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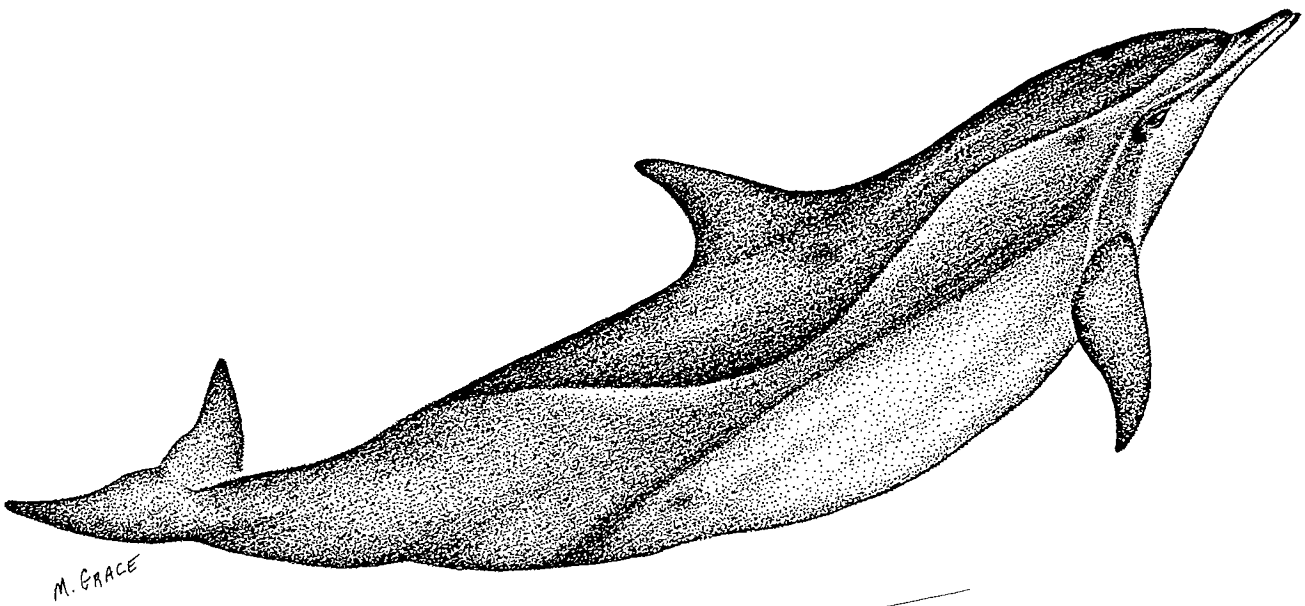
MMS 96-0026

Distribution and Abundance of Cetaceans in the North-Central and Western Gulf of Mexico, Final Report

Volume I: Executive Summary



MMS U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

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Distribution and Abundance of Cetaceans in the North-Central and Western Gulf of Mexico, Final Report

Volume I: Executive Summary

Editors

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Prepared under MMS Contract
14-35-0001-30619 and
Interagency Agreement 16197
by
Texas Institute of Oceanography
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Southeast Fisheries Science Center
National Marine Fisheries Service
75 Virginia Beach Drive
Miami, Florida 33149

Published by

U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

New Orleans
August 1996

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CITATION

Suggested citation:

Davis, R.W., and G.S. Fargion, eds. 1995. Distribution and abundance of cetaceans in the north-central and western Gulf of Mexico: Final report. Volume I: Executive summary. OCS Study MMS 96-0026. Prepared by the Texas Institute of Oceanography and the National Marine Fisheries Service. U.S. Dept. of the Interior, Minerals Mgmt. Service, Gulf of Mexico OCS Region, New Orleans, LA. 29 pp.

ABOUT THE COVER

The cover art depicts a clymene dolphin and is the work of Mark Grace, an employee of the National Marine Fisheries Service Laboratory at Pascagoula, MS.

ABSTRACT

The purpose of this study (hereafter referred to as the GulfCet Program) was to determine the distribution and abundance of cetaceans (whales and dolphins) in areas potentially affected by future oil and gas activities along the continental slope in the north-central and western Gulf of Mexico. This 3.75 year project commenced on 1 October 1991 and concluded on 15 July 1995. The study area was bounded by the Florida-Alabama border, the Texas-Mexico border, and the 100 m and 2,000 m isobaths. The distribution and abundance of cetaceans were determined from seasonal aerial and shipboard visual surveys and shipboard acoustic surveys. In addition, hydrographic data were collected *in situ* and by satellite remote sensing to characterize the habitats of cetaceans in the study area. Finally, tagging and tracking of sperm whales using satellite telemetry was attempted.

Cetaceans were observed throughout the study area during all four seasons. Nineteen species were identified, including two species (melon-headed whales and Fraser's dolphins) that were previously thought to be rare in the Gulf. Pantropical spotted dolphins, bottlenose dolphins, clymene dolphins, striped dolphins, Atlantic spotted dolphins, and melon-headed whales were the most common small cetaceans. The most common large cetacean was the sperm whale. Only one species of baleen whale, the Bryde's whale, was sighted, and the estimated abundance of this species was very low. The mean annual abundance for all cetaceans was estimated to be 19,198 animals.

The oceanography in the study area was complex and dynamic, with mesoscale features that showed large annual and interannual variability. Warm- and cold-core rings (eddies) and the fresh water effluent from the Mississippi River were the most distinctive hydrographic features observed in the study area. The marine habitat for this area can be characterized as tropical to subtropical with a mixed layer that is seasonally deepest in the winter.

With the exception of bottom depth, there was no significant correlation of cetacean distribution with any of the hydrographic variables examined. Cetaceans could be divided into three groups relative to bottom depth. The first group, which occurred on the continental shelf or along the shelf break, consisted of Atlantic spotted dolphins and bottlenose dolphins. The second group consisted only of Risso's dolphin and occurred along the mid-to-upper slope. The third group included sperm whales, pygmy/dwarf sperm whales, pantropical spotted dolphins, striped dolphins, and *Mesoplodon* spp. This third or deep-water group typically occurred along the mid-to-lower slope in water over 1,000 m deep. There was some indication that sperm whales may be found in conjunction with the edge of warm-core rings, where upwelling events may enhance productivity and prey abundance.

The potential effects of oil and gas exploration and production activity on cetaceans along the continental slope cannot be predicted with certainty. However, it can be anticipated that cetaceans will encounter construction activity, ship traffic, seismic exploration, and underwater noise as the oil and gas industry moves into yet deeper water. The GulfCet Program has

demonstrated that any future monitoring programs would need to be long-term, with relatively intensive sampling effort in order to detect significant changes in the abundance and distribution of most cetaceans.

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Many persons contributed to this study, including the crews and graduate students who worked on the research vessels and aircraft, laboratory technicians, and the data management staff. The contributors to this report would like to recognize the efforts of T. Adams, M. Armstrong, A. Baldridge, N.B. Barros, M.F. Baumgartner, L. Bellaponni, S. Benson, S. Bräger, E. Brandon, P. Brown, I. Burke, T. Byrne, D.K. and M.C. Caldwell, R. Carroll, G. Childress, R. Clark, N. Clauss, V.G. Cockcroft, S. Collier, J. Cotton, P. Crotwell, L. Delos Santos, K. Dudzinski, T. Engelhardt, D. Fertl, A. Forest, T. Frohoff, C. Graham, A. Grundt, M.J. Hafner, E. Haubold, H.J. Herring, L. Higgins, W. Hoggard, M. Howley, D. Johnson, S. Kanatous, A. Landry, Jr., S. Leatherwood, D. Ljungblad, B. Mase, M.L. Mate, L. May, M.B. McDuff, J.G. Mead, L. Montaña-Luna, P. Mumford, S. Nieukirk, D.K. Odell, S. O'Sullivan, W.F. Perrin, W.L. Perryman, J. Peterson, R. Pitman, K. Rademacher, L. Respess, F. Risinger, C. Roden, C. Rogers, D.J. Schmidly, L. Sharp, L.K.M. Shoda, K. Stafford, W.E. Stevens III, H. Svehlak, R.J. Tarpley, T. Tenbrink, Wang Ding, L. West, L. Wilkins, B. Wilson, and G.A.J. Worthy. M. Armstong, P. Brown, N. Clauss, and H. Whitehead contributed significantly to Section 8. Special thanks to the officers and crew of NOAA Ship *Oregon II* and the NOAA Aircraft Operations Center and pilots B. Taggart, S. Nokutis, T. O'Mara, S. Pape, M. Pickett, M. White. We thank Aspen Helicopters, Inc. and their pilot J. Drust. Special thanks also go to LUMCON's S. Rabalais, R/V *Pelican*'s captain, C. Riffe and his crew, and the crew of University of Texas' R/V *Longhorn*. The direction and advice of R. Avent (Contracting Officer's Technical Representative) was of great service throughout this project. Thanks also go to the Scientific Review Board (SRB) members for their thoughtful review and comments on the goals and results of this project. The GulfCet Data Management Office wishes to express its appreciation to all those who served as reviewers of this document. D. Brandon served as data analyst and technical illustrator.

