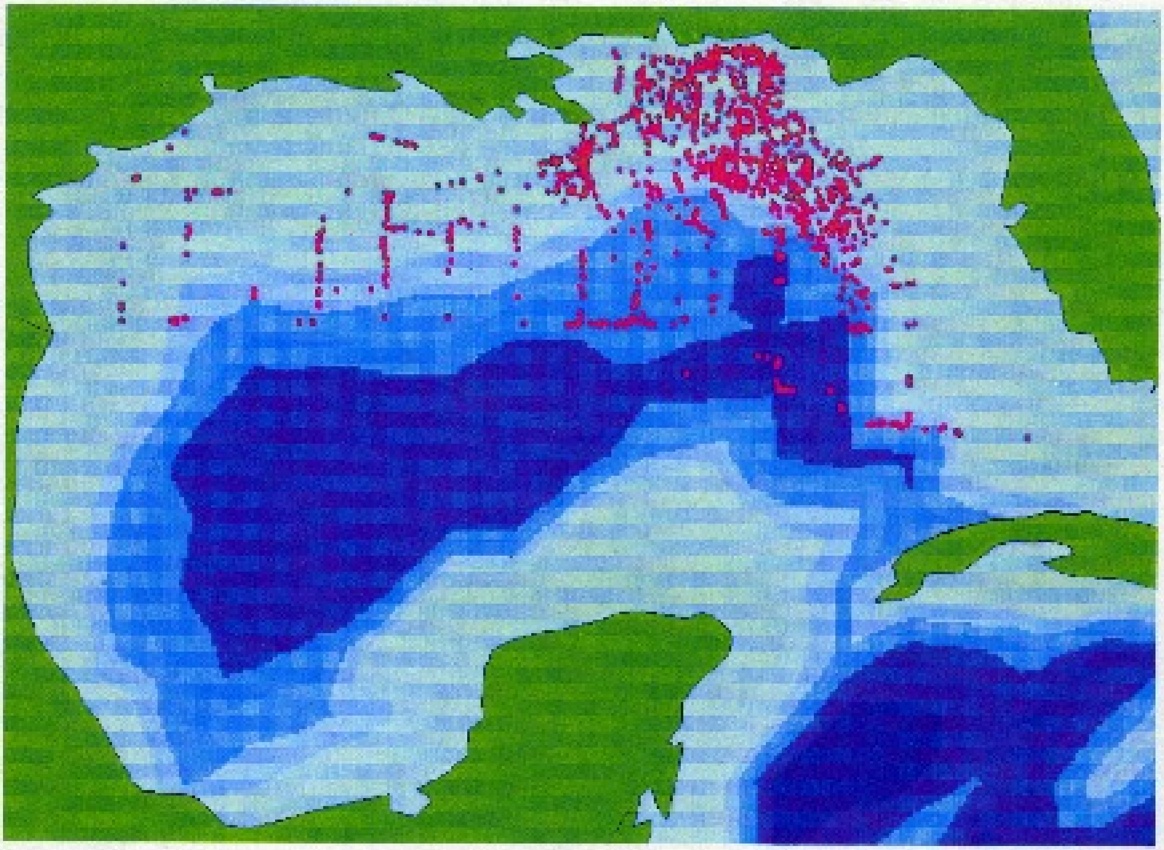
science for a changing world

Contractor Report
USGS/BRD/CR-1999-0005
OCS Study MMS 2000-002



Cetaceans, Sea Turtles and Seabirds in the Northern Gulf of Mexico: Distribution, Abundance and Habitat Associations

Volume I: Executive Summary

U.S. Department of the Interior
U.S. Geological Survey
Biological Resources Division

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

Contractor Report
USGS/BRD/CR--1999-0006
OCS Study MMS 2000-002

Cetaceans, Sea Turtles and Seabirds in the Northern Gulf of Mexico: Distribution, Abundance and Habitat Associations

Volume I: Executive Summary

Editors

Randall W. Davis
William E. Evans
Bernd Würsig

January 2000

Prepared under
U.S. Geological Survey, Biological Resources Division
Contract Number 1445-CT09-96-0004 and 1445-IA09-96-0009
by
The GulfCet Program
Department of Marine Biology
Texas A&M University at Galveston
5007 Avenue U
Galveston, Texas 77551

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

PROJECT COOPERATION

This study was procured to meet information needs identified by the Minerals Management Service (MMS) in concert with the U.S. Geological Survey, Biological Resources Division (BRD).

DISCLAIMER

REPORT AVAILABILITY

Extra copies of this report may be obtained from the Public Information Office at the following address:

U. S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region
Public Information Office (MS 5034)
1201 Elmwood Park Boulevard
New Orleans, LA 70123-2394

Telephone: (504) 736-2519 or
(800) 200-GULF

CITATION

Davis, R.W., W.E. Evans, and B. Würsig, eds. 2000. Cetaceans, Sea Turtles and Seabirds in the Northern Gulf of Mexico: Distribution, Abundance and Habitat Associations. Volume I: Executive Summary. Prepared by Texas A&M University at Galveston and the National Marine Fisheries Service. U.S. Department of the Interior, Geological Survey, Biological Resources Division, USGS/BRD/CR—1999-0006 and Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2000-002 27 pp.

PREFACE

This study entitled "Cetaceans, Sea Turtles and Seabirds in the Northern Gulf of Mexico: Distribution, Abundance and Habitat Associations", also known as the GulfCet II study, provides synoptic data and analyses on the species diversity, abundance, and habitat characteristics for cetaceans, sea turtles and seabirds in the northern Gulf of Mexico. Results of the study are described in three volumes including this volume ("Volume I: Executive Summary"), "Volume II: Technical Report" and "Volume III: Data Appendix."

This study was sponsored and administered by the U.S. Department of Interior, U.S. Geological Survey, Biological Resources Division to provide environmental information to the U.S. Department of Interior, Minerals Management Service. It was managed by Texas A&M University at Galveston in partnership with the National Marine Fisheries Service at the Southeast Fisheries Science Center.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

The following acronyms and abbreviations are used throughout this Executive Summary and the Technical Report:

ADCP	Acoustic Doppler Current Profiler
AVHRR	Advanced Very High Resolution Radiometer
BRD	Biological Resources Division
CCAR	Colorado Center for Astrodynamics Research, University of Colorado
CCR	Cold-Core Ring
CHL	Chlorophyll
CI	Confidence Interval
CON	Confluence between ring structures
CTD	Conductivity, Temperature, and Depth Profiler
CV	Coefficient of Variation
dB rel μP	Decibels relative to 1 micro Pascal
DCM	Deep Chlorophyll Maximum
DFA	Discriminant Function Analysis
EPA	Eastern Planning Area
GIS	Geographic Information System
GPS	Global Positioning System
GulfCet I	Distribution and Abundance of Cetaceans in the North-Central and Western Gulf of Mexico (1991-1995)
GulfCet II	Cetaceans, Sea Turtles and Seabirds in the Northern Gulf of Mexico: Distribution, Abundance and Habitat Associations (this study)
HCLS	High Chlorophyll, Low Salinity
HPLC	High Pressure Liquid Chromatography
IKMT	Isaacs Kidd Midwater Trawl
LC	Loop Current
LCE	Loop Current Eddy
MAR	Mississippi-Atchafalaya River
MLD	Mixed Layer Depth
MOCNESS	Multiple Opening/Closing Net and Environmental Sampling System
MOM	Mouth of the Mississippi
MMS	Minerals Management Service
NE	Northeast
NEGOM	Northeastern Gulf of Mexico
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OCS	Outer Continental Shelf
PER	Periphery of ring structures
PMB	Predicted Mean Biomass
PSD	Perpendicular Sighting Distance
SAIL	Serial ASCII Interface Loop
SD	Standard Deviation
SEFSC	Southeast Fisheries Science Center, NMFS

SSH	Sea Surface Height
SST	Sea Surface Temperature
Stenellids	Dolphins of the genus *Stenella*
S_v	Acoustic backscattering strength
TAMU	Texas A&M University (College Station)
TAMUG	Texas A&M University at Galveston
TOPEX/ERS	Topography Experiment Mission/European Research Satellite
TOPEX/POSEIDON	Topography Experiment Mission/Poseidon
T-S	Temperature-Salinity Relationship
UC	University of Colorado
USGS	United States Geological Survey
WCR	Warm-Core Ring
WCWRU	Wisconsin Cooperative Wildlife Research Unit
XBT	Expendable Bathythermograph

ACKNOWLEDGMENTS

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 Alejandro Acevedo, Ilona Berk, Steve Berkowitz, Jose Bersano, Robert Blaylock, Ned Brinkley, British Petroleum, Cheryl Brown, Carolyn Burks, Shane Collier, Melissa Davis, Brad Dawe, Theia DeLong, Captain Dana Dyer, Wesley Elsberry, Dagmar Fertl, Michelle Finn, Michael Flinn, Holly Fortenberry, Rachel Gross, Jeff Hagan, Terry Henwood, Shannon Hesse, Lesley Higgins, Markus Horning, Carrie Hubard, Clint Jeske, John Lamkin, Kosrow Lashkari, Nicole LeBoeuf, John Longnecker, Steven Lowder, Kimberly Marks, Greg Marshall, Tony Martinez, Blair Mase, Kathy Maze, National Geographic Society, Scott Nichols, Steve Nokutis, Dwight Peake, Mike Peccini, Jon Peterson, Matt Pickett, Robert Pitman, Todd Pusser, Danielle Raha, Logan Respess, Carol Roden, Diego Rodriguez, Gerald Scott, Mari Smultea, Jon Stern, Sarah Stienessen, Jim Tobias, Erika Vidal, Melany Würsig, and Mindy Zuschlag.

Special thanks to Paula Canton, Kate deMedeiros, Jenny Ogrodnick, and Mary Beth Rew for technical editing. The GulfCet Data Management Office also wishes to express its appreciation to those who served as reviewers of this document.

We gratefully acknowledge the Department of Oceanography, Texas A&M University, the Texas Institute of Oceanography and the National Marine Fisheries Service for cost-sharing the use of all research vessels used for the surveys on this project. Two colleagues not on the GulfCet team provided important help with data reduction: Steve DiMarco (TAMU) carried out the initial quality control on the ADCP data from RV *Gyre* cruises 96G06 and 97G08 to produce the data sets plotted in Figures 2.8 and 2.10, following protocols developed to support the MMS-sponsored Northeast Gulf of Mexico Chemical Oceanography and Hydrography project (NEGOM-COH). Dr. DiMarco then provided the gridded files of ADCP near surface velocity that are plotted in Figures 2.9 and 2.11. Peter Hamilton (SAIC) produced the gridded files of geostrophic velocity at 0 m relative 800 m that are plotted in Figures 2.30 and 2.33.

Special thanks to the Scientific Review Board members Daryl Boness, Roger Hanlon and Lawrence Pomeroy for their thoughtful review and comments on the goals and results of this project, and very special thanks to BRD Contracting Officers Technical Representative Gary Brewer and MMS Contracting Inspectors Robert Avent and Dagmar Fertl for their guidance in the writing of this report.

This study was funded by the U.S. Department of the Interior, Geological Survey, Biological Resources Division under contracts 1445-CT09-96-0004 and 1445-IA09-96-0009.

