NOAA Technical Memorandum NMFS-SEFSC-747

DISTRIBUTION AND ABUNDANCE OF CETACEANS IN THE NORTHERN GULF OF MEXICO

BY

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Notice

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Cover photo: Fraser's dolphin (*Lagenodelphis hosei*) photographed in the eastern Gulf in 2012.

Acknowledgments

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Executive Summary

Over two decades of cetacean sightings in the Gulf of Mexico are summarized in this report providing a comprehensive overview of species distribution in the northern Gulf. Data displayed in the maps were collected during ship and aerial-based line-transect and *ad hoc* surveys conducted in the northern Gulf by the SEFSC between 1992 and 2014. Summaries of published abundance and density estimates and new analysis of SEFSC data, which resulted in updated estimates for several cetacean species, including Bryde's whales are also provided.

This report was part of the Deepwater Horizon (DWH) Natural Resource Damage Assessment (NRDA) process and submitted as supporting documentation for the Programmatic Damage Assessment and Restoration Plan (PDARP) in 2015.

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1. The Gulf of Mexico Environment

The Gulf of Mexico is a complex body of water with dynamic oceanography and diverse physical-biological interactions. Cetacean distribution and abundance studies (ship-based and aerial surveys) typically include areas in the northern Gulf of Mexico (within the United States Exclusive Economic Zone (U.S. EEZ), hereafter referred as Gulf) along the continental shelf (broad and flat areas with waters less than 200 m deep), continental slope (narrow and steep systems with waters 200-2000 m deep), as well as abyssal waters (waters greater than 2000 m deep) (Davis et al., 1998; Baumgartner et al., 2001; Mulling and Fulling, 2004; Mullin et al., 2004). Most of the Gulf's waters within the U.S. EEZ are within the 2000 m isobath, with the shelf comprising 36% and the slope 26% of the total area. Furthermore, the continental slope can be classified as upper (200 – 1000 m) and lower (1000 – 2000 m) (Baumgartner, 1997).

The Gulf's most dominant oceanographic feature is the Loop Current, a warm and oligotrophic oceanic current that enters the Gulf through the Yucatan Strait, pushes north into the eastern Gulf sometimes reaching as far as the Mississippi-Alabama-Florida shelf then exiting via the straits of Florida. The Loop Current periodically sheds anticyclonic (warm-core, high salinity, poor nutrient) eddies as well as cyclonic (cold-core) eddies associated with the Current's front, producing upwelling and greatly enhancing productivity in local areas. In addition, nutrient-rich shelf waters (e.g. from the Mississippi River) are periodically entrained in the confluence of these cyclone/anticyclone pairs and transported to oceanic waters (Baumgartner, 1997; Mullin and Fulling, 2004).

There are many environmental, biotic and physical factors that influence the distribution and abundance of cetaceans in the Gulf. In general, a species has high use of specific areas (Baumgartner et al., 2001) which are primarily determined by concentration of prey species, which are in turn fundamentally promoted by the physical environment (Baumgartner, 1997; Davis et al., 1998). The main physical and biotic characteristics affecting cetacean distributions in the Gulf are bottom depth (water depth), bottom-depth gradient (seafloor slope), and zooplankton biomass (Davis et al., 1998; Baumgartner et al., 2001; Mullin et al., 2004; Mulling and Fulling, 2004). Together with the Loop Current, these oceanographic and biotic features contribute to locally increase primary productivity in the otherwise oligotrophic waters of the Gulf (Baumgartner, 1997; Mullin and Fulling, 2004).

2. Cetaceans in the Gulf of Mexico

A diverse community of tropical and subtropical cetacean species occupies waters of the northern Gulf of Mexico reflecting its complex physical oceanographic environment (Waring et al., 2012, Table 1).

Table 1: Cetacean species inhabiting the northern Gulf of Mexico based on Waring et al., 2012.

Common name	Species name	Area
Bryde's whale	*Balaenoptera edeni*	Oceanic Gulf
Pygmy killer whale	*Feresa attenuata*	Oceanic Gulf
Short-finned pilot whale	*Globicephala macrorhynchus*	Oceanic Gulf
Risso's dolphin	*Grampus griseus*	Oceanic Gulf
Pygmy sperm whale	*Kogia breviceps*	Oceanic Gulf
Dwarf sperm whale	*Kogia sima*	Oceanic Gulf
Fraser's dolphin	*Lagenodelphis hosei*	Oceanic Gulf
Blainville's beaked whale	*Mesoplodon densirostris*	Oceanic Gulf
Gervais' beaked whale	*Mesoplodon europaeus*	Oceanic Gulf
Killer whale	*Orcinus orca*	Oceanic Gulf
Melon-headed whale	*Peponocephala electra*	Oceanic Gulf
Sperm whale	*Physeter macrocephalus*	Oceanic Gulf
False killer whale	*Pseudorca crassidens*	Oceanic Gulf
Pantropical spotted dolphin	*Stenella attenuata*	Oceanic Gulf
Clymene dolphin	*Stenella clymene*	Oceanic Gulf
Striped dolphin	*Stenella coeruleoalba*	Oceanic Gulf
Atlantic spotted dolphin	*Stenella frontalis*	Shelf and Oceanic Gulf
Spinner dolphin	*Stenella longirostris*	Oceanic Gulf
Rough-toothed dolphin	*Steno bredanensis*	Shelf and Oceanic Gulf
Common bottlenose dolphin	*Tursiops truncatus*	Shelf and Oceanic Gulf
Cuvier's beaked whale	*Ziphius cavirostris*	Oceanic Gulf

This report summarizes the distribution of cetaceans in the northern Gulf of Mexico based on published and unpublished data sources (Table 2). Maps (Figures 5-18) were produced using sighting data collected during Southeast Fisheries Science Center (SEFSC) ship and aerial-based surveys between 1992 and 2014 and include the location of both on and off effort sightings, which were not normalized for effort.. Survey designs during these projects varied from line-transect to *ad hoc* studies primarily during spring and summer with a few surveys conducted during fall and winter. Data between 2003-2014 were directly accessed at the SEFSC Miami laboratory, and data from 1992-2001 were downloaded on 6 May 2014 from

OBIS-SEAMAP (http://seamap.env.duke.edu/; Halpin et al., 2009). Sighting data used in many of the studies listed on Table 2 were also incorporated in the maps shown here. Also summarized in this report are analyses of NMFS SEFSC ship-based surveys conducted in 2003, 2004 and 2009, which resulted in updated estimates of cetacean abundance for the Gulf.

Table 2: Sources of data used in this report.

Parameter	Source
Distribution patterns	Baumgartner, M., 1997. The distribution of Risso's dolphin (*Grampus griseus*) with respect to the physiography of the northern Gulf of Mexico. Marine Mammal Science, 13(4):614-638.
	Davis et al., 1998. Physical habitat of cetaceans along the continental slope in the north-central and western Gulf of Mexico. Marine Mammal Science, 14(3):490-507.
	Baumgartner et al., 2001. Cetacean habitats in the northern Gulf of Mexico. Fish.Bull.99:219-239
	Maze-Foley and Mullin, 2006. Cetaceans of the oceanic northern Gulf of Mexico: Distributions, group sizes and interspecific associations. J. Cetacean Res. Manage. 8(2):203-213.
	SEFSC unpublished marine mammal sighting data: ship-based surveys 2007, 2008, 2009, 2010, 2012 and 2014; aerial surveys: 2007, 2010, 2011 and 2012.
	Waring et al., 2012. US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments 2012. NOAA Technical Memorandum NMFS-NE-223.
	Jochens et al., 2008. Sperm whale seismic study in the Gulf of Mexico. Synthesis report. U.S. Department of the Interior. Minerals Management Service.
Abundance and distribution patterns	Fulling et al., 2003. Abundance and distribution of cetaceans in outer continental shelf waters of the U.S. Gulf of Mexico. Fish. Bull. 101:923-932.
	Mullin and Fulling, 2004. Abundance of cetaceans in the oceanic northern Gulf of Mexico, 1996-2001. Marine Mammal Science, 20(4):787-807.
	Mullin et al., 2004. Abundance and seasonal occurrence of cetaceans in the outer continental shelf and slope waters of the north-central and northwestern Gulf of Mexico. Gulf of Mexico Science, 2004 (1), pp.62-73.
	Mullin, 2007. Abundance of cetaceans in the oceanic northern Gulf of Mexico from 2003 and 2004 ship surveys. SEFSC.
Updated density and abundance estimates	SEFSC marine mammal sighting data: ship-based surveys 2003, 2004 and 2009.
	Hildebrand et al., 2012. Passive acoustic monitoring of cetaceans in the northern Gulf of Mexico during 2010-2011. Progress report for research agreement #20105138.
	Garrison, unpublished. Abundance and Spatial Distribution of Sperm Whales in the Northern Gulf of Mexico: Application of spatially explicit density models. Draft summary of analysis and results. 27 Jun 2014.

3. SEFSC's Ship and Aerial-based Cetacean Surveys

Since the 1990's the SEFSC has been recording cetaceans in the Gulf. Effort covers U.S. waters (Northern Gulf) from shore to the Economic Exclusive Zone (EEZ) (Figures 1-4).

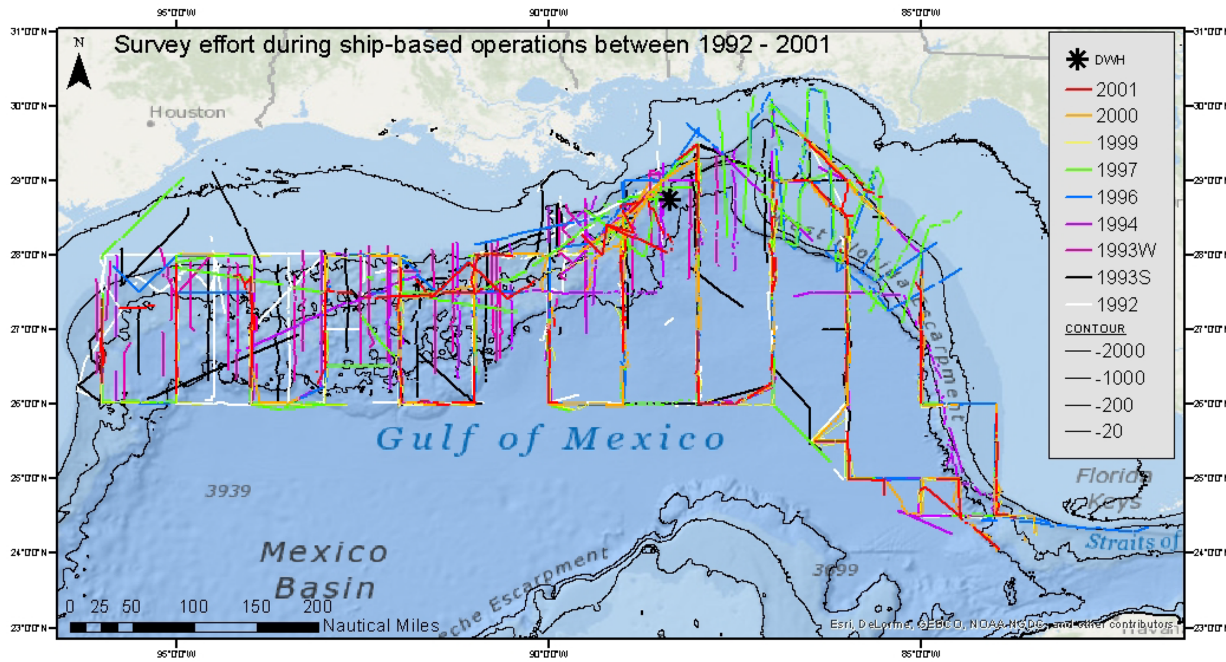


Figure 1: Survey effort during ship-based operations, 1992-2001.

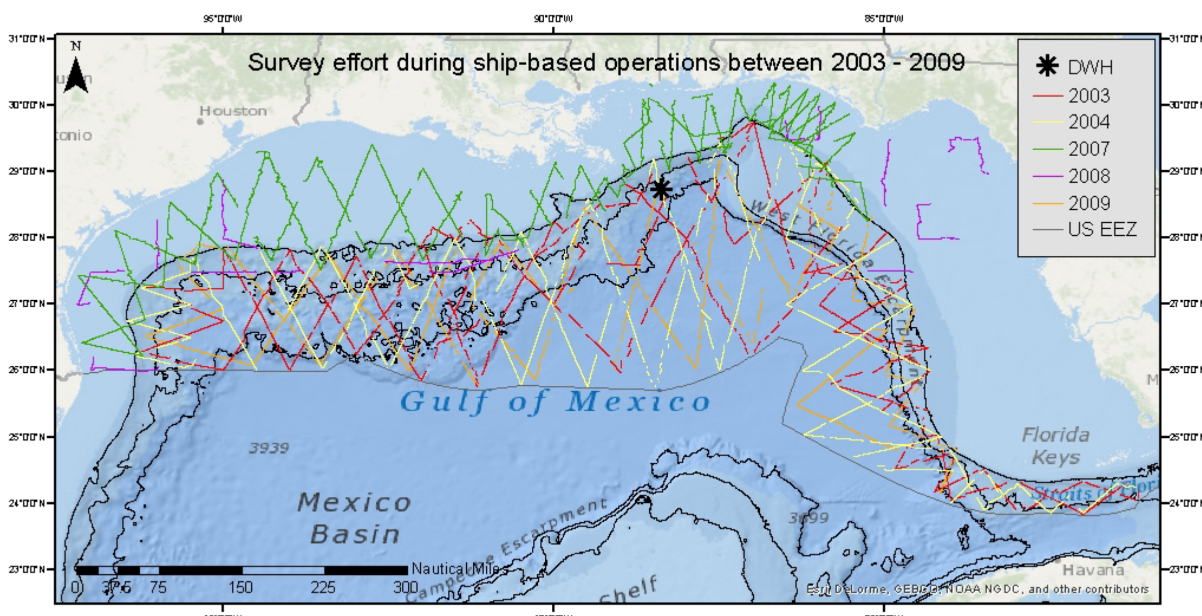


Figure 2: Survey effort during ship-based operations, 2003-2009.

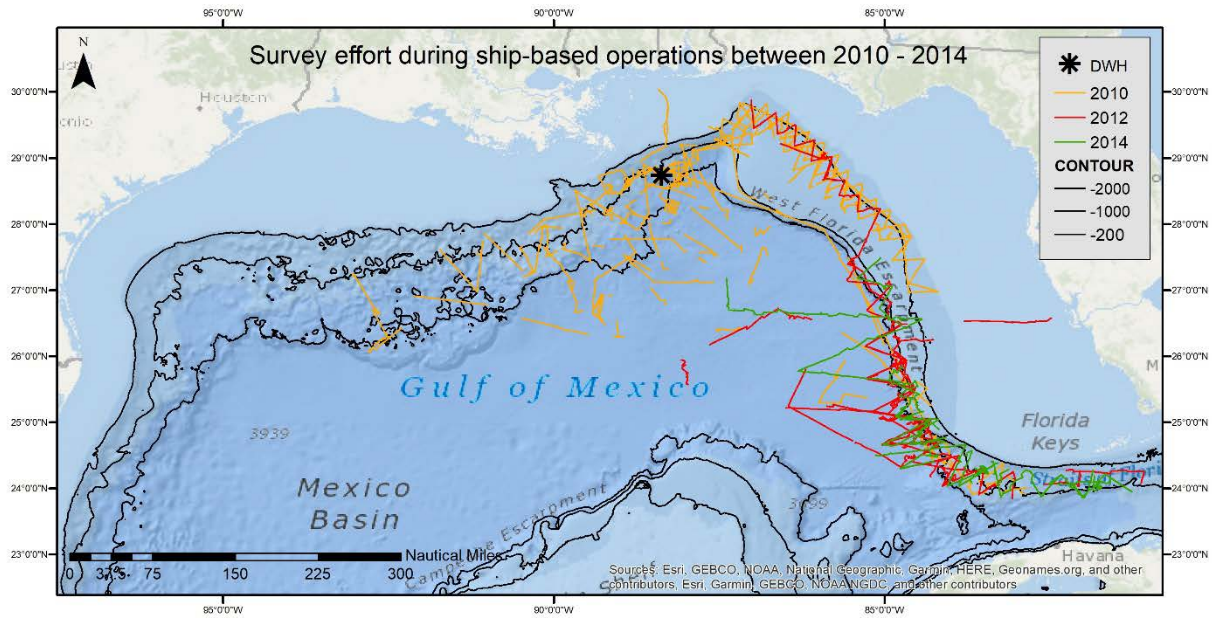


Figure 3: Survey effort during ship-based operations, 2010-2014.