We gratefully acknowledge the Texas Institute of Oceanography and the National Marine Fisheries Service for cost-sharing the use of all research vessels used for the surveys and sperm whale tagging cruises on this project, and the Institute of Marine Life Sciences (TAMUG) for cost-sharing one set of "Big Eye" binoculars and various other research items.

This study was funded by the U.S Department of the Interior, Minerals Management Service, under contract C 14-35-0001-30619, and Interagency Agreement 16197 with the National Marine Fisheries Service.

I. INTRODUCTION

The Minerals Management Service (MMS) is responsible for assuring that the exploration and production of oil and gas reserves located more than three miles offshore and within the U.S. Exclusive Economic Zone are conducted in a manner that reduces risks to the marine environment. To meet their responsibilities under the Marine Mammal Protection Act of 1972 and the Endangered Species Act of 1973, the MMS must understand the effects of oil and gas operations on marine mammals. As the oil and gas industry moves into deeper water along the continental slope in its continuing search for extractable reserves, information is needed on the distribution, abundance, behavior, and habitat of cetaceans, especially large and deep-water species in the Gulf of Mexico (Table 1.1). This study, hereafter called the GulfCet Program, was designed to help the MMS assess the potential effects of deep-water oil and gas exploration and production on marine mammals in the Gulf of Mexico.

The purpose of this study was to determine the distribution and abundance of cetaceans along the continental slope in the north-central and western Gulf of Mexico. The study was restricted to an area bounded by the Florida-Alabama border, the Texas-Mexico border, and the 100 m and 2,000 m isobaths (Figure 1.1). This 3.75 year project commenced on 1 October 1991 and concluded on 15 July 1995. In addition to conducting aerial visual, shipboard visual, and shipboard acoustic marine mammal surveys, the GulfCet Program collected hydrographic data *in situ* and by remote sensing to characterize the marine habitat of cetaceans in the study area. An attempt was also made to tag sperm whales and track their movements using satellite telemetry.

The GulfCet Program was administered by the Texas Institute of Oceanography (TIO), which is part of the Texas A&M University System. Researchers at Texas A&M University campuses at Galveston and College Station provided expertise in marine mammal biology, bioacoustics, and oceanography. Expertise in aerial and shipboard surveys of marine mammals, satellite remote sensing, and Geographical Information Systems was provided by the National Marine Fisheries Service (NMFS) at the Southeast Fisheries Science Centers (SEFSC), with facilities in Miami, Pascagoula, and at Stennis Space Center. The NMFS effort was contracted under a separate Interagency Agreement with MMS. Finally, the program included scientists from the Hatfield Marine Science Center at Oregon State University, who had developed techniques to tag and track whales using satellite telemetry. The GulfCet Program had a Scientific Review Board composed of five scientists who reviewed and commented on the project's goals, methodologies, results, analyses, and conclusions.

Table 1.1 Cetaceans of the Gulf of Mexico.[1]

Balaenidae[2]	
Northern Right Whale	*Eubalaena glacialis*
Balaenopteridae[2]	
Blue Whale	*Balaenoptera musculus*
Fin Whale	*Balaenoptera physalus*
Sei Whale	*Balaenoptera borealis*
Bryde's Whale	*Balaenoptera edeni*
Minke Whale	*Balaenoptera acutorostrata*
Humpback Whale	*Megaptera novaeangliae*
Physeteridae	
Sperm Whale	*Physeter macrocephalus*
Pygmy Sperm Whale	*Kogia breviceps*
Dwarf Sperm Whale	*Kogia simus*
Ziphiidae	
Cuvier's Beaked Whale	*Ziphius cavirostris*
Blainville's Beaked Whale	*Mesoplodon densirostris*
Sowerby's Beaked Whale	*Mesoplodon bidens*
Gervais' Beaked Whale	*Mesoplodon europaeus*
Delphinidae	
Melon-headed Whale	*Peponocephala electra*
Pygmy Killer Whale	*Feresa attenuata*
False Killer Whale	*Pseudorca crassidens*
Killer Whale	*Orcinus orca*
Short-finned Pilot Whale	*Globicephala macrorhynchus*
Rough-toothed Dolphin	*Steno bredanensis*
Fraser's Dolphin	*Lagenodelphis hosei*
Bottlenose Dolphin	*Tursiops truncatus*
Risso's Dolphin	*Grampus griseus*
Atlantic Spotted Dolphin	*Stenella frontalis*
Pantropical Spotted Dolphin	*Stenella attenuata*
Striped Dolphin	*Stenella coeruleoalba*
Spinner Dolphin	*Stenella longirostris*
Clymene Dolphin	*Stenella clymene*

[1] Adapted from Mullin et al. 1991.
[2] Rarely sighted.

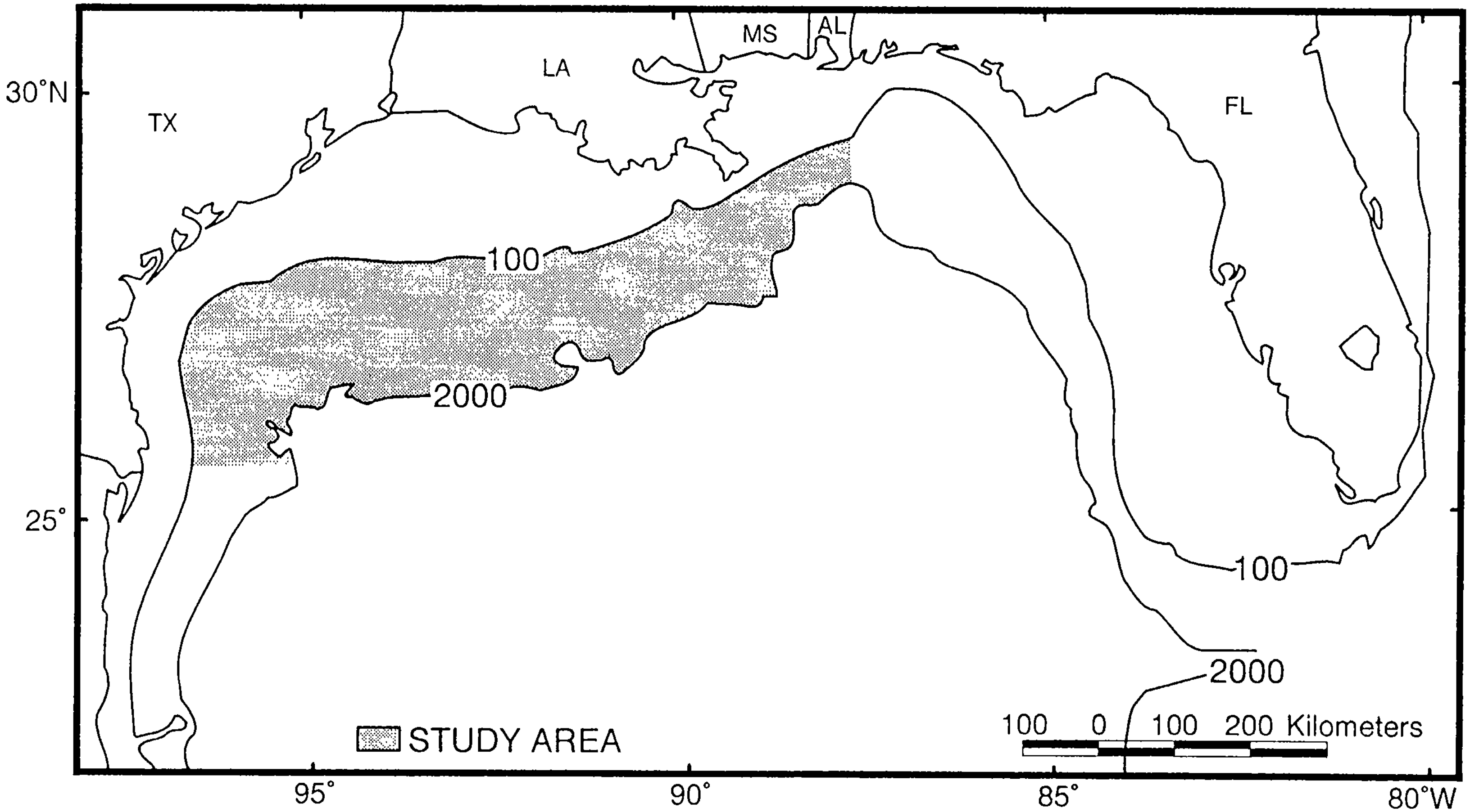

Figure 1.1. Study area between the 100 and 2,000 m isobaths, extending as far east as the Florida-Alabama border, and as far southwest as the Texas-Mexico border.