CONTRIBUTORS

Douglas C. Biggs	Department of Oceanography, Texas A&M University, College Station, Texas 77843-3146; dbiggs@ocean.tamu.edu
Robert B. Cady	Department of Oceanography, Texas A&M University, College Station, Texas 77843-3146; robcady@ocean.tamu.edu
Randall W. Davis	Department of Marine Biology, Texas A&M University, 5007 Avenue U, Galveston, Texas 77551; davisr@tamug.tamu.edu
William E. Evans	Department of Marine Biology, Texas A&M University, 5007 Avenue U, Galveston, Texas 77551; evansw@tamug.tamu.edu
Elizabeth J. Harris	Department of Oceanography, Texas A&M University, College Station, Texas 77843-3146; lizh@ocean.tamu.edu
Nancy A. Hess	Department of Wildlife Ecology, University of Wisconsin, 226 Russell Labs, 1630 Linden Drive, Madison, Wisconsin 53706-1598; nahess@students.wisc.edu
Wayne Hoggard	Southeast Fisheries Science Center, National Marine Fisheries Service, P.O. Drawer 1207, Pascagoula, Mississippi 39568; whoggard@triton.pas.nmfs.gov
Robert R. Leben	Colorado Center for Astrodynamic Research, University of Colorado, Campus Box 431, Boulder, Colorado 80309-0431; leben@orbit.colorado.edu
Spencer K. Lynn	GulfCet Program Office, Texas A&M University, 5007 Avenue U, Galveston, Texas 77551
Keith D. Mullin	Southeast Fisheries Science Center, National Marine Fisheries Service, P.O. Drawer 1207, Pascagoula, Mississippi 39568; kmullin@triton.pas.nmfs.gov
Jeffrey C. Norris	Marine Acoustics Lab, Texas A&M University, 5007 Avenue U, Galveston, Texas 77551; norrisj@tamug.tamu.edu
Joel G. Ortega-Ortiz	Marine Mammal Research Program, Texas A&M University, 4700 Avenue U, Bldg. 303, Galveston, Texas 77551; ortegaj@tamug.tamu.edu
Shannon Rankin	Marine Acoustics Lab, Texas A&M University, 5007 Avenue U, Galveston, Texas 77551

Patrick H. Ressler — Department of Oceanography, Texas A&M University, College Station, Texas 77843-3146; pressler@ocean.tamu.edu

Christine A. Ribic — Department of Wildlife Ecology, University of Wisconsin, 226 Russell Labs, 1630 Linden Drive, Madison, Wisconsin 53706-1598; caribic@facstaff.wisc.edu

Andrew J. Schiro — Marine Mammal Research Program, Texas A&M University, 4700 Avenue U, Bldg. 303, Galveston, Texas, 77551

Troy D. Sparks — Marine Acoustics Lab, Texas A&M University, 5007 Avenue U, Galveston, Texas 77551; sparkst@tamug.tamu.edu

David W. Weller — Marine Mammal Research Program, Texas A&M University, 4700 Avenue U, Bldg. 303, Galveston, Texas, 77551

John H. Wormuth — Department of Oceanography, Texas A&M University, College Station, Texas 77843-3146; jwormuth@astra.tamu.edu

Bernd Würsig — Marine Mammal Research Program, Texas A&M University, 4700 Avenue U, Bldg. 303, Galveston, Texas 77551; wursigb@tamug.tamu.edu

INTRODUCTION

Background

The mission of the U.S. Geological Survey (USGS) Biological Resources Division (BRD) is to provide the scientific understanding and technologies needed to support the sound management and conservation of the nation's biological resources. The U.S. Department of the Interior's Minerals Management Service (MMS) is a client agency of the BRD. The MMS has the responsibility for leasing, minerals exploration and development of submerged Federal lands on the U.S. Outer Continental Shelf (OCS) under the provisions of the OCS Lands Act Amendments of 1978. The BRD administered this study, hereafter called the GulfCet II program. The GulfCet II program was managed by Texas A&M University at Galveston (TAMUG) in partnership with the National Marine Fisheries Service (NMFS) at the Southeast Fisheries Science Centers (SEFSC).

Until recently, relatively little was known about cetaceans inhabiting deeper waters of the Gulf of Mexico (Table 1) (Fritts et al. 1983, Shane et al. 1986, Scott et al. 1989, Scott and Hansen 1989, Leatherwood and Reeves 1990, Mullin et al. 1994, Jefferson and Schiro 1997). The most extensive survey of cetaceans in the offshore waters (100-2,000 m deep) of the north-central and western Gulf of Mexico (Figure 1) was conducted jointly by Texas A&M University and the NMFS, Southeast Fisheries Science Center beginning in 1992 and called the GulfCet I program (Davis and Fargion 1996, Baumgartner 1997, Davis et al. 1998). This three-year study provided synoptic information on the distribution and abundance of cetaceans using both visual and acoustic survey techniques. It also provided limited information on cetacean-habitat associations. In addition to cetaceans, the GulfCet I program provided synoptic information on the distribution and abundance of sea turtles using aerial survey techniques. Finally, over 30 species of seabirds were sighted during visual shipboard surveys of the study area (Davis and Fargion 1996).

GulfCet II Study Area and Objectives

The GulfCet II program used aerial surveys and shipboard visual and acoustic surveys to document cetacean, sea turtle and seabird populations. This work was accompanied by data acquisition designed to further characterize habitat and reveal habitat associations for cetaceans and seabirds. This study was intended as a spatial and temporal extension of the GulfCet I program.

The GulfCet II study area included:

(1) The MMS Eastern Planning Area (EPA) continental slope from 100-2,000 m deep east of 88°10.0'W and north of 26°00.0'N (70,470 km^2) and the EPA continental shelf (12,326 km^2) located from 18.5 km offshore to 100 m deep between 88°10.0'W and 85°55.0'W (Figure 2). This area was surveyed using both aircraft and ships (R/V *Oregon II and* R/V *Gyre*).

Table 1. Cetaceans of the Gulf of Mexico. The (E) next to the common name indicates that the species is listed under the Endangered Species Act of 1973 as endangered.

	Balaenidae	
Northern right whale (E)		*Eubalaena glacialis*
	Balaenopteridae	
Blue whale (E)		*Balaenoptera musculus*
Fin whale (E)		*Balaenoptera physalus*
Sei whale (E)		*Balaenoptera borealis*
Bryde's whale		*Balaenoptera edeni*
Minke whale		*Balaenoptera acutorostrata*
Humpback whale (E)		*Megaptera novaeangliae*
	Physeteridae	
Sperm whale (E)		*Physeter macrocephalus*
	Kogiidae	
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*

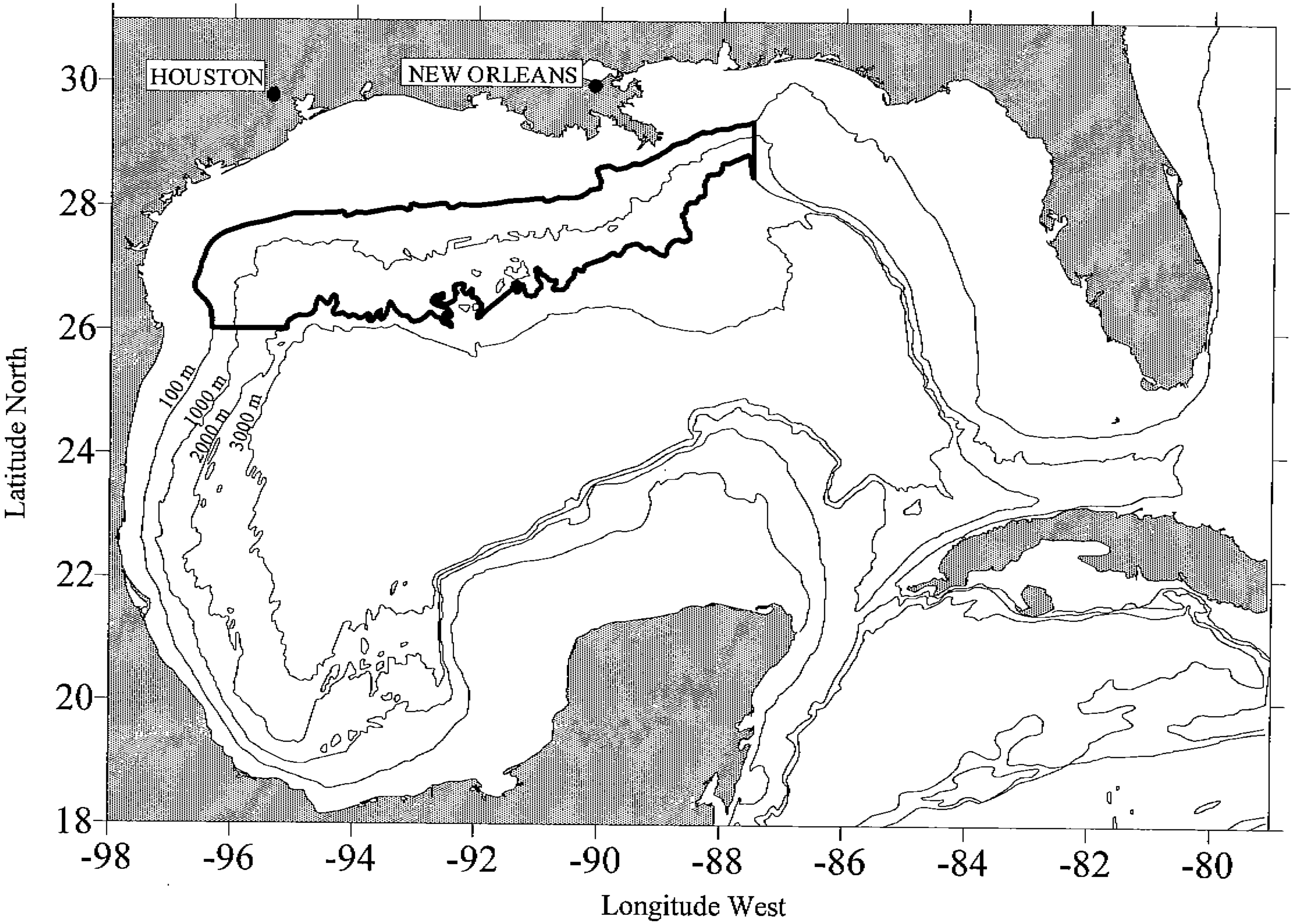


Figure 1. GulfCet I study area in the western and north-central Gulf between the 100 and 2,000-m isobaths.