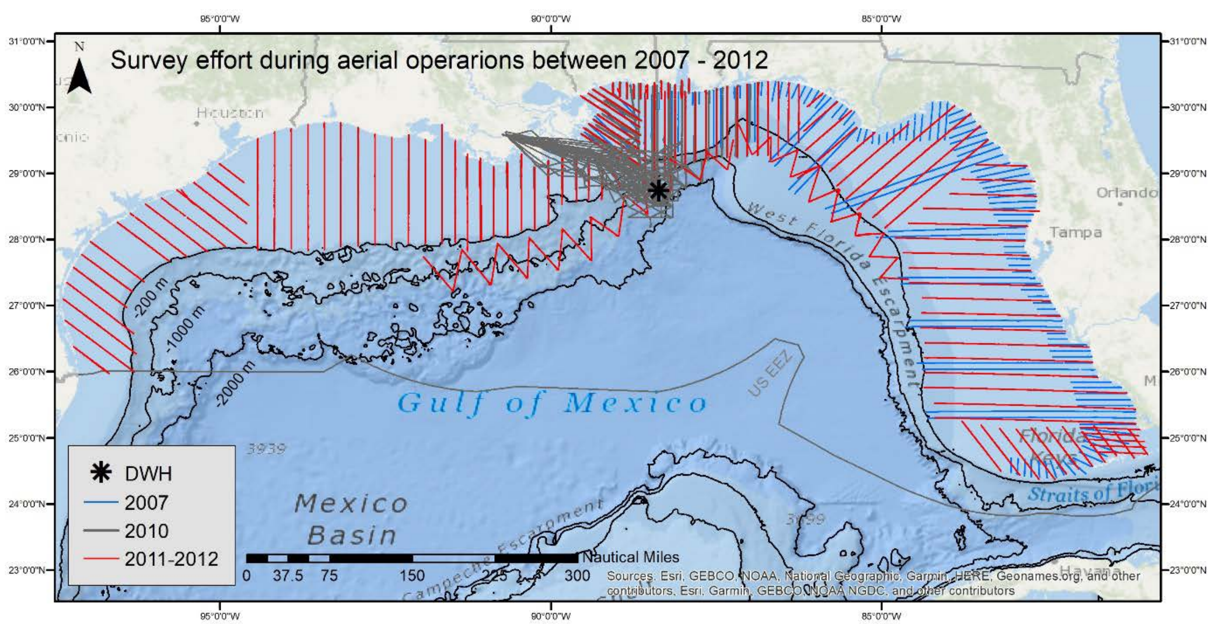


Figure 4: Survey effort during aerial-based operations, 2007-2012.

Ship and aerial-based cetacean surveys in the continental shelf, slope, and oceanic waters of the Gulf usually detect between 17 and 19 species of cetaceans (Mullin and Fulling, 2004; Mullin et al., 2004; Maze-Foley and Mullin, 2006; Mullin, 2007; SEFSC data, 1992-2014; Table 3). Species that are not easily identified at sea are usually categorized according to family (e.g., unidentified Ziphiid for beaked whales including *Mesoplodon* species and Cuvier's beaked whales) or genus (e.g., *Kogia* sp. for pygmy and dwarf sperm whales and *Stenella* spp. for Stenellid dolphins, among others). In addition, unidentified cetaceans, which primarily include unidentified dolphins that are seen at a distance and hence cannot be reliably identified, constitute a considerable percentage of sightings during distribution and abundance surveys (between 10% and 14% of all cetacean sightings, as reported in Mullin et al., 2004; Mullin and Fulling, 2004 and Mullin 2007) and contribute to negatively bias abundance estimates per species (Mullin and Fulling, 2004). Cryptic species, such as beaked whales and the pygmy and dwarf sperm whales, also tend to have negatively biased abundance estimates. Their cryptic behavior renders detection at sea difficult and whenever detected, it is difficult to identify animals to species.

During aerial and ship-based cetacean surveys, the most commonly sighted species in the Gulf are bottlenose dolphins, pantropical spotted dolphins, Atlantic spotted dolphins, Risso's dolphins, sperm whales, and dwarf and pygmy sperm whales (Baumgartner et al., 2001; Mullin and Fulling, 2004; Mullin et al., 2004, Maze-Foley and Mullin, 2006; Mullin, 2007; SEFSC data, Table 3). Short-finned pilot whales, striped dolphins, Clymene dolphins, spinner dolphins and beaked whales (including *Mesoplodon* spp. and unidentified ziphiids) are somewhat commonly observed during surveys and have different rates of detection (Mullin et al., 2004; Mullin and Fulling, 2004; SEFSC data, Table 3). Rarely recorded species include melon-headed whales, false killer whales, killer whales and pygmy killer whales. Bryde's whales are also infrequently seen and are the only species of baleen whale (mysticete) recurrently seen in the Gulf (Baumgartner et al., 2001; Mullin and Fulling, 2004; Mullin et al., 2004, Maze-Foley and Mullin, 2006 and Mullin, 2007; SEFSC data, Table 3). Fraser's dolphins are extremely rare and, although present in the Gulf, detection rates are very low (Mullin and Fulling, 2004; SEFSC data, Table 3).

Table 3: Cetacean sightings recorded between 1992 and 2014 during SEFSC aerial and ship-based surveys. Unid = unidentified.

Species	**92**	**93**	**94**	**96**	**97**	**98**	**99**	**00**	**01**	**03**	**04**	**07**	**08**	**09**	**10**	**11**	**12**	**14**	**Total**	**Rate of encounter**
Bottlenose dolphin	48	53	116	40	43	26	32	61	117	34	25	677	46	21	553	825	302	6	3025	Most common
Pantropical spotted dolphin	42	63	97	56	57		53	65	48	97	55		2	52	32	1	54	52	826	
Unid. Dolphin	26	46	102	35	44	4	16	47	72	28	22	78	11	34	91	38	64	30	788	
Sperm whale	19	20	34	24	15		35	22	30	68	38	9	2	40	66	8	29	16	475	
Atlantic spotted dolphin	7	13	80	21	23	10	4	12	64	2	5	88	22	4	18	16	8	1	398	
Risso's dolphin	24	15	50	31	19		9	10	14	31	12	2		12	23	3	18	14	287	
Pygmy/Dwarf sperm whale (*Kogia* spp.)	35	23	11	16	21		15	9	20	26	5			5	8		9	8	211	
Unid. Odontocete	16	14	10	3	7		5	4	4	14	9	2	2	21	16	7	9	9	152	
Spinner dolphin	6	5	12	6	8		2	6	1	5	7	1		3	19	1	5	4	91	Somewhat common
Stenella spp.	1	5	6	1	2		2	2	5	12	1			5	13	13	19	4	91	
Striped dolphin	7	11	15	3	3		7	6	5	10	9			2	3		1	5	87	
Unid. Ziphiid	2	5	8	3	2		1	3	1	17	3			4	7	1	19	10	86	
Clymene dolphin	6	11	9	8	2		8	7	1	11	6			2				1	72	
Rough-toothed dolphin	5	4	4		3		4	4	6	13		3	2	5	7		5	1	66	
Pilot whale	3	3	2	2	4	1	1	2	4	11	1	3	2	7	1	1	1	2	51	
Unid. Small whale	3	2	5	5	3		4	5		9	3	1			5	1		2	48	
Unid. Mesoplodont	6	5	6	5	2	1	2	1	1	4				2	3		1	4	43	
Unid. Large whale	1	6	7	2	1		7	1	2	3	2			2	5				39	Rare
Bryde's whale	1			2	1		2	3			4	6		3	6		2		30	
Cuvier's beaked whale		3	4	2	1		1	3	4	1	1			1	3		4	2	30	
Melon-headed whale	3	3	4	1			1	3	3	3	2		2	2	1			2	30	
False killer whale	1	1	2		3		1	1	1	8				1		2	1		22	
Killer whale	1	4	2	1	1		3		1		3			1	1				18	
Pygmy killer whale	2	1					1	3	1	3	3			1					15	
Balaenoptera sp.	2		2	1					1		1				1				8	Rarest
Melon-headed / Pygmy killer whale	1		1		1		1							1	2				7	
Fraser's dolphin	1				1			1									1	1	5	
Blainville's beaked whale	1				1													1	3	
Unid. Mammal															3				3	
Gervais' beaked whale								1											1	
Total	**270**	**316**	**589**	**268**	**268**	**42**	**217**	**282**	**406**	**410**	**217**	**870**	**91**	**231**	**887**	**917**	**552**	**175**	**7008**	

4. Cetacean Distribution in the Gulf

Cetacean species are sighted throughout the Gulf, widely distributed along the continental shelf, shelf break, and slope waters (Mulling and Fulling, 2004; Mullin et al., 2004). Even after compensating for unequal effort, spatial distributions of sightings indicate that different species may be selecting habitats according to specific oceanographic features (Baumgartner et al., 2001). In addition, species may overlap in range but finer scale partitioning probably allows sympatric species to share the ecosystem and avoid or minimize competition (Baumgartner et al., 2001; Maze-Foley and Mullin, 2006). Bottom depth and bottom depth-gradient are some of the main features influencing cetacean distribution (Davis et al., 1998) (Table 4).

Table 4: Cetacean distribution in the Gulf in relation to bottom depth.
References used to construct this table: Davis et al., 1998, Maze-Foley and Mullin, 2006, SEFSC data (1992-2014).
Mean bottom depth excludes sightings in water depths less than 100 m. Main areas of occurrence are based upon visual inspection and summary of sightings maps (Figures 5-18).
* Group found in the steepest depth-gradient (Davis et al., 1998).

Species	Mean bottom depth (m)	Habitat	Main areas of occurrence
Atlantic spotted dolphin	197	Mostly shelf (between coast and 200 m isobath).	Overall uniform distribution in deeper waters over the continental shelf.
Common bottlenose dolphin	293	Estuarine and coastal (estuarine waters and coastal waters between coast and 20 m isobath, not included in this report), shelf (between 20– 200 m isobath) and upper slope (between 200– 1000 m isobaths).	Overall uniform distribution; slight concentration on the shelf break at the MSRD and the shelf break/upper slope off FL Panhandle
Rough-toothed dolphin	950	Mostly slope (between 200 m and 1500 m isobaths) and some sightings on the Texas shelf.	Overall uniform distribution
Bryde's whales	226	Shelf along the 200 m isobath off the west coast of Florida.	De Soto Canyon
Risso's dolphin*	714	Upper slope (between the 200 m and 1000 m isobaths)	Overall uniform distribution, mainly concentrated at MS Canyon and FL Escarpment
Short-finned pilot whale	863	Upper slope (between 500 m and 1000 m isobaths).	West of the Mississippi River Delta

Species	Mean bottom depth (m)	Habitat	Main areas of occurrence
Spinner dolphin*	1111	Upper slope (between the 200 m and 1000 m isobaths)	East of the Mississippi River Delta (S of Mobile Bay) along the FL Escarpment
Striped dolphin*	1235	Lower slope (>1000 m) and abyssal	Overall uniform distribution; slight concentration S of Mobile Bay
Sperm whale*	1000	Slope (along the 1000 m isobath) and abyssal	Overall uniform distribution with concentrated areas off the MS Canyon and FL Escarpment (Dry Tortugas)
Pygmy/Dwarf sperm whale (*Kogia* spp.)	928	Slope (between the 200 m and 2000 m isobaths)	Overall uniform distribution; slightly focused towards central-eastern Gulf
Pantropical spotted dolphin	1242	Slope, abyssal (>1000 m)	Overall uniform distribution; slightly concentrated S Mobile Bay and along the FL Escarpment
Beaked whales (*Mesoplodon* spp., Unid. Ziphiid)	~1200	Slope (between 1000 m and 2000 m isobath) and abyssal (>2000 m) waters	Overall uniform distribution; concentration along the FL Escarpment
Clymene dolphin	1260	Slope and abyssal (>1000 m)	Overall uniform distribution towards the west of the Mississippi River Delta and central abyssal waters
False killer whale	1301	Slope and abyssal (>200 m)	Overall uniform distribution; slightly concentrated towards central-eastern Gulf (off FL Escarpment)

Species	Mean bottom depth (m)	Habitat	Main areas of occurrence
Melon-headed whale	1401	Slope (between the 1000 m and 2000 m isobaths).	Central Gulf and west of the Mississippi River Delta
Fraser's dolphin	1483	Abyssal (?)	Uniform distribution, however sightings are extremely rare
Killer whale	1866	Slope and abyssal (>1500 m)	Central Gulf off the Mississippi River Delta
Pygmy killer whale	2406	Slope and abyssal	Overall uniform distribution; slightly towards central-east

4.1. Shelf and Shelf-break Species

Three species of dolphins are normally recorded in the shallow shelf waters of the Gulf: Atlantic spotted dolphins, bottlenose dolphins and to a lesser degree, rough-toothed dolphins.

Atlantic spotted dolphins occur mainly over the continental shelf, and sightings are usually associated with the shallowest bottom depths and bottom depth gradients when compared to other cetacean species (Davis et al., 1998; Figure 5). However some opportunistic sightings indicate that this species occupy deeper waters (up to 500 m), especially on the northeastern part of the Gulf, south of the Florida Panhandle on the west Florida Escarpment (Fulling et al., 2003).