II. OVERVIEW

The Gulf of Mexico

The Gulf basin encompasses an area of about 1.5 million km^2 and is bounded by the United States, Mexico, and Cuba. The basin consists of sialic basement materials, and in the east and southeast, the carbonate structures of the Florida-Bahama Platform and Campeche-Yucatan Bank, respectively (Brooks 1973). The Gulf is connected to the Caribbean Sea via the Yucatan Straits, a relatively deep (2,000 m) channel, and to the Atlantic Ocean through the Florida Straits, a silled channel with a depth of about 860 m (Jones 1973). Based on tabulations from Herring's (1993) bathymetric data, continental shelf waters less than 180 m deep cover about 35.4% of the total area of the Gulf. The continental shelf varies greatly in width. Along the Florida west coast, the southern coast of Texas, and the northern coast of the Yucatan Peninsula, the continental shelf is 160-240 km wide. In contrast, it is only 32-48 km wide at the mouth of the Mississippi River and along certain coastal areas of the Bay of Campeche, Mexico. The continental slope, defined as bottom depths between 180 and 3,000 m, covers about 39.2% of the total area and contains steep escarpments and numerous submarine canyons. The areas located in depths greater than 3,000 m (i.e., Sigsbee Plain and sections of the Lower Mississippi Fan) make up the remaining 25.4% of the total area. At its deepest point, on the Sigsbee Plain, the Gulf is 3,700 m deep. Whereas the continental shelf is a smooth, gently sloping plain, the upper continental slope in the north-central and western Gulf is characterized by complex hill and basin topography. The average gradient in the study area is less steep than the average gradient for the entire Gulf of Mexico.

The Gulf of Mexico is a dynamic body of water dominated by two major circulation features. The Loop Current, formed by the interconnection of the Yucatan and Florida Currents, governs the circulation of the eastern Gulf. In the western Gulf, a warm water anticyclonic eddy with associated cold water cyclones is the primary circulatory feature. Waters of the Gulf of Mexico are derived from three water masses: Subtropical Underwater, Antarctic Intermediate Water, and North Atlantic Deep Water. Each of these water masses has its own characteristic temperature and salinity range. These characteristics allow the identification and tracking of these water masses in the Gulf. As mixing and dilution of these water masses occurs, the conversion to Gulf Common Water takes place. Gulf Common Water is identified by a salinity of 36.4-36.5 psu. The dynamics of the Gulf are made more complex by the large fresh water inflow. Nearly two-thirds of the continental U.S. and half of Mexico's land area drains into the Gulf. The associated nutrient input from this fresh water inflow increases the level of primary production with a subsequent increase in secondary production as well. The overall resulting circulation of the Gulf of Mexico is remarkable because of its interannual variability and intensity.

Historical Overview of the Distribution of Cetaceans in the Offshore Gulf of Mexico

All available cetacean records of strandings, sightings, and captures from the waters of the Gulf of Mexico were compiled. A total of 1,223 records for 28 species were available for this analysis. There were often strong geographic and seasonal biases in sighting and stranding recovery efforts. For essentially all types of records, almost none were available for the southern Gulf of Mexico. However, there is no reason to believe that any species known from the northern Gulf does not also occur in the southern part of the Gulf of Mexico.

There have been few systematic surveys of marine mammals in the Gulf, especially in offshore areas. Two reports have previously summarized information on historical cetacean records for the Gulf (Schmidly 1981, Jefferson et al. 1992). However, both reviews were unable to verify species identification for some historical records. For species other than the bottlenose dolphin, what is known of their natural history in the Gulf comes mostly from occasional strandings or opportunistic sightings. Townsend (1935) extracted entries of large whale target species (sperm, humpback, and right whales) from logbooks of Yankee whalers.

The first large-scale vessel surveys to assess marine mammal distribution and abundance in the Gulf of Mexico began in 1990. Studies of continental slope waters of the northern Gulf (Fritts et al. 1983, Mullin et al. 1994) indicated that cetaceans were diverse (at least 18 species) and that some species (e.g., sperm whale, Risso's dolphin, pantropical spotted dolphin), at least seasonally, were relatively abundant. However, some of these studies were restricted to relatively small geographic areas and the results could not be meaningfully extrapolated to a broader region of the Gulf of Mexico. One of the major sources of high-quality data, the NOAA Ship *Oregon II* surveys (SEFSC unpubl.), though geographically expansive in the northern Gulf, has occurred almost exclusively in the spring.

The poorly understood ecology and demography of cetaceans in the Gulf of Mexico, and the unknown effects of past, present, and future offshore development on these animals, prompted recommendations for studies such as the GulfCet Program to collect data which might serve as a baseline and foundation for long-term studies (Tucker and Associates 1990).

III. VISUAL SURVEYS ABOARD SHIPS AND AIRCRAFT

The primary objectives of the GulfCet aerial and shipboard visual surveys were: 1) to obtain data on cetacean species composition in the study area, 2) to obtain a minimum population estimate of each cetacean species encountered in order to establish a baseline with the potential for monitoring trends in abundance over time, 3) to study the seasonal abundance and distribution patterns of each species, and 4) to collect location data for use in cetacean habitat studies. Seasonal surveys were conducted for two years (Table 3.1). Additionally, line transect data from each sea turtle species sighted during the aerial surveys were used to estimate sea turtle abundance.

Line transect methods were used to make two independent sets of abundance estimates. One set was based on the aerial surveys and the other on the ship surveys. Sea turtle densities were estimated from aerial survey data only. Seasons were defined as follows: summer, July-September; fall, October-December; winter, January-March; and spring, April-June.

Ship-board Surveys

Shipboard surveys were conducted seasonally, lasting from 10 to 55 days per survey. The survey tracks followed one of three designs that sampled the entire GulfCet study area. The R/V *Pelican/Longhorn* surveys followed fixed north-south track-lines that were designed to allow oceanographic sampling as well as visual and acoustic sampling of marine mammals. The ship continually traversed the cruise-track once each survey. Visual sampling occurred during daylight hours on the north-south track-lines or on transit between the track-lines. The NOAA Ship *Oregon II* surveys followed two sampling designs, sampling the study area three times during each survey period. The spring *Oregon II* surveys consisted of one or two transits of equidistant north-south track-lines (surveyed during daylight hours) with a random start, and one or two transits of a predetermined track for sampling ichthyoplankton stations, which were transited 24 hours a day. The winter *Oregon II* survey transited the north-south tracks three times. Visual sampling of the ichthyoplankton track could be latitudinal or longitudinal, or a combination of both. The *Oregon II* north-south track-lines were designed specifically for visual sampling of marine mammals along transects perpendicular to the depth gradient. Marine mammal sighting data were collected by teams of observers during daylight hours, using high-power binoculars mounted on the ship's flying bridge. Cetaceans were identified to the lowest taxonomic level possible.

A total of 21,350 km of transect was visually sampled during the GulfCet ship surveys. The cumulative survey effort each season was: spring - 13,507 km, summer - 2,085 km, fall - 1,275 km, and winter - 4,483 km. Overall, 19 cetacean species were identified in 683 sightings made on-effort. The number of on-effort sightings each season ranged from 509 during spring to 14 during fall. Most of the survey effort occurred during the spring, with the least effort in the fall.

Sighting rates of cetacean groups were consistent during the spring surveys, averaging about 4.0 groups/100 km. The sighting rates for two summer seasons were 2.7 and 7.6 groups/100 km. The fall sighting rates were 0.8 and 1.4 groups/100 km. The winter sighting rates were similar to fall, and were 1.1 and 1.7 groups/100 km. The shipboard survey effort was not designed to provide information on seasonal occurrence of cetaceans. More than 50% of the total effort and 75% of all sightings occurred during the spring.

Table 3.1. Types of data collected by season and survey.