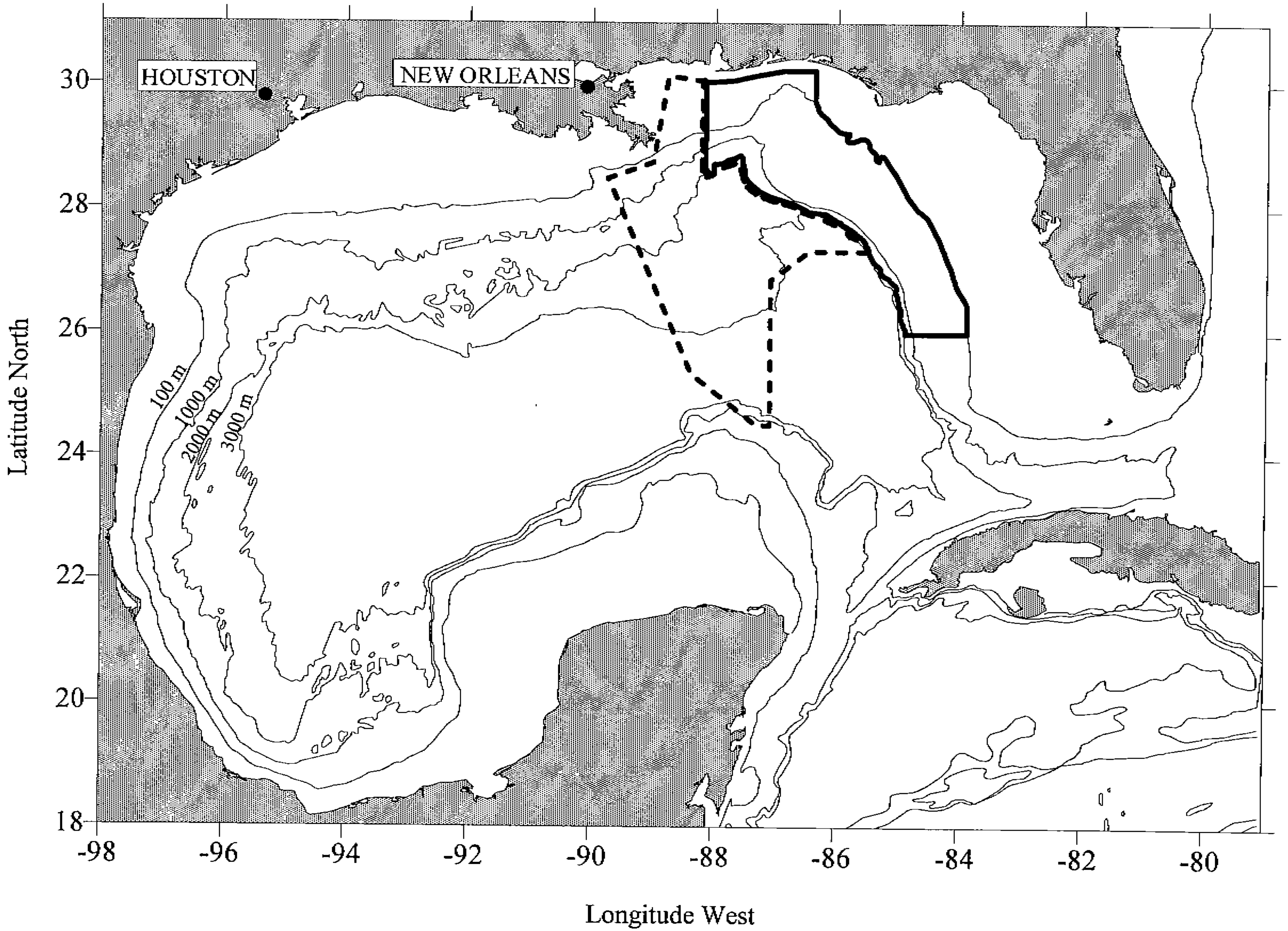


Figure 2. GulfCet II study area including the Minerals Management Services' Eastern Planning Area (bold line) and the focal study area for cetacean habitat surveys (dashed line).

(2) GulfCet I Study Area (154,621 km^2) (Figure 1). U.S. waters from 100-2,000 m deep west of 87°30.0'W. This area is a subset of the oceanic northern Gulf study area (Figure 4) and was surveyed during spring with the R/V *Oregon II*.

(3) Oceanic northern Gulf of Mexico (398,960 km^2) (Figure 3). Waters within the U.S. Economic Exclusive Zone (EEZ) greater than 100 m deep. This area was surveyed using the R/V *Oregon II* during spring.

(4) Focal study area for cetacean habitat surveys (Figure 2). This area was surveyed during late summer 1996 and mid-summer 1997 by the R/V *Gyre* to assess the relationship between cetacean distribution and habitat characteristics (i.e., bathymetry, hydrography and biological oceanography).

Both the EPA slope and GulfCet I study areas are within the boundaries of the oceanic northern Gulf study area.

The specific objectives of the study were to:

(1) Obtain data on temporal and spatial patterns of distribution and minimum abundance of cetaceans using line-transect and acoustic survey techniques directly comparable to those used in previous surveys. This included incidental sightings of sea turtles and seabirds.

(2) Identify possible associations between cetacean and seabird high-use habitats and the ocean environment, and attempt to explain any relationships that appear to be important to cetacean distributions.

Objective 1 was a continuation of surveys in the north-central and western Gulf that began during the GulfCet I program and extended into MMS's Eastern Planning Area. To accomplish this objective, we conducted aerial surveys and simultaneous shipboard visual and acoustic surveys using line-transect methods.

To characterize cetacean and seabird habitat (Objective 2), we used an integrated approach that included the analysis of hydrographic and bathymetric features (e.g., anticyclonic and cyclonic eddies, ocean depth). In addition to physical features, we measured zooplankton and micronekton biomass derived from both net and acoustic sampling to indicate the amount of potential food available for higher trophic level foraging by cetaceans and seabirds (Table 2). Although the diets of most cetaceans and seabirds in the Gulf are poorly known, we hypothesized that hydrographic regimes in the study area have different levels of potential prey that influence their distribution. We further hypothesized that these food stocks would be locally concentrated in nutrient-rich areas offshore from the Mississippi River, within cyclonic eddies, and along the high-shear edges of warm-core eddies.

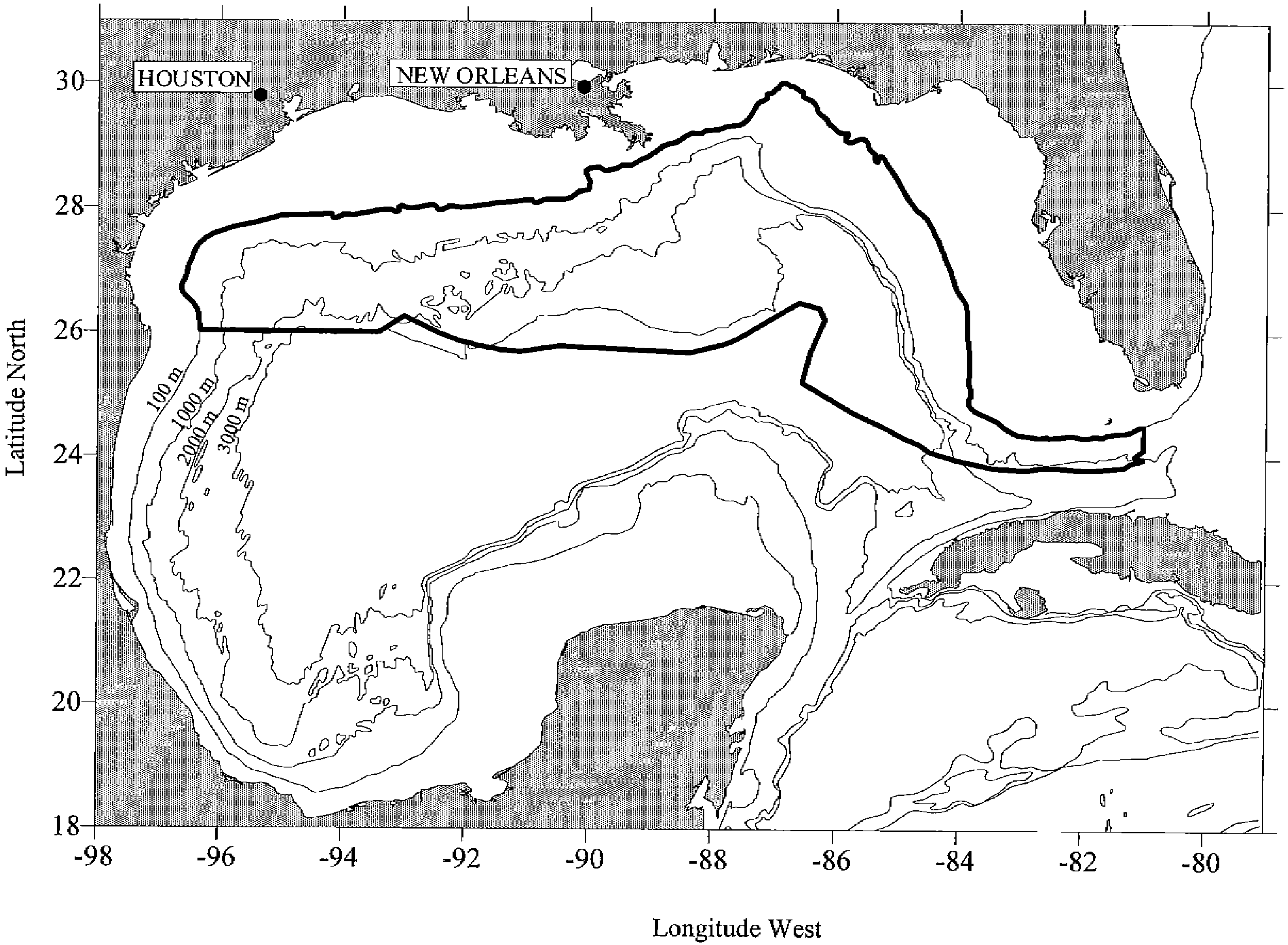


Figure 3. U.S. oceanic northern Gulf of Mexico.

Table 2. Types of data collected by season and survey for the GulfCet II Program. Abbreviations: CTD = conductivity/temperature casts; XBT = expendable bathythermograph; SST = sea surface temperature; SSS = sea surface salinity; ADCP = Acoustic Doppler Current Profiler; MOCNESS = Multiple Opening and Closing Net and Environmental System; SSH = sea surface height.

			Mammal Surveys		Hydrographic Surveys								
Survey		Dates	Visual	Acoustic	CTD	XBT	Chlorophyll	SST	SSS	Nutrients	ADCP	MOCNESS	Satellite SSH
SPRING 1996													
R/V *Oregon II*	Cruise 220												
	Leg 1	17 Apr-4 May 1996											✓
	Leg 2	8-25 May 1996	✓										✓
	Leg 3	29 May-8 Jun 1996	✓		✓	✓							✓
SUMMER 1996													
Aerial 9		11-31 Jul 1996	✓										✓
LATE SUMMER 1996													
R/V *Gyre*	Cruise *Gyre*96G06	11-19 Oct 1996	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
WINTER 1997													
Aerial 10		7 Feb-20 Mar 1997	✓										✓
SPRING 1997													
R/V *Oregon II*	Cruise 222												
	Leg 1	17 Apr-5 May 1997	✓										✓
	Leg 2	9-25 May 1997	✓										✓
	Leg 3	29 May-9 Jun 1997	✓	✓	✓	✓							✓
SUMMER 1997													
Aerial 11		15 Jul-6 Aug 1997	✓										✓
R/V *Gyre*	Cruise *Gyre*97G08	6-20 Aug 1997	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
WINTER 1998													
Aerial 12		8 Feb-14 Mar 1998	✓										✓

THE GULF OF MEXICO: OCEANOGRAPHY AND BIOLOGY

General Oceanography of the 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 central and western Gulf, a warm-water anticyclonic eddy with associated cold-water cyclones is the primary circulatory feature. The Loop Current enters the Gulf in a nearly annual cycle. TOPEX/ERS satellites produce sea surface altimetry maps that show Gulf warm-core eddies originating as pinched-off, northward penetrations of Loop current meanders (Figure 4). After their separation from the Loop Current, these anticyclonic eddies drift westward until their progress is eventually constrained by shoaling topography over the northwestern continental slope of the Gulf. These anticyclonic and cyclonic eddies remain in the region, slowly decaying or coalescing with another approaching eddy. The overall resulting circulation of the Gulf of Mexico is remarkable because of its inter-annual variability and intensity.

