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Distribution and Abundance of Cetaceans in the Northern Gulf of Mexico

Interim Report No. 1

GulfCet

April 1997

Prepared under
U.S.G.S. Biological Resources Division Contract 1445-C109-96-004
by
The GulfCet Program
Texas A&M University at Galveston
P.O. Box 1675
Galveston, Texas 77553

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ABSTRACT

This report describes activities conducted from March 1996 (Program initiation) to September 1996 under a study titled "Distribution and Abundance of Marine Mammals in the Northern Gulf of Mexico" (hereafter called the GulfCet II Program), contract 1445-C109-96-004 from the U.S.G.S. Biological Resources Division to Texas A&M University, and interagency agreements with the National Marine Fisheries Service and University of Wisconsin.

An abundance and distribution survey of cetaceans was conducted in the northern Gulf of Mexico during 17 April-9 June 1996 from NOAA Ship *Oregon II*. The survey sampled all U.S. Gulf waters greater than 100 m deep. Leg 3 focused the northeastern Gulf (the Minerals Management Service's Eastern Planning Area) and included continental shelf waters (> 9 NM offshore) from Mobile Bay to Cape San Blas including Destin Dome Block 56. Line-transect sampling methods and 25-power "bigeye" binoculars were used. In total, 6401 transect km were searched and 266 cetacean groups sighted. Commonly sighted species included the pantropical spotted dolphin (56 sightings), bottlenose dolphin (40), Risso's dolphin (30), sperm whale (24) and Atlantic spotted dolphin (21). Several extremely large (for the Gulf of Mexico) groups of pantropical spotted dolphins and spinner dolphins were sighted. The largest groups were estimated to contain 650 and 750 dolphins, respectively. These group sizes were nearly two times larger than groups of these species seen in previous years. In addition, three Bryde's whales were sighted in the eastern Gulf and a group of four killer whales was photographed. Forty-nine skin/blubber biopsy samples were taken from a total of five species. Environmental data collected included those from CTDs, XBTs, and a thermosalinograph operational while on-effort. Dynamic height and geostrophic transport for the Leg 3 XBT and CTD stations have been computed.

Concurrent with Leg 3 fieldwork aboard *Oregon II*, R/V *Gyre* and USTS *Texas Clipper II* dropped approximately 36 XBTs in the western Gulf of Mexico, surveying the remnants of Loop Current Eddy A. These data were shared with the GulfCet II Program as Ship-of-Opportunity cruises. The two-ship survey showed that this aging warm-core eddy was interacting with what remained of another, older warm core eddy in the "eddy graveyard" at the western margin of the Gulf.

The first of four seasonal aerial surveys of the GulfCet II Program was conducted during the summer from 10 July through 1 August 1996. The survey was conducted on the continental slope (waters approximately 100-

2000 m deep) and a portion of the continental shelf in northeastern Gulf of Mexico. The continental shelf study area overlapped the Minerals Management Service Destin Dome leasing area and included, as requested, Block 56. The objectives of the survey were to collect line-transect data and location data in order to estimate the abundance of each species of cetacean and sea turtle encountered and to delineate each species' distribution in the study area.

At least 12 species of cetaceans were sighted during the aerial survey. Bottlenose dolphins (13 sightings), Atlantic spotted dolphins (2 sightings) and one dwarf/pygmy sperm whale were the only species sighted on the continental shelf. These species were also sighted on the continental slope where bottlenose dolphins were the most common species sighted (21 sightings) followed by pantropical spotted dolphins (17 sightings), dwarf/pygmy sperm whales (12 sightings) and Risso's dolphins (7 sightings). A group of seven Bryde's whales was sighted on 21 July in water 237 m deep. Certain species tended to be found over waters of different depths. In general, cetacean groups were sighted throughout the entire study area.

Sea turtles were sighted 42 times. Continental shelf sightings consisted of loggerheads (18 sightings), unidentified chelonids (4), and leatherbacks (4). Slope sightings consisted of 15 leatherback sightings and one chelonid. Leatherback sightings were generally made in the northern half of the study area.

Progress has been made in developing procedures to identify dolphin vocalizations to species. Using recordings made during GulfCet I cruises, discriminant function analyses were performed on measured acoustic parameters (e.g., maximum frequency, time duration, number of inflection points, etc.) and a dichotomous key was developed. These procedures were able to classify certain whistle types from pantropical spotted, clymene, rough toothed, and bottlenose dolphins with up to 87% accuracy.

A geographic information system (GIS) computer laboratory has been established at Texas A&M University, Galveston. The GIS lab is an important part of the GulfCet Program's analytical capabilities. These facilities will be integral to realizing the Program's objective of identifying associations between cetacean abundance and distribution, and environmental features. Assembly of the lab began in January 1996. The lab has been operational since April 1996.

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LIST OF ABBREVIATIONS AND ACRONYMS

The following acronyms and abbreviations are used throughout this report:

ADCP	Acoustic Doppler Current Profiler
AVHRR	Advanced Very High Resolution Radiometer
CCAR	Colorado Center for Astrodynamics Research, University of Colorado
CI	Confidence Interval
CTD	Conductivity, Temperature, and Depth Profiler
CV	Coefficient of Variation
dB rel μP	Decibels Relative to 1 micro Pascal
GIS	Geographic Information System
GPS	Global Positioning System
GulfCet I	MMS North-central and Western Gulf of Mexico Cetacean Study
GulfCet II	U.S.G.S. Biological Resources Division Northern Gulf of Mexico Cetacean Study (this study)
HPLC	High Pressure Liquid Chromatography
MOCNESS	Multiple Opening Closing Net and Environmental Sampling System
MMS	U.S. Department of the Interior, Minerals Management Service
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OCS	Outer Continental Shelf
SD	Standard Deviation
SEFSC	Southeast Fisheries Science Center, NMFS
SSH	Sea surface height
SST	Sea Surface Temperature
TAMU	Texas A&M University (College Station)
TAMUG	Texas A&M University at Galveston
T-S	Temperature-salinity Relationship
U.S.G.S.	United States Geological Service
XBT	Expendable Bathythermograph

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I. INTRODUCTION

1.1 BACKGROUND

1.1.1 Federal Requirement for the Program

The mission of the U.S.G.S. 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 BRD endeavors to meet its goals by:

- developing scientific and statistically reliable methods and protocols to assess the status and trends of the nation's biological resources,

- utilizing tools from the biological, physical, and social sciences to understand the causes of biological and ecological trends and to predict the ecological consequence of management practices,

- leading in the development and use of the technologies needed to synthesize, analyzed and disseminate biological and ecological information,

- striving for quality, integrity, and credibility of its research and technology by consistently improving its scientific programs through internal quality control, external peer review, and competitive funding.

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 (92 Stat. 629). The National Environmental Policy Act of 1969 requires that all Federal Agencies use a systematic interdisciplinary approach that will ensure the integrated use of the natural and social sciences in any planning and decision making that may have an effect on the human environment.

The Biological Resources Division, as the Department of the Interior bureau tasked with providing the scientific understanding and technologies needed to support sound management and conservation of the Nation's biological resources, administers this study.

The Endangered Species Act (ESA) of 1973, as amended, provides for the conservation of animal and plant species that have been determined to be endangered or threatened. The act requires that major federal actions do not jeopardize the continued existence of listed species or result in the destruction or adverse modification of habitats determined to be critical. It also requires interagency consultation regarding the potential effects of proposed activities on protected species in the northern Gulf of Mexico.

The Marine Mammal Protection Act (MMPA) of 1972, as amended, recognizes that certain species and populations of marine mammals are, or may be, in danger of extinction or depletion as a result of human activities, and establishes a national policy that marine mammal populations should be protected and encouraged to develop to the greatest extent feasible, commensurate with sound policies of resource management. The Secretaries of the Departments of the Interior and Commerce are charged with all responsibility, authority, funding, and duties under the ESA and MMPA.

1.1.2 Cetacean Surveys of the Northern Gulf Prior to 1991

There are several sources of information on the distribution, abundance, and diversity of cetaceans in the Gulf of Mexico. Aerial surveys have been and continue to be conducted in the Gulf. Cetacean stranding information has been systematically collected since the late 1970's. A considerable amount of research has been conducted on localized populations of bottlenose dolphins (for a review see Shane et al. 1986, Scott and Hansen 1989, Leatherwood and Reeves 1990). In U.S. Gulf of Mexico waters less than 200 m deep, bottlenose dolphins and Atlantic spotted dolphins appear to be the most abundant cetacean species. Other directed studies, historic whaling records, animal strandings, and opportunistic sightings have expanded the list of cetacean species known to occur in the Gulf.

Until recently, relatively little was known about cetaceans inhabiting deeper waters of the Gulf of Mexico. The MMS and U.S. Fish and Wildlife Service supported aerial surveys of birds, marine turtles, and cetaceans in the Gulf from 1981-82 (a pilot survey was conducted in 1979). These surveys sampled nearly 75,000 km^2 of the Gulf, including approximately 20,000 km^2 in waters deeper than 200 m offshore of western Louisiana and southern Texas (Fritts et al. 1983). Other than bottlenose dolphins (205 sightings) and unidentified dolphins, there were 32 sightings of cetaceans in the Louisiana and Texas survey areas. Twenty-two sightings of eight species of pelagic or "deep water" cetaceans occurred in waters deeper than 200 m. Forty-five percent of the sightings of pelagic species were sperm whales, 18% were identified as short-finned pilot whales, 14% were unidentified beaked whales (*Mesoplodon* or *Ziphius* spp.), and 14% were dolphins of the genus *Stenella*.

These surveys included about 25,000 km^2 of Gulf waters less than 200 m offshore of southwestern Florida. Bottlenose dolphins were the most frequently sighted cetacean (322 groups) in this area, followed by *Stenella* dolphins (49 groups), and one sperm whale. Nearly all of the sightings of *Stenella* dolphins were in waters greater than 25 m deep.

From 1983-86, the NMFS-SEFSC investigated the distribution, abundance, and diversity of cetaceans in U.S. Gulf of Mexico waters less than 200 m deep, which in some areas ranged to 280 km offshore (a total area of about 360,000 km^2, Scott et al. 1989). Bottlenose dolphins were the most commonly sighted cetacean, with an estimated abundance of 35,000 to 45,000 animals. Nine other cetacean species were also observed during these surveys, but they accounted for only 2.4% of cetacean sightings (total sightings = 1,271). These species included: *Stenella* spp., Risso's dolphins, false killer whales, pygmy killer whales, fin whale, and unidentified beaked whales (*Mesoplodon* spp. or *Ziphius cavirostris*). All of these species have been reported as strandings in the Gulf (Schmidly 1981).

During the fall of 1986 and spring and fall of 1987, NMFS conducted aerial surveys designed to estimate the relative abundance of red drum (*Sciaenops ocellatus*) in the shallow U.S. Gulf of Mexico waters, from shore to about 27 km offshore in waters generally less than 200 m deep (Mullin et al. 1991). Observations of cetaceans and other species were also recorded during these surveys. Bottlenose dolphins were the most commonly sighted cetaceans; 494 groups were sighted during the spring surveys and 548 groups during the fall surveys. Atlantic spotted dolphins were sighted infrequently. Two unidentified baleen whales (*Balaenoptera* spp.) and one group of pygmy killer whales were sighted.

From July 1989 through June 1990, NMFS conducted aerial surveys of cetaceans along the continental slope of the north-central Gulf of Mexico in water ranging from 180-1,800 m deep (Mullin et al. 1991). The objectives were to: (1) examine cetacean species diversity in the region, (2) determine the temporal and spatial distribution of cetaceans, and (3) estimate relative abundance. Over 7,000 dolphins and whales were counted during 320 sightings. Ranked from most to least commonly sighted groups, with percentage of total sightings, these were: (1) Risso's dolphins, 22%; (2) sperm whales, 15%; (3) bottlenose dolphins, 14%; (4) Atlantic spotted dolphins, 13%; (5) dwarf/pygmy sperm whales, 12%; (6) striped/spinner/clymene dolphins, 9%; (7) pantropical spotted dolphins, 8%; (8) beaked whales, 3%; (9) short-finned pilot whales, 2%. The remaining 2% of group sightings were comprised of melon-headed/pygmy killer whales, false-killer whales, killer whales, rough-toothed dolphins, a fin whale and a Bryde's/sei whale.

Average sighting rate for the entire study was 1.6 sightings per 100 transect km. Cetacean species had a wide spatial and temporal distribution on the upper continental slope. Six species were sighted in every season (summer, fall, winter, and spring) and two additional species were sighted in each season but winter. Twelve species were sighted in summer, 10 in spring and fall, and only six in winter. Except for the short-finned pilot whale, all species sighted more than once were sighted throughout the length (east-west) of the study area. Sperm whales were found throughout the study area but were concentrated in the region near the Mississippi River delta.

1.1.3 The GulfCet I Program

The most intensive field study of cetaceans in the Gulf of Mexico to date was that of the GulfCet I surveys conducted jointly by Texas A&M University and the NMFS, Southeast Fisheries Science Center (Davis and Fargion 1996). This three year study provided synoptic information on the distribution and abundance of the more common cetaceans, as well as others that are seen less frequently (Table 1.1). It also provided limited information on habitat preference. GulfCet I surveys, for one of the first times (see also Thomas et al. 1986), provided detailed complementary information of marine mammal presence from both visual and acoustic platforms.

Shipboard Visual Surveys. A total of 21,350 km of transect was visually surveyed during the GulfCet I shipboard surveys. The cumulative survey effort from both platforms for each season was: spring: 13,507 km, summer: 2,085 km, fall: 1,275 km, and winter: 4,483 km. The number of on-effort sightings each season ranged from 14 during fall to 509 during spring. Nineteen cetacean species were identified during 683 sightings made on-effort. Most of the survey effort occurred during the spring, with the least effort during the fall.

The bottlenose dolphin, pantropical spotted dolphin, and sperm whale were the most commonly sighted species; each was sighted more than 70 times. Risso's dolphin, clymene dolphin, dwarf sperm whale, striped dolphin, and unidentified ziphiids 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 141 for melon-headed whales.

The overall visual estimate of cetacean abundance (CV in parentheses) in the GulfCet I 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

Table 1.1. Cetaceans of the Gulf of Mexico and their estimated abundance (N) in the GulfCet I study area (Davis and Fargion 1996). CV = coefficient of variation.