			Marine Mammal Surveys		Hydrographic Surveys					
Survey		Dates	Visual	Acoustic	CTD	XBT	Chlorophyll	Salinity	Nutrients	Remotely sensed SST
Spring 1992										
R/V *Longhorn*	Cruise 1	15 Apr-1 May 1992	✔	✔	✔	✔	✔	✔		✔
NOAA Ship *Oregon II*	Cruise 199									
	Leg 1	17 Apr-4 May 1992	✔		✔	✔	✔	✔		✔
	Leg 2	6-25 May 1992	✔		✔	✔	✔	✔		✔
	Leg 3	26 May-8 Jun 1992	✔		✔	✔	✔	✔		
Summer 1992										
R/V *Pelican*	Cruise 2	10-24 Aug 1992	✔	✔	✔	✔	✔	✔		✔
Aerial 1		10 Aug-19 Sep 1992	✔							✔
Fall 1992										
Aerial 2		3 Nov-16 Dec 1992	✔							✔
R/V *Pelican*	Cruise 3	8-22 Nov 1992	✔	✔	✔	✔	✔	✔		✔
Winter 1993										
NOAA Ship *Oregon II*	Cruise 203									
	Leg 1	5-17 Jan 1993	✔		✔	✔	✔	✔		✔
	Leg 2	18-30 Jan 1993	✔		✔	✔	✔	✔		✔
	Leg 3	1-14 Feb 1993	✔		✔	✔	✔	✔		✔
Aerial 3		1 Feb-22 Mar 1993	✔							✔
R/V *Pelican*	Cruise 4	12-27 Feb 1993	✔	✔	✔	✔	✔	✔		✔
Spring 1993										
Aerial 4		25 Apr-1 Jun 1993	✔							✔
NOAA Ship *Oregon II*	Cruise 204									
	Leg 1	3-17 May 1993	✔		✔	✔	✔	✔		✔
	Leg 2	18 May-2 Jun 1993	✔		✔	✔	✔	✔		✔
	Leg 3	4-15 Jun 1993	✔		✔	✔	✔	✔		✔
R/V *Pelican*	Cruise 5	23 May-5 Jun 1993	✔	✔	✔	✔	✔	✔		✔

Table 3.1. Types of data collected by season and survey. (continued)

Survey		Dates	Marine Mammal Surveys: Visual	Marine Mammal Surveys: Acoustic	Hydrographic Surveys: CTD	Hydrographic Surveys: XBT	Hydrographic Surveys: Chlorophyll	Hydrographic Surveys: Salinity	Hydrographic Surveys: Nutrients	Remotely sensed SST
Summer 1993										
Aerial 5		1-21 Aug 1993	✔							✔
R/V *Pelican*	Cruise 6	28 Aug-5 Sep 1993	✔	✔	✔	✔	✔	✔	✔	
Fall 1993										
Aerial 6		31 Oct-16 Dec 1993	✔							✔
R/V *Pelican*	Cruise 7	3-14 Dec 1993	✔	✔	✔	✔	✔	✔		✔
Winter 1994										
Aerial 7		31 Jan-15 Mar 1994	✔							✔
Spring 1994										
NOAA Ship *Oregon II*	Cruise 209									
	Leg 1	15-24 Apr 1994	✔		✔	✔		✔		✔
	Leg 2	27 Apr-18 May 1994	✔		✔	✔		✔		✔
	Leg 3	20-29 May 1994			✔	✔		✔		✔
	Leg 4	30 May-10 Jun 1994	✔		✔	✔		✔		✔
Aerial 8		2 May-2 Jun 1994	✔							✔
Summer 1994										
R/V *Pelican*	Cruise 8	20-28 Aug 1993	✔	✔		✔				

The sperm whale, bottlenose dolphin, and pantropical spotted dolphin were the most commonly sighted species during ship surveys. Each species was sighted more than 70 times. Dwarf sperm whale, unidentified ziphiid, Risso's dolphin, striped dolphin, and clymene dolphin were each sighted 21-44 times, with the other species sighted fewer than 20 times. Average group sizes ranged from 1.2 for pygmy sperm whales and Cuvier's beaked whale to 140.7 for melon-headed whales.

The shipboard estimate of annual cetacean abundance (with coefficient of variation in parentheses) in the GulfCet study area was 19,198 (0.12) animals. The most common species was the pantropical spotted dolphin, with an estimated abundance of 7,105 (0.22) animals. The bottlenose dolphin was the next most common species with 2,538 (0.26) animals and was followed by the striped dolphin and the melon-headed whale, with 2,091 (0.52) and 2,067 (0.34) animals, respectively. The clymene dolphin and Atlantic spotted dolphin estimates were 1,695 (0.37) and 1,145 (0.37) animals, respectively, and were the only other species with estimates of over 1,000 animals. Relatively precise estimates were achieved for the sperm whale with 313 (0.25) animals and Risso's dolphin with 519 (0.26) animals. The only other species with estimates of more than 200 animals were the spinner dolphin and the short-finned pilot whale with estimates of 840 (0.60) and 215 (0.50) animals, respectively.

Aerial Surveys

The aerial survey study area (85,815 km^2) included only waters from 100-1,000 m deep west of 90°00.0'W; however, the entire continental slope was surveyed east of 90°00.0'W. Aerial surveys were conducted once each season for two years, from summer 1992 through spring 1994 (eight seasonal surveys). During each season, the aerial survey study area was covered uniformly by flying 74 track-lines placed equidistantly apart from a random start. Track-lines were oriented perpendicular to the bathymetry. The survey platform was a NOAA-operated DeHavilland Twin Otter aircraft modified with a large bubble window on each side. Surveys were conducted from an altitude of 229 m (750 feet) and at a speed of 204 km/hour (110 knots).

A total of 49,960 km of transect was visually sampled during the eight GulfCet aerial surveys. Except for fall 1992, all of the proposed aerial track-lines were completed each survey. The transect kilometers sampled each survey ranged from 5,330-6,592 km, and each season, from 11,756-12,942 km.

In total, 351 cetacean groups were sighted on-effort during aerial surveys. The number of sightings per survey ranged from 24 to 61, and the number of sightings per season ranged from 49 to 109. Except for fall, group sighting rates were generally similar each season and ranged from 0.73-0.86 groups/100 km. During fall, the group sighting rate was lower (0.42 groups/100 km). The animal sighting rates were much more variable and ranged from 5.1 to 23.1 animals/100 km for fall and winter, respectively.

At least 17 cetacean species were identified during GulfCet aerial surveys. The only sighting of killer whales during aerial surveys was off-effort. All species sighted during aerial surveys were also sighted during ship surveys.

Seasonally, the number of species sighted ranged from 11 in fall to 15 in winter. Five species that were each sighted 20 or more times accounted for 71% of the identified sightings: sperm whales, pygmy/dwarf sperm whales, bottlenose dolphins, Risso's dolphins, and pantropical spotted dolphins.

Annually, there were an estimated 16,986 (CV = 0.14) cetaceans in the GulfCet aerial survey study area. Seasonally, the cetacean abundance was about the same in winter (21,894 [0.27]) and spring (19,215 [0.25]), less in summer (14,959 [0.24]), but two-to-three times lower in the fall (6,051 [0.32]).

Pantropical spotted dolphins were the most abundant species in the aerial survey study area (5,251 [0.22]) followed by melon-headed whales (2980 [0.60]), bottlenose dolphins (2,890 [0.20]) and Risso's dolphins (1,214 [0.24]). The sperm whale and pygmy/dwarf sperm whale population was estimated to be 87 (0.27) and 176 (0.31) respectively. All the other delphinid species were represented by less than 1,000 individuals each, and balaenopterids and ziphiids, less than 100 individuals each. Mean group sizes ranged from 315 for melon-headed whales to less than four for sperm whales, pygmy/dwarf sperm whales, and ziphiids.

The density estimates of cetacean species were generally similar between the aerial and ship survey platforms. Seasonal densities were lowest during the fall for all categories except sperm whales, which had the lowest densities in the summer and winter. Most of the seasonal estimates were not significantly different ($p > 0.05$) using the criteria of non-overlap of 85% CI. These differences suggest that the GulfCet study area was less heavily utilized by cetaceans during fall.

Species Accounts

Cetaceans were found throughout the GulfCet study area. The distribution of most species was related to bottom depth. There was no evidence that any species shifted distribution seasonally within the study area. Table 3.2 presents mean group sizes and estimates of minimum abundance from shipboard observations.

Bryde's whale was the only baleen whale sighted in the study area. Two Bryde's whales were sighted together from a ship during spring. Both sightings were made near the 100 m isobath in the west-central part of the study area.

Sperm whales were sighted during all seasons and throughout the study area. However, concentrations occurred near the 1,000 m isobath in the vicinity of the Mississippi River delta and on the central slope in the west-central part of the study area. Sperm whales were the most abundant large cetacean in the study area.

Pygmy sperm whales were sighted in the central part of the study area. Based on stranding data, pygmy sperm whales were thought to be more common than dwarf sperm whales. However, the shipboard visual surveys indicate the opposite.

Table 3.2 Group-sizes and abundances from shipboard surveys (G = mean group size, CV = coefficient of variation, N = abundance estimate).