The dynamics of the Gulf are made more complex by the large fresh water inflow. Nearly two-thirds of the U.S. mainland and half the area of Mexico drains into the Gulf. The Mississippi River discharges into the northern Gulf through the Balize and Atchafalaya delta regions. Approximately 30% of the Mississippi River enters the northern Gulf through the Atchafalaya, and the remaining 70% goes through the Balize bird-foot delta. The Mississippi and other rivers with their associated pollutants, nutrients, and sediment loads have a great impact on all aspects of continental shelf oceanography in the northern Gulf. The input of nutrients ensures high phytoplankton production and thus higher zooplankton productivity (Lohrenz et al. 1990). River discharge into the Gulf is distinctly seasonal, with the highest flow occurring from March through May, and the lowest flow occurring from August through October. Wind forcing and shelf currents are major factors controlling the distribution of Mississippi River outflow onto the continental shelf. Loop Current eddies and filaments provide the major control of plume circulation over the continental slope and into the northern Gulf. The fresh water of the Mississippi River affects the spatial and temporal distribution of areas of higher primary and secondary production that may influence the distribution of cetaceans, sea turtles and seabirds in the northern Gulf of Mexico.

Four cruises of R/V *Oregon II* and R/V *Gyre* (Table 2) were combined with tandem remote sensing of sea surface height using the TOPEX/POSEIDON and ERS-2 satellite altimeters to characterize the hydrographic regime of the northeastern Gulf of Mexico for the GulfCet II program. In May-June (early summer) 1996, October (late summer) 1996, May-June (early summer) 1997, and August (mid-summer) 1997, the two ships dropped 560 expendable bathythermographs (XBTs) that profiled the temperature structure of the upper 760 m of the water column. These XBT stations were supplemented with 32 conductivity-temperature-depth (CTD) stations. The early summer cruises focused on the continental slope of the Eastern Planning Area (EPA) (Figure 2). The late and mid-summer cruises also surveyed this region of the slope, but these surveyed farther seaward as well, within a deepwater "focal area" where near real-time altimetry maps of sea surface height anomaly provided by the University of Colorado

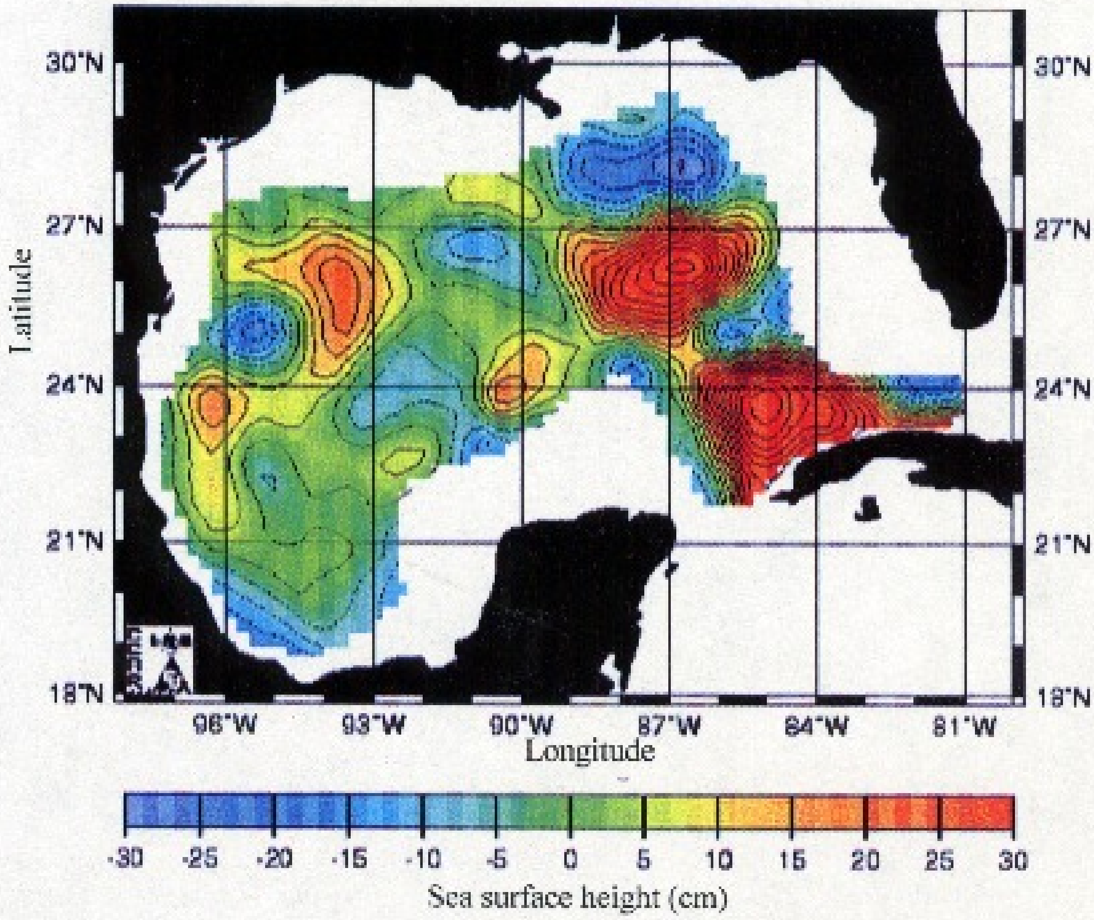


Figure 4. Contour map of the sea surface height for the Gulf of Mexico showing major hydrographic features of the region. Data were collected by altimeters aboard the TOPEX/POSEIDON and ERS-2 satellites and used to objectively map the height field for August 1, 1997. The northward penetration of the Loop Current (red) into the eastern Gulf has resulted in the separation of an anticyclone (warm-core eddy), identified by the large region of closed contours in red around a high in the sea surface height. Cyclonic, cold-core eddies (blue) are lows in the sea surface height and visible on the periphery of the anticyclone. The eddy field in the western gulf is made up of anticyclones and companion cyclones that are remnants of an older Loop Current eddy interacting with the continental slope along the Texas and Mexican coasts. Data for ocean depths less than 200 meters have been masked.

Center for Astrodynamics Research indicated that there was a mesoscale cyclone (cold-core eddy) and anticyclone (warm-core eddy) pair.

The sea surface height anomaly data showed that a broad area of cyclonic circulation was located in the northeastern Gulf throughout 1996. This appeared in weekly altimetry maps as a consistent region of negative height anomaly. This cyclonic feature was seen from January to September in the region of 27-29°N latitude and 89-84°W longitude. By late summer 1996, the cyclone was centered between 27-28°N latitude and 87-89°W longitude, roughly halfway between the Mississippi River delta and the northwest edge of the anticyclone. The R/V *Gyre* documented a 62 dyn cm difference in height between the interior of the cyclone and anticyclone. This created a flow confluence between the two features with an upper layer geostrophic volume transport of 24×10^6 $m^3 \cdot s^{-1}$ (24 Sverdrups).

In mid-summer 1997, the R/V *Gyre* again surveyed a deepwater cyclone-anticyclone pair. This time, the cyclone was centered on the northeast side of the anticyclone and was over the DeSoto Canyon. The R/V *Gyre* documented a 84 dyn cm difference in height between the interior of the cyclone and anticyclone. This created a flow confluence between the two features with an upper layer geostrophic volume transport of 31×10^6 $m^3 \cdot s^{-1}$ (31 Sverdrups). Continuous shipboard measurements of sea surface temperature, salinity and chlorophyll concentration showed that low salinity, high chlorophyll river water was entrained from off the shelf and transported around the periphery of the cyclone.

Bottle sampling at CTD stations showed that there was a significant relationship between water temperatures less than 22°C and nitrate concentration. As a result, the depth of the 19°C isotherm provided a good estimation of the depth of the 10 µM nitrate concentration. Within the cyclone, the nitracline domed 40-60 m shallower than in the anticyclone. This doming increased the flux of new nitrogen into surface waters so that the deep chlorophyll maximum (DCM) was locally shallower and chlorophyll reached higher maximum concentration in the cyclone. The higher standing stocks of chlorophyll in the upper 100 m of the water column in the cyclones meant that these were biological "oases" of locally high productivity, while the interior of the anticyclones were more oligotrophic. During GulfCet II, net trawls and bioacoustic surveys showed that the cyclones also had locally higher standing stocks of zooplankton and micronekton. We hypothesized that the higher secondary productivity of the cyclones supported local aggregations of squid and mid-water fishes that are preyed on by cetaceans.

The four shipboard surveys also found that the depth of the 19°C isotherm was locally shallow at the shelf-slope break, particularly in the early summer. Unfortunately, no surface chlorophyll data were available for either of the two early summer cruises, so we do not know whether this shelf edge upwelling was expressed at the surface as locally high primary production and/or high surface chlorophyll concentrations. In mid-summer, the shelf-edge doming of the 19°C isotherm depth was not as strong, and the shelf-slope break was not an area of locally high surface chlorophyll. In late summer, we found no evidence for shelf edge upwelling from either surface or subsurface data. However, a 6-10 m thick lens of low salinity river water was transported completely across the shelf in late summer to be entrained into the deepwater flow confluence between deepwater cyclone/anticyclone pair. This water of river origin had locally high surface chlorophyll, resulting in more chlorophyll within the confluence than would have been predicted from DCM characteristics alone.

Biological Oceanography

The goal of the biological oceanography segment of the GulfCet II Program was to estimate the temporal and spatial distribution of potential cetacean prey. To this end, a series of mostly nighttime net tows were taken whenever time permitted. A 1 m^2 Multiple Opening/Closing Net and Environmental Sampling System (MOCNESS) was used to sample zooplankton. Tow speeds were 1.5-2.0 knots. A 14.7 m^2 Isaacs Kidd Midwater Trawl was used to sample micronekton. It was towed at 4-5 knots. These samples can be thought of as discrete measurements of zooplankton and micronekton biomass. Continuous measurements of zooplankton and micronekton biomass were made using a 153 kHz Acoustic Doppler Current Profiler (ADCP). Regression analysis was used to relate the net tow biomass to ADCP measurements of acoustic volume backscattering strength (S_v). This allowed us to considerably extend our characterization of the regions transected during late summer 1996 and mid-summer 1997 *Gyre* cruises.

