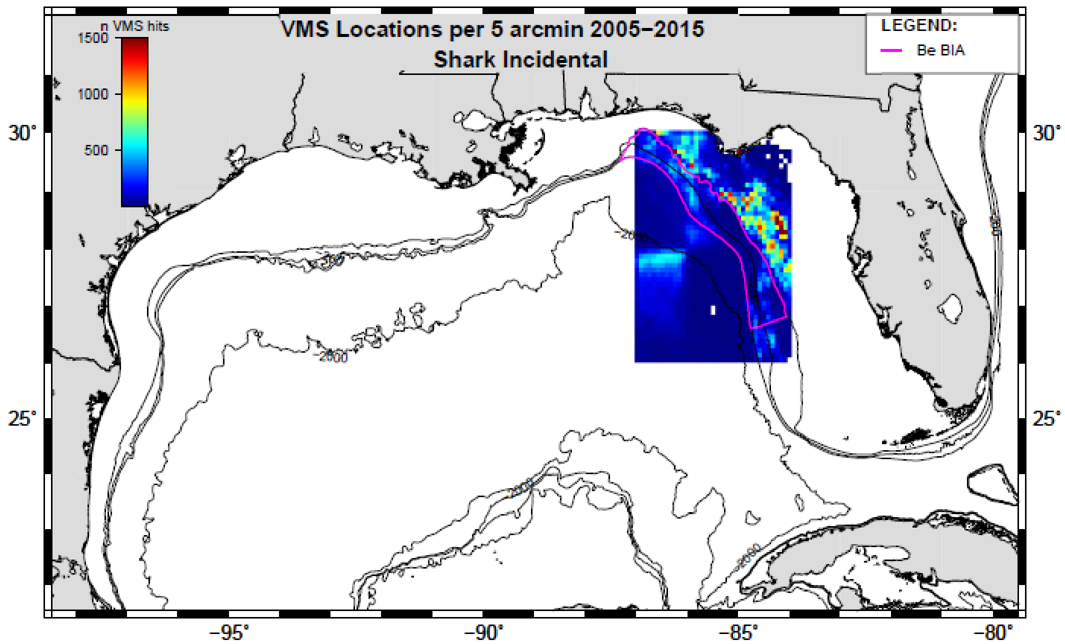


Figure 9. VMS ping locations from vessels with Shark Incidental permits (fishers may hold multiple permits and the target species being fished during each trip is unknown). Locations may represent transiting as well as active fishing. Shark incidental permit holders without reef fish or pelagic longline permits are not required to carry VMS and will not be represented in these maps. VMS data were obtained from Rivero (2015)