Species	G	CV	N	CV
Bryde's whale	2.0	-	3	0.81
Sperm whale	2.7	0.14	313	0.25
Pygmy sperm whale	1.2	0.12	19	0.40
Dwarf sperm whale	2.1	0.17	88	0.34
Pygmy/dwarf sperm whale	2.0	0.15	53	0.39
Cuvier's beaked whale	1.2	0.14	14	0.41
Unidentified Ziphiidae	2.4	0.13	124	0.29
Melon-headed whale	140.7	0.19	2,067	0.34
Pygmy killer whale	11.5	0.13	36	0.64
False killer whale	3.5	0.14	10	0.63
Killer whale	11.2	0.04	71	0.46
Short-finned pilot whale	15.3	0.33	215	0.50
Rough-toothed dolphin	13.2	0.18	177	0.35
Fraser's dolphin	44.0	-	65	1.17
Bottlenose dolphin	11.2	0.12	2,538	0.26
Risso's dolphin	9.2	0.14	529	0.26
Atlantic spotted dolphin	22.6	0.15	1,145	0.37
Pantropical spotted dolphin	59.8	0.11	7,105	0.22
Striped dolphin	37.0	0.14	2,091	0.52
Spinner dolphin	47.0	0.41	840	0.60
Clymene dolphin	54.3	0.28	1,695	0.37
All	-	-	19,198	0.12

Dwarf sperm whales were sighted throughout the study area.

Cuvier's beaked whales were sighted six times during spring. Sightings were distributed throughout the deepest part of the study area, near the 2,000 m isobath.

Unidentified ziphiid whales were sighted during all seasons. They were sighted throughout the study area, generally in water well beyond the shelf break.

Melon-headed whales were sighted in the west-central portion of the study area, well beyond the 100 m isobath. Group size for melon-headed whales varied greatly (30-400 animals), and this species was frequently observed in association with Fraser's dolphin and rough-toothed dolphins.

Pygmy killer whales were sighted from ship two times. The sightings were in the west-central portion of the study area well beyond the 100 m isobath.

False killer whale sightings were not concentrated in any particular portion of the study area.

Killer whale sightings were confined to an relatively small area south and southwest of the Mississippi River delta in water deeper than 100 m.

Short-finned pilot whales were sighted during all seasons. They were sighted primarily in the west and central portion of the study area.

Rough-toothed dolphins were sighted during every season. They were not sighted in the extreme eastern portion of the study area.

Fraser's dolphins were sighted four times and associated with melon-headed whales in all four sightings. They were sighted in the central portion of the study area.

Bottlenose dolphins were sighted during all seasons. They were sighted throughout the study area almost exclusively at depths less than 1,000 m.

Risso's dolphins were sighted during all seasons. They were sighted throughout the study area.

Atlantic spotted dolphins were sighted during all seasons. They were generally sighted throughout the length of the study area but almost exclusively near the 100 m isobath.

Pantropical spotted dolphins were sighted during all seasons. They were sighted throughout the study area generally well beyond the 100 m isobath.

Striped dolphins were sighted in every season. They were sighted throughout the study area and were generally well beyond the 100 m isobath.

Spinner dolphins were generally sighted in the eastern one-half of study area usually in water deeper than 100 m.

Clymene dolphin sightings occurred almost exclusively in a central portion of the study area well beyond the 100 m isobath.

Common dolphins were never sighted and are not known to occur in the Gulf of Mexico.

With the exception of the clymene dolphin, groups of oceanic dolphins (i.e., pantropical spotted, spinner, and striped dolphins) were generally sighted more frequently in the eastern part of the GulfCet study area. Atlantic spotted dolphins, which occur in all but the very nearshore habitats on the continental shelf in the Gulf, were only sighted near the 100 m isobath during these surveys. Bottlenose dolphins were most commonly sighted in association with the continental shelf edge. Clymene dolphins, short-finned pilot whales, melon-headed whales, and pygmy killer whales were found primarily in the central to western region of the GulfCet study area. The distributions of melon-headed whales and clymene dolphins throughout the entire northern Gulf of Mexico suggests that the GulfCet study area may make up a significant portion of the range of both of these species. The distribution of Risso's dolphin was concentrated along the upper continental slope near the Mississippi River, but sightings were made throughout the study area. Killer whales were found in a broad, but distinct region just southwest of the Mississippi River delta.

A total of 20 species or genera were sighted in the GulfCet study area, which is comparable in diversity to that reported for the eastern tropical Pacific (ETP) (Wade and Gerrodette 1993). The estimated abundance of all cetaceans sighted in the GulfCet study area was 19,198 animals. With a total area of 154,621 km^2, the cetacean density was 0.12 animals/km^2. This is about one-fourth the estimated density (0.52 animals/km^2) for cetaceans in the ETP. It appears that the GulfCet study area is as species rich as the ETP, but supports a lower density of cetaceans. This may be due to the more oligotrophic conditions in the Gulf.

Sea Turtles

Leatherback sea turtles were the most abundant sea turtle in the aerial survey area, with a minimum abundance estimate of 153 (CV = 0.19) turtles. Estimates of abundance for loggerhead and Kemp's ridley sea turtles were 41 (0.29) and 7 (0.71) turtles, respectively. Leatherback sea turtles were sighted throughout the aerial survey study area. The majority of the sightings occurred in the eastern part of the study area from Mississippi Canyon to the DeSoto Canyon. Another aggregation occurred in the central part of the study area. Sightings of Kemp's ridley, loggerhead, and unidentified chelonid sea turtles occurred throughout the study area.

The data suggest that in the northwestern Gulf, the primary habitat of the leatherback sea turtle is oceanic (> 200 m). Leatherbacks were found to occur in similar numbers throughout the GulfCet study area in all seasons. The region from Mississippi Canyon to DeSoto Canyon appears to be an important habitat for leatherbacks.

IV. ACOUSTIC SURVEYS

Acoustic surveys were conducted during R/V *Pelican/Longhorn* Cruises 1-7. A total of 12,219 km and 1,055 hours of effort were completed. On-effort acoustic sampling occurred 95% of the available time for *Pelican* Cruises 2-7. There were two cruises for each season, except winter, which had one. The four spring and summer cruises had approximately the same effort, whereas the two fall cruises were shorter.

A total of 487 acoustic contacts was recorded. Of that number, 124 contacts were from 12 species. Sperm whales were the most commonly recorded species, accounting for 56% of identified contacts. The most commonly recorded small cetacean was the pantropical spotted dolphin, with 22 contacts. A single recording of an unidentified baleen whale was made, probably a sei or Bryde's whale. An additional 331 contacts were of unidentified dolphins. There were 30 contacts with unidentified cetaceans. These were typically pulsed signals that did not sound like sperm whales or dolphins, and were possibly either dwarf/pygmy sperm whales or beaked whales. Also recorded were 19 unidentified biological contacts, probably shrimp. Approximately half of the species known to occur in the Gulf were recorded, including the rarely recorded clymene and rough-toothed dolphins as well as the first recording ever of Fraser's dolphin.

Noteworthy in their absence were many baleen whale signals. No identified recordings were made of beaked whales, though they were seen on several occasions. Only a single identified recording was made from either pygmy or dwarf sperm whales. Of the expected delphinids, only killer and pygmy killer whales were not recorded.

There were no significant seasonal differences between observed and expected number of sperm whale contacts, nor was there any apparent pattern to seasonal changes in sperm whale distribution. The number of contacts showed no significant difference by time of day (in four-hour intervals) or by trackline. Contact bottom depths (mean = 1,244 m) were not significantly different between seasons and were fairly uniformly distributed throughout the study area in waters deeper than 200 m.

Other cetaceans showed less consistency. There was a significant difference between the observed and expected number of non-sperm whale contacts by season. This was due to fewer than expected dolphin contacts in the fall and more than expected during the summer cruises. Additionally, dolphin acoustic contacts showed a strong diel pattern. Although acoustic effort was evenly divided between day and night, 65% of all dolphin contacts occurred at night and 35% occurred during the day.

Acoustic analysis was able to distinguish some dolphin species. A total of 191 whistles were used in the analysis: 89 from bottlenose dolphins, 20 from clymene dolphins, 48 from pantropical spotted dolphins, and 34 from striped dolphins. Analysis of these whistles, based on frequency and duration, using canonical correlation tests, significantly separated all four species. However, the relationship between the clymene dolphin and pantropical spotted dolphin was closer than for the other two species.

The total estimated populations of sperm whales and dolphins were 316 (95% confidence interval = 265-377) and 36,760 (30,835-43,821) individuals, respectively. Thus a dolphin group was detected on average every 31 km and a sperm whale group every 161 km.

Sperm whales were consistently located by the acoustic survey along tracklines 2, 6, 11, and 12, in the western and eastern regions of the study area. This suggests the possibility of site fidelity in sperm whales (the same individuals consistently located in the same area). Alternatively, there may be large populations in those locales and the animals were simply contacted more often there.

The manner in which sperm whales occupied their habitat, as measured by the dimensions of acoustic contacts, varied by season and cruise. Sperm whale groups occupied larger areas in the later cruises (Cruises 6 and 7) than the first five *Pelican/Longhorn* cruises. They occupied larger areas in the summer than spring. Similarly, contacts during both summer and fall occupied greater areas than during winter. In other words, sperm whale groups appeared to occupy larger areas in the warm weather seasons than during periods with colder weather. This is probably a better indication of the distribution of food resources, which are more temperature dependent, than whale distributions.