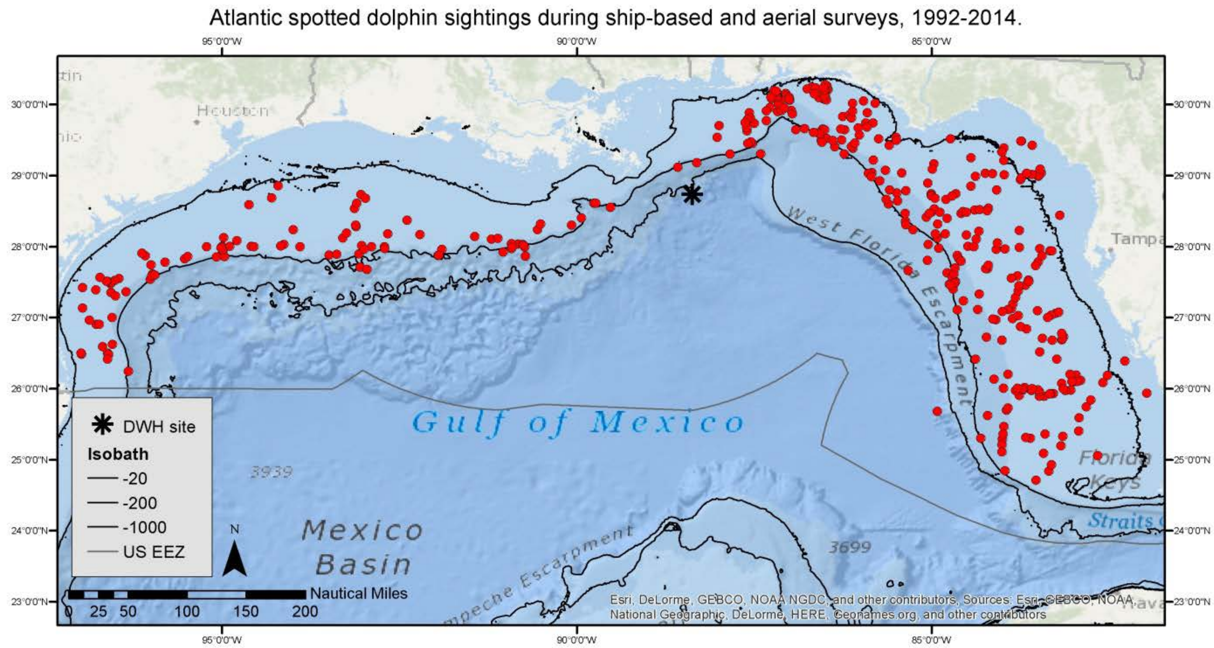


Figure 5: Sightings distribution of Atlantic spotted dolphins, SEFSC data, 1992-2014.

Rough-toothed dolphins are broadly distributed in the oceanic waters, at various depths but usually in deep waters of the Gulf (Davis et al., 1998; Maze-Foley and Mullin, 2006). The detection of a few rough-toothed dolphins in waters less than 200 m deep mainly off the Texas coast is an interesting finding since this species is usually described as inhabiting oceanic waters (Fulling et al., 2003) (Figure 6).

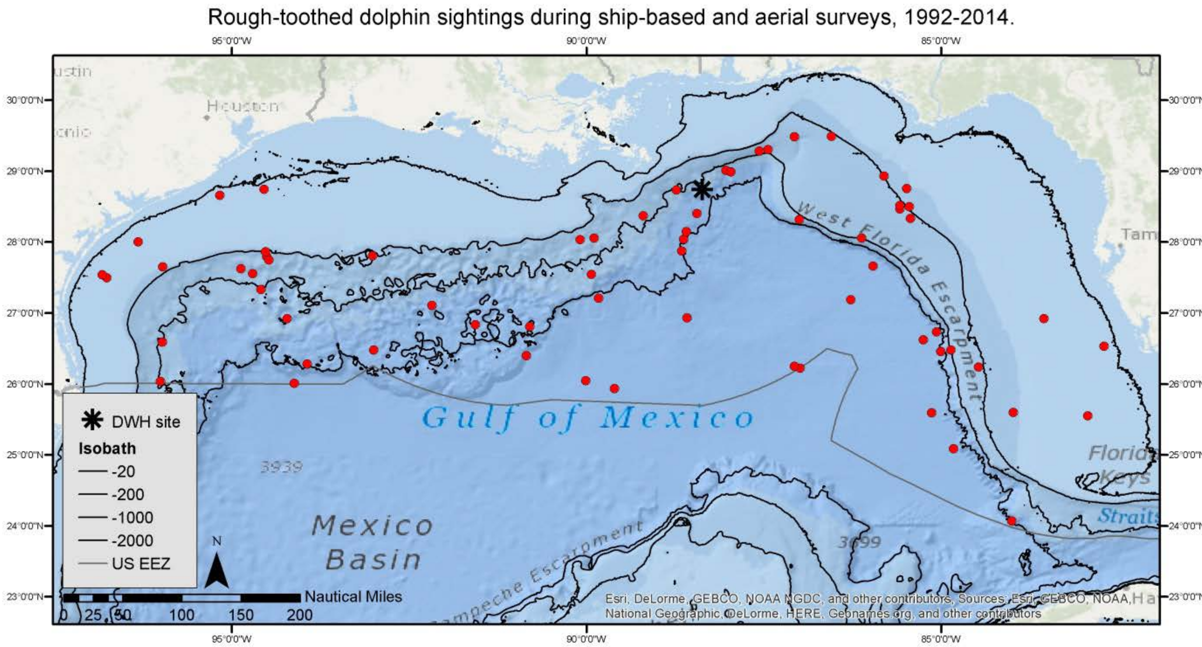


Figure 6: Sightings distribution of rough-toothed dolphins, SEFSC data, 1992-2014.

Common bottlenose dolphins are recorded throughout the continental shelf and shelf-break waters of the Gulf (Figure 7). Currently two genetically distinct ecotypes of common bottlenose dolphins are recognized: 1- coastal, inhabiting inshore waters (bays, sounds and estuaries) as well as from the shoreline to the 20 m isobath and continental shelf and, 2- offshore, which occurs mainly along the 200 m isobath and in deeper waters of the Gulf (Vollmer 2011).

The common bottlenose dolphin is the only species that is currently divided into multiple stocks in the Gulf. In total, 37 stocks are currently delimited in the northern Gulf across four major habitat types: 1- oceanic, 2- shelf, 3- coastal and 4- BSE (bay, sound and estuary). The oceanic stock is found throughout the Gulf, in waters deeper than 200m and consists of the offshore ecotype. The continental shelf stock is distributed Gulf-wide in waters between 20 m and 200 m deep, and probably consists of a mixture of both the coastal and offshore ecotypes. The coastal and BSE stocks are delineated in coastal waters between the shoreline and the 20 m isobath and in estuarine waters (Waring et al., 2012); this latter stock is not included in this report.

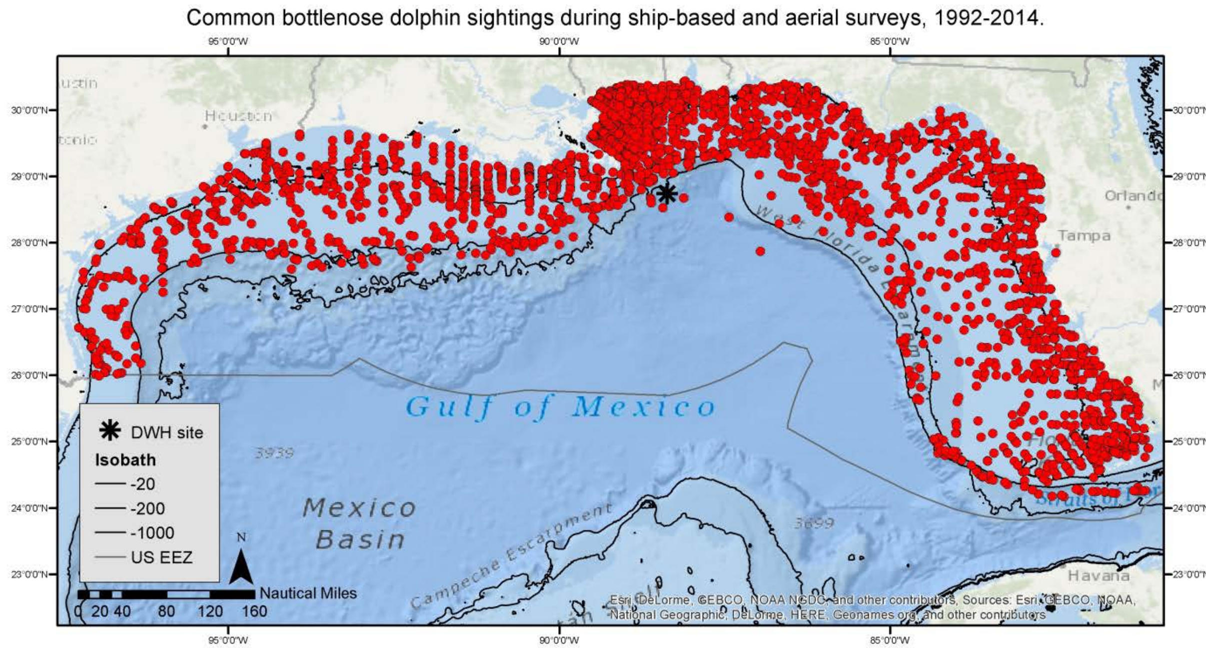


Figure 7: Sightings distribution of common bottlenose dolphins, SEFSC data, 1992-2014.

Bryde's whales are the only mysticete species known to regularly inhabit Gulf of Mexico waters. Their distribution is restricted to the northeast region of the Gulf, roughly between the 180 m and 360 m isobaths in the De Soto Canyon region (Mullin and Fulling, 2004; Maze-Foley and Mullin, 2006). Between 1992 and 2012 there was only one sighting of a balaenopterid west of the Mississippi River Delta (Figure 8).

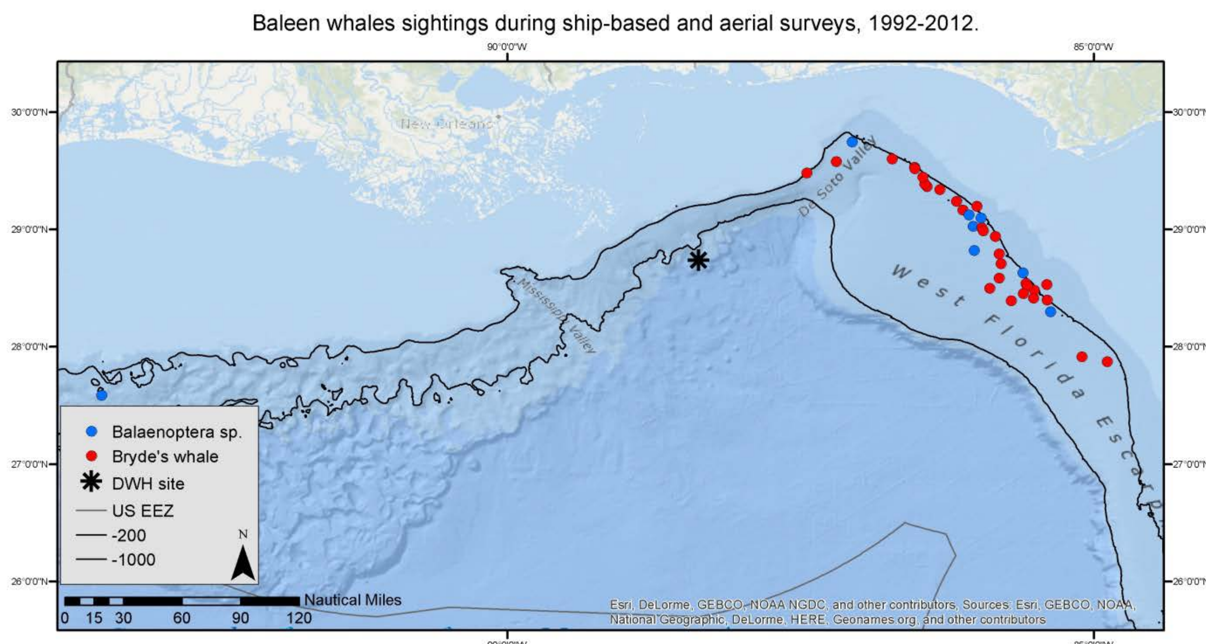


Figure 8: Sightings distribution of Bryde's whales, SEFSC data, 1992-2012.

4.2. Oceanic Species

Short-finned pilot whales and Risso’s dolphins inhabit areas of the upper continental slope of the Gulf. Sightings of short-finned pilot whales are primarily located west of the Mississippi River Delta, between 500 m and 2000 m water-depths (Maze-Foley and Mullin, 2006) (Figure 9).

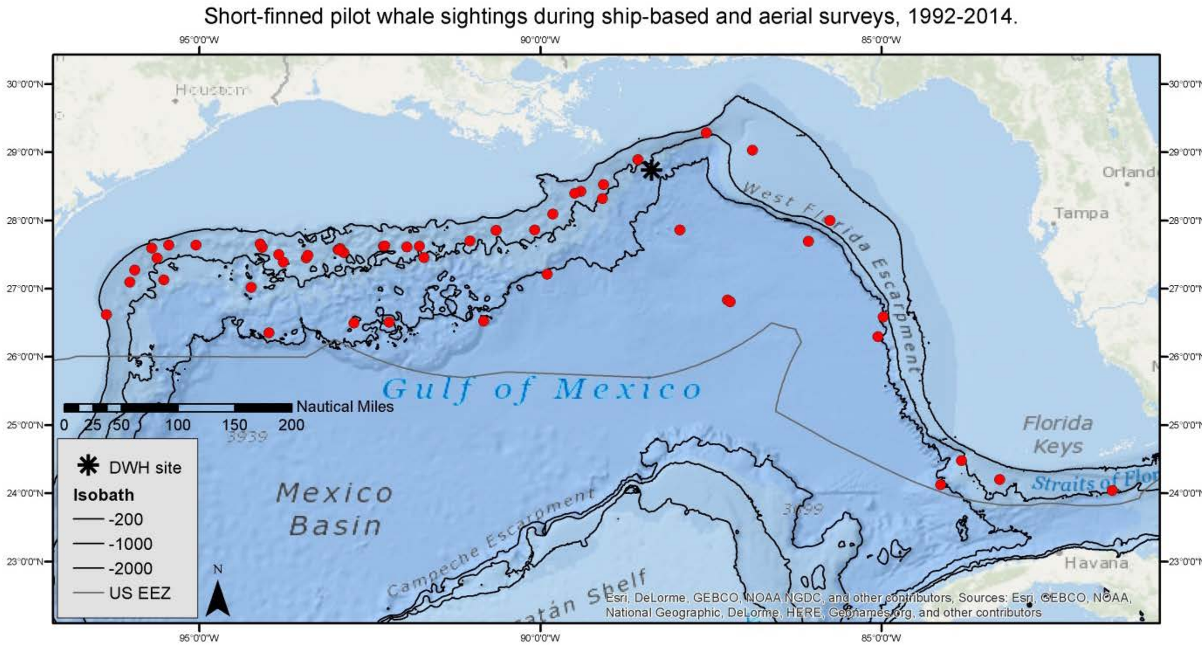


Figure 9: Sightings distribution of short-finned pilot whales, SEFSC data, 1992-2014.

Risso’s dolphins are deep water species, usually found in narrow core habitats between the 350 m and 975 m isobaths where steep water depth-gradients are present (Baumgartner, 1997). Sightings are seen throughout the Gulf but with two core areas: 1- Mississippi River Delta and, 2- along the Florida Escarpment off the west coast of Florida as identified by Baumgartner (1997) (Figure 10). According to Baumgartner (1997), sighting rates within these regions are five and six times higher than the average rates for ship and aerial-based surveys, respectively.

Risso's dolphin sightings during ship-based and aerial surveys, 1992-2014.