Species		N	CV
Balaenidae			
Northern right whale	*Eubalaena glacialis*		
Balaenopteridae			
Blue whale	*Balaenoptera musculus*		
Fin whale	*Balaenoptera physalus*		
Sei whale	*Balaenoptera borealis*		
Bryde's whale	*Balaenoptera edeni*	3	0.81
Minke whale	*Balaenoptera acutorostrata*		
Humpback whale	*Megaptera novaeangliae*		
Physeteridae			
Sperm whale	*Physeter macrocephalus*	313	0.25
Pygmy sperm whale	*Kogia breviceps*	19	0.40
Dwarf sperm whale	*Kogia simus*	88	0.34
Ziphiidae			
Cuvier's beaked whale	*Ziphius cavirostris*	14	0.41
Blainville's beaked whale	*Mesoplodon densirostris*		
Sowerby's beaked whale	*Mesoplodon bidens*		
Gervais' beaked whale	*Mesoplodon europaeus*		
Unidentified Ziphiidae		124	0.29
Delphinidae			
Melon-headed whale	*Peponocephala electra*	2067	0.34
Pygmy killer whale	*Feresa attenuata*	36	0.64
False killer whale	*Pseudorca crassidens*	10	0.63
Killer whale	*Orcinus orca*	71	0.46
Short-finned pilot whale	*Globicephala macrorhynchus*	215	0.50
Rough-toothed dolphin	*Steno bredanensis*	177	0.35
Fraser's dolphin	*Lagenodelphis hosei*	65	1.17
Bottlenose dolphin	*Tursiops truncatus*	2538	0.26
Risso's dolphin	*Grampus griseus*	529	0.26
Atlantic spotted dolphin	*Stenella frontalis*	1145	0.37
Pantropical spotted dolphin	*Stenella attenuata*	7105	0.22
Striped dolphin	*Stenella coeruleoalba*	2091	0.52
Spinner dolphin	*Stenella longirostris*	840	0.60
Clymene dolphin	*Stenella clymene*	1695	0.37

2,538 (0.26) animals. This 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 for 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.

Shipboard Acoustic Surveys. The acoustic surveys were conducted concurrently with the visual surveys. A total of 12,219 km and 1,055 hours of acoustic effort was completed during GulfCet I. On-effort acoustic sampling occurred 95% of the available time. A total of 487 acoustic contacts were recorded. Of that number, 124 contacts were from 12 identified 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 based on its spectral characteristics. An additional 331 contacts were made of unidentified dolphins at times when there was no visual effort, such as during poor weather and at night. 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 expected to occur in the Gulf as determined by Jefferson et al. (1992) were recorded, including the rarely recorded clymene and rough-toothed dolphins as well as the first recording ever of Fraser's dolphin.

A total of 67 sperm whale on-effort, acoustic contacts were made along 85 track lines. The mean sperm whale contact density was 2.8×10^{-4} contacts/km^2, or 44 groups in the study area. Using 7.3 individuals per group, the overall corrected mean sperm whale density was 2.041 individuals/1,000 km^2 (SD = 2.38, n = 85). The coefficient of variation was 12.6%. The log-normal upper and lower confidence intervals were 1.712 and 2.433 individuals/1,000 km^2. Within the 154,621 km^2 study area, the total estimated population of sperm whales is 316 individuals (265-377). This means that one sperm whale group was detected, on average, every 161 km.

A total of 369 dolphin on-effort, acoustic contacts were made along the same 85 track lines used to estimate sperm whale abundance. The mean dolphin contact density was 8.08×10^{-3} contacts/km^2 or 1298 groups in the entire study area. Using a weighted mean of 28.32 animals/group, the overall mean dolphin density was 2.29×10^{-1} animals/km^2 or 229 dolphins/1000 km^2. The log-normal upper and lower confidence intervals were 273 and 193 dolphins/1000 km^2. The total estimated dolphin population within the study area was 36,760 animals (30,835-43,821). This means that, on average, one dolphin group was detected every 31 km.

During GulfCet I, encounter rates were 22% higher for the acoustic survey than the concurrent visual survey. The acoustic survey was on effort 95% of the time for *Pelican* cruises 2-7. Total acoustic effort was 12,219 km. Poor meteorological conditions can prevent visual sightings, whereas acoustic detection is much less affected by poor weather. Similarly, acoustic surveys can continue at night. For example, during GulfCet I, 65% of dolphin contacts were at night even though acoustic survey effort was evenly divided between night and day. In addition, acoustic surveys create a physical record in the form of tape-recordings that document encounters and permit future analysis of data. By making tape-recordings of sounds heard during the survey, future researchers can verify the survey results, identify and count vocalizations (and possibly individuals), and describe biases. These recordings also allow comparisons of the present acoustic environment in the Gulf with recordings made on later surveys.

Aerial Surveys. A total of 49,960 km of transect was visually sampled during eight aerial surveys. The transect kilometers sampled by survey ranged from 5,330-6,592 km, and by season from 11,756-12,942 km. In total, 351 cetacean groups were sighted on-effort. The number of sightings each survey ranged from 24 to 61 for fall 1992 and winter 1994, respectively. By season the number of sightings ranged from 49 to 109 for fall and winter, respectively.

At least 17 cetacean species were identified during GulfCet I aerial surveys (each of these species was also sighted during ship surveys). Seasonally, the number of species sighted ranged from 11 in the fall to 15 in winter. Eight species were identified in all four seasons, two in three seasons, four in two seasons and four in only one season. Five species, which were each sighted 20 or more times, accounted for 71% of the identified sightings: bottlenose dolphins, pantropical spotted dolphins, Risso's dolphins, pygmy/dwarf sperm whales, and sperm whales.

Overall, there were an estimated 16,986 (CV = 0.14) cetaceans in the GulfCet I aerial survey study area. There were an estimated 12,690 (CV = 0.23) cetaceans the first year and 20,669 (CV = 0.18) the second. Most of the difference between years was a consequence of the two winter and the two spring estimates. In both cases, the point estimates were about twice as large the second year compared to the first. Cetacean abundance was about the same in winter (21,894; CV = 0.27) and spring (19,215; CV = 0.25), a little less in summer (14,959; CV = 0.24), but two to three times lower in the fall (6,051; CV = 0.32).

Pantropical spotted dolphins were the most abundant species in the aerial survey study area (5,251; CV = 0.22) followed by melon-headed whales (2,980; CV = 0.60), bottlenose dolphins (2,890; CV = 0.20) and Risso's dolphins (1,214; CV = 0.24). The sperm whale population was estimated to be 87 whales (CV = 0.27) and pygmy/dwarf sperm whales, 176 (CV = 0.31). All the other delphinid species were represented by less than 1,000 individuals each, and balaenopterids and ziphiids, by less than 100 individuals each. Mean group sizes ranged from 315 for melon-headed whales to less than four for pygmy/dwarf sperm whales, sperm whales and ziphiids.

Habitat Studies. The GulfCet I Program provided limited information on habitat preference, which showed the strongest correlation of species distribution with ocean depth. However, this study failed to establish strong correlations with other oceanographic variables such as sea surface temperature, salinity, water column structure and distinctive features such as warm-core and cold-core eddies. This may have resulted from the fact that: (1) the oceanography of the Gulf of Mexico is very dynamic with the periodic intrusion of the Loop Current from the southeast and the formation of warm-core eddies that move across the northern Gulf and (2) cetaceans are large, warm-blooded mammals whose wide-ranging movements are not physiologically constrained by water temperature or other hydrographic features.

The distribution and movements of cetaceans are probably better explained by the availability of prey, which may secondarily be influenced by oceanographic features. As a result, we will use models of dynamic height (determined by satellite altimetry) to monitor the weekly locations of the Loop Current and eddy systems and gather data on nekton distribution and biomass during focal studies to assess cetacean distribution and habitat. For example, we hypothesize that the concentration of cetaceans, especially sperm whales, found offshore from the Mississippi River delta results from the nutrient- enriched waters that support a large biomass of prey. Likewise, cold-core eddies or the edge of warm-core eddies may concentrate nekton that is preyed upon by cetaceans. Based on our experience during GulfCet I, a better understanding of cetacean habitat preference (a primary objective of the research) can only be achieved through focal studies of the physical environment and prey availability.

1.2 OBJECTIVES

The purpose of the GulfCet II program is to conduct studies on cetaceans at sea in the northern Gulf of Mexico to determine their seasonal and geographic distribution in areas potentially affected by oil and gas activities now or in the future. This program includes systematic aerial overflights and shipboard visual and acoustic surveys to document cetacean and sea turtle populations. This work is accompanied by data acquisition designed to further characterize habitats and reveal cetacean-habitat associations. The work is intended as an areal and temporal extension of the GulfCet I Program.

The specific objectives of the study are to:

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

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

A goal of this program is to determine which cetacean species may potentially be affected by present and future oil and gas activities based on analyses of seasonal and geographic distribution of each species, habitat associations, and an interpretation of behavioral information collected during this study and from previous surveys. Evaluation will result in the determination of which species could potentially be affected, estimation of the proportion of the population this would represent, geographic and temporal degree of effect, and effect on critical activities (i.e., breeding, feeding, and mating areas).

Objective 1 represents a continuation of surveys in the north-central and western Gulf that began during the GulfCet I program, and extends them into the MMS's Eastern Planning Area. To accomplish this objective, we will conduct aerial surveys and simultaneous shipboard visual and acoustic surveys using line-transect methods. We hypothesize that cetaceans are non-uniformly distributed (which we confirmed during GulfCet I) and that their distributions are related to variability in prey availability and physical oceanographic features in the marine environment.

To characterize habitat (part of Objective 2), we will use a multidisciplinary approach and include physical features (i.e., sea surface temperature, ocean depth, oceanographic features such as warm-core and cold-core eddies, bottom topography) as well as biological features such as prey availability. We hypothesize that the distribution and abundance of marine mammals in the northern Gulf of Mexico are positively correlated with spatial and temporal variations in regional food stocks of zooplankton and micronekton. These food stocks are concentrated in nutrient-rich areas offshore from the Mississippi River, within cold-core eddies, or along the edge of warm-core eddies.

The study area includes the entire continental slope of the northern Gulf of Mexico (i.e., the continental slope north of 26° N latitude) between the 100- and 2,000-m isobaths (Figure 1.1). We conducted synoptic shipboard surveys of the entire study area using line-transects methods. We focused additional shipboard and aerial survey effort on the Eastern Planning Area, which was not included in the GulfCet I program and for which there is little

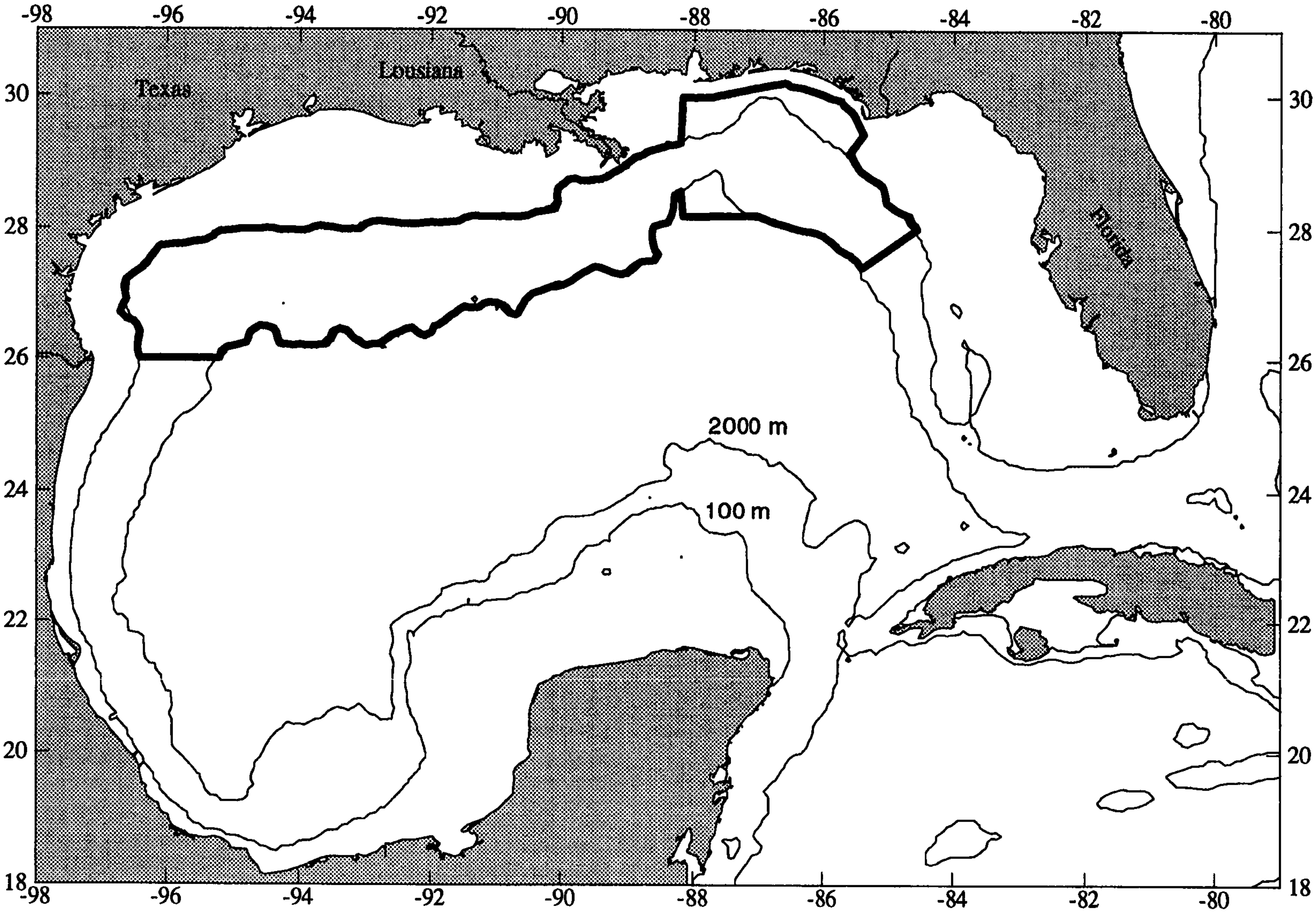


Figure 1.1. Outline of the GulfCet II study area.

information on cetacean abundance and distribution. Finally, we will conduct focal shipboard studies (e.g., south of the Mississippi River delta and along the edge of eddies) in order to better understand the effect of oceanographic features and prey availability on cetacean distribution.

II. VISUAL SURVEYS FROM SHIPS AND AIRCRAFT

2.1 SHIPBOARD SURVEYS

2.1.1 NOAA Ship *Oregon II* Spring 1996 Cruise

Introduction

The first of two GulfCet II spring vessel surveys was conducted in three legs from 17 April through 09 June 1996 in the northern Gulf of Mexico. The survey was conducted in oceanic and upper continental slope waters of the U.S. Gulf of Mexico (waters >100 m deep; Figures 2.1-2). A portion of the continental shelf in the northeastern Gulf of Mexico (Figure 2.3) was surveyed which overlapped the Minerals Management Service's Destin Dome leasing area and included, as requested, Block 56.

Objectives

1. Collect line-transect data to estimate abundances and define the distributions of cetaceans in oceanic and selected continental shelf waters of the northern Gulf of Mexico.

2. Collect associated environmental data at designated stations in order to define cetacean habitats.

3. Obtain biopsy samples of skin from selected cetacean species for genetic analysis in order to study the stock structure of Gulf of Mexico cetaceans.