The shipboard visual and shipboard acoustic density estimates were similar (2.02 and 1.96, respectively). The estimates were not significantly different using the criteria of non-overlap of the 95% confidence interval. This indicated that the acoustic estimate may be as reliable as the visual estimates, and that there was little, if any, bias in the accuracy of the visual estimates due to lack of detection because of long-duration diving. However, this conclusion assumes accurate determination of sperm whale group size and requires further evaluation regarding the compatibility of the visual and acoustic methods.

This project demonstrated that visual and acoustic survey methodologies complement each other and can be conducted simultaneously from the same platform. This provides a comprehensive and efficient survey technique that optimizes ship time by increasing percentage of time on-effort. Continued development of hydrophone array technology will permit higher towing speeds and improved signal-to-noise ratio which will increase detection range and contact rate. These array advancements, in conjunction with improved signal recognition methods, may eventually permit acoustic censusing to be a stand alone technology.

V. BEHAVIOR OF CETACEANS RELATIVE TO SURVEY VESSELS

Distance at initial sighting of cetaceans from the survey ships were described for 655 sightings for which cetaceans were identified to species or species category. Mean initial sighting distance was 2.3 ± 1.77 (SD) km (n = 655), with mean sightings as close as 1.6 ± 1.50 (SD) km (n=110) for bottlenose dolphins, 1.6 ± 1.33 (SD) km (n=46) for beaked whales, and as far as 4.2 ± 1.46 (SD) km (n=6) for killer whales.

With the exception of striped dolphins, all stenellids habitually approached the vessel and rode the bow: 83% of pantropical spotted dolphins (137 of 165 sightings), 100% of spinner dolphins (14 of 14 sightings), and 92% of clymene dolphins (22 of 24 sightings) bowrode. The overall reaction for striped dolphins was different, however, with only 14 of 27 sighted groups (52%) riding the bow. Sperm whales were sighted at a mean distance of 3.0 ± 1.86 (SD) km (n = 87). Generally, sperm whale reaction was not described in the sighting notes, but the overall impression was that reactions tended to be non-existent for all but approaches to within several hundred meters. Eleven of 15 sightings with behavioral notes were labeled as no reaction, none as positive reaction, and four as negative, consisting of the whales diving abruptly in apparent response to the vessel, all within 200 m. Pygmy/dwarf sperm whales and beaked whales showed the most negative reactions towards the ship (73%, 11 of 15 sightings), with large delphinids at 15% (7/48), small delphinids at 6% (15/247), and Atlantic spotted and bottlenose dolphins at 0% each (26 and 88 sightings, respectively). Striped dolphins, of the small delphinid category, reacted negatively (orienting away from the vessel or abrupt diving) in 33% (9/27) of sightings.

Species which responded to the ship (either positively or negatively) also changed behavior in response to the survey aircraft. Pygmy/dwarf sperm whales changed their behavior in response to the airplane during 40% (12/30) of sightings, and beaked whales during 89% (8/9). Several of the smaller delphinids also showed sensitivity to disturbance by the airplane. "Diving" and "other" were the most common responses to the airplane. Over all cetacean species, the behavioral states "milling" and "resting" appeared to be sensitive to disturbance; over 39% of initial observations of these behaviors were followed by a new behavior. Cryptic species, such as pygmy/dwarf sperm whales and beaked whales, which were seen resting on most occasions, responded to the airplane a high proportion of the time. Less cryptic species, such as the small delphinids, may respond as often, but their response did not necessarily make them harder to identify. These data indicate that the sightability and identification of cetaceans may change with the variable behavior of species, and should be taken into account when extrapolating from sightings to population status.

VI. OCEANOGRAPHIC SURVEYS

The GulfCet program gathered hydrographic data from seven *Pelican/Longhorn* surveys (one cruise per season) and four NOAA Ship *Oregon II* surveys (three spring and one winter) in the north-central and western Gulf of Mexico. Data were also gathered synoptically by satellite remote sensing.

Temperature versus salinity (T-S) plots showed that for temperatures colder than 18 °C, there was a close T-S relationship with little scatter. This indicated that waters in the study area constituted essentially a single system. Hydrographic stations revealed a distinct salinity maximum greater than 36.6 psu with an accompanying temperature of approximately 22-23 °C. A minimum salinity of less than 34.9 psu excluded the surface fresh water found near the Mississippi River plume (which was as low as 12.8 psu). The intense salinity maximum was found in the region of the Loop Current and in warm anticyclonic eddies derived from that current. Several warm anticyclonic eddies in the study area were characterized by a salinity greater than 36.6 psu. These eddies were: Eddy Triton (T), Eddy Unchained (U), Eddy Vazquez (V), Eddy Whopper (W), and Eddy Extra (X).

Surface water temperatures (SST) throughout the study area ranged from 16.8-30.4 °C. The mixed layer varied seasonally, ranging from the shallower spring-summer depth range of 0-50 m and a fall-winter depth range of 35-110 m. A good deal of the scattering observed in the temperature profiles may have possibly been due to the presence of warm or cold eddies in the Gulf.

The 8 °C isotherm, when referenced to the dynamic height topography, proved to be the most useful tool to detect warm-core and cold-core eddies at depths greater than 800 m. In shallower water, the 15 °C isotherm was the only usable isotherm with which to detect warm or cold eddies.

Chlorophyll a concentrations from inshore stations had a mean of 0.4 mg/m^3 and a maximum of 28.15 mg/m^3, while offshore stations had a mean of 0.2 mg/m^3 and a maximum of 2.74 mg/m^3. The data indicated that neither a spring nor fall bloom occurred during the survey period. Even when the Mississippi River influence was removed as a possible bias, the data show that no spring or fall phytoplankton bloom occurred. While seasonal chlorophyll signals were detected in the surface chlorophyll a values, they seemed to be a poor estimate of total chlorophyll in the water column.

"Hot spots" of chlorophyll were detected offshore in *Pelican* Cruises 3 and 4. The higher values on Cruise 3 (integral = 40 mg/m^2) were probably due to fresh water that was pushed seaward to at least the 1,000 m isobath by northeasterly winds. The high values (integral $\geq$ 65 mg/m^2) seen in *Pelican* Cruise 4 were located at the edge of a warm anticyclonic eddy ("no name") off the Mississippi delta. The other area showing a high offshore value (integral = 50 mg/m^2) was probably related to fresh water from the Mississippi River extending offshore from wind forcing.

The Mississippi River plume was detected using shipboard data, fresh water fraction maps, salinity maps, sea surface temperature (from continuous flow-through data), and AVHRR satellite images. Two major events related to the Mississippi River plume and fresh water input into the Gulf occurred during 1992-1993. The first occurred in the fall of 1992 when Mississippi River fresh water extended outward into the Gulf to the 1,000 m isobath. The second event was the "Great Flood" during summer 1993. Colder coastal waters were trackable as a distinct plume using sea surface temperature AVHRR images.

The fresh water seen in late October traveled further seaward, extending as far as the 2,000 m isobath. Northeasterly to easterly wind forcing was responsible for the southerly intrusion of the Mississippi River plume fresh water into the Gulf. During the summer of 1993, anomalously high rainfall was experienced over the midwestern U.S.A. During the subsequent flood, the Mississippi River discharge was described as streaming to the east. This was a rare occurrence as ordinarily the flow of fresh water is to the west. This event was shown in an August 1993 satellite image and confirmed by salinity data. Wind was also thought to be a significant factor in the eastward flow of the river water during this interval.

A maximum of 56% fresh water was found east of the Mississippi delta during the summer cruise in 1993. The Mississippi River water was moving eastward, and the freshwater fraction remained above 20% to 87°30'W and seaward to the 2,000 meter contour. The values east of the delta were approximately double those obtained in August 1992. The freshwater fraction southwest of the delta was 35% in 1993, considerably lower than the fresh water contribution east of the delta, but slightly higher than that encountered in August 1992 (22%).

Over the period 1992-1993, ship surveys, aerial surveys and satellite coverage allowed continuous monitoring of the Loop Current, eddy shedding, and eddy propagation at unprecedented spatial and temporal resolution. At least three anticyclonic eddies (U, W, and X), each with a diameter of at least 300 km, were shed from the Loop Current during this period, and moved with their associated cyclonic eddies into the western Gulf.

The *Pelican* and *Oregon II* sampling grid proved to be useful in sampling the meso- to large-scale features of the Gulf of Mexico. GulfCet was able to detect all the major eddies and events present in the northern Gulf from 1992 to 1993. The hydrographic sampling program was able to detect all the major warm-core eddies as well as their affiliated cold-core eddies. The detection of these cold or cyclonic eddies is particularly significant as upwelled water, with its subsequently higher nutrient and oxygen content, is the result of these oceanographic features.