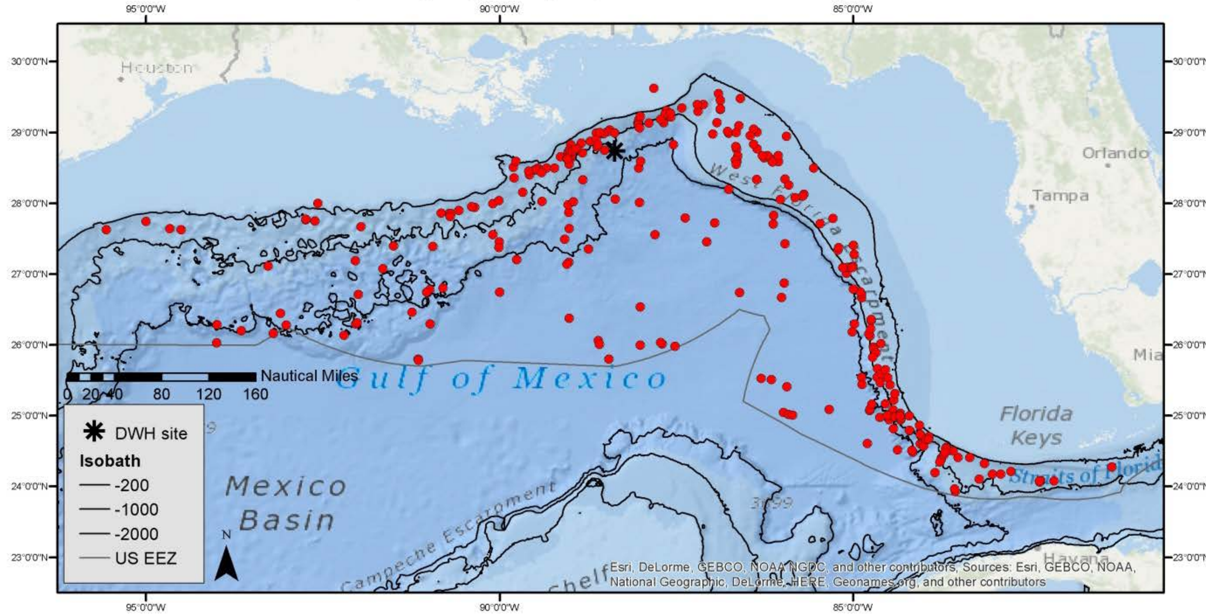


Figure 10: Sightings distribution of Risso's dolphins, SEFSC data, 1992-2014.

Similarly to Risso's dolphins, spinner and striped dolphins tend to occur in waters with the steepest bottom-depth gradients (Davis et al., 1998). Sightings of spinner dolphins primarily occur east of the Mississippi River Delta along the Florida Escarpment. Sightings of striped dolphins are also primarily observed in the eastern Gulf, but have a wider distribution pattern and occupy deeper waters of the Gulf (Maze-Foley and Mullin, 2006)(Figure 11).

Spinner and Striped dolphins sightings during ship-based and aerial surveys, 1992-2014.

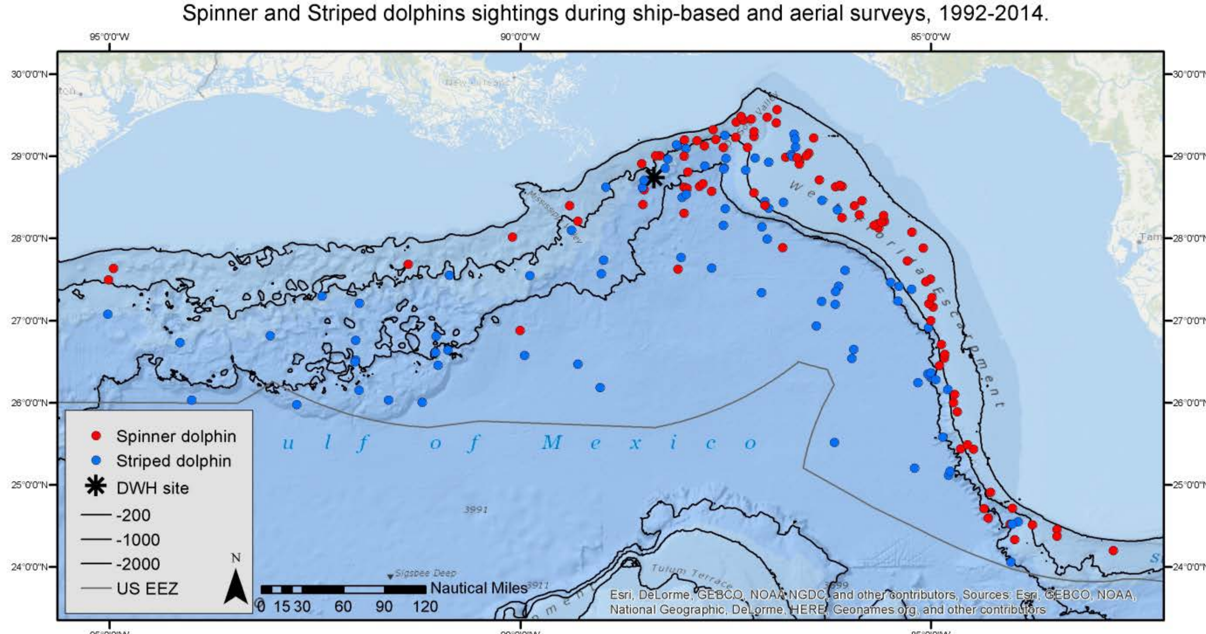


Figure 11: Sightings distribution of spinner and striped dolphins, SEFSC data, 1992-2014.

Sperm whales are widely distributed in the oceanic waters of the Gulf, usually along and deeper than the 1000 m isobath (Figure 12). Two regions show high rates of encounters: 1- Mississippi Canyon just seaward of the Mississippi River Delta and 2- Florida Escarpment between Tampa and Key West (including the Dry Tortugas area) (Baumgartner et al., 2001; Mullin and Fulling, 2004; Maze-Foley and Mullin, 2006). Satellite tagging of whales along the 1000 m isobath, between Mississippi and De Soto canyons showed no discernible seasonal migrations and a high degree of site-fidelity and year-round usage of the Gulf, primarily by females (Jochens et al., 2008). In addition, tracking of movements of immature males had great variability, which suggested that males have larger individual home ranges and used deeper waters than females, which are rarely documented in waters deeper than 2000 m. Furthermore, males tended to occur in deeper waters than females, exhibiting a significant difference of nearly 300 m between the median bottom depth of 1171 m for males and 884 m for females (thus females are frequently located at the upper slope, but also at areas of increased depth-gradients) (Jochens et al., 2008).

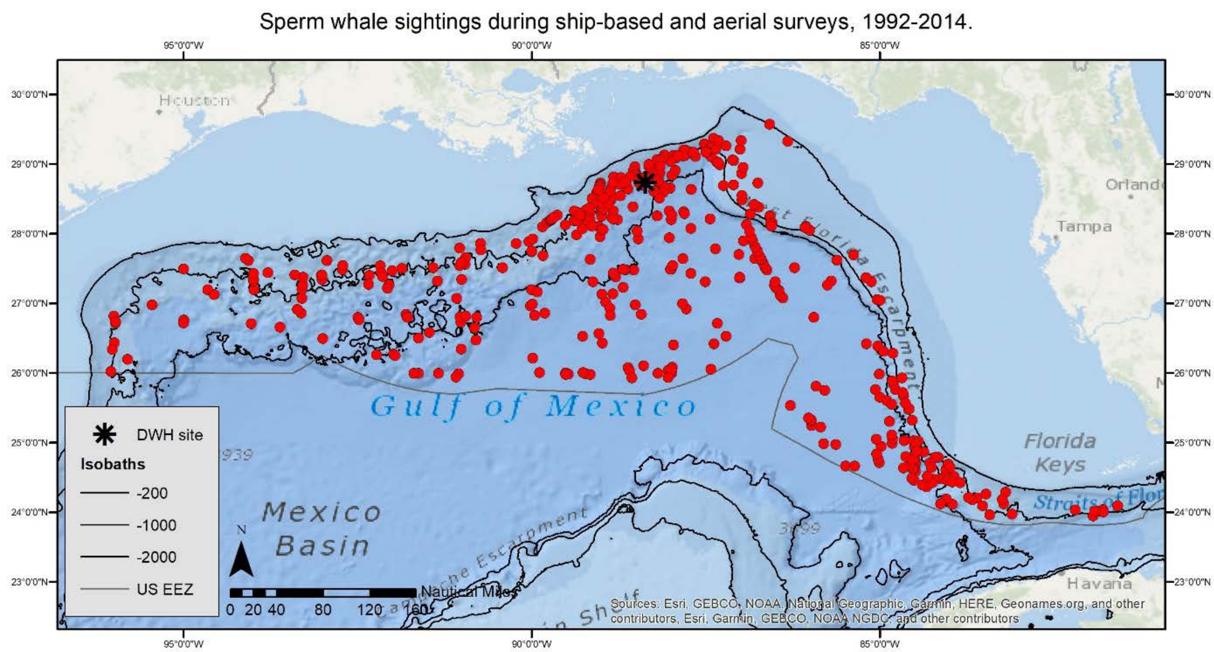


Figure 12: Sightings distribution of sperm whales, SEFSC data, 1992-2014

Sightings of dwarf and pygmy sperm whales (*Kogia* spp.) are widely distributed in the oceanic waters of the Gulf (Maze-Foley and Mullin, 2006) (Figure 13). However, an analysis of their occurrence in relationship to physical and biological features found that sightings rates are 2.5 times higher in the upper continental slope when compared to the Gulf-wide average. This increased density was associated with increased zooplankton biomass (Baumgartner et al., 2001).

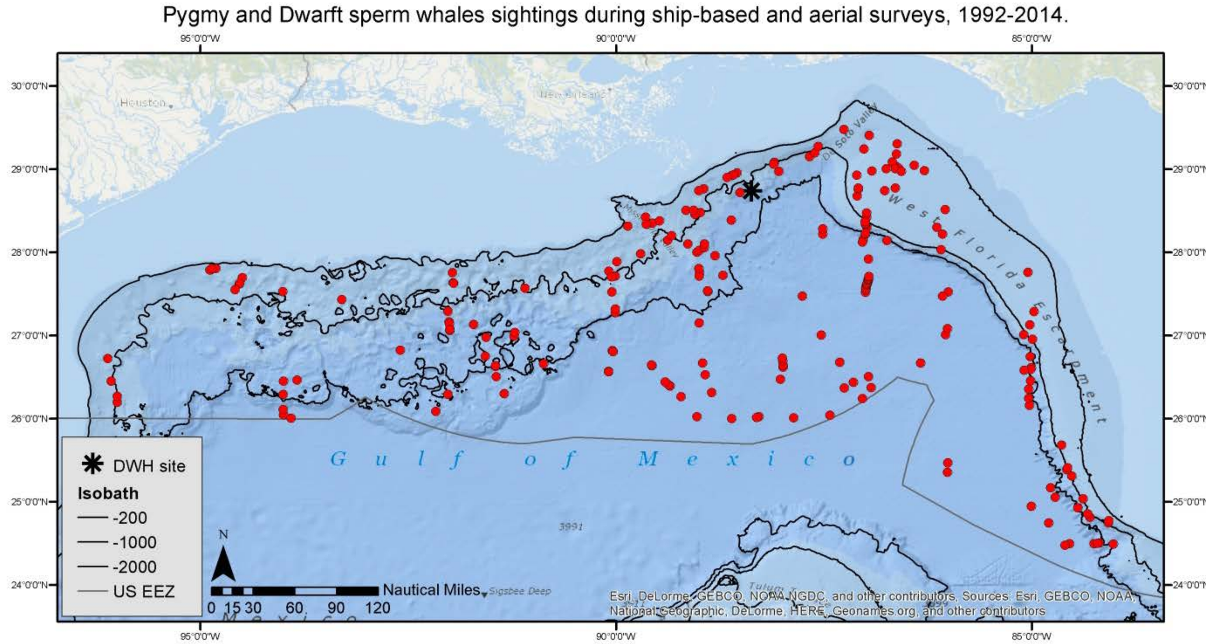


Figure 13: Sightings distribution of pygmy and dwarf sperm whales, SEFSC data, 1992-2014.

Pantropical spotted dolphins are the most common and abundant species in the oceanic Gulf and are widely distributed in waters deeper than 1000 m (Maze-Foley and Mullin, 2006) (Figure 11). Baumgartner et al., (2001) found that, even though widely distributed along the slope and abyssal waters of the Gulf, pantropical spotted dolphins reach a maximum sighting rate just east of the Mississippi River Delta and south of Mobile Bay, AL. In addition, even though no significant correlation was found between the high use of these two areas and environmental characteristics analyzed during the study, depth may influence the distribution of this species in the oceanic waters of the Gulf (Baumgartner et al., 2001).

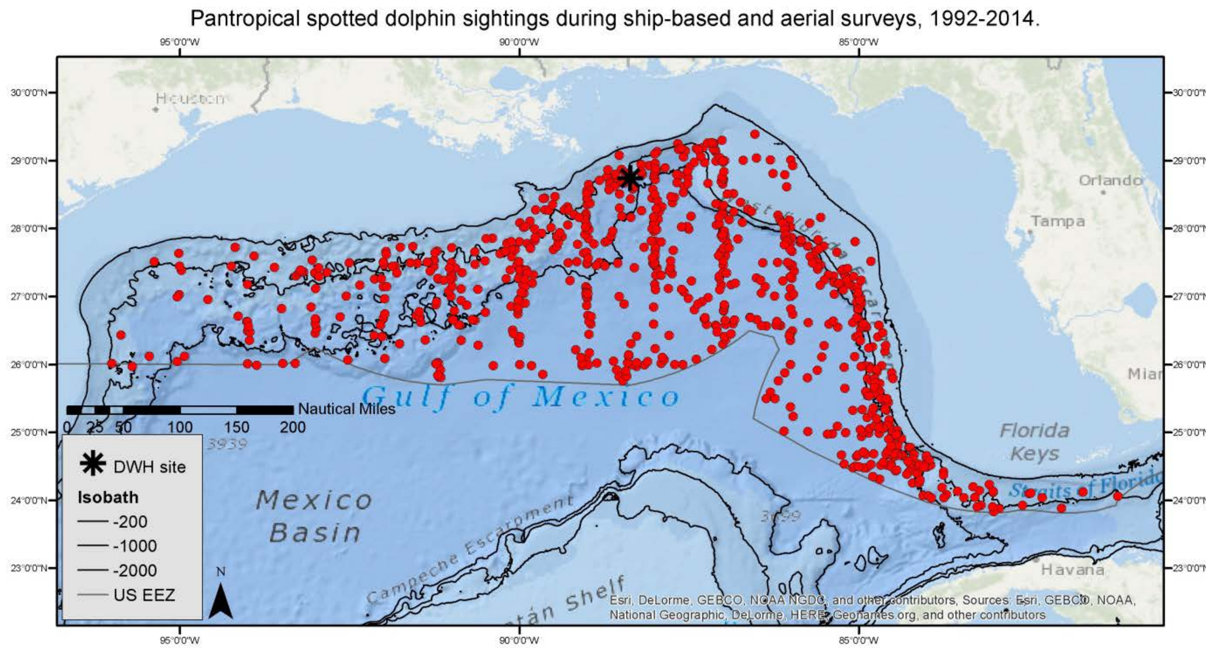


Figure 14: Sightings distribution of pantropical spotted dolphins, SEFSC data, 1992-2014.

Other deep water cetaceans include beaked whales (*Mesoplodon* spp. and unidentified ziphiids), which show an overall uniform distribution in slope waters deeper than 1000 m (Davis et al., 1998; Maze-Foley and Mullin, 2006) (Figure 15). Like *Kogia* species, beaked whales are highly cryptic and difficult to identify at sea, therefore most sightings are usually classified as unidentified ziphiids or *Mesoplodon* spp.