4. Collect data on the distribution and abundance of seabirds and other marine life.

5. Collect data on species identity, distribution and abundance, and stock structure of flyingfish.

Methods

Cetacean Survey. The survey platform was the 53 m NOAA Ship *Oregon II* which has been used extensively since 1990 for cetacean surveys in the Gulf of Mexico. Line-transect data were collected by two teams of three observers during daylight hours, weather permitting (i.e., no rain, Beaufort sea state < 6). Each team consisted of skilled observers experienced in shipboard cetacean observation and identification techniques. Two observers searched

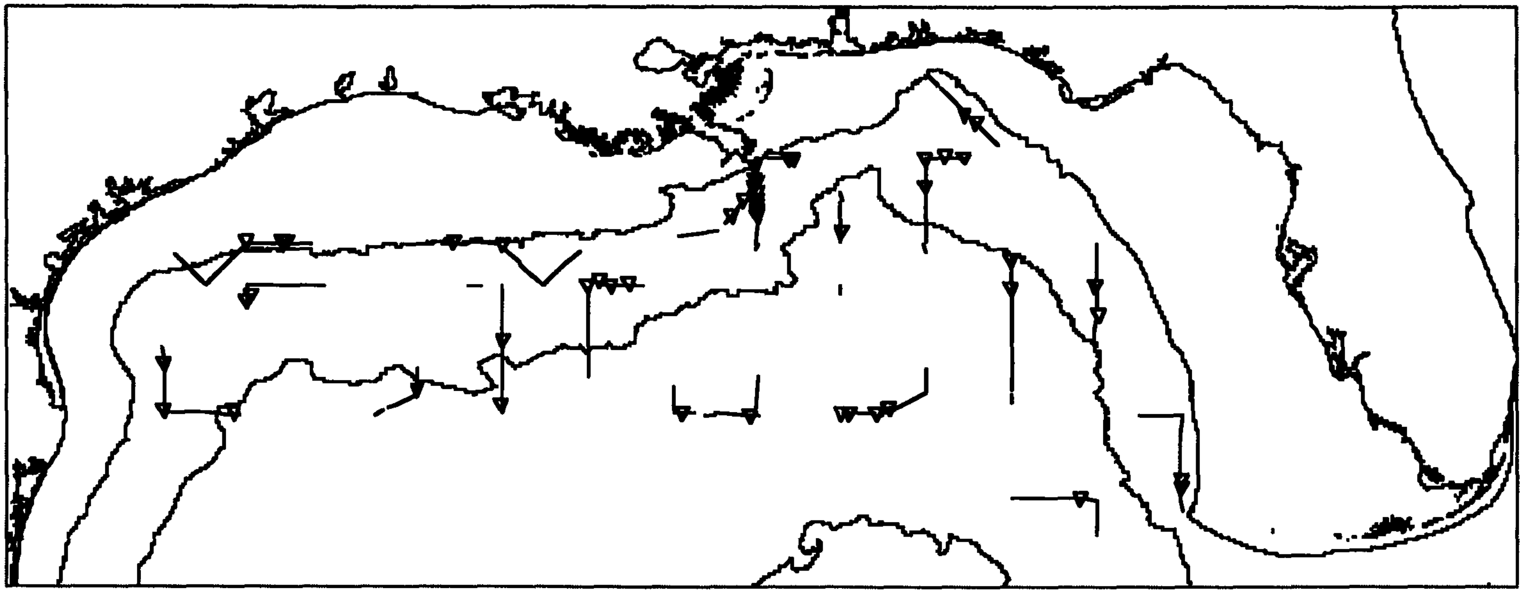


Figure 2.1. Location of line-transect survey effort (2580 km) and locations of cetacean sightings (n = 52) during NOAA Ship *Oregon II* Cruise 220, Leg 1 (17 April-04 May 1996). The 100 m and 2000 m isobaths are shown.

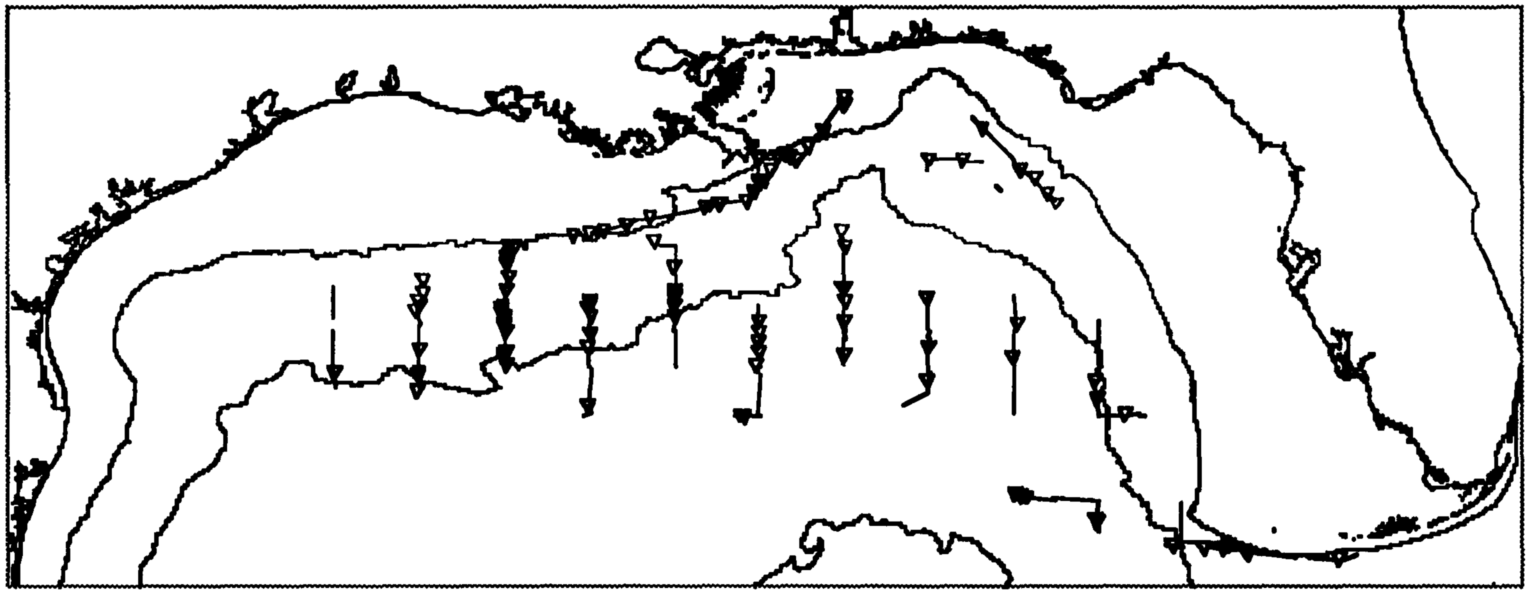


Figure 2.2. Location of line-transect survey effort (2428 km) and locations of cetacean sightings (n = 125) during NOAA Ship *Oregon II* Cruise 220, Leg 2 (07 May - 26 May 1996). The 100 m and 2000 m isobaths are shown.

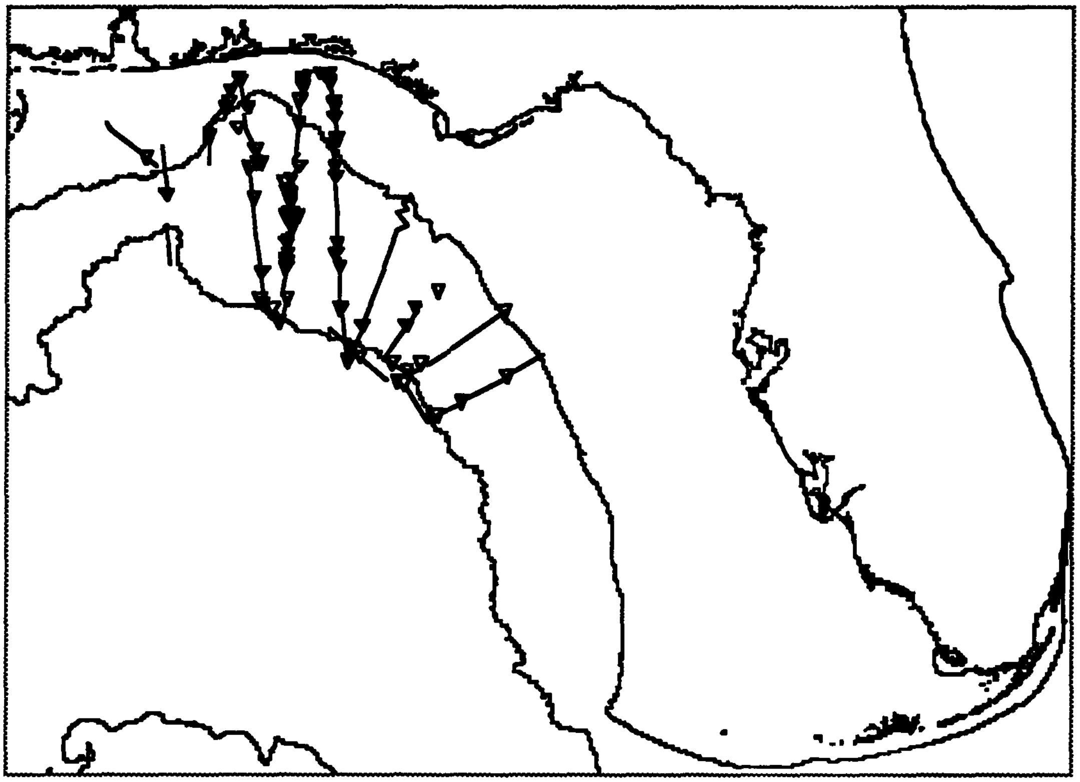


Figure 2.3. Location of line-transect survey effort (1393 km) and locations of cetacean sightings (n = 86) during NOAA Ship *Oregon II* Cruise 220, Leg 3 (29 May-09 June 1996). The 100 m and 2000 m isobaths are shown.

for cetaceans using 25X "bigeye" binoculars mounted on the left and right sides of the ship's flying bridge. "Bigeye" observers searched from 90° abeam on their respective sides, past 0° (straight-ahead), to 10° on the other side. The third observer maintained a search of the area near the ship using unaided eye or 7X hand-held binoculars, and recorded data. Data were recorded on a laptop computer using a BASIC data acquisition program interfaced with a global positioning system (GPS). Data collected on the survey environment included measures of sea state, weather, wind and glare. Cetacean sighting data included species, group-size, presence of calves, bearing from the bow, linear distance from the ship, surface temperature, depth, and behavioral observations.

Legs 1 and 2 were conducted in conjunction with NMFS bluefin tuna ichthyoplankton sampling (performed by a separate team of scientists). Ichthyoplankton sampling was conducted along a predetermined track-line at stations uniformly spaced throughout the oceanic U.S. Gulf. The track-line was transited 24-hours a day. Line-transect sampling was conducted while traveling between stations during daylight hours (Figures 2.1-2). Leg 3 was a dedicated cetacean survey that focused on the northeastern Gulf continental slope (100-2000 m) and shelf (i.e., Destin Dome leasing area) waters (Figure 2.3). As required by Marine Mammal Research Permit No. 738 issued to the Southeast Fisheries Science Center under Marine Mammal Protection Act guidelines, data on the behavioral responses of cetaceans to the survey vessel were recorded.

On Leg 3, equipment to obtain recordings of cetacean vocalizations was temporarily installed on the ship (eight sonobuoys, a receiver, tape recorder and antenna). Sonobuoys were deployed among separate groups of bottlenose dolphins and Atlantic spotted dolphins but technical problems prevented any recordings from being made. Because the problems could not be resolved, only four sonobuoys were deployed.

Cetacean Biopsy. Biopsy samples of skin and blubber were collected from selected cetacean species (designated by Permit No. 738) for genetic and contaminant analyses. A pole-spear, cross-bow, and modified rifle were used for obtaining samples and each was fitted with specially designed heads that extract a small plug of tissue from animals at close range. Samples were collected from bow-riding animals at the bow of the *Oregon II* and from a small boat. Because of the additional staffing requirements of biopsy sampling, almost all of the effort was confined to Leg 3 when additional staff could be accommodated. As required by Permit No. 738, data on each sampling attempt was recorded and included date, time, platform, sampler and recorder name, field number, device, species, location (GPS), number of hits and misses, body location struck, and whether a sample was taken.

Birds. Data on seabirds and non-passerines encountered by observers while searching for cetaceans were recorded. Species were identified to the lowest taxonomic level possible and flock-size enumerated. While observers had a wide range of experience in identifying birds, searching for cetaceans was the primary objective and most observers could not quickly identify bird sightings to species except under the best circumstances. Passerine neotropical migrants, which can be numerous in the Gulf during spring, were not recorded.

Flyingfish. As part of a taxonomic revision of the flyingfishes (family Exocoetidae), flyingfish specimens were opportunistically collected with a dipnet during a standardized one-hour sampling period each night when the ship was stopped for environmental sampling (Leg 1 and 2) or for the night (Leg 3).

Results

Cetacean Survey. During the 44 survey days, 6401 transect kilometers were surveyed (Leg 1, 2580; Leg 2, 2428; and Leg 3, 1393 km) (Table 2.1, Figures 2.1-3). Daily effort ranged up to 10.8 hours/day and 207 km/day and averaged 145 km/survey day. Mechanical problems with the ship eliminated effort on one day during Leg 2 and delayed the departure of Leg 3 by one day. Poor weather eliminated effort on one day during Leg 3.

During the entire cruise, 263 cetacean groups were sighted (Leg 1, 52; Leg 2, 125; and Leg 3, 86 groups) with 235 and 28 groups classified as on- and off-effort sightings, respectively. At least one group was sighted each survey day with a maximum of 29 sightings on one day (Table 1). At least 16 species were sighted. The most commonly sighted species were pantropical spotted dolphins (56 sightings), bottlenose dolphins (40), Risso's dolphin (31), sperm whales (24), and Atlantic spotted dolphins (21) and these five species comprised about 65% of the identified sightings (Table 2.2). Associations between cetacean species included Risso's dolphin and bottlenose dolphin, Atlantic spotted dolphin and bottlenose dolphin (twice), and Risso's dolphin and pantropical spotted dolphin.

The largest group sizes for Gulf of Mexico cetaceans encountered to date were sighted during this cruise and consisted of an estimated 750 spinner dolphins and 650 pantropical spotted dolphins in separate sightings. Eight spinner dolphin groups averaged 355 dolphins and other *Stenella* spp., about

Table 2.1. Effort, Beaufort sea state and number of sightings for each day of NOAA Ship *Oregon II* Cruise 220, April-June 1996.