Both integrated zooplankton biomass and integrated cephalopod paralarvae numbers in the study area showed higher values in the cyclone and confluence areas than in the anticyclone. Predicted Mean Biomass (PMB) estimates, derived from the significant positive relationship between integrated zooplankton biomass (as determined by direct net sampling and underway measurements of S_v using the ADCP), also showed that the cyclone and confluence areas were enriched in integrated zooplankton and micronekton biomass relative to the anticyclone. In addition, a statistically significant relationship existed between integrated zooplankton biomass and integrated cephalopod (a major component of cetacean prey) paralarvae numbers, indicating that higher zooplankton and micronekton biomass may correlate with higher concentrations of cetacean prey. Finally, the abundance and diversity of myctophids, another important cetacean prey group, appeared to be greater in the cyclones and confluence regions than in the anticyclones. Together, these measurements suggest that the amount of prey for cetaceans and seabirds may be consistently greater in the cyclone and confluence areas (as opposed to anticyclone), making these mesoscale features preferential habitats for foraging.

Visual Surveys of Cetaceans and Sea Turtles

The primary objectives of the visual aerial and ship surveys were: 1) obtain a minimum abundance estimate of each cetacean and sea turtle species in the northeastern Gulf (Figure 2) to establish a baseline for monitoring trends in abundance over time; 2) study the seasonal abundance and distribution patterns of cetacean and sea turtle species in the northeastern Gulf; 3) compare spring abundance estimates of cetaceans in continental slope waters of the north-central and northwestern Gulf (GulfCet I study area, Figure 1) to previous estimates; and 4) compare ship-based spring abundance estimates of cetaceans in the oceanic northern Gulf (Figure 3) to previous estimates.

During all ship surveys, two rotating teams of three observers using 25x binoculars collected line-transect data. In spring and early summer 1996 and 1997, ship surveys were conducted in three "legs" from the R/V *Oregon II* (Table 2). Legs 1 and 2 were conducted along transect lines that were uniformly spaced 60 nautical miles apart throughout the oceanic northern Gulf. Leg 3 focused on the Eastern Planning Area (EPA) shelf and slope. The R/V *Gyre* was used to conduct surveys of the EPA shelf and slope and a deepwater focal area during late summer 1996 and mid-summer 1997.

Aerial surveys were conducted during summer 1996 and 1997, and winter 1997 and 1998 (Table 2). During each season, the goal was to survey 42 transect lines in the EPA slope and 16 transect lines in the EPA shelf. Two observers and a data recorder collected line-transect data from a DeHavilland DHC-6 Twin-Otter with large convex "bubble" windows on each side of the fuselage.

Line-transect methods were used to make abundance estimates. For aerial surveys, overall abundance estimates for cetaceans and sea turtles were made separately for the EPA shelf and EPA slope. Summer and winter abundance estimates of common species were also made for each study area. For ship surveys, cetacean abundance estimates were made for the spring for the oceanic northern Gulf and the GulfCet I study areas, and for early summer for the EPA shelf and the EPA slope.

Study Area Summaries

EPA Continental Shelf, Aerial and Ship Surveys- All of the proposed transect lines were completed during both summer (1,826 km) and winter (1,826 km) aerial surveys. During spring ship surveys, 449 km were surveyed. Bottlenose dolphins and Atlantic spotted dolphins were sighted during all seasons surveyed. During aerial surveys, 61 bottlenose dolphin and nine Atlantic spotted dolphin groups were sighted, and during ship surveys, 31 and 19, respectively. The overall abundances from early summer ship surveys of bottlenose dolphins and Atlantic spotted dolphins were 1,056 (CV = 0.33) and 1,827 (0.46), respectively. Overall abundances from aerial surveys were 1,824 (0.25) and 1,096 (0.50) for bottlenose and Atlantic spotted dolphins, respectively. The abundance of bottlenose dolphins from aerial surveys during summer, 3,281 (0.37) was significantly different than the winter estimate, 1,119 (0.30) ($p<0.10$). Too few sightings of Atlantic spotted dolphins were made to examine seasonal differences in abundance. Both species were widely distributed in the study area.

Three species of sea turtles were sighted during aerial surveys: 85 loggerheads, four leatherbacks and three Kemp's ridleys. The overall abundance of loggerhead sea turtles was 503 (0.20). Loggerhead sea turtle abundances were similar during summer and winter with estimates of 480 (0.30) and 524 (0.23), respectively. Loggerhead sea turtles were sighted throughout the EPA shelf during both summer and winter.

EPA Continental Slope, Aerial and Ship Surveys - All of the proposed transect lines were completed during summer aerial surveys (10,440 km), but due to poor weather, only 80% of the proposed winter effort was completed. In total, 2,586 km of transects were surveyed during early summer ship surveys. Combining ship and aerial surveys, 17 cetacean species were sighted on the EPA slope. Fifteen species were sighted during summer and 14 during winter. In general, cetaceans were found throughout the study area each season. The most abundant species were the pantropical spotted and spinner dolphins. Abundances of pantropical spotted dolphins were 13,649 (0.26) and 7,432 (0.40) from aerial and ship surveys, respectively, and those of spinner dolphins were 8,670 (0.48) and 5,319 (0.75), respectively. Other species with abundance estimates over 1,000 from aerial or ship surveys were bottlenose dolphins, Atlantic spotted dolphins, Risso's dolphins, striped dolphins and clymene dolphins. Seasonal aerial survey abundances varied by a factor of two or more for dwarf/pygmy sperm whales (summer peak), bottlenose dolphins (winter peak), Risso's dolphins (winter peak), and pantropical spotted dolphins (summer peak), but the difference was only significant for dwarf/pygmy sperm whales ($p<0.10$).

Except for the sperm whale, commonly sighted species were widely distributed in the study area, although at different depth ranges. There was no evidence of seasonal shifts in the distribution of all cetaceans in general or of any species; however, sightings of many species were too few in at least one season to speculate about seasonal differences in their spatial distributions. While there was no evidence of seasonal shifts in distribution within the study area, seasonal abundance patterns indicated that many individuals might move completely out of the study area during different seasons.

Two sea turtle species were sighted: 28 leatherbacks and 27 loggerheads. The overall abundance estimate of leatherbacks was 168 (0.23) turtles. Leatherbacks were about 2.5 times more abundant in summer than winter with estimates of 230 (0.58) and 90 (0.48), respectively. However, the difference was not significant ($p>0.10$). Leatherbacks were sighted throughout the EPA slope. The overall abundance estimate of loggerheads was 141 (0.27). Loggerheads were about 12 times more abundant in winter than summer with estimates of 286 (0.27) and 24 (0.77), respectively ($p<0.10$). Loggerheads were sighted throughout the EPA slope with most sightings near the 100 m isobath.

<u>Oceanic Northern Gulf of Mexico, Ship Surveys</u> - The combined effort from the spring ship surveys of this area was 8,596 km. Nineteen cetacean species were identified. Pantropical spotted dolphins were the most abundant species with an estimate of 46,625 (0.24) animals followed by 11,251 (0.66) spinner dolphins and 10,093 (0.40) clymene dolphins. Estimates for bottlenose dolphins, striped dolphins, melon-headed whales, Atlantic spotted dolphins, Risso's dolphins, and short-finned pilot whales ranged from 5,618 to 1,471. Abundances of all other species were less than 900. Cetaceans were sighted throughout the study area, but fewer were sighted in the western Gulf. The abundance estimates of common species were very similar to those reported by Hansen et al. (1995).

<u>GulfCet I Study Area, Ship Surveys</u> - The combined effort from spring ship surveys of this area was 3,596 km. Fourteen cetacean species were sighted. Pantropical spotted dolphins were the most abundant species (6,141; CV = 0.37) followed by clymene dolphins (6,557; 0.70), short-finned pilot whales (2,253; 0.58) and bottlenose dolphins (2,158; 0.76). Estimates for striped dolphins, Risso's dolphins, and melon-headed whales ranged from 1,000 to 2,000. The abundances of all other species were less than 1,000. The abundance estimates for commonly sighted species were generally similar to those reported by Hansen et al. (1996).

Overview of Cetacean Distribution

Cetaceans occur throughout the northern Gulf, but each species' distribution appears to be affected by water depth and/or geographic region. The continental shelf and shelf-edge region are inhabited almost exclusively by bottlenose dolphins and Atlantic spotted dolphins, and in oceanic waters, these species do not range beyond the upper continental slope. However, during GulfCet II, compared to the rest of the northern Gulf, bottlenose dolphins were more widely distributed on the continental slope in the northeastern Gulf. The oceanic cetacean community in the northern Gulf is composed of at least 17 species that usually inhabit deep tropical waters. With few exceptions, Bryde's whales have been found along a narrow corridor near the 100 m isobath in the northeastern Gulf. Spinner dolphins primarily inhabit the north-central and northeastern Gulf. Short-finned pilot whales and melon-headed whales have been sighted almost exclusively in the north-central and northwestern Gulf. Pantropical spotted dolphins and striped dolphins occur throughout the northern Gulf, but sightings of both species have been rare in the extreme northwestern Gulf. Killer whales range throughout the northern Gulf, but most sightings occurred in a broad, but distinct, region just southwest of the Mississippi River delta. Pygmy/dwarf sperm whales have been found throughout the northern Gulf. Sperm whales also range throughout the northern Gulf, but there has usually been an aggregation of sightings along the 1,000 m isobath near the Mississippi River delta. Sperm whales were not sighted in the northwestern Gulf during GulfCet II. Risso's dolphins concentrate in areas along the upper continental slope, but sightings occur throughout the northern Gulf. False killer whales, pygmy killer whales, and Fraser's dolphins are uncommon but widely distributed. *Mesoplodon* spp. and Cuvier's beaked whales are widely distributed in deep water (i.e., usually >1,000 m). In previous studies, nearly all sightings of rough-toothed dolphins and clymene dolphins were west of the Mississippi River delta. However, during GulfCet II, all of the rough-toothed dolphin groups were sighted east of the delta, and clymene dolphins were sighted five times in the northeastern Gulf.

Most of the cetacean species that are routinely sighted in the northern Gulf of Mexico apparently occur there throughout the year. Including the results of this study, there are sighting records from three or more seasons of at least 16 cetacean species. The seasonal abundance of several species (e.g., dwarf/pygmy sperm whale, Risso's dolphin, pantropical spotted dolphin) may vary in continental slope waters at least regionally; however, the season of a species' maximum or minimum abundance is not completely consistent among studies.

Acoustic Surveys of Cetaceans

The primary purpose of the acoustic surveys was to describe the distribution and habitat association of cetaceans in the northeastern Gulf of Mexico based on species-specific vocalizations detected by a towed hydrophone array. In addition, these surveys recorded man-made noise that could impact cetaceans. This information might prove useful in the management of future oil and gas development in the Gulf.

Two acoustic surveys were conducted in the EPA (Figure 2 and Table 2) during late summer 1996 (5,228 km of effort) and mid-summer 1997 (2,784 km of effort) as part of the GulfCet II program. Sperm whales were the most commonly identified cetacean during the late summer cruise, while pantropical spotted dolphins were the most commonly detected species during the mid-summer cruise. Recordings were made for sperm whales, pantropical spotted dolphins, clymene dolphins, spinner dolphins, striped dolphins, Atlantic spotted dolphins, false killer whales, bottlenose dolphins, rough-toothed dolphins and Fraser's dolphins.