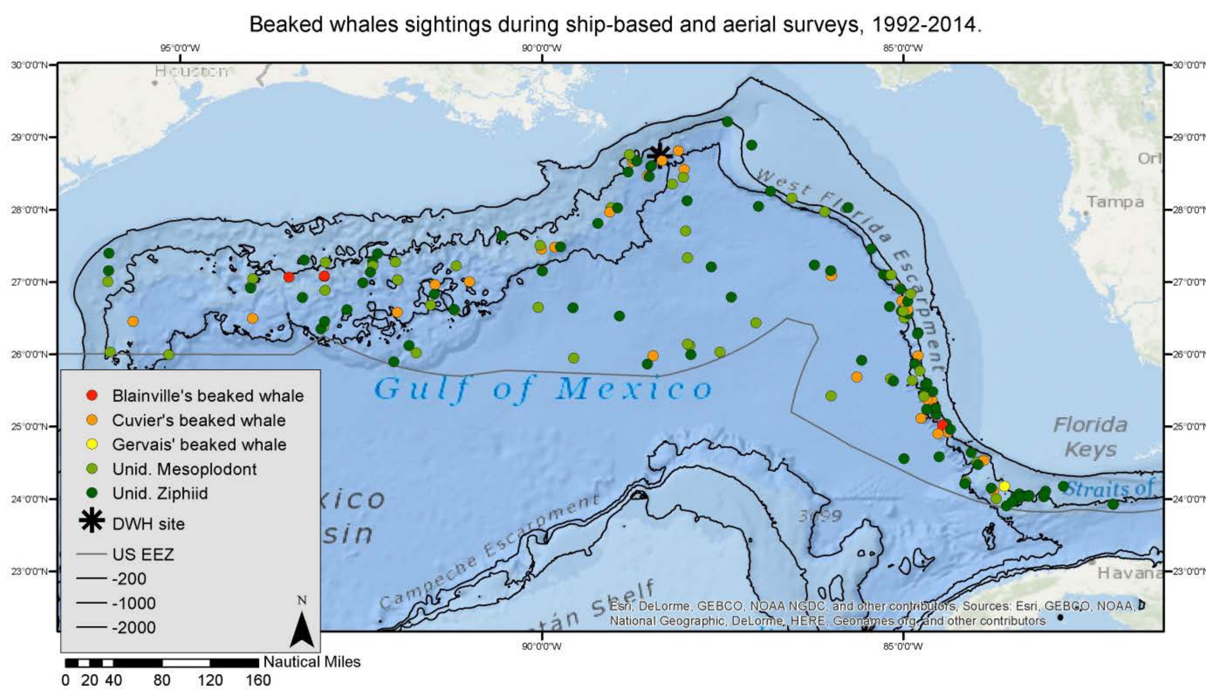


Figure 15: Sightings distribution of beaked whales, SEFSC data, 1992-2014.

Sightings of Clymene dolphins are mostly distributed in the deep waters of western Gulf (Davis et al., 1998; Maze-Foley and Mullin, 2006). Fraser's dolphin sightings show varied distribution in the deep Gulf (Maze-Foley and Mullin, 2006) but since sightings are so rare it is difficult to establish a main area of occurrence (Figure 16).

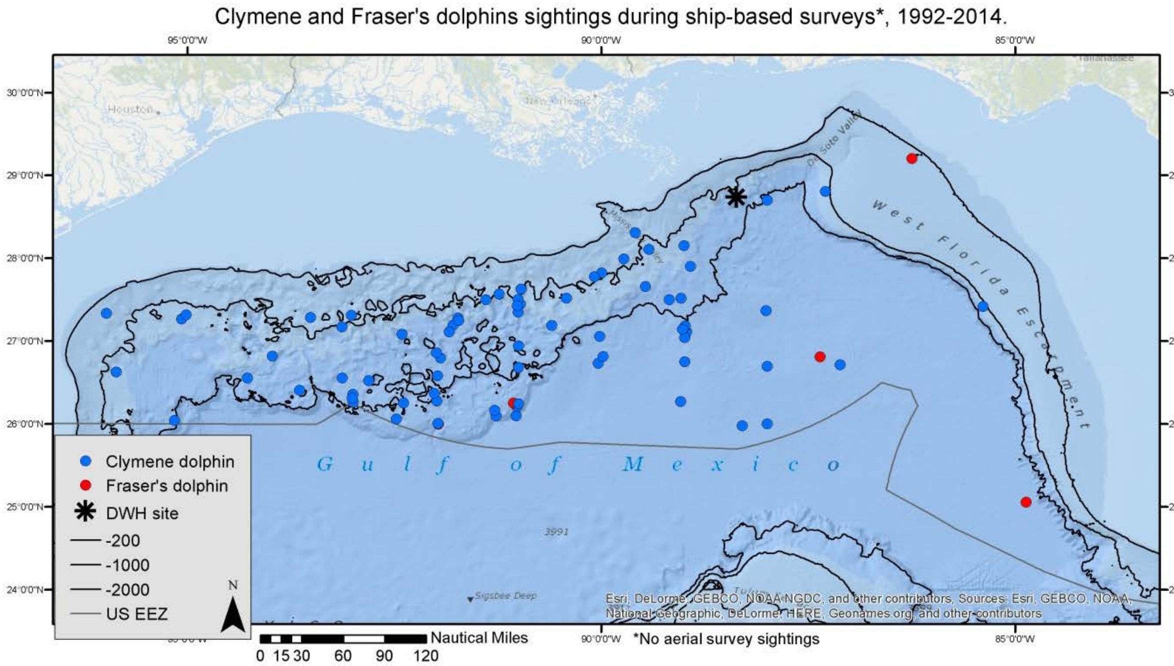


Figure 16: Sightings distribution of Clymene and Fraser's dolphins, SEFSC data, 1992-2014.

Melon-headed whales, false killer whales, and pygmy killer whales are rarely observed during cetacean surveys. With the data that are available, melon-headed whale sightings are mostly seen in the western waters of the Gulf along the 1000 m isobath while false killer and pygmy killer whales sightings occur primarily in the deep waters of the eastern Gulf (Maze-Foley and Mullin, 2006) (Figure 17).

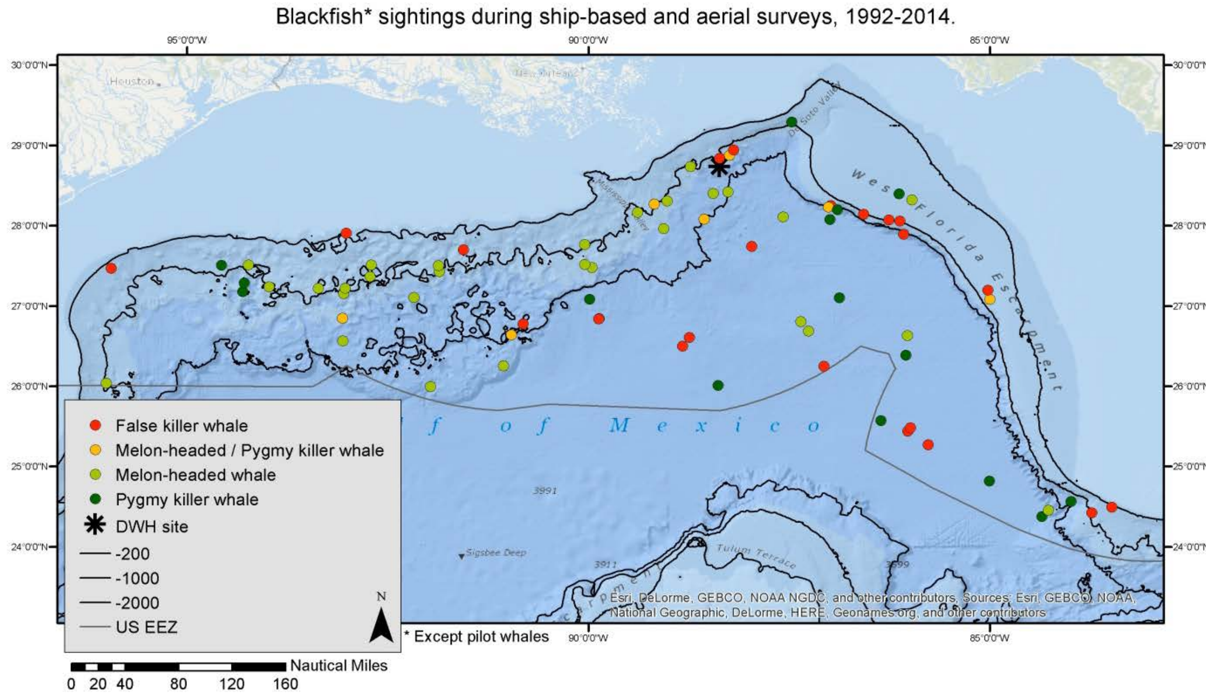


Figure 17: Sightings distribution of blackfish (*melon-headed, false killer and pygmy killer whales), SEFSC data, 1992-2014.

Sightings of killer whales are extremely rare. When observed, killer whales occur primarily west of the Mississippi River Delta in waters deeper than 700 m (Maze-Foley and Mullin, 2006) (Figure 18).

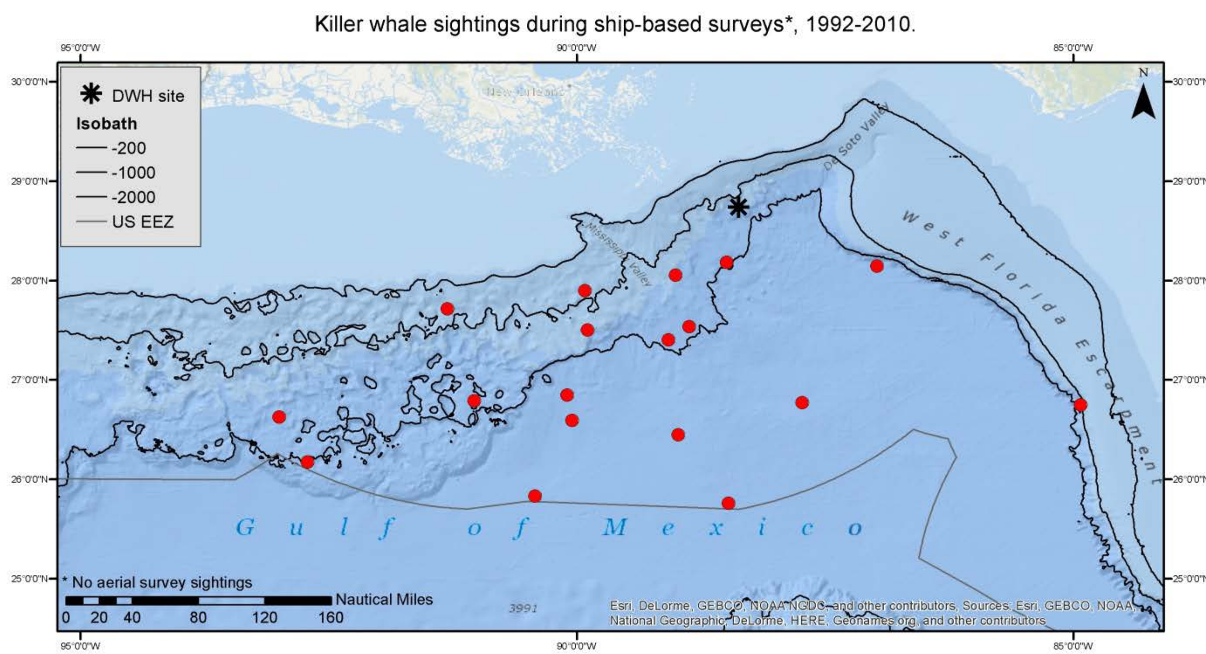


Figure 18: Sightings distribution of killer whales, SEFSC data, 1992-2010.

5. Cetacean Abundance and Density

5.1. Published Abundance and Density Estimates

Pantropical spotted dolphins are the most commonly sighted and abundant species in the Gulf (Table 5), comprising nearly 63% of all cetaceans encountered (Mullin and Fulling, 2004). This was the only species for which Mullin and Fulling (2004) detected a large number of groups during each survey year, therefore allowing for a more precise estimate of abundance compared to other species. However, the estimated abundance for this species is highly variable throughout time and there are large inter-survey differences; these differences are likely due to both sampling and oceanographic variability (Mullin and Fulling, 2004; Mullin, 2007).

Clymene, spinner, and striped dolphins are somewhat frequently observed and their high abundance estimates are due to large group sizes observed (Table 5, Mullin et al., 2004; Maze-Foley and Mullin, 2006). For Atlantic spotted dolphins, Fulling et al. (2003) estimated their abundance numbers at 30,772 (CV = 0.27) for the outer continental shelf (Table 6.); Atlantic spotted dolphins are rarely observed in waters deeper than 200 m (Mullin et al., 2004; Mullin and Fulling, 2004; Maze-Foley and Mullin, 2006).

Melon-headed whales, false killer whales, and short-finned pilot whales are observed less frequently; however, they still have moderately large abundance estimates. Their abundance estimates are primarily due to the large number of individuals observed during the few sightings recorded. This is especially the case for melon-headed whales, which average group sizes in the hundreds of animals, while false killer and short-finned pilot whales average group sizes between 20 and 27 whales (Mullin et al., 2004; Maze-Foley and Mullin, 2006).

Rough-toothed dolphins are widely distributed and occur over both continental shelf and oceanic waters. Three sightings along the outer continental shelf yielded an abundance estimate of 1,238 (CV = 0.65) dolphins during the Fulling et al. (2003) study (Table 6). The majority of sightings however, occur in deeper waters resulting in abundance estimates of 985 (CV = 0.44) and 1,508 (CV = 0.59) animals (Mullin and Fulling, 2004 and Mullin, 2007, respectively).

Risso's dolphins are commonly observed during cetacean surveys in the Gulf and are widely distributed with evidence of occupying core regions based on water depth and steep bottom depth gradient (Baumgartner, 1997; Davis et al., 1998; Mullin and Fulling, 2004; Maze-Foley and Mullin, 2006; Mullin, 2007). They are relatively abundant in the Gulf, with estimates ranging from 1,237 (CV = 0.28) to 2,169 (CV = 0.32) dolphins (Table 5) (Mullin et al., 2004; Mullin and Fulling, 2004; Mullin, 2007). Mullin et al. (2004) found evidence of seasonal variation in the abundance of Risso's dolphins in the Gulf, with the lowest estimates during the fall; however, poor precision of estimates provided little power to detect significant seasonal differences.

Dwarf and pygmy sperm whales (*Kogia* spp.) are commonly seen and widely distributed in the slope waters of the Gulf. Similar to Risso's dolphins, a weak seasonal variation in the abundance of *Kogia* spp. was found by Mullin et al. (2004), with greatest numbers in the summer and spring. Current abundance estimate numbers are under 1,000 whales present in the Gulf; however, this number may be considerably underestimated due to the cryptic behavior of these species and difficulty of detection in less than ideal sea conditions (Beaufort sea state greater than one).

Bryde's and sperm whales are the only large whales regularly seen in the Gulf (Mullin and Fulling, 2004; Mullin et al., 2004; Mullin, 2007). Bryde's whales constitute a small and genetically isolated population restricted to the northeastern shelf-edge in the De Soto Canyon area; they occupy a very narrow water depth range and are present year-round in the Gulf (Maze-Foley and Mullin, 2006; Rosel and Wilcox 2014). Available abundance estimates are less than 40 animals in the Gulf (Waring et al., 2012).