Leg	Date	Effort hours	Transect kilometers	Average sea state	Number of sightings
Leg 1					
	16 April 1996	Depart Pascagoula			
	17 April 1996	6.8	117	2.4	2
	18 April 1996	6.8	108	4.2	2
	19 April 1996	8.7	166	4.3	2
	20 April 1996	8.1	155	4.7	1
	21 April 1996	9.1	183	4.4	2
	22 April 1996	9.6	160	4.4	4
	23 April 1996	7.5	126	3.0	4
	24 April 1996	3.3	69	4.3	1
	25 April 1996	8.1	149	3.6	12
	26 April 1996	7.8	168	3.3	2
	27 April 1996	8.7	168	2.8	4
	28 April 1996	8.3	174	5.1	2
	29 April 1996	3.9	75	2.3	1
	30 April 1996	5.5	117	2.8	2
	01 May 1996	9.2	174	4.7	3
	02 May 1996	10.8	197	4.6	3
	03 May 1996	9.6	193	3.3	2
	04 May 1996	3.4	81	2.0	3
	04 May 1996	Arrive Pascagoula			
		Total	2580		52
Leg 2					
	07 May 1996	Depart Pascagoula			
	08 May 1996	7.1	134	3.0	5
	09 May 1996	9.0	168	4.7	3
	10 May 1996	8.6	151	5.4	3
	11 May 1996	Key West for repairs			
	12 May 1996	6.8	170	2.3	5
	13 May 1996	7.7	139	2.1	5
	14 May 1996	7.8	151	5.0	2
	15 May 1996	3.6	71	5.6	2
	16 May 1996	9.7	158	4.5	4
	17 May 1996	7.7	150	2.8	8
	18 May 1996	8.6	170	2.3	11
	19 May 1996	7.4	142	3.4	7
	20 May 1996	8.4	165	3.0	8
	21 May 1996	6.7	124	2.8	7
	22 May 1996	5.8	104	1.0	29

Table 2.1., continued.

Leg	Date	Effort hours	Transect kilometers	Average sea state	Number of sightings
Leg 2, continued					
	23 May 1996	6.4	114	3.3	9
	24 May 1996	6.1	115	5.0	1
	25 May 1996	9.6	202	3.1	16
	26 May 1996	Arrive Pascagoula			
		Total	2428		125
Leg 3					
	28 May 1996	Delay for repairs			
	29 May 1996	Depart Pascagoula			
	29 May 1996	2.2	54	5.1	1
	30 May 1996	10.1	207	3.8	7
	31 May 1996	8.7	171	2.7	6
	01 June 1996	0	0	>6.0	1
	02 June 1996	10.8	193	3.9	2
	03 June 1996	8.6	164	2.1	8
	04 June 1996	7.1	138	1.8	19
	05 June 1996	6.0	111	1.2	23
	06 June 1996	8.4	160	2.9	11
	07 June 1996	6.3	116	3.2	7
	08 June 1996	4.4	79	4.1	1
	09 June 1996	Arrive Pascagoula			
		Total	1393		86
		Grand Total	6401		263

20-90 dolphins/group. Groups-sizes of other species were more typical of previous years (e.g., Mullin et al. 1991, Hansen et al. 1996) (Table 2.2). Groups of sperm whales, Kogidae, and Ziphiidae generally contained fewer than five animals; and Risso's dolphins and bottlenose dolphins groups averaged 8.6 and 15.4, respectively.

Cetaceans were encountered in all areas of the Gulf of Mexico surveyed (Figures 2.1-3). Sightings were more common in some areas than others (e.g., near the Mississippi River delta), but in some cases, this may reflect sighting conditions rather than true cetacean distribution. Locations of groups of individual species are plotted in Figures 2.4-10. Bottlenose dolphins and Atlantic spotted dolphins were the only species sighted in continental shelf waters (e.g., Destin Dome lease area) (Figures 2.4 and 2.8) and were sighted at maximum depths of 702 and 222 m, respectively (Table 2.2).

Table 2.2. Number of sightings (n) and mean group-size, water depth and sea surface temperature of species of cetaceans in the U.S. Gulf of Mexico sighted during NOAA Ship *Oregon II* Cruise 220, April-June 1996.

		Group Size (animals)			Water Depth (meters)			Sea Surface Temperature (°C)		
Species	n	Mean	SE	Range	Mean	SE	Range	Mean	SE	Range
Balaenoptera edeni	2	3.0	1.00	2-4	210	5	206-215	25.5	2.50	23.0-28.0
Balaenoptera sp.	1	1.0			215			28.0		
Physeter macrocephalus	24	1.9	0.25	1-5	1850	227	547-3428	25.4	0.43	22.3-27.8
Kogia breviceps	4	1.3	0.25	1-2	1237	285	384-1544	27.4	0.13	27.0-27.6
Kogia simus	4	4.0	0.82	2-6	697	112	458-888	26.9	1.34	22.9-28.4
Kogia sp.	8	1.8	0.53	1-5	663	142	411-1538	27.3	0.27	26.3-28.7
Ziphius cavirostris	2	2.5	1.50	1-4	1393	182	1212-1575	26.3	0.05	26.3-26.4
Mesoplodon sp.	5	1.4	0.24	1-2	1612	284	1019-2594	26.4	0.92	23.3-28.6
Z. cavirostris/Mesoplodon	3	1.3	0.33	1-2	2193	220	1797-2557	25.5	1.23	23.1-27.2
Stenella coeruleoalba	3	43.7	18.35	21-80	715	301	410-1316	26.3	0.89	24.6-27.6
Stenella longirostris	6	355.3	112.2	32-750	481	56	356-731	25.6	0.98	22.4-28.1
Stenella clymene	8	77.0	13.55	15-150	1926	240	1130-3057	24.4	0.53	22.1-26.4
Stenella attenuata	56	91.6	13.44	5-650	1808	127	463-3372	26.2	0.23	21.9-28.8
Stenella frontalis	21	19.9	3.41	4-70	107	16	22-222	26.6	0.31	22.3-28.3
Stenella cly/longir/coerul	1	2.0			428			24.6		
Tursiops truncatus	40	15.4	4.52	1-172	212	26	30-702	25.6	0.36	19.4-28.3
T. truncatus/S. frontalis	10	2.5	0.52	1-5	128	68	22-719	26.6	0.27	25.1-28.4
Grampus griseus	31	8.6	1.02	2-24	1133	191	111-3437	26.3	0.39	20.4-27.9
Orcinus orca	1	4.0			1946			26.6		
Globicephala sp.	2	31.0	4.00	27-35	724	164	560-888	27.4	1.05	26.3-28.4
Peponocephala electra	1	125.0			1038			26.9		
Unidentified dolphin	25	2.9	0.62	1-15	924	212	50-3187	26.3	0.37	21.6-28.4
Unidentified small whale	5	1.4	0.40	1-3	1049	561	124-3196	26.4	1.11	22.0-28.1
Unidentified large whale	2	1.0	0.00	1-1	2001	1260	741-3261	25.3	2.30	23.0-27.6
Unidentified odontocete	3	1.3	0.33	1-2	883	339	406-1538	25.3	1.99	21.3-27.4

Pantropical spotted dolphin sightings were widely distributed in deep waters that averaged just over 1800 m. All of the ziphiid sightings were in waters over 1000 m. All (4 sightings) of the "blackfish" (Globicephalinae) were sighted west of the Mississippi River delta. The two Bryde's whale sightings and the unidentified balaenopterid whale sighting occurred on the upper continental slope in the northeastern Gulf. All of the spinner dolphin sightings were east of the Mississippi River delta and all of the Clymene dolphins west of the delta.

Preliminary observations were recorded on the prevalence of bite wounds from cookie-cutter sharks (*Isistius* sp.) on Gulf of Mexico cetaceans. As indicated by the presence of crater wounds or healed scars, a minimum of 66 (30.2%) of 218 groups of identified cetaceans contained at least one animal that showed evidence of *Isistius* attacks, including at least 15 of the 16 species recorded during the cruise.

Behavioral responses to the survey vessel were very typical of those from previous surveys (e.g., Würsig et al., submitted, 1996). Some species (dwarf/pygmy sperm whales and all ziphiids) are very intolerant of the vessel and usually dove, while others regularly came to the bow to ride the pressure wave (bottlenose dolphins and most *Stenella* spp.). Some displayed a mixed response that ranged from bow-riding to mild to strong avoidance behavior ("blackfish," Risso's dolphin, and striped dolphins).

Cetacean Biopsy. Forty-nine biopsy samples were collected (Leg 1, 2; Leg 2, 0; and Leg 3, 47 samples) from six species which include bottlenose dolphin (21 samples), Atlantic spotted dolphin (14), pantropical spotted dolphin (6), spinner dolphin (5), Risso's dolphin (2) and striped dolphin (1). Most (38/49) samples were collected from the bow of the *Oregon II* and the rest (11/49) from a an inflatable launch. All skin and blubber samples were sent to the NMFS Charleston (South Carolina) Laboratory for storage and analyses.

A single skin biopsy sample from a whale shark (*Rhiniodon typus*) was also obtained during the cruise; the specimen was sent to Dr. Scott Eckert, Hubbs SeaWorld, San Diego, California, and will be used in conjunction with a worldwide molecular genetic analysis of the species.

Birds. Over 2250 bird flocks and 28 species were recorded (Table 3.3). Unidentified storm petrel flocks were recorded most often and made up 509 (23%) of the sightings. Identified storm petrel species consisted of Madeiran (band-rumped) (47 sightings), Wilson's (14) and Leach's (2). Unidentified terns made up the next largest category with 219 flock sightings. Identified

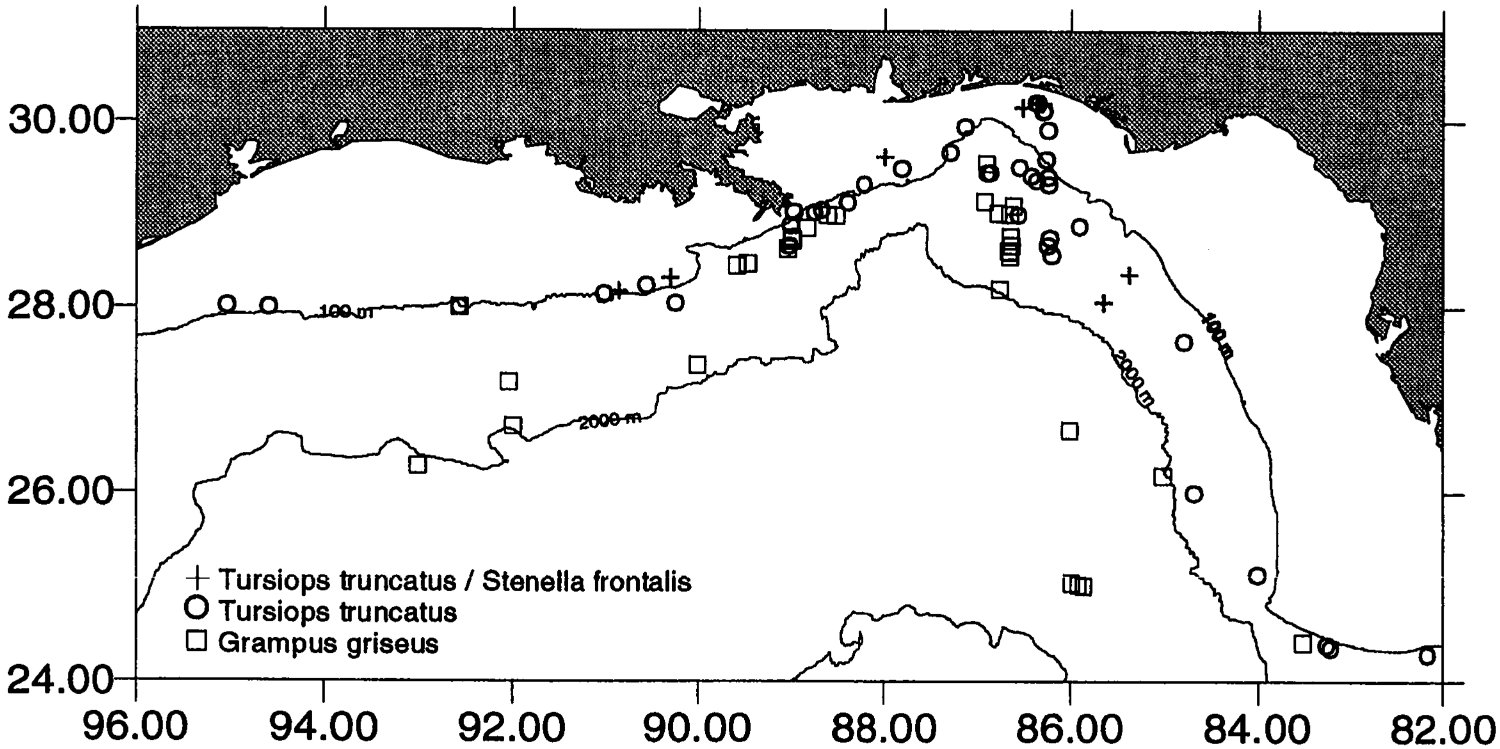


Figure 2.4 Locations of sightings of *Tursiops truncatus/Stenella frontalis* (n=10), *Tursiops truncatus* (n=40), and *Grampus griseus* (n=31) during NOAA Ship *Oregon II* cruise 220, April-June 1996.

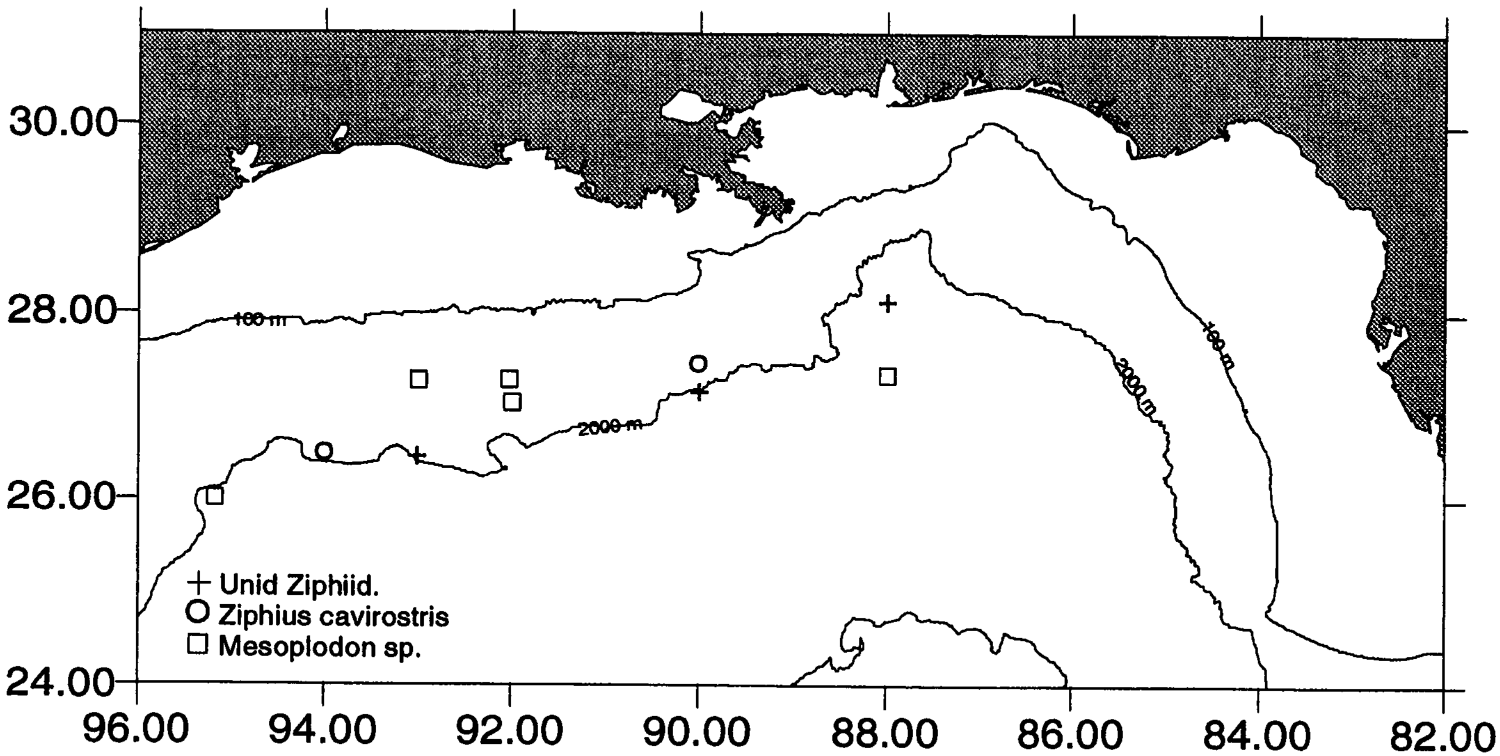


Figure 2.5 Locations of sightings of unidentified ziphiids (n=3), *Ziphius cavirostris* (n=2), and *Mesoplodon* sp. (n=5) during NOAA Ship *Oregon II* Cruise 220, April-June 1996.