The distribution of deep-water cetaceans appeared to be influenced by a cyclone and anticyclone pair in the northeastern Gulf. Sperm whales in the northeastern Gulf were more closely associated with the cyclone and the mouth of the Mississippi River (MOM) and less with the confluence zones than some of the pelagic dolphin species. Almost half of the dolphin contacts in 1996 were in shallow water north of the influence of the cyclone and anticyclone. Pelagic dolphin contacts were recorded in the confluence zone. In 1997, dolphins appeared to have three association patterns relative to hydrographic features. Some contacts appeared to be influenced by the entrainment of Mississippi River outflow as it was transported seaward by the confluence zone, while others occurred in the cyclone the strong western current produced by the geostrophic flow. There were only two dolphins and a single sperm whale contact inside or near the northern periphery of the anticyclone. This distribution pattern suggests that anticyclones are not preferred areas for cetaceans in the Gulf of Mexico.

The whistles of nine dolphin species were characterized. There were species-specific patterns to whistle usage and acoustic structure. Based on these patterns, four unknown contacts were identified as coming from a pantropical spotted dolphin, Atlantic spotted dolphin, rough-toothed dolphin and false killer whale.

A diversity of anthropogenic signals was recorded during nearly 17,000 km of acoustic effort during GulfCet I and II. Many of these were low frequency seismic exploration signals, but higher frequency signals were also recorded. Bryde's and sperm whales can probably hear these signals. Cetaceans were exposed to seismic noise, particularly off the MOM and in the eastern Gulf. Seismic exploration signals were detected during 21% of recordings, ranging from a low of 10% during the earlier GulfCet I project (encompassing waters from 100-2000 m deep west of 87°30'W) to more than half during the last GulfCet II cruise (encompassing waters from 100-2000 m deep between 84°W and 89°W). There was no significant difference in the cetacean sighting frequency for low, medium, and high noise levels in different hydrographic features.

Cetacean Habitat

An objective of the GulfCet II program was to characterize cetacean habitat in the eastern Gulf of Mexico (Figure 2). Correlation of environmental features with sighting data may improve our understanding of cetacean ecology and indicate which, if any, physical and biological oceanographic variables influence cetacean distribution. During two of the four GulfCet II cruises, we conducted visual cetacean surveys and simultaneously collected data on the marine environment and zooplankton biomass. Cetacean-habitat associations were statistically analyzed for six physical and biological oceanographic variables. In addition, we retrospectively analyzed satellite remote sensing data for sea surface height (SSH) anomaly and shipboard cetacean sightings for the GulfCet I study area (Figure 1). These data were combined with the GulfCet II data to examine the relationship between cetacean distribution and hydrographic features for the entire oceanic northern Gulf (Figure 3).

Cetaceans in general were concentrated along the continental slope in areas of cyclonic circulation where chlorophyll was elevated. They were less likely to occur over water deeper than 2,000 m and in anticyclones. Sperm whales tended to occur along the lower slope and, in some areas, in cyclonic eddies with elevated predicted mean biomass (PMB) of zooplankton and micronekton in the depth range of 10-50 m. Squid-eaters (dwarf and pygmy sperm whales, false killer whales, melon-headed whales, pilot whales, pygmy killer whales, Risso's dolphins, rough-toothed dolphins and all members of the Family Ziphiidae) occurred more frequently along the upper slope in areas outside of anticyclones. Oceanic stenellids (oceanic dolphins from the genus *Stenella* including clymene dolphins, pantropical spotted dolphins, spinner dolphins and striped dolphins) occurred more often over the lower slope and deepwater regions in areas of cyclonic or confluence circulation. Finally, bottlenose dolphins and Atlantic spotted dolphins were seen most frequently on the continental shelf or along the upper slope, but outside of deepwater hydrographic features such as cyclones and anticyclones.

In the north-central Gulf, an additional factor affecting cetacean distribution may be the narrow continental shelf south of the Mississippi River delta. Low salinity, nutrient-rich water may occur over the continental slope near the MOM or be entrained within the confluence of a cyclone-anticyclone eddy pair and transported beyond the continental slope. This creates a deep-water environment with locally enhanced primary and secondary productivity and may explain the presence of a resident population of endangered sperm whales within 50 km of the Mississippi River delta.

In summary, cetaceans in the northeastern and oceanic northern Gulf of Mexico were concentrated along the continental slope in or near cyclones. These eddies are mesoscale features with locally concentrated zooplankton and micronekton stocks that appear to develop in response to increased nutrient-rich water and primary production in the mixed layer. The exceptions were bottlenose dolphins, Atlantic spotted dolphins and possibly Bryde's whale that typically occur on the continental shelf or along the shelf break outside of major influences of eddies. Low salinity, nutrient-rich water from the Mississippi River, which may also contribute to enhanced primary and secondary productivity in the north-central Gulf, may explain the presence of a resident population of endangered sperm whales south of the delta. However, since cyclones in the northern Gulf are dynamic, cetacean distribution will undoubtedly change in response to the movement of prey associated with these hydrographic features.

The Special Case of Sperm Whales: Behavior and Site Fidelity

The GulfCet II program did not concentrate on behavioral observations of marine mammals. However, an attempt was made to gather behavioral and other data on sperm whales, due to their endangered status. Therefore, sperm whales were targeted at limited times when sufficient hours were available after the major goals of gathering hydrographic and census data had been obtained. These times were 20-28 August 1994, and again during two half-days on 20 and 28 October 1996. In addition, a non-GulfCet sperm whale focal study occurred from July-August 1995, from an oil production platform near the Mississippi Canyon in the north-central Gulf. The goal of this latter study was to attach "Crittercam" (Marshall 1998) video/hydrophone systems to whales and thereby record underwater vocalizations during dives. All focal sperm whale work occurred over or near the Mississippi Canyon.

During focal observation sessions, the general behavior of sperm whales (rafting, travel, social) was described through 25x pedestal-mounted and hand-held binoculars, within two kilometers of the research vessel. Group sizes, orientations, lengths of surfacings, number and spacings of respirations, and types of dives (fluke-up and slip-under) were described. In addition, vocal repertoire and click sequences, or coda patterning, were recorded when possible.

Sperm whales were observed at close range by a small inflatable boat when weather and logistics allowed. As a priority, photographs of naturally varying fluke edge patterns were taken for photoidentification of individuals, using both still photography and videography. Size measurements were made by photogrammetry on five whales when an accurate distance-measuring device, coupled with known focal length of still photo lens, was available.

Sperm whales tended to concentrate between the edges of cyclonic and anticyclonic eddies. Group sizes were generally two-to-three individuals, and did not change significantly by hour of day. As many as 12 sperm whales aggregated during an apparent agonistic interaction with pilot whales on 24 August 1994. It is likely that sperm whales sighted together tend to be sub-groupings of larger, probably acoustically-interacting, pods.

A total of 37 sperm whales were individually identified during 1994 and 1996, with four resightings on multiple days within a year and four others resighted inter-annually. Distance between resightings ranged from 2.4-9.9 km on the same day; 17.3-24.3 km between days within one season; and 36.6-46.2 km between years. These findings indicate remarkable small-range site fidelity for at least some sperm whales of this population. Body sizes determined from photogrammetry ranged from 6.6-10.4 m (n=5), and fell within the known sizes of adult females and immature young of either sex. No large, adult males were sighted in this area.

Rafting was the most common behavior at the surface and accounted for 57.7% of behavior types. Socializing occurred at low levels and sporadically throughout the day. Orientations of whales tended to be away from the survey vessel when whales were first sighted, indicating that they may have reacted to the survey vessel at up to several kilometers. Fluke-up and slip-under dives appeared to alternate in prevalence by time of day, with more fluke-up dives in morning and afternoon, but more slip-under dives from 1200 to 1300 hours. Data on this point are limited, however, and the significance of dive types and diel occurrence has not been fully explored. It is surmised, but not proved, that fluke-out dives relate to steep and deep dives, presumably for feeding. Mean blow intervals were shorter before fluke-out than slip-under dives, indicating a faster respiration pattern, possibly related to hyperventilation prior to the hypothesized steep and deep feeding dives.

Coda patterns of individual sperm whales were recorded during attachment of the "Crittercam" to three whales; the longest attachment duration was nine minutes. Five distinct coda types were recorded from about six whales during the first two sessions. Two distinct codas (a four-click and an eight-click pattern) were recorded from two whales that dove to about 600 m during the 9 minute session. This final session indicated communication between the two whales.

Focal sperm whale studies in the Gulf of Mexico have just begun during the GulfCet and ancillary cruises, and much more behavioral and ecological information needs to be gathered. However, the present "snapshots" of behavior of endangered sperm whales indicate diel patterns of dive types, surface activity, and respiration patterns. Female-based groups, as has been found elsewhere, appear to make up the society in and near the Mississippi Canyon, with large males not yet documented. It is not known whether presumed female societies leave the area to mate, or whether males come in sporadically. The intra- and inter-year site fidelity of at least some photoidentified sperm whales suggests that the Mississippi Canyon is important habitat for sperm whales of the northern Gulf. The affiliation with the edges of cyclonic and anticyclonic eddies suggests some relationship to distribution and abundance of prey.

Seabird Ecology

As part of the GulfCet II program, three seabird surveys occurred during cruises conducted in the northern Gulf of Mexico. From 17 April to 9 June 1996, surveys were conducted from the NOAA ship *Oregon II.* The northern slope and oceanic Gulf, and northeast Gulf shelf and slope waters were surveyed during the spring cruise (Figure 3). From 10 to 29 October 1996 and 5 to 21 August 1997, surveys were conducted from the R/V *Gyre*. The October (late summer) and August (mid-summer) cruises covered the central pelagic and northeastern continental shelf and slope regions of the Gulf (Figure 2). Seabird observations on the *Oregon II* (spring cruise) were made as time and observer interest allowed during marine mammal observations. Observations on the R/V *Gyre* were made with a three- person crew dedicated to counting seabirds.

Seabird groups and species present in the Gulf of Mexico varied by season. The spring cruise data suggest that terns, storm-petrels and gulls were common in the Gulf during May and June. Jaegers and shearwaters were also present but in lower numbers. Tropicbirds, sulids and frigatebirds were rarely seen in the Gulf during the spring. The species composition of the late summer cruise was different from that of the spring cruise, as October reflects a pattern of migration and winter distribution of seabirds in the Gulf. Two of the three most commonly identified species (laughing gull and royal tern) were year-round residents of the Gulf. Pomarine jaegers, a Gulf winter migrant, were the third most commonly identified bird. The mid-summer cruise sightings included a large number of species. Black terns, the most abundant species during the mid-summer cruise, were summer migrant pelagic species. The four next most abundant species were: band-rumped storm-petrels (summer migrant pelagic), magnificent frigatebirds (permanent residents), Audubon's shearwaters (summer migrant pelagic) and sooty terns (summer residents).

In terms of hydrographic environments, the cyclone had the greatest species diversity of the hydrographic environments. Additionally, the confluence and Loop Current eddy during mid-summer had a greater species diversity than the continental shelf. We found species-specific habitat relationships with hydrographic environments for several species. Pomarine jaegers were more likely to be present in the MOM during late summer. Audubon's shearwaters during mid-summer were more likely to be encountered inside the cyclone, while band-rumped storm-petrels were more likely present in the other margin areas. Black terns, also during mid-summer, were encountered more frequently in the MOM. An interesting result for the mid-summer cruise was that while the MOM was higher overall in chlorophyll concentration, many pelagic species were not seen at all inside transects in the MOM (Audubon's shearwater, band-rumped storm-petrel, bridled tern and sooty tern).