For sperm whales, genetic analysis (Engelhaupt et al., 2009) as well as movement patterns documented by Jochens et al. (2008) indicated that the population in the Gulf is fairly isolated from other populations around the globe. Jochens et al. (2008) data suggest a core population size of 140 individuals in the central northern Gulf (in the Mississippi River Delta), of which 88 animals were females. Gulf-wide (within US waters), the sperm whale population is estimated at 1,665 (CV = 0.20) individuals based on the surveys conducted in 2003 and 2004 (Mullin, 2007).

Table 5: Abundance estimates from ship-board surveys in waters deeper than 200 m in the U.S. EEZ. Mullin et al. 2004 included aerial surveys conducted during 1992-1994, Mullin and Fulling 2004 included ship surveys from 1996-2001, and Mullin 2007 included ship surveys from 2003-2004. Comparisons between aerial and vessel surveys should be made with caution due to differences in detection probability between the platforms.

Species	**Number of individuals / CV – aerial survey during 1992-1994** (Mullin et al., 2004)	**Number of individuals / CV – ship-based survey during 1996-2001** (Mullin and Fulling, 2004)	**Number of individuals / CV – ship-based surveys during 2003 and 2004** (Mullin, 2007)
Common bottlenose dolphin (oceanic stock)	2,890 / 0.20	2,239 / 0.41	3,708 / 0.42
Bryde's whale	2 / 1.08	40 / 0.61	15 / 1.98
Clymene dolphin	479 / 0.44	17,355 / 0.65	6,575 / 0.36
Cuvier's beaked whale	11 / 0.71	95 / 0.47	65 / 0.67
False killer whale	167 / 0.72	1,038 / 0.71	777 / 0.56
Fraser's dolphin	146 / 1.00	726 / 0.70	127 / 0.89
Killer whale	NA	133 / 0.49	49 / 0.77
Kogia spp.	176 / 0.31	742 / 0.29	453 / 0.35

Species	Number of individuals / CV – aerial survey during 1992-1994 (Mullin et al., 2004)	Number of individuals / CV – ship-based survey during 1996-2001 (Mullin and Fulling, 2004)	Number of individuals / CV – ship-based surveys during 2003 and 2004 (Mullin, 2007)
Melon-headed whale	2,561 / 0.74	3,451 / 0.55	2,283 / 0.76
Mesoplodon spp.*	52 / 0.30	106 / 0.41	57 / 1.40
Pantropical spotted dolphin	5,097 / 0.24	91,321 / 0.16	34,067 / 0.18
Short-finned pilot whale	684 / 0.48	2,388 / 0.48	716 / 0.34
Pygmy killer whale	NA	408 / 0.60	323 / 0.60
Risso's dolphin	1,237 / 0.28	2,169 / 0.32	1,589 / 0.27
Rough-toothed dolphin	237 / 0.59	985 / 0.44	1,508 / 0.39
Sperm whale	87 / 0.27	1,349 / 0.23	1,665 / 0.20
Spinner dolphin	1,000 / 0.66	11,971 / 0.71	1,989 / 0.48
Stenella spp.	624 / 0.51	643 / 0.58	1,564 / 0.60
Striped dolphin	863 / 0.60	6,505 / 0.43	3,325 / 0.48
Unid. Ziphiid	71 / 0.53	146 / 0.46	337 / 0.40

* *Mesoplodon* spp. include: Blainville's (*M. densirostris*) and Gervais' (*M. europaeus*) beaked whales.

Table 6: Abundance from shipboard surveys in continental shelf waters (waters between 20m and 200m deep in the U.S. EEZ). Fulling et al. (2003) includes vessel surveys conducted in 2000-2001.

Species	Number of individuals / CV – shelf (Fulling et al., 2003)
Atlantic spotted dolphin	30,772 / 0.27
Common bottlenose dolphin (shelf stock)	25,320 / 0.26
Rough-toothed dolphin	1,238 / 0.65

Mullin (2007) estimated the density of cetaceans in the oceanic northern Gulf using data collected during ship-based surveys in 2003 and 2004 (Table 7). Even though commonly sighted and widely distributed, Risso's, common bottlenose, and pantropical spotted dolphins showed high regional densities at specific areas. At the northeastern portion of the Gulf (slope waters south of the Florida Panhandle), Risso's and common bottlenose dolphins showed the highest densities of 12.9 animals/1000 km^2 and 50.3 animals/1000 km^2, respectively. Pantropical spotted dolphins showed the highest density of 100.1 animals/1000 km^2 in abyssal waters (Table 7). Similarly, although not frequently sighted, other species showed regional densities: false killer whales in abyssal waters, melon-headed whales in the NW Gulf, spinner and striped dolphins in the northeastern Gulf and Clymene dolphin in the northwestern Gulf.

Table 7: Cetacean density estimates from ship-based surveys in oceanic waters (waters deeper than 200m in the U.S. EEZ). Mullin and Fulling 2004 included ship surveys from 1996-2001 and Mullin 2007 included ship surveys from 2003-2004.

Species	**Average density (animals/1000 km²) – Gulf-wide**		**Regional density (animals/1000 km²) / main area of occurrence**	
	Mullin and Fulling, 2004	Mullin, 2007	Mullin and Fulling, 2004	Mullin, 2007
Bottlenose dolphin	5.9	9.7	29.4 / NE	50.3 / NE
Bryde's whale	0.1	< 0.1	0.6 / NE	0.2 / NE
Clymene dolphin	45.6	17.3	58.3 / AB	32.9 / NW
Cuvier's beaked whale	0.2	0.2	NA	0.5 / NW*
False killer whale	2.7	2.0	5.3 / NE	3.5 / AB
Fraser's dolphin	1.9	NA	11.2 / NE	NA
Killer whale	0.3	0.1	0.5 / AB	0.3 / AB*
Kogia spp.	2.0	1.2	2.1 / AB	1.6 / AB
Melon-headed whale	9.1	4.0	26.7 / NW	18.8 / NE
Mesoplodon spp.	0.3	0.1	0.5 / NW	0.2 / AB and NE
Pantropical spotted	240.0	89.5	298.3 / AB	100.1 / AB
Short-finned pilot whale	6.3	1.9	18.5 / NW	3.2 / NW
Pygmy killer whale	1.1	0.8	2.2 / AB*	1.8 / NE
Risso's dolphin	5.7	4.2	8.5 / NE	12.9 / NE
Rough-toothed dolphin	2.6	4.0	2.4 / NE	4.0 / NW
Sperm whale	3.5	4.4	4.3 / NW	6.0 / NW
Spinner dolphin	31.5	5.2	173.0 / NE	17.0 / NE
Stenella spp.	1.7	4.1	1.9 / AB	7.8 / NW
Striped dolphin	17.1	8.7	25.1 / NW	22.7 / NE
Unid. Ziphiid	0.4	1.0	0.7 / AB	2.0 / NW

* Not recorded in other areas.

NE: northeast slope, 200-2000m, -88°30.0'W to -83°55.0'W; NW: northwest slope, 200-2000m, west of -88°30.0'W; AB: abyssal, water deeper than 2000m out to the US EEZ.

For species recorded on the continental shelf, Atlantic spotted, common bottlenose and rough-toothed dolphins, density estimates are shown on Table 8.

Table 8: Cetacean density estimates from ship-based surveys in continental shelf (waters between 20m and 200m deep). Fulling et al. 2003 includes ship surveys conducted in 2000-2001.

Species	**Average density (animals/1000 km²)–shelf** (Fulling et al., 2003)	**Regional density (animals/1000 km²) / main area of occurrence** (Fulling et al., 2003)
Atlantic spotted dolphin	125.0	109.0 / NE
Bottlenose dolphin	103.0	201.0 / NE
Rough-toothed dolphin	5.0	6.0 / NW

NE: northeast slope, 200-2000m, -88°30.0'W to -83°55.0'W; NW: northwest slope, 200-2000m, west of -88°30.0'W;

5.2. Updated Density and Abundance Estimates

5.2.1. Passive Acoustic Density Estimates

Hildebrand et al. (2012) used passive acoustic monitoring to estimate the density of cetaceans in the Gulf during and after the Deepwater Horizon Oil Spill event (from May 2010 to September 2011). High-frequency Acoustic Recording Packages (HARPs) were deployed in four different sites, along the continental shelf (Main Pass and De Soto Canyon) and slope waters (Green and Mississippi canyons and Dry Tortugas). No strong seasonal variations were found in the detection rates of the different cetacean species studied, although the data set lacked complete seasonal coverage in the Dry Tortugas site (Hildebrand et al., 2012).

Sperm whales showed the highest density estimate in the Mississippi Canyon (12.1 animals/1000km^2), followed by Green Canyon (2.9 animals/1000km^2) and Dry Tortugas (0.6 animals/1000km^2). As expected, no detections were recorded in the shallowest sites (De Soto Canyon and Main Pass) of HARP deployment.

Dwarf and pygmy sperm whales are deep diving foragers, difficult to differentiate at sea; therefore both species are usually grouped under the *Kogia* spp. category. There is little data available for *Kogia* spp. vocal rates in the wild. Hildebrand et al. (2012) found higher detection rates of *Kogia* spp. for HARPs deployed at the Green (28 animals/1000km^2) and Mississippi (18.9 animals/1000km^2) canyons and a lower rate in the Dry Tortugas area (5.9 animals/1000km^2, Table 9).

Beaked whales are rarely observed during aerial and ship-based cetacean surveys and when observed, their identification is difficult usually yielding classifications such as *Mesoplodon* spp. or unidentified ziphiid. These are deep diving and very cryptic cetaceans but they display well defined and documented acoustic signatures, which allow classification to the species-level. Hildebrand et al. (2012) detected Cuvier's and Gervais' beaked whales during the HARPs study in the Gulf. Beaked whales showed a significant higher detection rate in the Dry Tortugas site (13.4 animals/1000km^2) when compared to the Mississippi and Green canyons sites (2.6 animals/1000km^{2}and 1.8 animals/1000km^2, respectively; Table 9).

Table 9: Cetacean density estimates from passive acoustic studies.

Species	**Average density (animals/1000 km^2)**	**Main area of detection**	**Reference**
Sperm whale	12.1 (highest)	Mississippi Canyon	Hildebrand et al., 2012
Kogia spp.	28.0 (highest)	Green Canyon	Hildebrand et al., 2012
Beaked whales	13.4 (highest)	Dry Tortugas	Hildebrand et al., 2012

5.2.2. Visual Surveys Abundance Estimates

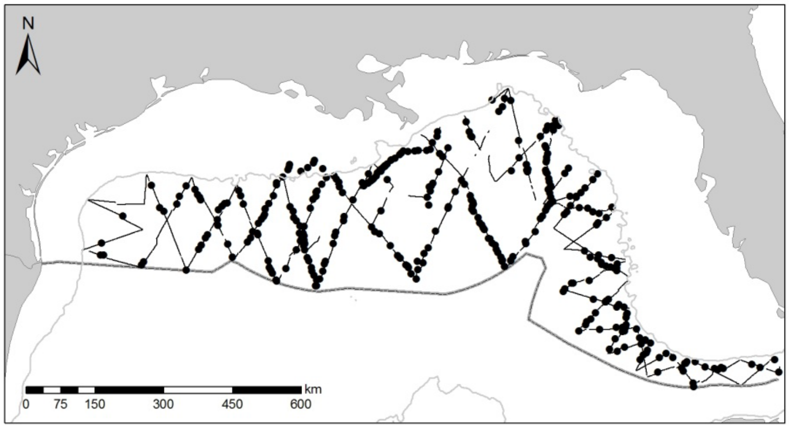
This analysis used visual line transect survey data collected by the SEFSC during three large vessel surveys of the northern Gulf of Mexico conducted during June-August, 2003, April-June, 2004 and June-August, 2009 aboard the NOAA ship *Gordon Gunter* (Tables 10 and 11).

The 2003 and 2004 surveys were previously analyzed in Mullin (2007) and the 2009 survey was the basis of Gulf of Mexico abundance estimates for annual stock assessment reports (Waring et al. 2012). However, there is a high degree of interannual variability in estimated abundance that is associated with underlying variation in both survey conditions and the spatial distribution of the animals. The goal of this analysis is to combine these surveys into a common analytical approach to develop more precise estimates of abundance that reflect longer-term average abundances.

Table 10: Time period and on-effort trackline length during SEFSC large vessel surveys of the northern Gulf.

Survey	Dates	Effort (km)
GU0302	6/14 – 8/17 2003	6,752
GU0402	4/15 – 6/10 2004	6,214
GU0903	6/18 – 8/09 2009	4,233

All surveys followed similar survey procedures and design. Briefly, each survey was conducted along a “double saw-tooth” trackline pattern with tracks oriented to cross roughly perpendicular to bathymetry gradients (Figure 19 A-C). Data were collected by a team of three visual observers stationed on the flying bridge of the vessel. Two of the observers searched the area ahead of the vessel with 25x bigeye binoculars while the third searched with the naked eye or handheld binoculars. Continuous data were recorded on survey effort status and visual conditions (e.g., Beaufort sea state, swell height, visibility, etc.). Upon sighting a cetacean group, the team went “off effort” to either approach the group, or to estimate the number of animals visible within the immediate area of the sighting. The sighting distance was measured based upon reticle marks in the bigeye binoculars. The sighting distance and bearing were converted to the perpendicular sighting distance for the purposes of estimating detection probabilities using Distance analysis (Buckland et al, 2001).



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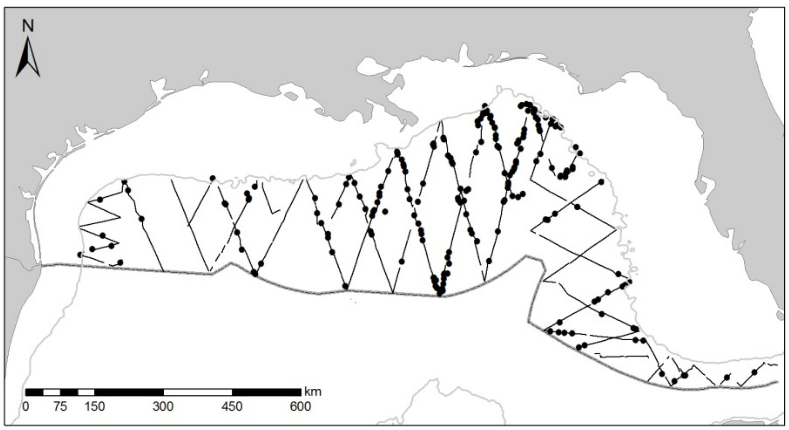

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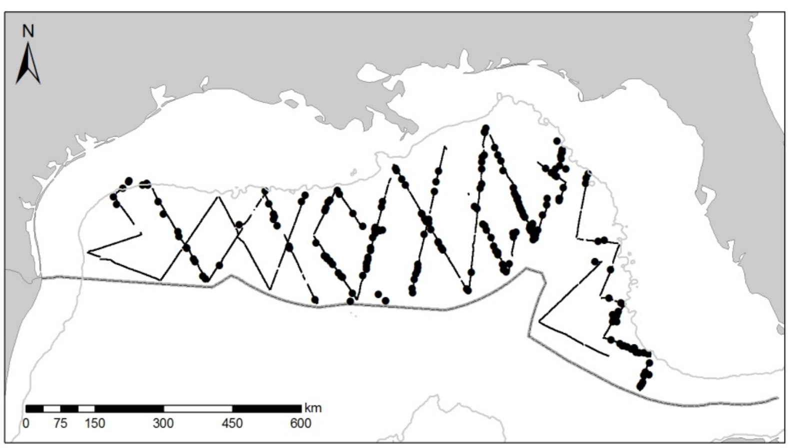

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Figure 19: Tracklines and cetacean group sightings during (A) Summer 2003, (B), Spring 2004 and (C) Summer 2009. The 200m isobath and the US EEZ are indicated.