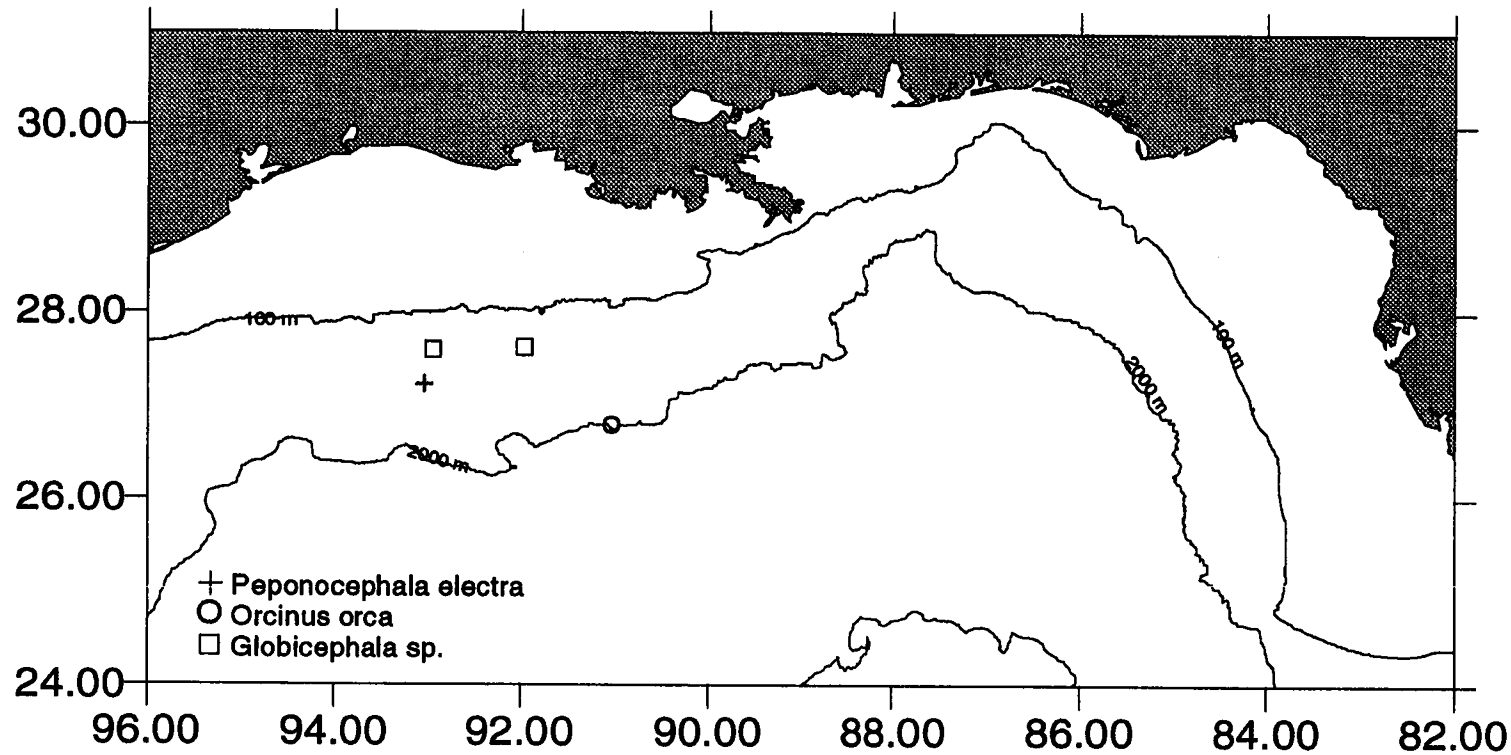


Figure 2.6 Locations of sightings of *Peponocephala electra* (n=1), *Orcinus orca* (n=1), and *Globicephala* sp. (n=2) during NOAA Ship *Oregon II* Cruise 220, April-June 1996.

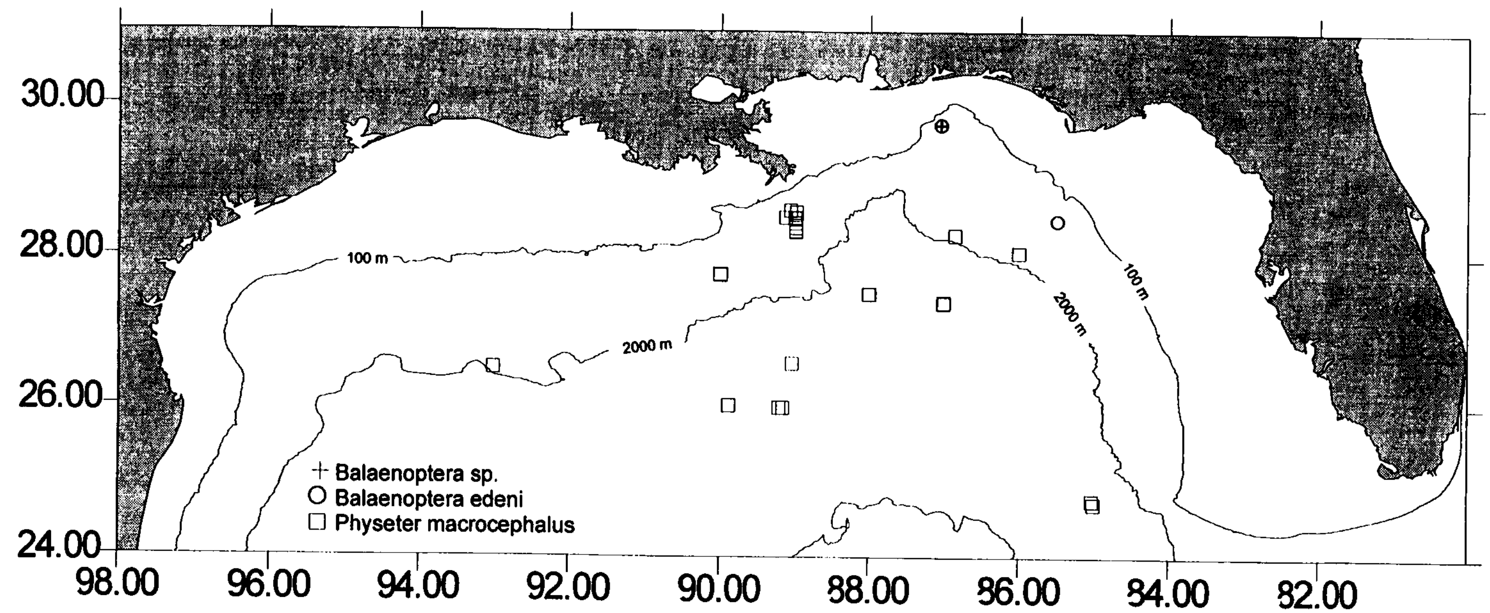


Figure 2.7. Locations of sightings of *Balaenoptera* sp. (n=1), *Balaenoptera edeni* (n=2), and *Physeter macrocephalus* sp. (n=24) during NOAA Ship Oregon II Cruise 220, April-June 1996.

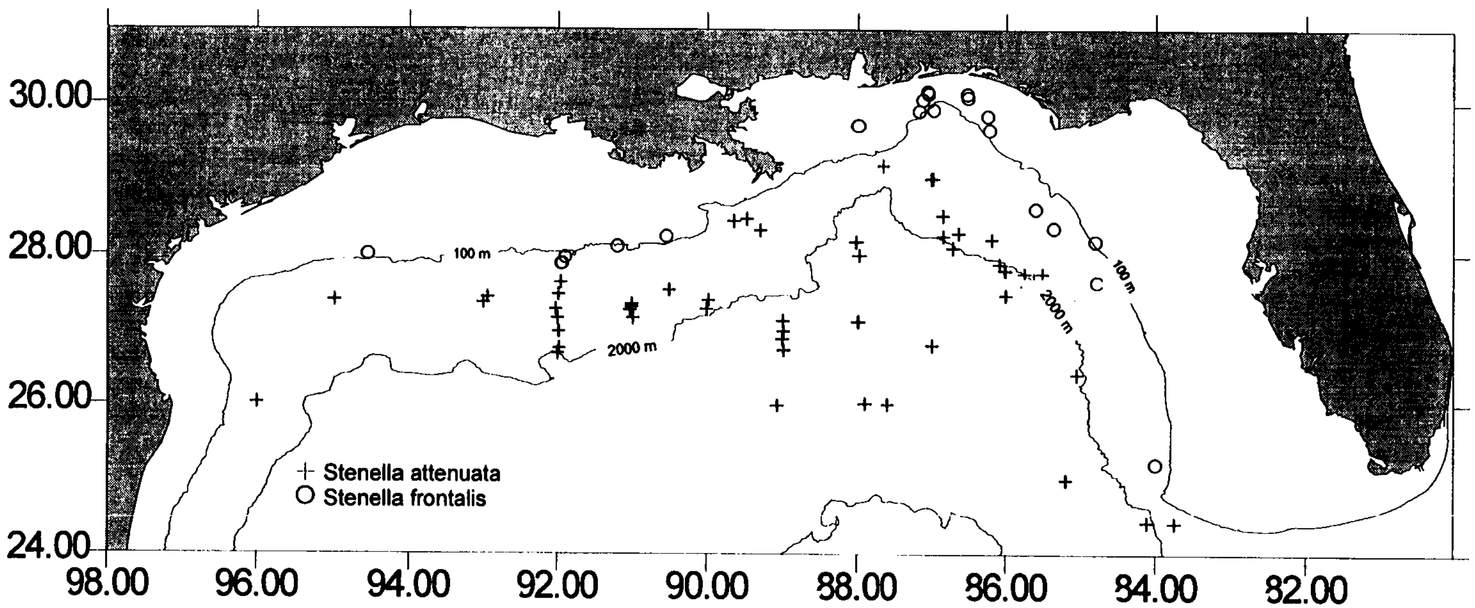


Figure 2.8 Locations of sightings of *Stenella attenuata* sp. (n=56) and *Stenella frontalis* (n=21) during NOAA Ship *Oregon II* Cruise 220, April-June 1996.

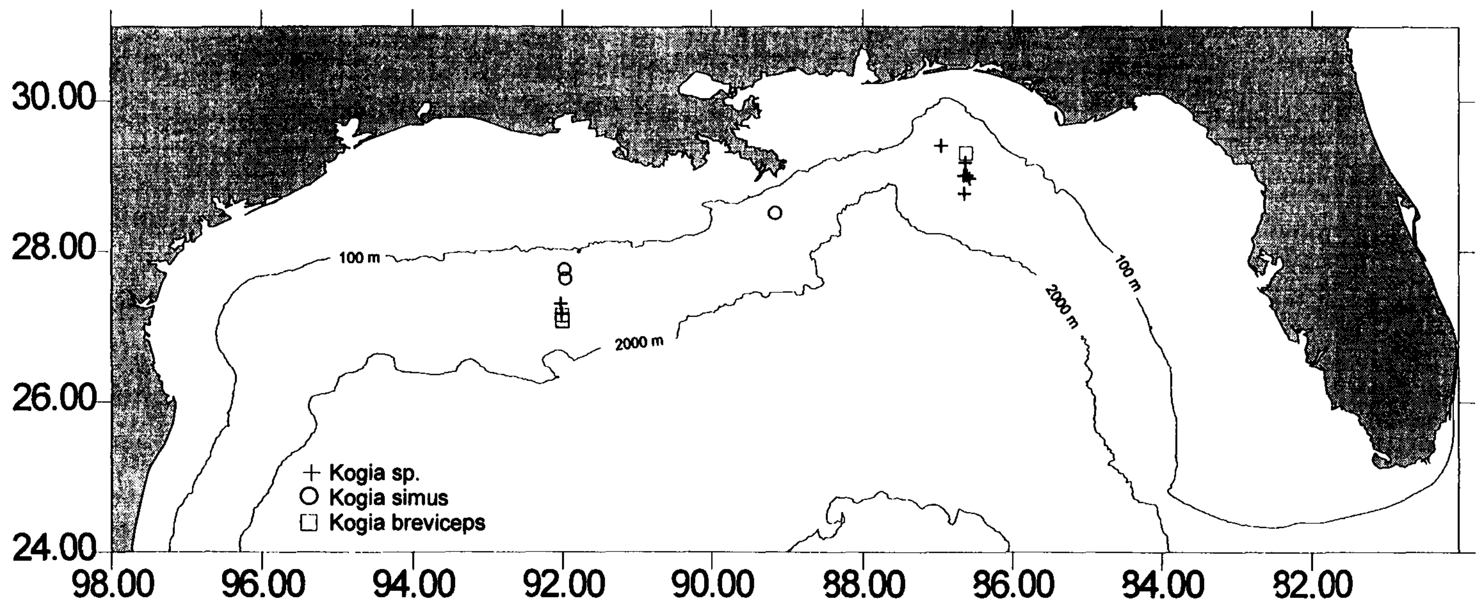


Figure 2.9. Locations of sightings of *Kogia* sp. (n=8), *Kogia simus*, and *Kogia breviceps* (n=4) during NOAA Ship *Oregon II* Cruise 220, April-June 1996.