The study area in 1992-1993 presented a complex hydrographic scenario. The following features were seen: a) new warm anticyclonic eddies with associated cyclonic eddies moved in and out the northern Gulf, b) recently formed warm anticyclonic eddies interacted with older eddies in the northwestern corner of Gulf, and c) unusual fresh water outflow extended offshore as far as the 2,000 m isobath in fall of 1992 and in the summer of 1993 fresh water discharge streamed to the east of the delta. As a result of eddy movement, each of the GulfCet surveys had a unique opportunity to view meso- to large-scale hydrographic features. No generalizations can be made regarding eddy path, residence time, or frequency of occurrence in the study area. Generally, however, after separation from the Loop Current, anticyclonic eddies drift westward until their progress is halted by the northwestern continental slope, in the "eddy graveyard". Some eddies reached the western margin in just a few months, while others took longer and cleaved into secondary eddies during the westward transit.

VII. BIRD SURVEYS

The GulfCet bird data provided new information on the seasonal occurrence, relative abundance, and distribution of offshore avifauna.

Of 3,276 total sightings, 2,692 were seabirds, and 584 were non-seabirds. Thirty-two species representing nine families and three orders of seabirds were observed. Of the birds identified to species, 14 species represented over 99% of the total sightings. While birds were sighted throughout the study area during all four seasons, the species composition varied during the year. Spring produced the greatest species diversity (28 species) and the second highest total bird sighting rate (19.8 bird sightings per day). Summer had the second highest species diversity (14 species), and the highest number (23.2) of bird sightings per day. Summer had the fewest observation days, and all of the data were from one cruise. The fall data provided the lowest total bird sightings per day (8.11); 12 species were sighted. Winter ranked third in the number of bird sightings (12.0 per hour) and tied with fall for the lowest species diversity (12 species of seabirds). Although the complexity of the hydrography of the Gulf made the analysis of habitat difficult, at least one variable (water depth) appeared significantly related to bird distribution.

New insight was added into the distribution and abundance of Audubon's Shearwaters, storm-petrels (especially the Band-rumped Storm-Petrel), phalaropes, jaegers (especially the Pomarine Jaeger), Laughing Gulls, Herring Gulls, Bridled Terns, Sooty Terns and Black Terns. Some conclusions regarding distribution relative to water depth for some species were possible. Records of species rare in the north-central and western Gulf, including White-tailed and Red-billed Tropicbird and Brown Noddy, were obtained. Although much data has been collected covering most of the year, information regarding species present during March, July, and October was low, and habitat variables for all of the Gulf pelagic species need further investigation. Most of the pelagic bird species, including species with limited Atlantic Ocean populations, such as the Audubon's Shearwater and the Band-rumped Storm-Petrel, could potentially be negatively affected by oil spills.

VIII. STUDIES OF SPERM WHALES

This section describes the results of two aspects of the GulfCet Program: (1) satellite tagging of sperm whales, and (2) a sperm whale focal cruise (*Pelican* Cruise 8).

Satellite Tagging of Sperm Whales

Oregon State University (OSU) attempted to place satellite-linked depth recorders (SLDRs) and location-only satellite telemeters on sperm whales to determine their movements, diving behavior, and preferred habitat. To accomplish this goal, three cruises were undertaken: two in the Gulf of Mexico (October 1992 and June 1993) and one in the Galapagos (March 1993). The Galapagos cruise was intended as a test for tag deployment and attachment.

The first tagging cruise was conducted from 30 September-14 October 1992 aboard the R/V *McGrail*. On 9 October, 8-10 sperm whales were sighted. Unfortunately, the boat could not maneuver well enough at slow speed to get close enough to tag any animals.

The second cruise was conducted in the eastern Pacific Ocean, near the Galapagos Islands, from 20-31 March 1993 aboard the R/V *Odyssey*. The purpose of this cruise was to test techniques to approach and attach SLDRs to sperm whales. Several hundred sperm whales were located and followed over a five-day period using visual and acoustic contacts. On 26 March, a SLDR was successfully attached to a sperm whale. The telemeter was placed about 0.5 m from the whale's dorsal ridge and appeared to be flush against the animal's skin. The animal did not appear to startle or take flight after attachment of the telemeter, but continued its initial submergence pattern and surfaced a few minutes later, 100 m from the boat. Unfortunately, no data were received from its transmitter. Two other tagging attempts were unsuccessful.

The final tagging cruise used the R/V *Acadiana*. The ship covered 2,331 km. Sperm whales were seen on seven days and heard on 11 days. The number of sperm whales ranged from 4-22 per day with up to eight animals seen at one time. A maximum of 87 individuals was seen during the cruise. Animals were sighted most often in the afternoon. Two animals were tagged. The first whale (about 8 m in length) was tagged with an SLDR. Only one message was heard from this tag. It is believed that this tag fell off the animal shortly after attachment due to incomplete penetration of the tines into the blubber. The second animal (about 7 m in length) was tagged with a location-only telemeter. It is not known why this telemeter failed. The small size of the animals that were tagged may have exacerbated attachment problems. The attachment methods have worked very well on right whales and bowhead whales, but may have to be modified for sperm whales. While searching for sperm whales during this cruise, some circumstantial evidence was obtained that seismic-survey vessel activity may affect the distribution of sperm whales (Mate et al. 1994).

Sperm Whale Focal Cruise

Acoustic and visual means were used to locate and follow whales from 20-28 August 1994 in the vicinity of the mouth of the Mississippi River to monitor sperm whale movements and behavioral patterns.

Vocalizing sperm whales were localized in three dimensions with the use of horizontal and vertical hydrophone arrays, based on a matched field processing approach. Results from one trial analysis showed three of five vocalizing animals near 600 m deep, in water 1,247 m deep. The shallowest localization was at approximately 100 m. There were no indications of animals vocalizing at or near the surface.

Twenty individual sperm whales were identified from photographic and video images, two of them calves (Schiro et al. 1995). Nine of the 20 identified individuals were resighted during the cruise.

An unusual interaction between pilot whales and sperm whales was observed (Weller et al. in press). Interactions among 10 adult sperm whales (and two calves) and 30-45 pilot whales were observed for 150 minutes, and vocal activity was recorded. The observations provide suggestive evidence that short-finned pilot whales may aggress toward or at least threaten sperm whales.

IX. CETACEAN HABITAT

Shipboard and aerial sightings were analyzed to determine an average species habitat profile. Seven environmental variables were chosen to characterize habitat based on their ability to represent oceanographic, topographic, and acoustic variables. A Geographical Information System was used to integrate the marine mammal sightings and oceanographic data.

Atlantic spotted dolphins, striped dolphins and sperm whales occurred in the coolest water and, as a group, were significantly different from pantropical spotted dolphins, but overlapped with the group comprising bottlenose dolphins, Risso's dolphins, pygmy/dwarf sperm whales and beaked whales. Atlantic spotted dolphins and striped dolphins occurred in the shallowest sea surface temperature (SST) gradients and, as a group, were significantly different from beaked whales, but overlapped with bottlenose dolphins, Risso's dolphins, pantropical spotted dolphins, sperm whales and pygmy/dwarf sperm whales.

The cetaceans in this study occurred in water with a relatively narrow range of annual SSTs. The seasonal variation in SST in the Gulf typically ranges from 5-7 °C, with little interannual variation. The mean values for the depth of the 15 °C isotherm (<250 m), the temperature at 100 m (<22 °C) and surface salinity (<36.6 psu) indicated that most of the cetacean sightings were outside of the Loop Current and warm-core rings.

The relatively stable, mean surface salinity beyond the shelf edge was probably responsible for the absence of any significant difference for this environmental variable among cetacean species in the study area. However, the large range of salinities recorded (some as low as 15.8 psu) for those species frequently observed along the shelf break in the north-central Gulf reflected the mixing of the Mississippi River discharge and near-shore water.

Bottom depth showed the clearest indication of habitat partitioning in the study area. Atlantic spotted dolphins were consistently found in the shallowest water on the continental shelf and along the shelf break. In addition, the bottom depth gradient was less for Atlantic spotted dolphins than for any other species. The bottlenose dolphins in this study were found most commonly along the upper slope in water significantly deeper than that for Atlantic spotted dolphins. Risso's dolphins and short-finned pilot whales occurred most commonly along the mid-to-upper slope, often in areas with a steep bottom gradient. Rough-toothed, spinner, clymene, pantropical spotted, and striped dolphins are all small cetaceans that occur over deep water beyond the continental shelf, although their small size probably limited them to the upper 200 m of the water column. Their occurrence in deep water may be linked to the offshore location of their prey.