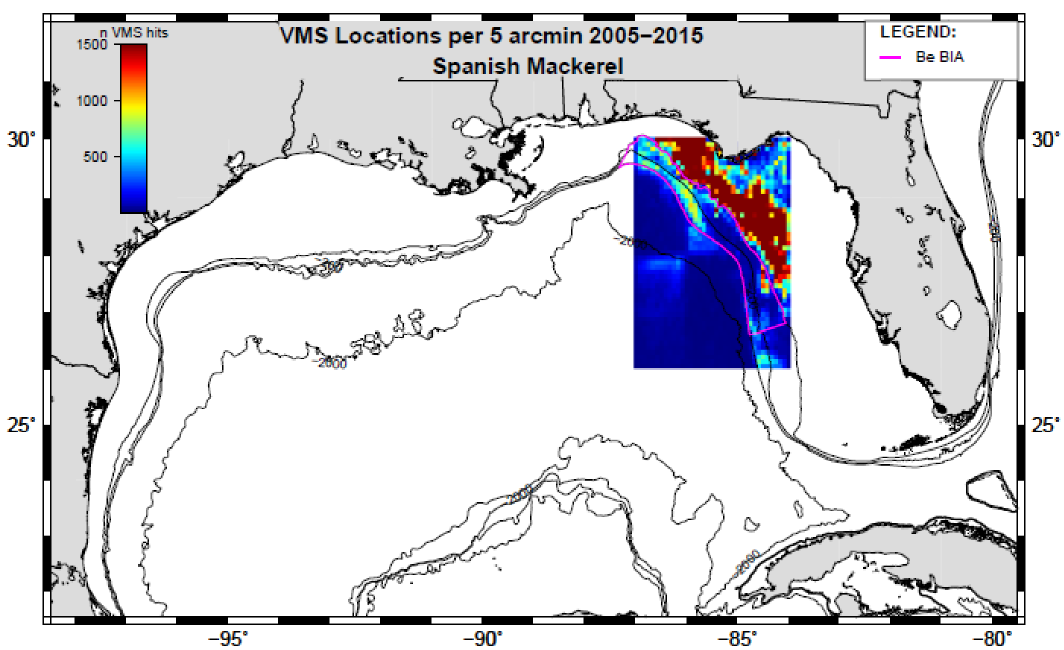


Figure 10. VMS ping locations from vessels with Spanish mackerel permits (fishers may hold multiple permits and the target species being fished during each trip is unknown). Locations may represent transiting as well as active fishing. Spanish mackerel permit holders without reef fish or pelagic longline permits are not required to carry VMS and will not be represented in these maps. VMS data were obtained from Rivero (2015)

Appendix 3: Scoring Tables for ESA Factors and Demographic Risks.

ESA Factors Scoring Table. Seven Team members scored severity and certainty for 27 specific threats in 4 threat categories. Team members where then instructed to provide an overall score for each of the threat categories, plus small population concerns, anthropogenic noise.

Scoring was as follows:
Definition of Severity – Current and future (over the next 3 generations or 55 years). The degree to which this threat is likely to contribute to the decline of the population currently and in the future. Specific rankings for this category are defined as follows:

3 = High: The threat is likely to *eliminate or seriously degrade* the population

2 = Moderate: The threat is likely to *moderately degrade* the population

1 = Low: The threat is likely to *only slightly impair* the population

Level of Certainty – Current and future risk. The level of certainty that the threat is affecting or is likely to affect the GOMx Bryde's whales. Specific rankings for this category are defined as follows:

3 = High: There are *definitive* published and/or unpublished data to support the conclusion that this threat did affect, is affecting, or is likely to affect the population with the severity ascribed

2 = Moderate: There are *some* published and/or unpublished data to support the conclusion that this threat did affect, is affecting, or is likely to affect the population with the severity ascribed

1 = Low: There are *little* published and/or unpublished data to support the conclusion that this threat did affect, is affecting, or is likely to affect the population with the severity ascribed

Overall Threat Ranking – The SRT's overall ranking for current and future threat categories are defined as follows:

High: This threat category includes *a high number* of threats that are moderately or very likely to contribute to the decline of the GOMx Bryde's whale, or contains some individual threats identified as very likely to contribute to the decline of the population.

Moderate: This threat category includes *an intermediate number* of threats that are likely to contribute to the decline of the GOMx Bryde's whale, or contains some individual threats identified as moderately likely to contribute to the decline of the population.

Low: This threat category includes *a low number* of threats that are likely to contribute to the decline of the population.

Individual Threats Scoring Table. Scores are presented for S, severity, and C, certainty, by Team member (1 through 7) followed by the mean and standard deviation (SDv).

		1		2		3		4		5		6		7					
Threat Factor	**Specific Threats**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**MeanS**	**MeanC**	**SDv S**	**SDv C**
Present or threatened habitat destruction, modification or curtailment of habitat or range	Energy Exploration and Development	3	2	3	3	3	2	3	2	3	2	3	3	2	1	2.86	2.14	0.35	0.64
	Persistent Organic Pollutants	1	1	1	2	2	2	1	2	1	1	1	1	1	2	1.14	1.57	0.35	0.495
	Harmful Algal Blooms	2	1	2	2	2	2	2	1	2	1	2	1	2	1	2.0	1.29	0.00	0.45
	Oil Spills and Spill Response	3	3	3	3	3	2	3	2	3	3	3	3	3	3	3.0	2.71	0.00	0.45
	Heavy Metals	1	1	1	2	2	2	1	1	1	1	1	1	1	1	1.14	1.29	0.35	0.45
Overutilization for commercial, recreational, scientific, or educational purposes	Historical Whaling	1	3	1	3	1	2	1	3	1	2	1	1	1	2	1.0	2.29	0.00	0.70
	Scientific Biopsy Sampling	1	3	1	3	1	3	1	1	1	3	1	1	1	2	1.0	2.29	0.00	0.88
Disease, parasites, or predation	Predation	2	1	1	3	1	3	1	1	1	1	1	1	1	1	1.14	1.57	0.35	0.90
	Disease, Parasites, or Predation	1	1	1	2	2	3	1	1	2	2	1	1	2	1	1.43	1.57	0.495	0.73
Other natural or human factors effecting its continued existence	Vessel Collision	2	2	3	3	3	3	3	2	3	3	2	3	2	3	2.57	2.71	0.495	0.45
	Military Activities (pressure waves, target training, vessel activities, vessel collisions)	2	1	2	3	2	2	2	1	2	1	1	1	2	1	1.86	1.43	0.35	0.73
	Fishing Gear Entanglements	2	2	3	3	3	3	2	2	2	2	2	2	2	3	2.29	2.43	0.45	0.495
	Trophic Impacts Due to Commercial Harvest of Prey Items	1	2	1	2	1	2	2	1	3	1	1	1	1	1	1.43	1.43	0.73	0.495
	Climate Change	1	1	1	2	1	2	1	1	2	1	2	1	1	1	1.29	1.29	0.45	0.45
	Plastics and Marine Debris	1	1	1	3	1	2	1	2	1	1	1	2	1	1	1.0	1.71	0.00	0.70
	Aquaculture	1	1	1	2	1	2	1	1	1	1	1	1	1	2	1.0	1.43	0.00	0.495
	Allee Effects	2	1	2	3	2	2	2	1	2	3	3	2	2	2	2.14	2.0	0.35	0.76