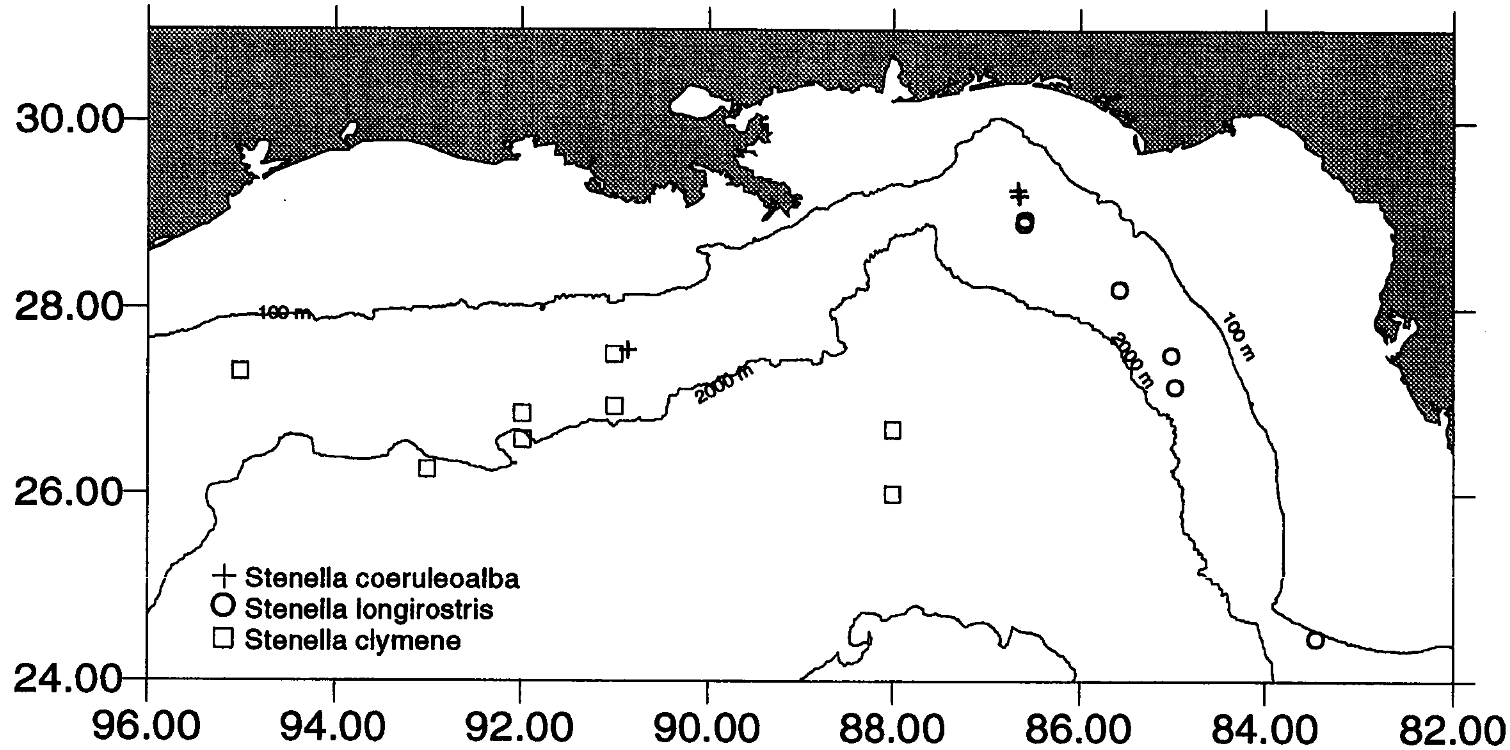


Figure 2.10 Locations of sightings of *Stenella coeruleoalba* sp. (n=3), *Stenella longirostris* (n=6), and *Stenella clymene* (n=8) during NOAA Ship *Oregon II* Cruise 220. April-June 1996.

Table 2.3. Number of sightings (n) and mean flock-size and water depth of species of birds sighted in the U.S. Gulf of Mexico during NOAA Ship *Oregon II* Cruise 220, April-June 1996.

Species	n	Flock Size (#birds) x̄	SE	Range	Water Depth (m) x̄	SE	Range
Double-crested cormorant *Phalacrocorax auritus*	2	1.0	0	1-1	762	708.0	54-1470
Ducks	42	6.8	1.11	1-35	939	153.9	64-3363
Coot *Fulica americana*	2	1.0	0	1-1	165	30.0	135-195
Audubon's shearwater *Puffinus lherminieri*	137	1.2	0.05	1-5	899	89.7	78-3394
Cory's shearwater *Calonectris diomedea*	1	1.0			47		
Unidentified shearwater *Puffinus/Calonectris*	10	1.5	0.40	1-5	774	280.9	124-3191
Leach's storm petrel *Oceanodroma leucorhoa*	2	1.0	0	1-1	229	69.5	159-298
Madeiran storm petrel *Oceanodroma castro*	47	1.1	0.06	1-3	1151	169.2	42-3485
Wilson's storm petrel *Oceanites oceanicus*	14	1.2	0.21	1-4	384	62.2	38-896
Unidentified storm petrel Hydrobatidae	509	1.8	0.08	1-12	988	50.0	27-3503
Brown pelican *Pelecanus occidentalis*	5	1.4	0.40	1-3	758	529.2	29-2752
Magnificent frigatebird *Fregata magnificens*	6	1.2	0.07	1-2	846	187.2	78-3354
Northern gannet *Sula bassana*	23	1.6	0.23	1-5	450	176.8	27-3198
Masked booby *Sula dactylatra*	2	1.0	0	1-1	656	436.0	2220-3092
White-tailed tropicbird *Phaethon lepturus*	1	1.0			3297		
Unidentified tropicbird *Phaethon sp.*	2	1.0	0	1-1	419	186.5	232-605
Parasitic jaegar *Stercorarius parasiticus*	8	1.1	0.13	1-2	850	312.2	117-2328
Pomarine jaegar *Stercorarius pomarinus*	65	1.3	0.08	1-4	1832	150.8	122-3357
Long-tailed skua *Stercorarius longicaudus*	1	1.0			195		

Table 2.3, continued.

Species	n	Flock Size (#birds) x̄	SE	Range	Water Depth (m) x̄	SE	Range
Unidentified jaegar *Stercorarius sp.*	19	1.4	0.17	1-4	1311	288.3	49-3350
Herring gull *Larus argentatus*	1	1.0			148		
Laughing gull *Larus atricilla*	238	1.8	0.22	1-45	1118	75.8	27-3505
Unidentified gull *Larus sp.*	5	1.6	0.24	1-2	1474	677.4	175-3136
Black tern *Chlidonias niger*	95	5.2	1.37	1-120	643	75.5	34-3361
Bridled tern *Sterna anaethetus*	35	1.8	0.30	1-8	816	137.9	42-3130
Bridled/sooty tern *Sterna anaethetus/fuscata*	62	8.6	1.70	1-60	977	141.6	40-3350
Common tern *Sterna hirundo*	5	1.3	0.25	1-2	1267	364.5	239-2251
Least tern *Sterna antillarum*	2	1.0	0	1-1	1535	1477.5	58-3013
Royal tern *Sterna maxima*	10	1.0	0	1-1	722	291.2	54-3205
Sandwich tern *Sterna sandvicensis*	61	8.5	2.15	1-120	637	59.8	74-2152
Sooty tern *Sterna fuscata*	139	6.0	0.71	1-50	1466	106.3	78-3485
Brown noddy *Anous stolidus*	1	1.0				129	
Unidentified tern Sternidae	219	7.6	1.03	1-100	935	70.5	31-3394
Unidentified seabirds	267	4.0	1.02	1-200	2120	70.7	38-3394
Egret	195	5.6	0.44	1-35	1632	88.9	31-3394
Great blue heron *Ardea herodias*	2	2.0	1.00	1-3	2043	151.0	1892-2194
Unidentified heron	1	4.0			38		
Non-seabirds	14	3.3	1.39	1-20	1427	335.4	107-3255
Unidentified shorebirds	5	7.4	2.32	2-15	1806	438.0	261-2662
Unidentified phalarope *Phalaropus sp.*	2	8.0	7.00	1-15	1163	1031.5	131-2194

terns included sooty (139), black (95), bridled/sooty (62) and sandwich (61). There were 195 egret flocks sighted. Most of these were probably cattle egrets (*Bubulcus ibis*). Laughing gulls (238 flocks) and Audubon's shearwater (137) were common seabirds. Flock-sizes were generally small (means < 10) but flocks containing up to 200 birds were recorded.

Flyingfish. A total of 34 one-hour dipnet stations were sampled and 243 flyingfish specimens comprising 10 species of five genera were collected. All specimens will be donated to the fish collection at the Los Angeles County Museum of Natural History.

2.1.2 Planned R/V *Gyre* Autumn 1996 Cruise

The R/V *Gyre* shipboard surveys will sample the continental slope and the deeper waters of the Gulf. Like the *Oregon II* cruise, the surveys will utilize line-transect methods and generally follow the design developed by the Southwest Fisheries Science Center for surveys of pelagic cetaceans (Holt and Sexton 1990). The vessel will be equipped with two pairs of deck-mounted, 25x binoculars for locating animals. The observation team will consist of six observers, divided into two groups with at least two experienced observers in each group. The groups will alternate every three hours to prevent fatigue.

Leg 1 will consist of a focal habitat survey of cetaceans in areas such as offshore from the Mississippi River delta and along the edge of eddies and the Loop Current. The TAMUG Autumn survey of the Eastern Planning Area (EPA), including Destin Dome Block 56 (Leg 2) will use a transect line design similar to that of the *Oregon II.* Although the surveys will target cetaceans, sightings of sea turtles, birds, human activities, pollution, and certain fish species will also be collected. Chapters 4 and 5 describe the suite of biological and physical oceanographic data which will be collected.

Port of departure and return will be Pascagoula, Mississippi. Cruise dates will be 11-28 October 1996, with a partial change of the scientific party at Pascagoula on about 20 October. The Focal Area will be sampled by eight track lines spanning an area between the northern end of the Loop Current (or a newly developed warm-core eddy) to an area defined by a east-west line running approximately 30 NM off the mouth of the Mississippi River. The exact location of these legs will be determined just before departure, based on the location of the Loop Current/eddy as revealed by altimetry data supplied by the CCAR. The EPA will contain nine transect legs. In the western five legs, the northern end of each leg begins at 10 NM offshore and ends at the 2000 m isobath. The four eastern legs begin at the 100 m isobath and end at the 2000 m isobath.

2.2 AERIAL SURVEYS

The first of four seasonal aerial surveys of the GulfCet II Program was conducted during the summer season from 10 July through 1 August 1996. The survey was conducted on the continental slope (waters approximately 100-2000 m deep) and a portion of the continental shelf in northeastern Gulf of Mexico (Figure 2.11). The continental shelf study area overlapped the Minerals Management Service Destin Dome leasing area and included, as requested, Block 56. The objectives of the survey were to collect line-transect data and location data in order to estimate the abundance of each species of cetacean and sea turtle encountered and to delineate each species' distribution in the study area.

The survey was conducted using standard cetacean line-transect aerial survey methods. The survey platform was a DeHavilland (DHC-6) Twin Otter, turbine engine aircraft modified for line-transect surveys. Data collected during the surveys included species, group size, location, number of calves and environmental parameters. As required by Marine Mammal Research Permit No. 738 issued to the Southeast Fisheries Science Center under Marine Mammal Protection Act guidelines, data on the behavioral responses of cetaceans to the survey aircraft were recorded.

As proposed, 42 transect lines on the continental slope (total of 5220 km) and 16 transect lines on the continental shelf (total of 913 km) were surveyed (Table 2.4, Figure 2.11). Excellent weather conditions allowed the survey to be completed in only 23 days (of a possible 45 day window): 13 survey days, 6 bad weather days, 2 rest days, and 2 transit days. Flight time totaled 80.3 hours.

At least 12 species of cetaceans were sighted during the survey period. Sixteen and 79 cetacean groups were sighted on-effort during the survey on the continental shelf and slope, respectively (Tables 2.5-6). Eleven off-effort sightings were made. Four sightings were comprised of two associated cetacean species. Bottlenose dolphins (13 sightings), Atlantic spotted dolphins (2 sightings) and one dwarf/pygmy sperm whale were the only species sighted on the continental shelf. These species were also sighted on the continental slope where bottlenose dolphins were the most common species sighted (21 sightings) followed by pantropical spotted dolphins (17 sightings), dwarf/pygmy sperm whales (12 sightings) and Risso's dolphins (7 sightings). Certain species tended to be found over waters of different depths. For example, bottlenose dolphins were sighted at a mean depth of 219 m and

Table 2.4. Summary of the Summer 1996 GulfCet II aerial survey effort and results.

Date	Flight hrs.	Effort	Number groups seen Mammals	Turtles
10 July 1996	3.5	transit to Pascagoula, Mississippi		
Depart Pascagoula, Mississippi				
11 July 1996	5.9	9 lines	9	4
12 July 1996	6.3	6 lines	9	5
13 July 1996	5.3	6 lines	4	8
14 July 1996	4.0	3 lines	2	3
Depart Panama City, Florida				
15 July 1996	5.5	5 lines	11	7
16 July 1996	0.0	rest day		
17 July 1996	1.5	bad weather		
18 July 1996	0.0	bad weather		
19 July 1996	6.7	6 lines	20	10
20 July 1996	6.2	5 lines	15	3
21 July 1996	5.1	2 lines	8	0
Depart St. Petersburg, Florida				
22 July 1996	6.3	4 lines	12	0
23 July 1996	6.4	4 lines	6	1
24 July 1996	0.0	rest day		
25 July 1996	2.1	bad weather		
26 July 1996	0.0	bad weather		
27 July 1996	5.0	search for Bryde's whales		
28 July 1996	0.0	bad weather		
29 July 1996	0.0	bad weather		
30 July 1996	4.7	4 lines	5	1
31 July 1996	5.3	4 lines	5	0
01 August 1996	0.5	transit		
Total	80.3	58 lines	106	42

pantropical spotted dolphins, 736 m. Group sizes also varied among species. For example, bottlenose dolphin groups averaged 9.3 dolphins/group, dwarf/pygmy sperm whales, 1.8 whales/group and pantropical spotted dolphins, 90.6 dolphins/group. In general, cetacean groups were sighted throughout the entire study area (Figures 2.12-2.17).