Although the study area covered 154,621 km^2 (about 10% of the Gulf), it may represent only a part of the home range of the species observed. Even during normal years, the oceanographic features of the north-central and western

Gulf are very complex and dynamic due to the formation of warm-core rings from the Loop Current and seasonal fresh water discharge from the Mississippi and other rivers. The GulfCet aerial and shipboard surveys occurred during a period when several warm-core rings moved through the northern Gulf. At the same time, there was an unusually large influx of fresh water from the Mississippi River due to record rainfall in the midwestern states in 1993. As a result, some of the oceanographic variables were atypical during the two years of this study, and the data were insufficient to address seasonal and interannual variability in habitat.

The mean annual marine habitat for cetaceans in the study area is subtropical to tropical in the upper 200-300 m, with relatively low primary productivity. Cooler, nutrient-rich water below this layer is brought to the surface by the upwelling influences of cold-core eddies. Nutrients are also introduced into the Gulf by the Mississippi River. This resulted in a patchy distribution of primary productivity with "hot spots" of chlorophyll a that may increase secondary productivity and attract cetaceans. Additional studies will be needed to examine the distribution of cetaceans around these areas of high productivity.

X. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE STUDIES

The GulfCet Program was the first attempt to determine the distribution and abundance of cetaceans along the entire continental slope in the north-central and western Gulf of Mexico. Although the scope of this program was greater than previous studies in this part of the Gulf (Fritts et al. 1983, Mullin et al. 1994), the total area surveyed represented only 10% of the entire Gulf and was small (0.008%) in comparison to cetacean surveys and habitat characterization in the eastern tropical Pacific (ETP) (Wade and Gerrodette 1993).

Cetaceans were commonly observed throughout the GulfCet study area during all four seasons. However, the determination could not be made whether animals were in transit or resident in the study area for extended periods, and it is likely that the small study area encompasses only a portion of the home range for many of the species observed.

The diversity of cetaceans in the study area was comparable to that along the continental slope of northeastern United States and in the ETP (Hain et al. 1985, Wade and Gerrodette 1993). However, the overall density of cetaceans in the GulfCet study area was significantly lower (< 25%) than in these latter two regions. In addition, baleen whales, especially fin whales (*Balenoptera physalus*), made up a significant number (ca. 10%) of identified sightings along the northeastern United States (Hain et al. 1985), but were practically absent from the GulfCet study area. Group density in the study area was approximately the same as that found in the ETP.

The lower densities of whales in the Gulf compared to the northeastern United States and ETP could be related to the more oligotrophic conditions and a smaller food base that cannot support a high density of cetaceans. The estimated biomass of cetaceans in the study area was 9,130 metric tons. Of this biomass, sperm whales represented 68.6%. Together, sperm whales, pantropical spotted dolphins, short-finned pilot whales, bottlenose dolphins, melon-headed whales, killer whales, and striped dolphins constituted 92.7% of the cetacean biomass. The minimum estimated food requirement for all cetaceans (assuming adult body masses for each species) was estimated to be approximately 81,000 metric tons/year, of which sperm whales consumed 42%. Dividing the minimum food requirement by the size of the study area gives a cetacean food consumption rate of 0.52 metric tons/km^2/year. This value is about 20% of the estimated annual food consumption per km^2 for cetaceans living along the continental slope in the northeastern United States, and it may reflect the lower primary and secondary productivity of the Gulf (Hain et al. 1985).

Without synoptic data on the abundance and distribution of cetaceans in the entire Gulf of Mexico, we cannot determine the importance of the GulfCet study area for the 19 species sighted. However, approximately 19,000 cetaceans utilize the study area annually, which indicates that the continental slope in the north-central and western Gulf is of importance to these animals. The dynamic hydrography of the north-central and western Gulf resulting from the formation and movement of warm-core and cold-core rings and the outflow of fresh water from the Mississippi River makes a description of average habitat difficult and may obscure important associations of cetacea with distinctive hydrographic features associated with feeding.

To obtain a more complete understanding of the seasonal and annual distribution, abundance, and habitat utilization of cetaceans, a survey of the entire Gulf and the satellite and conventional radio tracking of the predominant species, such as pantropical dolphins, should be conducted. In addition to location at sea, satellite telemeters can record information on diving behavior that will provide clues concerning potential prey species and resource partitioning among cetaceans. This information, in addition to trophic level studies of primary and secondary productivity and prey distribution, will enable researchers to gain a better understanding of the factors that influence the distribution of cetaceans. The diet of a significant number of the cetaceans in the Gulf is dominated by cephalopods and mesopelagic fishes associated with the vertically migrating acoustic deep scattering layer (DSL) (Perrin et al. 1973). A long-term monitoring program would be needed to obtain baseline information on cetaceans before oil and gas development moves further onto the continental slope. Concurrent with synoptic surveys, focal studies could examine the presence of cetaceans around distinctive oceanographic features, such as cold-core eddies and the Mississippi River freshwater plume, in order to better understand the influence of these features on cetacean distribution.

During the implementation of the focal studies, behavioral information should be gathered to determine whether animals are using certain areas for specific activities, such as social/sexual behavior, foraging, resting, or transiting. The behavioral studies can be conducted concurrently with aerial surveys and shipboard visual and acoustic surveys. However, dedicated cruises are also needed to study: 1) behavioral patterns, 2) at-sea movements and diving behavior, and 3) the reaction of cetaceans to oil and gas exploration and development activities. During these cruises, sperm whales might be photoidentified and skin and blubber biopsies taken to improve our understanding of their population biology and toxicology.

Seventy-eight percent of the oil and 97% of the gas production in United States federal waters occurs in the Gulf of Mexico, primarily along the Texas-Louisiana continental shelf (Minerals Management Service, New Orleans, LA, November 1995). During the period 1984 to 1994, the MMS western and central Gulf regions produced about 3.4×10^9 barrels of crude oil and 50.2×10^9 million cubic feet of natural gas (Technical Information Management System Database, Offshore Systems Center, Minerals Management Service, New Orleans, LA, July 1995). In addition to oil and gas exploration along the continental shelf, this area has considerable commercial shipping traffic that enters the northern Gulf ports. The long-term forecast for petroleum transportation is for the total volume to increase into the next century. This, coupled with the move of the petroleum industry into deeper waters in their continuing quest for new oil and gas reserves, may result in significant impact on cetaceans along the continental slope of the Gulf (Tucker and Associates, Inc. 1990). The long-term consequences of human activity cannot be predicted with certainty. However, it can be anticipated that cetaceans will encounter oil and gas exploration and production activity as these move further onto the continental slope. These activities include construction, oil spills, ship traffic, seismic exploration, and underwater noise.

Major construction activities will include the installation of drilling rigs, platforms, and pipelines. There are three primary concerns associated with construction activities on the continental shelf and slope. These involve sea floor disturbance, the attraction of fish and invertebrates to submerged structures, and the potential interaction of these structures with resident or migrating cetaceans (Phillips and James 1988). Stationary rigs may alter habitat by acting as fish attractants, enhancing prey availability for certain species of cetaceans. Negative impacts to cetaceans may result from seismic exploration activities (Richardson et al. 1995), the sounds produced by rig construction and oil and gas exploration and production, and the potential for collisions with increased ship activity. The only way to determine the long term effects of these activities is through a monitoring program that commences ahead of the widespread implementation of deep water exploration and production. Such a monitoring program would involve traditional aerial and shipboard visual surveys, shipboard acoustic surveys, behavioral observations of the cetaceans encountered, and satellite and conventional radio telemetry studies of the predominant cetacean species. The shipboard acoustic surveys are particularly useful because they monitor the presence of vocalizing cetaceans as well as ambient noise levels. In addition, this kind of data can be archived for later analysis as exploration and production activities develop and change over long periods of time.

The Gulf of Mexico is rich in species occurring throughout the food chain that are acoustically very detectable with passive instruments. It is unfortunate that so little information is available on ambient noise levels, source levels from fish and dolphins, and especially accurate data on exposure levels as a function of frequency during the explosive removal of platforms and other noise associated with oil and gas development. This fact makes the northern Gulf of Mexico ideal for using acoustic monitoring to study the seasonal movements, distribution, and abundance of cetaceans.

In conclusion, the continental slope in the north-central and western Gulf of Mexico is an area that supports a diverse cetacean community, but one whose density does not equal areas such as the northeastern United States and the ETP. Very complex and dynamic oceanographic and mesoscale features typify this area of the Gulf and show large annual and inter-annual variability. This makes it difficult to predict the distribution of cetaceans based on existing data. However, the GulfCet program has demonstrated that the most effective monitoring programs will need to be long-term, with relatively intensive sampling effort in order to detect significant changes in the density and distribution of cetaceans. Of special interest is the demonstration of acoustic monitoring techniques, which hold great promise for long-term monitoring programs of cetacean distribution and abundance.

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Royalty Management Program** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.

Minerals Management Service
Gulf of Mexico Region

Managing America's offshore energy resources

Protecting America's coastal and marine environments