In terms of specific habitat variables, indicators of plankton standing stock (measured by surface chlorophyll and predicted mean biomass [PMB] of zooplankton and micronekton integrated from 10-50 m depth) best predicted (or was tied with another model as best model) seabird presence for five of the seven species analyzed. Sea surface properties of temperature and salinity best predicted presence for black tern, sooty tern, and laughing gull (tied with plankton standing stock). Sea surface height and bathymetry explained pomarine jaeger and Audubon's shearwater presence, respectively. Sea surface salinity and temperature best predicted the presence of black and sooty terns.

Laughing gull presence in October was predicted by two competing sets of habitat variables: plankton standing stock and sea surface properties. Laughing gulls were predicted in transects of increased PMB and increased concentrations of chlorophyll by the plankton standing stock model. The sea surface properties model predicted laughing gulls in intermediate ranges of temperature.

In October, pomarine jaegers were predicted to be encountered in transects with higher geostrophic flow and intermediate sea surface height ranges. This suggests that pomarine jaegers may have been attracted to regions such as the confluence or the edge of the Loop Current eddy. However, in the analysis considering species presence and absence in the hydrographic environments, pomarine jaegers were more likely encountered in the MOM. This suggests that pomarine jaegers may not be attracted to one particular environment during October.

Surface chlorophyll and PMB best predicted Audubon's shearwater and band-rumped storm-petrel presence in August. Both species were predicted to be present at lower chlorophyll concentrations (generally less than 0.2 mg/m^3). This finding is consistent with the observation that neither species was present in transects in the MOM, which is where the majority of the high chlorophyll transects occurred.

CONCLUSIONS AND RECOMMENDATIONS

The Gulf of Mexico is a semi-enclosed, intercontinental sea with a total area of about 1.5 million square kilometers. As a large marine ecosystem, it has a unique bathymetry, hydrography and productivity. Cetaceans, sea turtles and seabirds are upper trophic level predators that play an important role in the pelagic marine ecosystem of the Gulf of Mexico. These are highly valued taxa, protected by national laws and international agreements, and knowledge of their distribution, abundance and ecology is vital to their protection. GulfCet II was planned to help resolve issues concerning the potential impacts of various oil and gas activities on cetaceans, sea turtles and seabirds that inhabit the northern and eastern regions of the Gulf of Mexico, emphasizing the continental slope where water depths range from 100 to 2,000 m.

An integrated methodology was used that included visual surveys from ships and aircraft, and acoustic recordings and hydrographic collections from ships. Near real-time sea surface altimetry from the TOPEX/POSEIDON and ERS satellites was used during ship surveys to determine the location of hydrographic features (e.g., cyclones, anticyclones and confluence zones). Archival satellite sea surface altimetry data were used to retrospectively determine the location of hydrographic features for analysis with cetacean sightings collected during GulfCet I. We measured zooplankton and micronekton biomass derived from both net and acoustic sampling to indicate the amount of potential food available for higher trophic level foraging by cetaceans and seabirds.

Cetaceans

Nineteen cetacean species were identified in the oceanic northern Gulf of Mexico (398,960 km^2, Figure 3) during GulfCet II surveys. Total abundance estimates ranged from 86,705 (based on shipboard surveys) to 94,182 (based on highest estimate for each species from either shipboard or aerial surveys) animals (Table 3). Cetaceans were sighted throughout the study area, but fewer were sighted in the western Gulf. There are now sighting records during three or more seasons for at least 16 cetacean species. The seasonal abundance of several species (e.g., dwarf/pygmy sperm whale, Risso's dolphin, pantropical spotted dolphin) may vary regionally in continental slope waters.

Seventeen cetacean species were sighted in the Minerals Management Service's Eastern Planning Area (EPA, 70,470 km^2, Figure 3). The abundance estimate based on aerial surveys (which were more extensive than the ship surveys in the EPA) was 38,184 total animals. In general, cetaceans were found throughout the EPA each season. The most abundant species were pantropical spotted dolphins (13,649) and spinner dolphins (8,670). Other species with abundance estimates over 1,000 based on aerial surveys were bottlenose dolphins, Atlantic spotted dolphins, Risso's dolphins, striped dolphins and clymene dolphins.

Cetaceans in the northeastern and oceanic northern Gulf of Mexico were concentrated along the continental slope in or near cyclones and confluence zones. Cyclonic eddies are mesoscale features with locally concentrated zooplankton and micronekton stocks that appear to develop in response to increased nutrient-rich water and primary production in the mixed layer. In the north-central Gulf, an additional factor affecting cetacean distribution may be the narrow continental shelf south of the Mississippi River delta. Low salinity, nutrient-rich water may occur over the continental slope near the MOM or be entrained within the confluence of a cyclone-anticyclone eddy pair and transported beyond the continental slope. This creates a deep-water environment with locally enhanced primary and secondary productivity and may explain the presence of a resident, breeding population of endangered sperm whales within 50 km of the Mississippi River delta. We suggest that this area may be essential habitat for sperm whales in the northern Gulf. Overall, the results suggest that the amount of potential prey for cetaceans (and seabirds) may be consistently greater in the cyclone, confluence areas, and south of the MOM, making them preferential areas for foraging. Since cyclones in the northern Gulf are dynamic and usually associated with westward moving cyclone-anticyclone pairs, cetacean distribution will be dynamic. However, with near real-time satellite remote sensing of sea surface altimetry, these features can be tracked and used to predict where pelagic cetaceans in general may be concentrated. The exceptions are bottlenose dolphins, Atlantic spotted dolphins

Table 3. Annual cetacean abundance in the oceanic northern Gulf of Mexico estimated from GulfCet II visual survey data.

Species	Abundance
Pantropical spotted dolphin	46,625
Spinner dolphin	11,251
Clymene dolphin	10,093
Bottlenose dolphin	5,618
Striped dolphin	4,858
Melon-headed whale	3,965
Atlantic spotted dolphin	3,213
Risso's dolphin	3,040
Short-finned pilot whale	1,471
Rough-toothed dolphin	852
False killer whale	817
Dwarf/pygmy sperm whale	733
Sperm whale	530
Pygmy killer whale	518
Killer whale	277
Cuvier's beaked whale	159
Fraser's dolphin	127
Bryde's whale	35
Total	94,182

and possibly Bryde's whales that typically occur on the continental shelf or along the shelf break outside of major influences of eddies.

Although cetaceans were commonly observed throughout the GulfCet study area during all four seasons, we could not determine whether animals were in transit or resident in the study area for extended periods. It is possible that the oceanic northern Gulf encompasses only a portion of the home range for many of the species observed. Without additional information on daily movement patterns and feeding behavior, significant uncertainties remain in our understanding of cetacean association with mesoscale hydrographic features. The seasonal movements of cetaceans may be affected by reproductive and migratory behavior, although we currently have little information on the behavior of pelagic species. The exception is sperm whales south of the MOM, which appear to reside along the lower slope throughout the year. We suggest that this area may be essential habitat for sperm whales in the northern Gulf, although additional information on population structure, seasonal movements and behavior is needed.

To obtain a better understanding of the seasonal and annual distribution, abundance and habitat-associations of cetaceans, a survey of the entire Gulf with simultaneous satellite and conventional radio tracking and photo-identification of the predominant species (e.g., pantropical dolphins, sperm whales) is needed. Skin biopsies and skin swabbing (Harlin et al. 1999) for genetic analysis of population structure and blubber biopsies for assessing diet (based on fatty acid profiles that can be used to identify prey) should be taken. In addition to tracking the movements of cetaceans at sea, animal-borne satellite telemeters can record information on diving behavior. When combined with dietary information from blubber fatty acid profiles, diving behavior can provide new and much needed information on foraging areas, prey species and resource partitioning among cetaceans (Evans 1971, Tanaka 1987, Mate 1989, Merrick et al. 1994, Davis et al. 1998). We believe that the diet of many cetaceans found in the Gulf is dominated by cephalopods and mesopelagic fishes associated with the vertically migrating acoustic deep scattering layer (Perrin et al. 1973, Clarke 1996). However, there is little direct dietary information for pelagic cetaceans in the Gulf. Future studies should increase acoustic and net sampling of zooplankton and micronekton in different hydrographic features so that we can develop stronger statistical correlations between cetacean distribution and their potential prey. Behavioral data are also needed to determine whether animals use certain areas for specific activities, such as social/sexual behavior, foraging, resting, or transiting.

Sea Turtles

GulfCet II aerial surveys provided the first assessment of sea turtle abundance and distribution over a large area of the oceanic northeastern Gulf of Mexico. Three sea turtle species occurred in the EPA study area: loggerhead, Kemp's ridley, and leatherback sea turtles. The leatherback and Kemp's ridley sea turtles are listed as endangered, and loggerhead sea turtles are listed as threatened. The overall density of loggerhead sea turtles in the EPA shelf was 20 times that of the EPA slope. The majority of loggerheads in the EPA slope were sighted during winter. While many winter sightings were near the 100 m isobath, there were sightings of loggerheads over very deep waters (i.e., >1000 m). It is not clear why adult loggerheads would occur in oceanic waters unless they were traveling between foraging sites. Leatherbacks were sighted throughout the EPA slope and were about 12 times more abundant in winter than summer. The nearly disjunct summer and winter distributions of leatherbacks indicates that specific areas may be important to this species either seasonally or for short periods of time.

Seabirds

Seabird species present in the Gulf of Mexico varied by season. The species composition of the sightings during late summer reflected a pattern of migration and transition to a winter distribution. Two of the three most commonly identified species (laughing gull and royal tern) in late summer are considered to be year-round residents in the Gulf. Pomarine jaegers, a wintering marine species in the Gulf, were the third most commonly identified species. During mid-summer, the black tern was the most abundant species, followed by band-rumped storm-petrels (summer migrant pelagic), frigatebirds (permanent resident), Audubon's shearwaters (summer migrant pelagic) and sooty terns (summer resident).

Cyclones had the greatest diversity of seabird species, although habitat use varied among species. Pomarine jaegers were more likely to be present in the MOM area during late summer. Audubon's shearwaters were more likely to be encountered inside a cyclone, while band-rumped storm-petrels were more likely to be present in the areas other than cyclones, anticyclones or confluence zones during mid-summer. Black terns were encountered more frequently in the MOM area during mid-summer. Generalized additive models incorporating indicators of plankton standing stock (surface chlorophyll and predicted mean biomass of zooplankton and micronekton) best predicted seabird presence for five of the seven species analyzed. Other predictive models were: sea surface properties of temperature and salinity for black tern, sooty tern, and laughing gull; sea surface height for pomarine jaeger; and bathymetry for Audubon's shearwater. Seasonal surveys are needed to better assess community structure and seabird-habitat associations.

Potential Effects of Oil and Gas Exploration and Production Activities

Eighty-three percent of the crude oil and 99% of the gas production in United States federal waters occurs in the Gulf of Mexico, primarily along the Texas-Louisiana continental shelf and slope (Cranswick and Regg 1997). By 2003, oil production in the Gulf is projected to increase 43%. Production from deepwater fields (depth >305 m) will account for about 59% of the daily oil production and 27% of the daily gas production in the Gulf (Melancon and Baud 1999) . In addition to oil and gas exploration and production, 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. The cumulative impact of these human activities on cetaceans in the northern Gulf cannot be predicted with certainty. However, it can be anticipated that cetaceans along the continental slope will encounter increasing oil and gas exploration and production activities. There are significant uncertainties in our understanding of short and long-term effects of seismic and other loud industrial sounds on the behavior and distribution of Gulf cetaceans. Against the background of growing oil and gas exploration and development, continued research and monitoring are needed to assess the potential impacts of these activities on pelagic cetaceans, sea turtles and seabirds in the Gulf of Mexico.