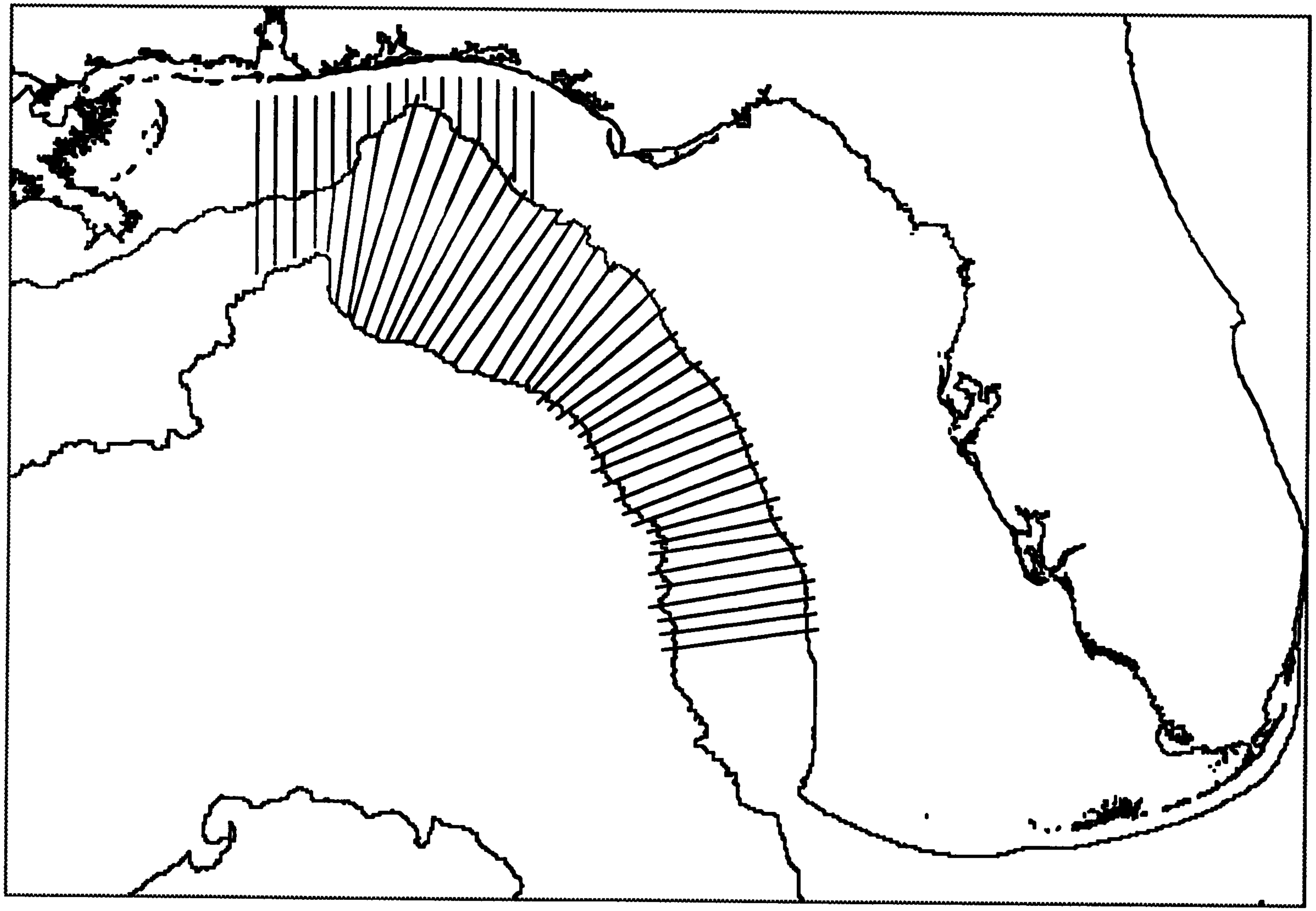


Figure 2.11. Aerial survey transect lins in the northeastern Gulf of Mexico - Summer 1996.

Table 2.5. Summary of cetacean sightings on the continental shelf during the Summer 1996 GulfCet II aerial survey.

Date	Species	Group size	Position		Depth (meters)	Effort status
11 July 1996	*Tursiops truncatus*	12	29°52.63'	87°23.85'	31	on
11 July 1996	*Tursiops truncatus*	10	29°27.16'	87°39.82'	64	on
11 July 1996	*Tursiops truncatus*	6	29°29.02'	87°40.04'	58	on
11 July 1996	*Tursiops truncatus*	5	29°33.67'	87°39.93'	45	on
12 July 1996	*Tursiops truncatus*	13	29°46.72'	87°49.00'	34	on
12 July 1996	*Tursiops truncatus*	32	29°44.04'	88°05.59'	34	on
12 July 1996	*Tursiops truncatus*	4	29°53.44'	88°05.95'	31	on
13 July 1996	Unidentified dolphin	5	30°14.43'	86°36.46'	25	off
13 July 1996	*Tursiops truncatus*	7	30°10.37'	86°41.51'	27	on
13 July 1996	*Stenella frontalis*	42	30°05.82'	86°41.07'	40	off
13 July 1996	*Stenella frontalis*	27	30°05.47'	86°58.44'	53	on
15 July 1996	*Tursiops truncatus*	7	29°24.81'	86°00.26'	58	on
19 July 1996	*Tursiops truncatus*	4	28°59.84'	85°30.89'	71	off
19 July 1996	*Tursiops truncatus*	3	29°49.14'	86°07.93'	40	on
19 July 1996	*Kogia* sp.	1	29°56.81'	86°07.96'	34	on
19 July 1996	*Tursiops truncatus*	5	29°59.00'	86°08.05'	32	on
19 July 1996	*T. truncatus/S. frontalis*	10	30°00.27'	86°07.87'	32	off
19 July 1996	*Tursiops truncatus*	4	30°05.86'	86°07.77'	29	on
19 July 1996	*Tursiops truncatus*	17	30°10.69'	86°23.81'	29	on
19 July 1996	*Stenella frontalis*	22	30°08.88'	86°24.05'	32	on

Table 2.6. Summary of cetacean sightings on the continental slope during the Summer 1996 GulfCet II aerial survey.

Date	Species	Group size	Position		Depth (meters)	Effort status
11 July 1996	*Tursiops truncatus*	5	29°16.43'	88°05.80'	138	on
11 July 1996	*Physeter macrocephalus*	2	28°58.37'	88°06.41'	1342	on
11 July 1996	*Kogia* sp.	2	28°57.46'	87°57.99'	1534	on
11 July 1996	*Stenella attenuata*	45	29°08.78'	87°24.17'	1124	on
11 July 1996	*Grampus griseus*	9	29°20.35'	87°23.48'	541	on
12 July 1996	*Grampus griseus*	10	29°31.15'	87°13.60'	325	off
	T. truncatus/S. frontalis	2				
12 July 1996	*Stenella attenuata*	36	29°24.75'	87°14.84'	440	on
12 July 1996	*Grampus griseus*	7	29°22.39'	87°15.17'	524	on
12 July 1996	*Stenella attenuata*	10	28°56.35'	87°19.74'	1205	on
12 July 1996	*Physeter macrocephalus*	1	28°39.22'	87°22.61'	1250	on
12 July 1996	*Stenella longirostris*	140	28°27.85'	87°20.93'	1356	on

Table 2.6., continued.

Date	Species	Group size	Position		Depth (meters)	Effort status
14 July 1996	*Stenella attenuata*	125	28°27.90'	87°00.76'	872	on
14 July 1996	*Kogia* sp.	5	28°53.91'	86°40.27'	446	on
15 July 1996	*Kogia* sp.	1	28°22.17'	86°50.26'	826	on
15 July 1996	*Kogia* sp.	1	28°17.78'	86°52.89'	941	on
15 July 1996	Unidentified Ziphiidae	2	28°11.52'	86°50.26'	1633	off
15 July 1996	*Kogia* sp.	1	28°12.71'	86°47.96'	1280	on
15 July 1996	*Physeter macrocephalus*	1	28°16.00'	86°45.58'	899	on
15 July 1996	*Kogia* sp.	1	29°04.80'	86°02.77'	226	on
15 July 1996	*Kogia* sp.	1	28°56.41'	86°08.85'	288	on
15 July 1996	*Tursiops truncatus*	51	28°54.85'	86°09.48'	290	on
15 July 1996	*Stenella coeruleoalba*	48	28°04.99'	86°36.88'	1596	off
15 July 1996	*Stenella clymene*	150	28°30.33'	86°16.88'	422	on
19 July 1996	*Tursiops truncatus*	2	28°55.19'	85°50.42'	199	on
19 July 1996	*Tursiops truncatus*	4	28°47.78'	85°55.14'	245	on
19 July 1996	*Stenella coeruleoalba*	14	28°14.11'	86°16.76'	672	on
19 July 1996	*Stenella attenuata*	250	28°10.05'	86°19.88'	773	on
	Kogia sp.	3				
19 July 1996	Unidentified odontocete	1	28°05.40'	86°23.04'	883	on
19 July 1996	*Stenella attenuata*	10	27°59.75'	86°15.56'	1161	on
19 July 1996	*Stenella longirostris*	250	28°27.66'	85°58.83'	331	on
19 July 1996	*Tursiops truncatus*	10	28°59.58'	85°38.01'	144	on
19 July 1996	*Tursiops truncatus*	4	28°31.66'	85°47.20'	256	on
19 July 1996	*Grampus griseus*	9	28°16.25'	85°56.79'	460	on
19 July 1996	*Stenella attenuata*	90	28°10.13'	86°01.15'	619	on
19 July 1996	*Tursiops truncatus*	10	28°46.65'	85°25.16'	107	on
20 July 1996	*Tursiops truncatus*	3	28°39.88'	85°17.16'	129	on
20 July 1996	*Tursiops truncatus*	5	28°23.46'	85°31.15'	221	on
20 July 1996	*Stenella attenuata*	170	28°17.58'	85°36.53'	303	on
20 July 1996	*Grampus griseus*	6	28°09.52'	85°43.62'	471	on
20 July 1996	*Tursiops truncatus*	1	27°55.94'	85°47.67'	810	on
20 July 1996	*Stenella attenuata*	55	28°00.82'	85°42.53'	658	on
20 July 1996	*Stenella attenuata*	45	28°10.30'	85°32.69'	374	on
20 July 1996	*Tursiops truncatus*	1	28°19.49'	85°23.46'	213	off
20 July 1996	Unidentified dolphin	1	28°32.90'	85°09.21'	126	on
20 July 1996	*Stenella frontalis*	35	28°39.08'	85°04.62'	87	on
20 July 1996	*Stenella attenuata*	160	27°54.68'	85°39.13'	733	on
20 July 1996	*Mesoplodon* sp.	2	27°53.20'	85°40.76'	791	on
20 July 1996	*Stenella attenuata*	165	27°48.13'	85°36.12'	822	on
20 July 1996	*Kogia* sp.	1	27°57.42'	85°23.10'	493	on
20 July 1996	*Tursiops truncatus*	5	28°12.74'	85°02.78'	159	on

Table 2.6., continued.

Date	Species	Group size	Position		Depth (meters)	Effort status
21 July 1996	*T. truncatus/S. frontalis*	2	28°13.34'	84°49.15'	82	off
21 July 1996	*Tursiops truncatus*	6	28°04.01'	85°02.73'	217	on
21 July 1996	*Tursiops truncatus*	15	27°59.25'	85°07.86'	298	on
21 July 1996	*Stenella clymene*	95	27°56.20'	85°13.28'	387	on
21 July 1996	*Tursiops truncatus*	5	27°38.46'	85°37.29'	1521	on
21 July 1996	*Kogia* sp.	4	27°37.24'	85°39.26'	2168	on
21 July 1996	*Tursiops truncatus*	1	27°34.45'	85°32.92'	1444	on
21 July 1996	*Balaenoptera edeni*	3	27°57.54'	84°58.61'	237	on
	Tursiops truncatus	6				
22 July 1996	*Tursiops truncatus*	1	27°57.35'	84°36.77'	96	on
22 July 1996	*Ziphius cavirostris*	1	27°21.15'	85°30.38'	2446	off
	Unidentified dolphin	1				
22 July 1996	*Stenella attenuata*	100	27°26.87'	85°18.73'	854	on
22 July 1996	*Kogia* sp.	2	27°33.33'	85°05.72'	460	on
22 July 1996	*Tursiops truncatus*	15	27°49.88'	84°31.67'	98	on
22 July 1996	*Stenella frontalis*	85	27°38.36'	84°35.63'	146	on
22 July 1996	*Grampus griseus*	8	27°28.28'	85°01.08'	400	on
22 July 1996	*Stenella clymene*	80	27°19.94'	85°19.84'	1014	on
22 July 1996	*Stenella attenuata*	16	27°20.07'	85°20.69'	1057	on
22 July 1996	*Mesoplodon* sp.	2	27°10.80'	85°21.10'	1453	on
22 July 1996	*Ziphius cavirostris*	1	27°12.85'	85°16.78'	1086	on
22 July 1996	*Stenella frontalis*	21	27°35.51'	84°22.26'	85	on
23 July 1996	*Stenella frontalis*	42	27°01.32'	84°14.24'	117	on
23 July 1996	*Kogia* sp.	1	26°55.06'	85°00.24'	865	on
23 July 1996	*Grampus griseus*	10	26°56.43'	85°15.93'	2569	on
23 July 1996	*Grampus griseus*	11	26°58.44'	85°18.35'	2801	off
23 July 1996	*Unidentified odontocete*	3	27°04.05'	85°14.81'	1351	on
23 July 1996	*Tursiops truncatus*	4	27°21.88'	84°32.21'	140	on
30 July 1996	*Stenella attenuata*	120	26°44.12'	84°52.19'	453	on
30 July 1996	*Mesoplodon* sp.	1	26°43.03'	84°58.98'	1907	on
30 July 1996	*Grampus griseus*	38	26°39.61'	84°47.17'	281	on
30 July 1996	*T. truncatus/S. frontalis*	2	26°37.69'	84°14.19'	144	on
30 July 1996	*Tursiops truncatus*	25	26°25.28'	84°41.26'	234	on
31 July 1996	*Stenella frontalis*	26	26°02.17'	83°54.77'	115	on
31 July 1996	*Tursiops truncatus*	27	26°01.17'	84°01.49'	137	on
31 July 1996	*Stenella attenuata*	23	25°54.76'	84°44.89'	854	on
31 July 1996	*Mesoplodon* sp.	2	25°54.30'	84°50.29'	1397	on
31 July 1996	*Stenella attenuata*	120	26°17.12'	84°37.16'	223	on