Table 11: Total groups (sightings) and numbers of individuals observed on effort during SEFSC vessel surveys in 2003, 2004, and 2009. Unidentified odontocetes were not included in any group due to uncertainty in identification. Fraser's dolphins were not sighted during these surveys.

Group	Species	GU0302		GU0402		GU0903	
		Sightings	Number	Sightings	Number	Sightings	Number
Cryptic	Beaked whales	18	52	4	7	5	11
Lg. Whale	Bryde's whale*	0	0	3	5	2	3
Dolphins	Clymene dolphin	11	586	4	418	2	36
NA	Killer Whale**	0	0	1	6	1	2
Sm. Whale	False killer whale	5	108	0	0	1	7
Sm. Whale	Melon-headed whale	2	143	2	128	2	162
Dolphins	Offshore common bottlenose dolphin	23	1328	14	361	13	335
Dolphins	Pantropical spotted dolphin	88	4022	44	2056	41	2477
Sm. Whale	Short-finned pilot whale	10	142	1	45	6	193
Sm. Whale	Pygmy killer whale	3	26	3	36	1	11
Cryptic	Pygmy/Dwarf sperm whales	23	35	4	5	5	5
Dolphins	Risso's dolphin	22	220	7	91	11	174
Dolphins	Rough-toothed dolphin	11	449	0	0	4	113
Lg Whale	Sperm whale	65	162	36	106	36	73
Dolphins	Spinner dolphin	4	359	6	658	4	531
Dolphins	Stenella spp.	9	228	1	30	4	214
Dolphins	Striped dolphin	9	441	8	309	2	86
Dolphins	unid. Dolphin	21	152	19	107	17	178
Lg Whale	unid. Large Whale	3	6	2	3	2	2
NA	unid. Odontocete	14	23	8	19	15	34
Sm. Whale	unid. Small Whale	8	24	3	4	0	0

***** Bryde's whale abundance estimates were derived using additional survey data
** There were too few sightings of Killer whales to develop an abundance estimate

The probability of detection was modeled within the Distance analysis framework (Buckland et al, 2001) incorporating the effects of covariates on the sighting function. For each sighting, covariates evaluated for the detection model included sea state, swell height, and horizontal visibility. Sequential deletion of terms and Akaike's Information Criterion (AIC) were used to select the most parsimonious model for the detection function. Detection probability models were fit separately for each survey, and different covariates were selected. Detection functions were fit to data from groups of species with similar sizes and behaviors: large whales (primarily sperm whales), small whales, oceanic dolphins, and cryptic species (Table 11). The resulting detection functions do not correct for the assumption that all animals on the trackline are detected. Hence, the resulting detection probabilities (Table 12) are over-estimated and density is underestimated.

Table 12: Average detection probabilities with coefficient of variation (CV) and model goodness of fit (GOF) tests for selected detection probability models. Models with significant GOF tests, indicating poor model fit are highlighted in bold.

Species Group	**Average Detection Probability (CV)**	**Goodess of Fit (Chi-square) P-Value**	**Covariates Included**
Summer 2003			
Large Whales	0.419 (0.141)	0.857	Visibility
Small Whales	0.401 (0.241)	0.218	visibility + swell
Dolphins	0.418 (0.095)	0.406	visibility + seastate + swell
Cryptic	0.363 (0.147)	**0.012**	visibility + seastate + swell
Spring 2004			
Large Whales	0.417 (0.181)	0.210	Visibility
Small Whales	0.420 (0.150)	0.330	None
Dolphins	0.478 (0.059)	**0.001**	None
Cryptic	0.437 (0.300)	0.458	None
Summer 2009			
Large Whales	0.422 (0.224)	0.124	visibility + seastate + swell
Small Whales	0.402 (0.123)	0.164	None
Dolphins	0.470 (0.065)	**0.001**	None
Cryptic	0.204 (0.263)	0.516	None

The estimated detection probabilities ranged from 0.204 to 0.478 (Table 12). Covariates were included in the detection functions for large whales in all cruises; however, covariates were not selected for the other species groups in either the 2004 or the 2009 survey. The goodness of fit tests indicated adequate model fit for most species groups with the exception of cryptic species during the 2003 survey and dolphins during the 2004 and 2009 surveys. In the case of dolphins, the sighting function in both of these surveys had a high peak near the trackline resulting in poor model fit (Figures 20-22).

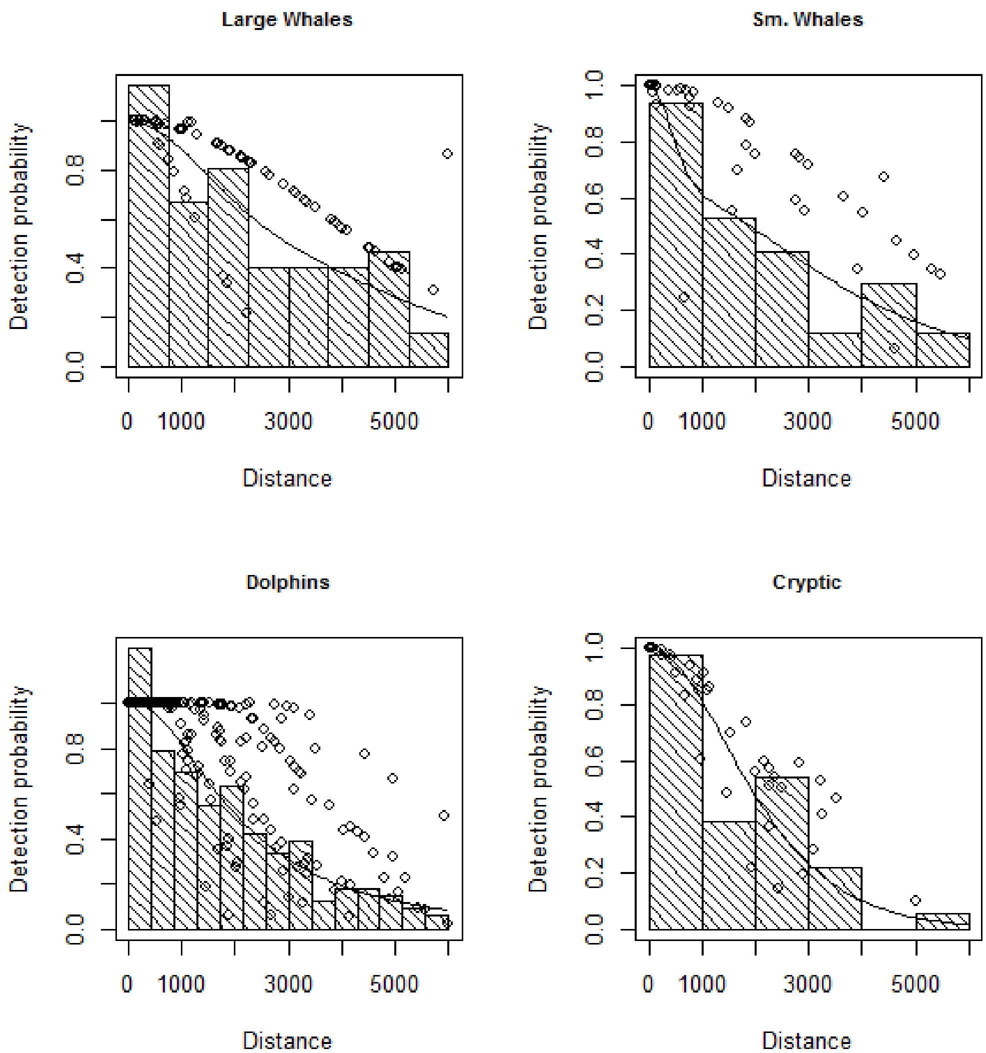

Figure 20: Sighting functions for species groups from the summer 2003 survey. The line indicates the average model fit while the points indicate estimated detection probabilities for different combinations of covariates when included in the model.

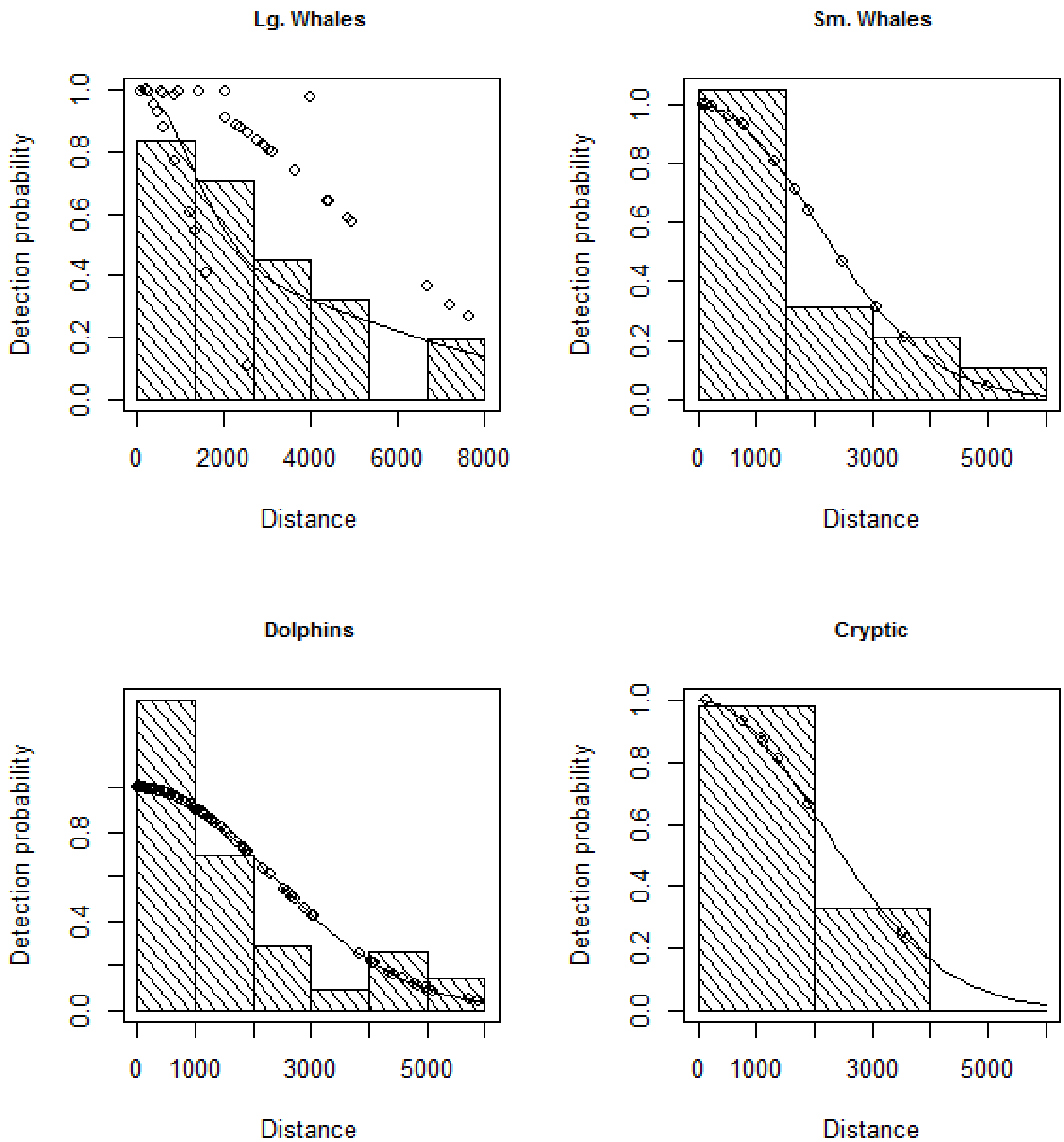

Figure 21: Sighting functions for species groups from the spring 2004 survey. The line indicates the average model fit while the points indicate estimated detection probabilities for different combinations of covariates when included in the model.

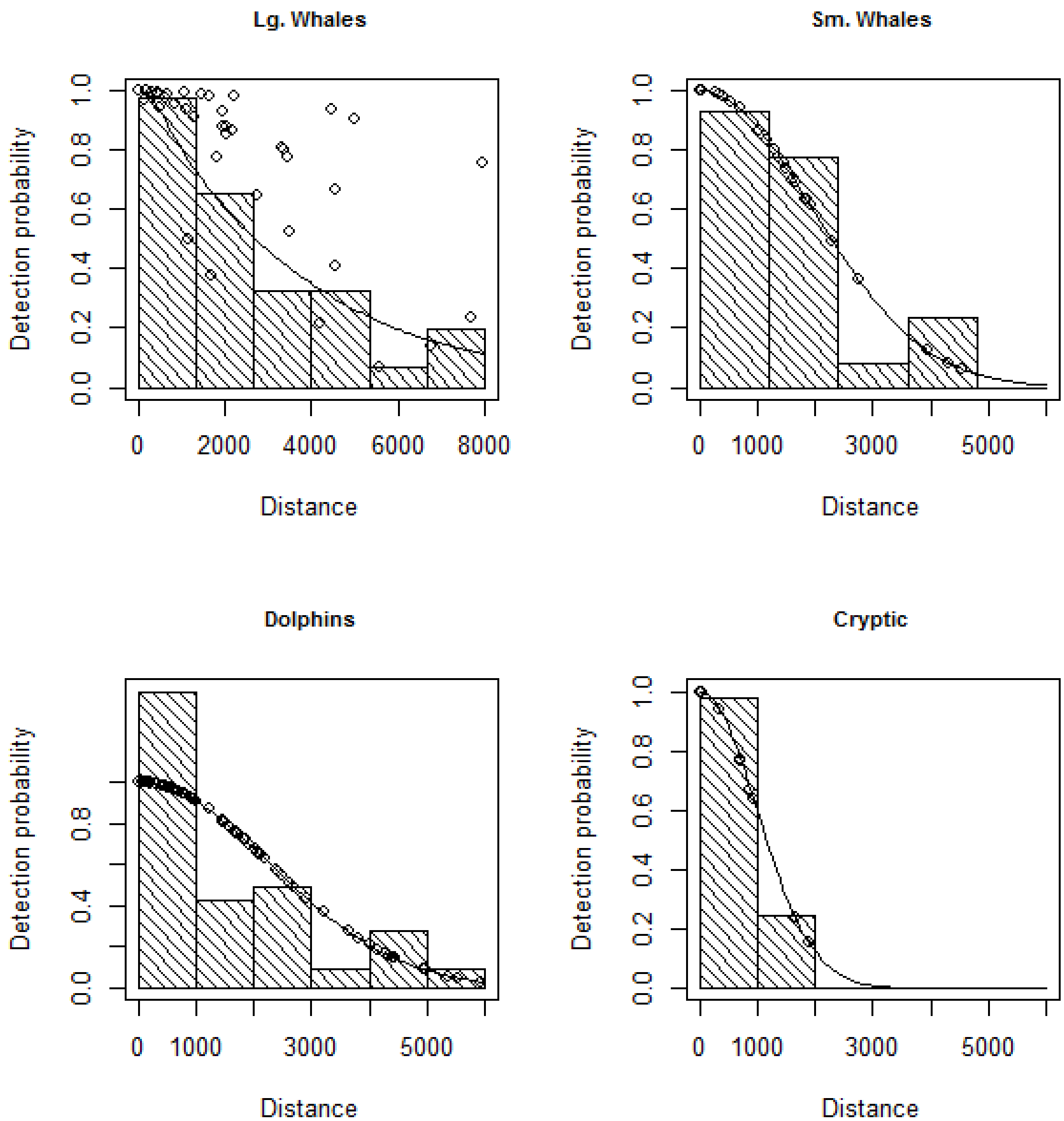

Figure 22: Sighting functions for species groups from the summer 2009 survey. The line indicates the average model fit while the points indicate estimated detection probabilities for different combinations of covariates when included in the model.