Recommendations for Future Research

In light of the current expansion of oil and gas activities into deep-water regions of the Gulf, more detailed information on the population biology, ecology, behavior and potential industry-related impacts is needed for cetaceans, sea turtles and seabirds. The following are research recommendations in approximate order of priority for the northern Gulf of Mexico:

Information is needed on the movements, diving behavior and site fidelity of endangered sperm whales along the continental slope southeast of the Mississippi River delta. Satellite telemeters should be attached to sperm whales to examine seasonal movements and diving behavior in relation to mesoscale hydrographic features and estimates of potential prey abundance. Skin biopsies and skin swabbing should be conducted to determine how closely related Gulf sperm whales are to those from the adjacent Atlantic Ocean and Caribbean Sea. Blubber biopsies should be taken to assess diet (based on fatty acid profiles that indicate dietary preferences). A photo-identification study in this region should be conducted to assess the site fidelity of individual whales.

Monitoring of cetacean and sea turtle distribution and abundance in the northern oceanic Gulf during the NMFS ichthyoplankton surveys should continue. These surveys can be conducted at relatively low cost because they occur simultaneously with ongoing cruises. Research on cetacean habitat-associations using satellite remote sensing and shipboard measurements should continue. Although progress was made during the GulfCet II study, much remains to be learned about cetacean habitat in the western and southern Gulf. If shifts in a species' distribution occur, a better understanding of habitat will be needed.

A GulfCet III Program for the southern Gulf of Mexico (south of the U.S. Economic Exclusive Zone including the Straits of Florida) should be initiated in cooperation with Mexico (this could be accomplished through U.S. and Mexico university cooperative research programs already in existence). Research objectives should be similar to those of GulfCet II (i.e., cetacean, sea turtle and seabird seasonal distribution and abundance surveys and habitat studies). This would complement studies of northern Gulf waters where oil and gas activities already occur.

We recommend controlled experiments on the effects of seismic sounds and other industrial sounds on cetaceans. In addition, researchers should monitor the effects of seismic ship activity on the behavior and distribution of cetaceans. Potential changes in sperm whale behavior, movements, and vocalizations during geophysical exploration should be examined. This may necessitate an experimental approach, with access to scaled-down or real-time industrial activity under investigator control. Finally, a retrospective analysis should be conducted of GulfCet cetacean distribution data relative to seismic vessel location, signal characteristics, and source level. This research wwould require the cooperation of the geophysical survey industry. Specifically, we would need information on when and where seismic survey activities occur and the types of seismic signals produced. Trained observers might be placed directly on seismic vessels to monitor cetacean behavior.

Research on genetic stock structure should be given added emphasis. The Marine Mammal Protection Act mandates that stocks of cetaceans be protected. Stocks can be defined in a number of ways, but genetic analyses can provide the clearest indication of divisions. Questions of interest for each species include: (1) Are cetaceans in the Gulf of Mexico separate stocks from the adjacent Atlantic/Caribbean? (2) Is there more than one Gulf of Mexico stock? (3) Are there seasonal differences in occurrence patterns? Genetic analysis of skin samples collected during vessel surveys both in the Gulf and adjacent waters could begin to answer these questions. Of particular interest is Bryde's whale. Bryde's whales have displayed considerable local variation world-wide, and analysis of skin biopsy samples could determine whether the northern Gulf stock of Bryde's whales is restricted geographically and genetically isolated from animals in the Atlantic Ocean.

Seasonal seabird surveys should continue to better assess community patterns and understand how patterns change within a season in response to varied marine environments, such as the presence of eddies. In the present study, we found that seabirds responded to different conditions created by the outflow of the Mississippi River and hydrographically defined mesoscale features.

Taxonomic analyses of the Multiple Opening/Closing Net and Environmental Sampling System and Isaacs Kidd Midwater Trawl samples collected during this study could allow us to identify indicator species for the hydrographic features and extend the usefulness of the Acoustic Doppler Current Profiler data. In future studies, we should increase our sampling intensity in the major hydrographic features so that we can develop stronger statistical correlations.

In conclusion, the continental slope in the northern Gulf of Mexico is an area that supports a diverse cetacean community, but one whose density does not equal areas such as the continental slope in the northeastern United States and the eastern tropical Pacific. We now have a better understanding of the mesoscale features that influence cetacean distribution, and the use of satellite remote sensing of sea surface altimetry is increasing our ability to predict where cetaceans may be concentrated. Against the background of growing oil and gas exploration and development, continued research and monitoring are needed to assess the potential impacts of these activities on pelagic cetaceans, sea turtles and seabirds in the Gulf of Mexico. The GulfCet program has demonstrated that any future monitoring programs would have to be long-term, with an intensive sampling effort to detect significant changes in the density and distribution of cetaceans.

LITERATURE CITED

Baumgartner, M.F. 1997. Distribution of Risso's dolphin (*Grampus griseus*) with respect to the physiography of the northern Gulf of Mexico. Mar. Mamm. Sci. 13: 614-638.

Clarke, M.R. 1996. Cephalopods as prey. III. Cetaceans. Phil. Trans. R. Soc. Lond. B: Biological Sciences. 351: 1053-1065.

Cranswick, D. and J. Regg. 1997. *Deepwater in the Gulf of Mexico: America's New Frontier.* OCS Report MMS 97-0004. U.S. Dept. of the Interior, Minerals Mgmt. Service, Gulf of Mexico OCS Region, New Orleans, LA. 43 pp.

Davis, R.W. and G.S. Fargion (eds). 1996. *Distribution and Abundance of Cetaceans in the North-Central and Western Gulf of Mexico: Final Report. Volume II: Technical Report.* OCS Study MMS 96-0027. Prepared by Texas Institute of Oceanography and National Marine Fisheries Service. U.S. Dept. of the Interior, Minerals Mgmt. Service, Gulf of Mexico OCS Region, New Orleans, LA. 357 pp.

Davis, R.W., G.S. Fargion, N. May, T.D. Leming, M. Baumgartner, W.E. Evans, L.J. Hansen, and K.D. Mullin. 1998. Physical habitat of cetaceans along the continental slope in the north-central and western Gulf of Mexico. Mar. Mamm. Sci. 14: 490-507.

Evans, W.E. 1971. Orientation behavior of dolphinids: Radio telemetric studies. Ann. New York Acad. Sci. 188: 142-160.

Fritts, T.H., A.B. Irvine, R.D. Jennings, L.A. Collum, W. Hoffman, and M.A. McGehee. 1983. *Turtles, Birds, and Mammals in the Northern Gulf of Mexico and Nearby Atlantic Waters.* Rept. FWS/OBS-82/65. U.S. Fish and Wildlife Service, U.S. Dept. of Interior, Washington, DC. 347 pp.

Hansen, L.J., K.D. Mullin, and C.L. Roden. 1995. *Estimates of Cetacean Abundance in the Northern Gulf of Mexico from Vessel Surveys.* Unpublished Contribution No. MIA-94/95-25. National Marine Fisheries Service, Miami, FL. 20 pp.

Hansen, L.J., K.D. Mullin, T.A. Jefferson, and G.P. Scott. 1996. Visual surveys aboard ships and aircraft. In: *Distribution and Abundance of Marine Mammals in the North-Central and Western Gulf of Mexico: Final Report. Volume II: Technical Report.* R.W. Davis and G.S. Fargion (eds). OCS Study MMS 96-0027. U.S. Dept. of the Interior, Minerals Mgmt. Service, Gulf of Mexico OCS Region, New Orleans, LA, pp. 55-132.

Harlin, A. D., B. Würsig, C.S. Baker, and T. Markowitz. 1999. Skin swabbing for genetic analysis: application to Dusky dolphins (*Lagenorhynchus obscurus*). Mar. Mamm. Sci. 15(2):409-425.

Jefferson, T.A. and A. J. Schiro. 1997. Distribution of cetaceans in the offshore Gulf of Mexico. Mamm. Rev. 27: 27-50.

Leatherwood, S. and R.R. Reeves (eds). 1990. *The Bottlenose Dolphin*. Academic Press, San Diego. 653 pp.

Lohrenz, S.E., M.J. Dagg, and T.E. Whitledge. 1990. Enhanced primary production at the plume/oceanic interface of the Mississippi River. Cont. Shelf Res. 10: 639-664.

Marshall, G. 1988. Crittercam: An animal-borne imaging and data logging system. Mar. Tech. Series. 32 11-17.

Mate, B.R. 1989. Satellite-monitored radio tracking as a method for studying cetacean movements and behavior. Rep. Int. Whal. Commn. 39: 389-391.

Melancon, J.M. and R.D. Baud. 1999. *Gulf of Mexico Outer Continental Shelf Daily Oil and Gas Production Rate Projections From 1999 Through 2003*. OCS Report MMS 99-0016. U.S. Dept. of the Interior, Minerals Mgmt. Service, Gulf of Mexico Region, New Orleans, LA. 20 pp.

Merrick, R.L., T.R. Loughlin, G.A. Antonelis, and R. Hill. 1994. Use of satellite-linked telemetry to study Steller sea lion and northern fur seal foraging. Polar Sci. 13: 452-463.

Mullin, K.D., W. Hoggard, C.L. Roden, R.R. Lohoefener, C.M. Rogers, and B. Taggart. 1994. Cetaceans on the upper continental slope in the north-central Gulf of Mexico. Fish. Bull. 92: 773-786.

Perrin, W.F., R.R. Warner, C.H. Fiscus, and D.B. Holts. 1973. Stomach contents of porpoise, Stenella spp., and yellowfin tuna, Thunnus albacares, in mixed-species aggregations. Fish. Bull. 71: 1077-1092.

Scott, G.P. and L.J. Hansen. 1989. *Report of the Southeast Fisheries Science Center Marine Mammal Program Review, 2-3 May, 1989*. NOAA Technical Memorandum NMFS-SEFC-235. National Marine Fisheries Service, 75 Virginia Beach Drive, Miami, FL. 81 pp.

Scott, G.P., D.M. Burn, L.J. Hansen, and R.E. Owen. 1989. *Estimates of Bottlenose Dolphin Abundance in the Gulf of Mexico from Regional Aerial Surveys*. Unpublished report available from National Marine Fisheries Service, 25 Virginia Beach Drive, Miami, FL, 70 pp.

Shane, S.H., R.S. Wells, and B. Würsig. 1986. Ecology, behavior and social organization of the bottlenose dolphin: A review. Mar. Mamm. Sci. 2: 34-63.

Tanaka, S. 1987. Satellite radio tracking of bottleose dolphins *Tursiops truncatus*. Nippon Suisan Gakkaishi 53: 1327-1338. (In Japanese).

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 Biological Resources Division Mission

The mission of the Biological Resources Division (BRD) of the U.S. Geological Survey (USGS) is to work with others to provide the scientific understanding and technologies needed to support the sound management and conservation of our Nation's biological resources.

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.