Small population concerns	Demographic Stochasticity	2	3	3	3	2	3	3	3	3	3	3	3	3	3	2.71	3.0	0.45	0.00
	Genetics	3	2	3	3	2	3	3	2	3	3	3	3	3	3	2.86	2.71	0.35	0.45
	K-Selected Life History Parameters	2	2	3	3	1	3	2	2	3	3	3	3	3	3	2.43	2.71	0.73	0.45
	Stochastic and Catastrophic Events	2	2	3	3	2	2	3	3	3	3	3	3	3	3	2.71	2.71	0.45	0.45
Anthropogenic noise	Aircraft and Vessel Associated with Oil and Gas Activities	2	1	2	3	2	2	2	2	2	2	2	1	2	2	2.00	1.86	0.00	0.64
	Oil Drilling and Production	2	1	2	3	2	2	2	1	2	2	2	1	2	1	2.00	1.57	0.00	0.73
	Fisheries Take and Acoustics	1	1	1	3	1	2	1	1	2	1	1	1	1	1	1.14	1.43	0.35	0.73
	Military Training and Exercises	2	1	1	2	2	2	1	2	1	1	1	2	2	1	1.43	1.57	0.495	0.495
	Shipping Traffic and Vessel Noise	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2.00	2.14	0.00	0.35
	Seismic Surveys	2	2	2	3	3	2	3	2	3	2	3	2	3	2	2.71	2.14	0.45	0.35

Overall Threats Scoring Table for each Threat Category. Scores are presented for S, severity, and C, certainty, by Team member (1 through 7) followed by the mean and standard deviation (SDv).

Threat Category	1	2	3	4	5	6	7	Mean	SD
Present or threatened habitat destruction, modification or curtailment of habitat or range	3	3	3	2	3	2	2	2.57	0.5
Overutilization for commercial, recreational, scientific, or educational purposes	1	1	1	1	1	1	1	1.00	0.0
Disease or predation	1	1	2	1	2	1	2	1.43	0.5
Other natural or human factors affecting its continued existence	2	3	3	2	3	1	2	2.29	0.7
Small population concerns	3	3	3	3	3	3	3	3.00	0.0
Anthropogenic noise	3	2	2	3	3	3	2	2.57	0.5

Demographic Risks Scoring Table

Scoring of demographic risks by the 7 Team members followed by the mean and standard deviation (SDv).

0 = No or low risk: It is unlikely that this factor contributes significantly to risk of extinction, either by itself or in combination with other factors

2 = Low risk: It is unlikely that this factor contributes significantly to risk of extinction by itself, but some concern that it may, in combination with other factors.

3 = Moderate risk: It is likely that this factor in combination with others contributes significantly to risk of extinction.

4 = High risk: It is likely that this factor, by itself, contributes significantly to risk of extinction

5 = Very high risk: It is highly likely that this factor, by itself, contributes significantly to risk of extinction

Topic/Team member	1	2	3	4	5	6	7	Mean	SDv
Abundance	5	5	5	5	5	5	5	5	0
Spatial distribution	5	5	5	5	5	4	5	4.9	0.35
Growth/productivity	3	5	5	3	3	4	3	3.7	0.885
Diversity	4	5	3	4	5	3	4	4.0	0.76