The detection probability functions were applied to the species in each group to develop estimates of abundance for each survey and then averaged across years for a final abundance estimate. Resulting abundance estimates are shown in Table 13. Estimates for the cryptic species (beaked whales and pygmy/dwarf sperm whales) are likely to be severely underestimated due to the long dive times of these species. Sperm whale abundance estimates (Table 14) were based upon the sighting functions shown here, however they were developed from a spatially explicit model of sperm whale density, which accounts for the probability of an animal being at the surface based upon dive behaviors (Garrison, unpublished). Abundance estimates for Bryde's whales are discussed in section 5.2.2.1.

Table 13: Abundance estimates for each survey and the average abundance estimates for each species. Fraser's dolphins were not sighted during these surveys and an abundance estimate for Killer whales was not conducted because there were only 2 sightings.

Taxon	Summer 2003		Spring 2004		Summer 2009		Average	
	Abundance	CV	Abundance	CV	Abundance	CV	Abundance	CV
Beaked whales	586	0.39	73	0.68	350	0.59	336	0.31
Clymene dolphin	5158	0.46	4002	0.71	525	0.85	3228	0.39
False killer whale	836	0.57	0	-	113	1.04	316	0.52
Melon-headed whale	953	0.97	1396	0.70	2740	0.72	1696	0.47
Common bottlenose dolphin	17541	0.49	3016	0.35	4845	0.54	8467	0.36
Pantropical Spotted dolphin	44605	0.18	19686	0.29	35854	0.27	33382	0.14
Short-finned pilot whale	1986	0.57	0	-	2937	0.64	1641	0.45
Pygmy killer whale	259	0.65	393	0.56	190	1.03	281	0.40
Pygmy/Dwarf sperm whale	426	0.45	52	0.70	167	0.61	215	0.34
Risso's dolphin	2155	0.30	871	0.46	2517	0.48	1848	0.26
Rough-toothed dolphin	5608	0.61	0	-	1633	0.68	2414	0.49
Spinner dolphin	5873	0.78	6300	0.47	7691	0.56	6621	0.35
Stenella spp.	2482	0.62	287	0.99	2373	0.93	1714	0.53
Striped dolphin	3612	0.42	2959	0.40	1244	0.73	2605	0.27

Table 14: Abundance estimates for each survey for sperm whales. Corrected group size average accounts for the probability of an animal being at the surface based upon dive behaviors (Garrison, unpublished).

Survey	Avg. Group Size corrected (CV)	Estimated Abundance	CV
GU0302	2.8 (0.098)	1,476	0.192
GU0402	3.0 (0.111)	914	0.331
GU0903	2.3 (0.148)	1,053	0.418

5.2.2.1. Bryde's Whale Abundance and Density Estimates

There were insufficient numbers of sightings during the 2003, 2004, and 2009 surveys to estimate the abundance of Bryde's whales. These surveys were designed to sample the entire oceanic northern Gulf, and therefore relatively little effort was expended within the small region where Bryde's whales are known to occur. However, there was overlap between the Deepwater Horizon surface oil footprint and the Bryde's whale habitat. Therefore, additional survey data were used that included dedicated survey effort within the Bryde's whale area. These included surveys conducted during summer 2007, summer 2010, fall 2010, and summer 2012. This analysis was conducted using only survey effort within the Bryde's whale habitat. This region was defined based upon the spatial distribution of past Bryde's whale sightings and was restricted to a region between the 180 m and 360 m isobaths between 27.87N and 29.87N latitude (Figure 23) with a total area of 12,135 km^2.

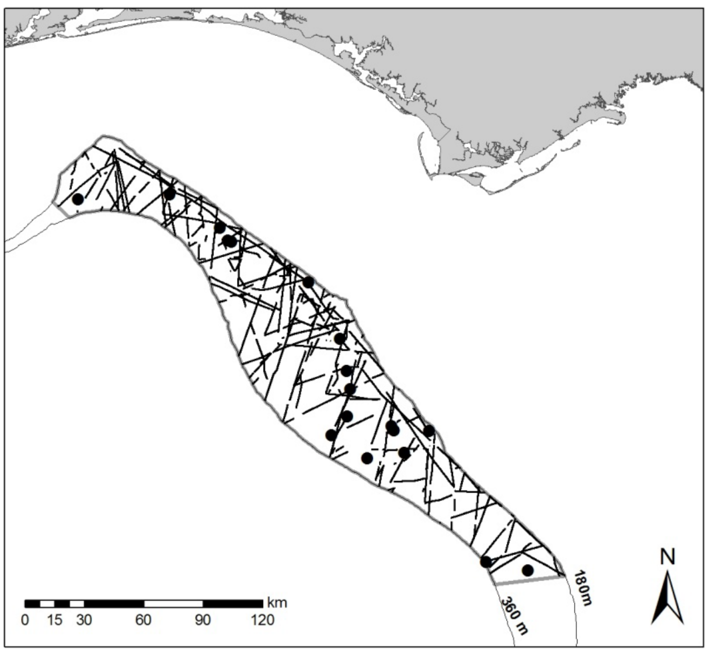

Figure 23: Survey effort and on effort sightings within the defined Bryde's whale area in the northeastern Gulf of Mexico.

The effort within the Bryde's whale habitat for each survey is shown in Table 15. The number of sightings is variable, and even with a relatively large amount of effort during the fall 2010 survey, there were only three encounters with Bryde's whale groups (Table 15).

Fifteen is a small number of sightings for a line transect analysis, and this limits the capability to obtain a robust estimate of abundance. There were insufficient sightings to fit reliable detection functions that included covariates. Therefore, a simple distance analysis was conducted using the half-normal key function with a truncation distance of 5,000 m. The fitted detection function (Figure 24) resulted in an average detection probability of 0.571 (CV = 0.224) and fit the data effectively (Goodness of Fit Test, p-value = 0.694). The resulting abundance estimate was 26 Bryde's whales (95% CI: 12 – 56) and a density of 0.002 animals/km^2 within the Bryde's whale habitat area.

Table 15: Effort and Bryde's whale sightings observed on effort within the Bryde's whale habitat area during SEFSC vessel surveys.

Survey	Survey Season and Year	Total Effort (km)	Bryde's whale sightings	Total Individuals
GU0302	Summer 2003	189	0	0
GU0402	Spring 2004	292	3	5
GU0704	Summer 2007	377	3	14
GU0903	Summer 2009	57	2	3
GU1003	Summer 2010	481	2	2
GU1005	Fall 2010	1037	3	8
GU1202	Summer 2012	509	2	5

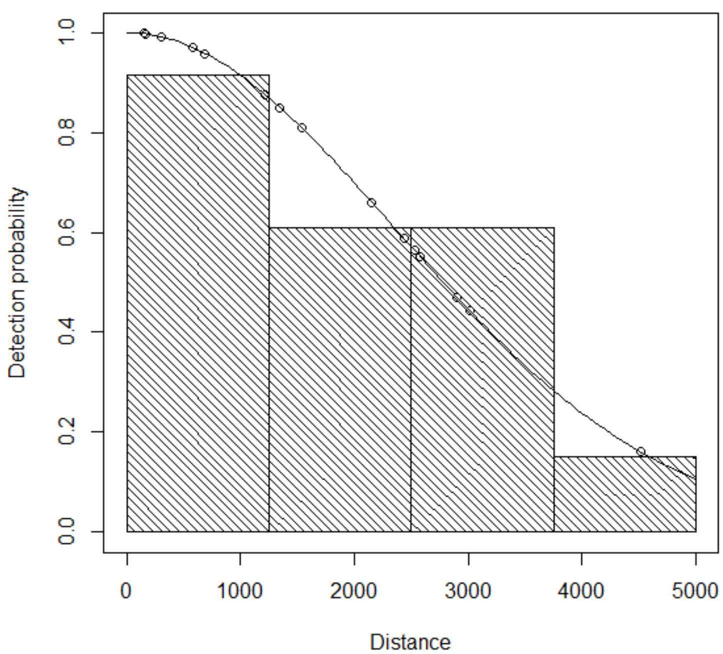

Figure 24: Detection function for Bryde's whales.

Conclusion and Future Work

Many environmental, biotic and physical factors influence the distribution and abundance of cetaceans in the Gulf. Bottom depth and ocean currents, which in turn fundamentally affect the concentration of prey species, are all major drivers in cetacean distribution. Different species select specific habitats based on these and other complex oceanographic features and sympatric species may partition the ecosystem at a fine-scale to minimize competition.

The shelf and shelf-break areas of the Gulf are dominated by sightings of Atlantic spotted and the common bottlenose dolphins, while the oceanic Gulf is shared by a range of different species. Pantropical spotted dolphins are most commonly seen and widely distributed in the oceanic waters of the Gulf; other dolphin species seem to select different habitats on a longitudinal scale. Sperm whales and to a greater extent, Bryde's whales, show marked concentration of sightings in very specific areas. Sperm whale sightings are highly concentrated in the MS Canyon and FL Escarpment regions and Bryde's whales are unanimously seen in the DeSoto Canyon region, usually restricted to the 180 m and 360 m isobaths.

The determination of cetacean abundance and density is complicated by lack of sighting records and by both sampling and oceanographic variability. Species such as Fraser's dolphins are seldom recorded to produce reliable estimates. In addition, cryptic species like beaked whales and the pygmy and dwarf sperm whales are rarely seen in less than ideal survey conditions. Nevertheless, there seem to be areas of high regional density in the northeastern Gulf for Risso's, common bottlenose, spinner and striped dolphins and in the northwestern Gulf for melon-headed whales and Clymene dolphins.

Passive acoustic methods help estimate abundance and density, particularly for cryptic species. High detection rates for the pygmy/dwarf sperm whales are found in the Green Canyon region. Beaked whales, which display well-defined acoustic signatures that allow classification to the species-level, show high detection rates in the Dry Tortugas area.

Combining visual surveys into a common analytical approach allows for the development of more precise estimates of abundance, reflecting long-term average trends. New abundance estimates that take probability of detection into account are available for most species, including sperm and Bryde's whales. Again, estimates for cryptic species (beaked whales and pygmy/dwarf sperm whales) are likely to be severely underestimated.

Even with more than 20 years of visual data, reliable distribution and abundance estimates for certain cetacean species remain lacking in the Gulf. Passive acoustic methods and technologies aid in these determinations. To continue assessing trends in cetacean distribution and abundance, regular and consistent surveys are needed. To further refine these assessments, seasonality and environmental parameters should be incorporated into future analyses.

References

Baumgartner, M. 1997. The distribution of Risso's dolphin (*Grampus griseus*) with respect to the physiography of the northern Gulf of Mexico. Marine Mammal Science, 13(4):614-638.

Baumgartner, M., Mullin, K.D., May, L.N., and T.D. Lemming. 2001. Cetacean habitats in the northern Gulf of Mexico. Fish.Bull.99:219-239

Buckland, S. T., Andersen, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L., and Thomas, L. 2001. Introduction to Distance Sampling: Estimating abundance of biological populations. New York: Oxford University Press.

Davis, R.W., Fargion, G.S., May, N., Lemming, D., Baumgartner, M., Evans, W.E., Hansen, L.J., and Mullin, K. 1998. Physical habitat of cetaceans along the continental slope in the north-central and western Gulf of Mexico. Marine Mammal Science, 14(3):490-507.

Engelhaupt, D., A. R. Hoelzel, C. Nicholson, A. Frantzis, S. Mesnick, S. Gero, H. Whitehead, L. Rendell, P. Miller, R. De Stefanis, A. Cañadas, S. Airoldi and A. A. Mignucci-Giannoni. 2009. Female philopatry in coastal basins and male dispersion across the North Atlantic in a highly mobile marine species, the sperm whale (*Physeter macrocephalus*). Mol. Ecol. 18: 4193-4205.

Fulling, G., Mullin, K.D., and Hubard, C.W. 2003. Abundance and distribution of cetaceans in outer continental shelf waters of the U.S. Gulf of Mexico. Fish. Bull. 101:923-932.

Garrison, L.P. Unpublished. Abundance and Spatial Distribution of Sperm Whales in the Northern Gulf of Mexico: Application of spatially explicit density models. Draft Summary of Analysis and Results. 27 Jun 2014.

Halpin, P.N., A.J. Read, E. Fujioka, B.D. Best, B. Donnelly, L.J. Hazen, C. Kot, K. Urian, E. LaBrecque, A. Dimatteo, J. Cleary, C. Good, L.B. Crowder, and K.D. Hyrenbach. 2009. OBIS-SEAMAP: The world data center for marine mammal, sea bird, and sea turtle distributions. Oceanography 22(2):104–115.

Hildebrand J., Merkens, K., Frasier, K., Bassett, H., Baumann-Pickering, S., Širović, A., Wiggins,S., McDonald, M., Marques, T., Harris, D. and L. Thomas. 2012. Passive acoustic monitoring of cetaceans in the northern Gulf of Mexico during 2010-2011. Progress report for research agreement #20105138.

Jochens, A., Biggs D., Benoit-Bird K., Engelhaupt D., Gordon J., Hu C., Jaquet N., Johnson M.,Leben R., Mate B., Miller P., Ortega-Ortiz J., Thode A., Tyack P., and Würsig B. 2008. Sperm whale seismic study in the Gulf of Mexico: Synthesis report. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2008-006. 341 pp.

Maze-Foley, K., and Mullin, K.D. 2006. Cetaceans of the oceanic northern Gulf of Mexico: Distributions, group sizes and interspecific associations. J. Cetacean Res. Manage. 8(2):203-213.

Mullin, K.D. 2007. Abundance of cetaceans in the oceanic Gulf of Mexico based on 2003-2004 ship surveys. Available from: NMFS, Southeast Fisheries Science Center, P.O. Drawer 1207, Pascagoula, MS 39568, 26 pp.

Mullin, K.D. and Fulling, G.L. 2004. Abundance of cetaceans in the oceanic northern Gulf of Mexico, 1996-2001. Marine Mammal Science, 20(4):787-807.

Mullin, K.D., Hoggard, W. and L.J. Hansen. 2004. Abundance and seasonal occurrence of cetaceans in the outer continental shelf and slope waters of the north-central and northwestern Gulf of Mexico. Gulf of Mexico Science (1), pp.62-73.

Rosel P.E. and Wilcox L. A. 2014. Genetic evidence reveals a unique lineage of Bryde’s whales in the northern Gulf of Mexico. Endangered Species Research 25:19-34.

Vollmer, N.L. 2011. Population structure of common bottlenose dolphins in coastal and offshore waters of the Gulf of Mexico revealed by genetic and environmental analyses. Ph.D. Dissertation from University of Louisiana at Lafayette. 420 pp.

Waring, G., Josephson, E., Maze-Foley, K., and Rosel, P.E. 2012. US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments 2009. NOAA Technical Memorandum NMFS-NE-223.