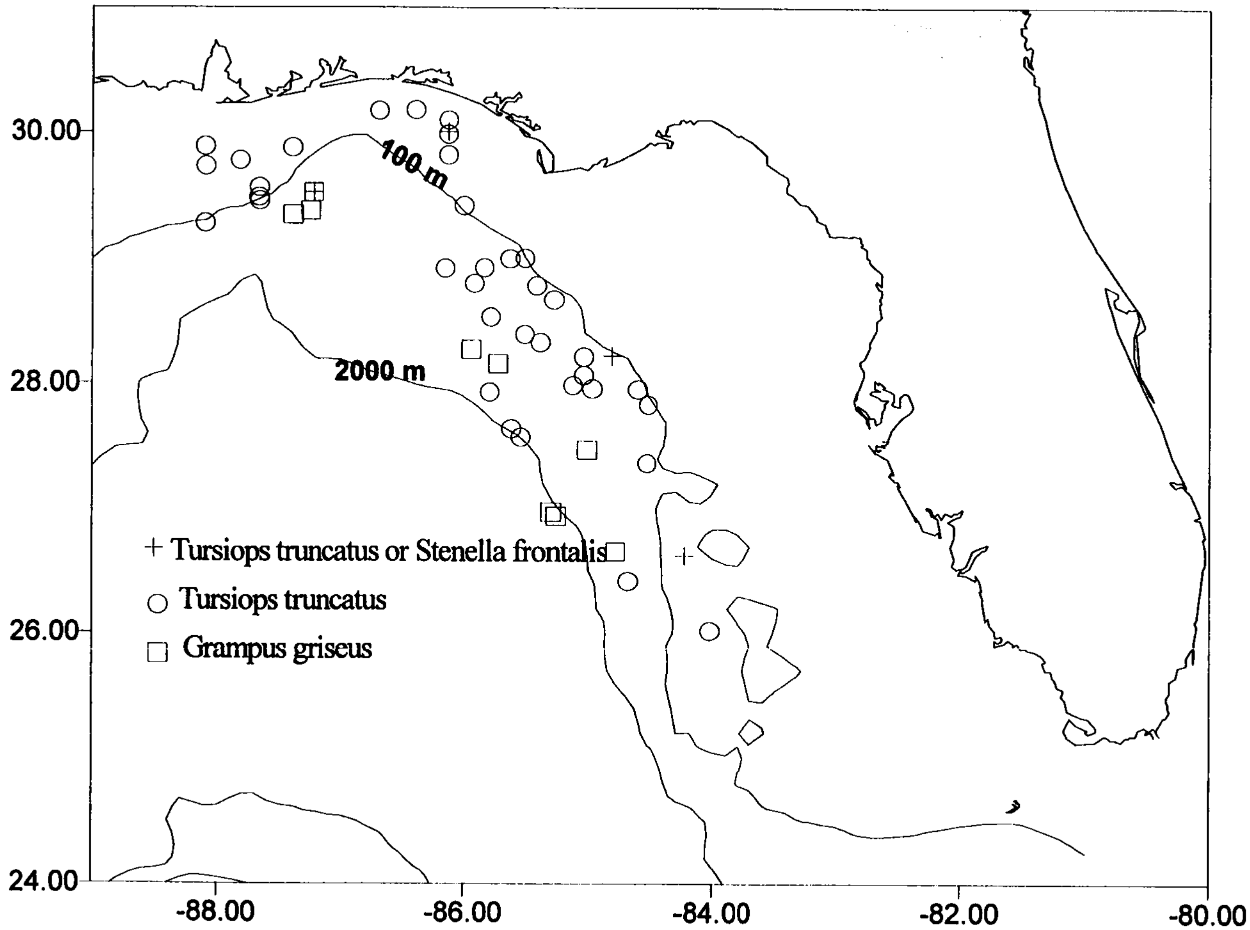


Figure 2.12. Location of *Tursiops truncatus/Stenella frontalis* (n=4), *Tursiops truncatus* (n=36), and *Grampus griseus* (n=9) sightings during the GulfCet II Summer 1996 aerial survey.

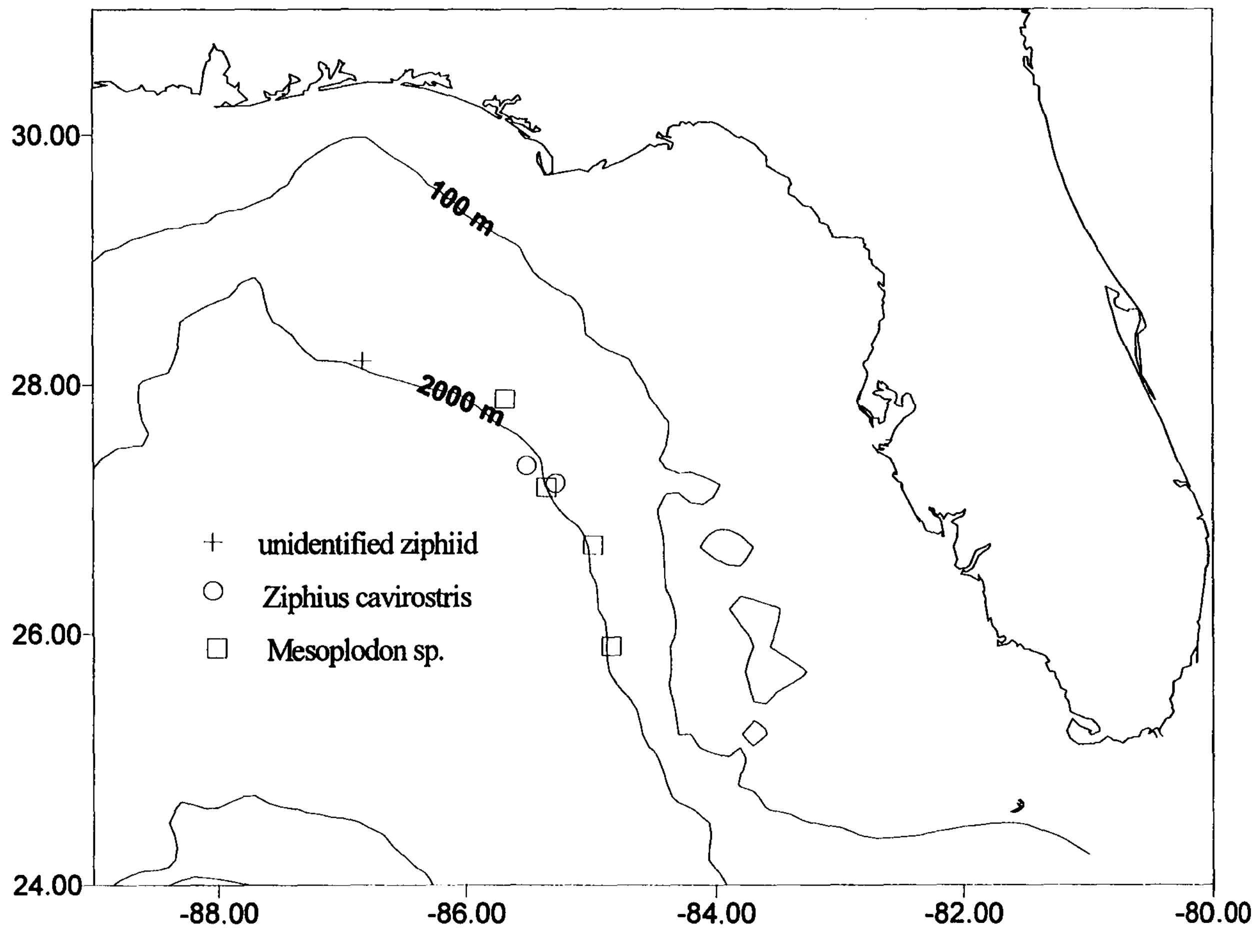


Figure 2.13. Location of unidentified ziphiid (n=1), *Ziphius cavirostris* (n=2), and *Mesoplodon* (n=4) sightings during the GulfCet II Summer 1996 aerial survey.

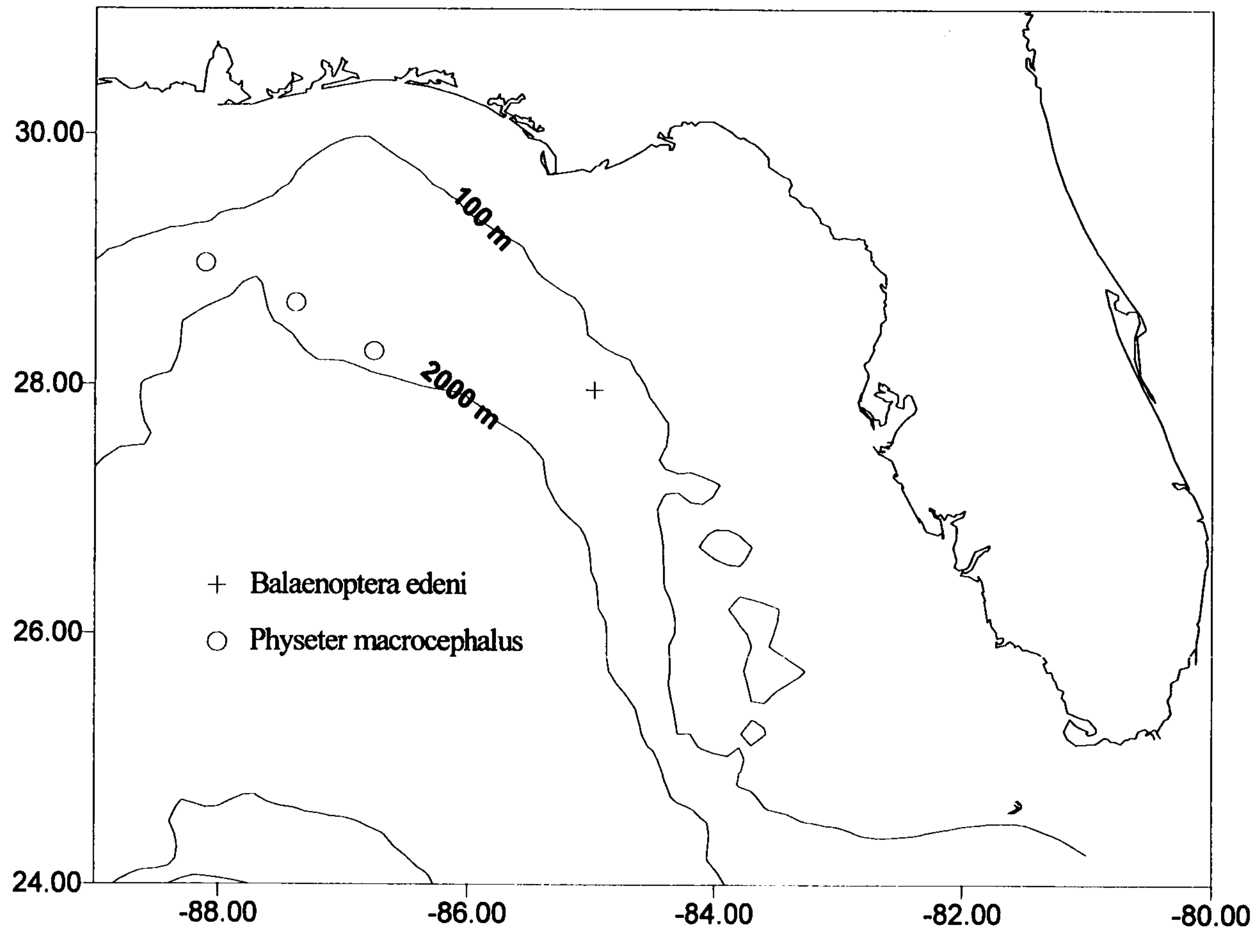


Figure 2.14. Location of *Balaenoptera edeni* (n=1) and *Physeter macrocephalus* (n=3) sightings during the GulfCet II Summer 1996 aerial survey.

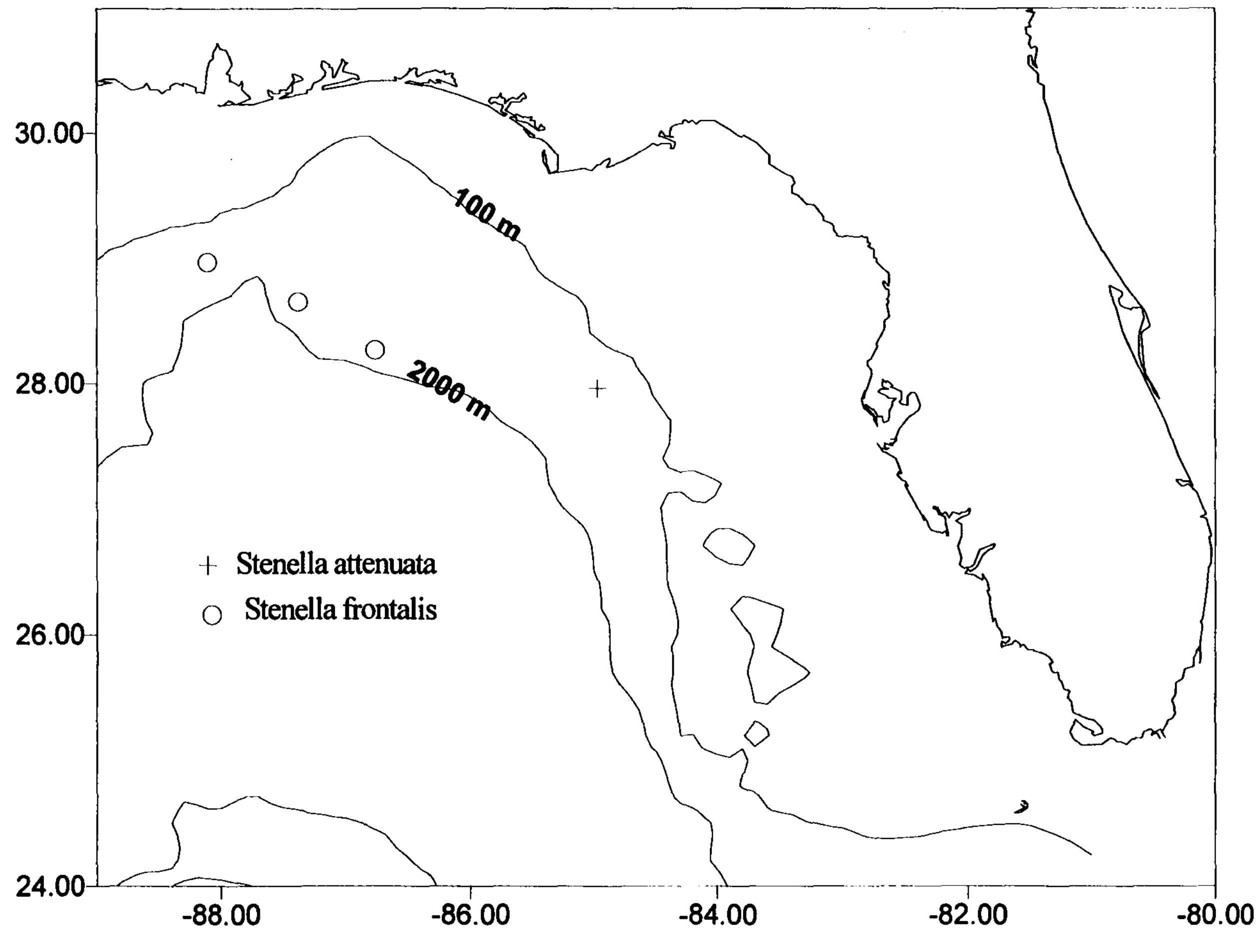


Figure 2.15. Location of *Stenella attenuata* (n=17) and *S. frontalis* (n=8) sightings during the GulfCet II Summer 1996 aerial survey.

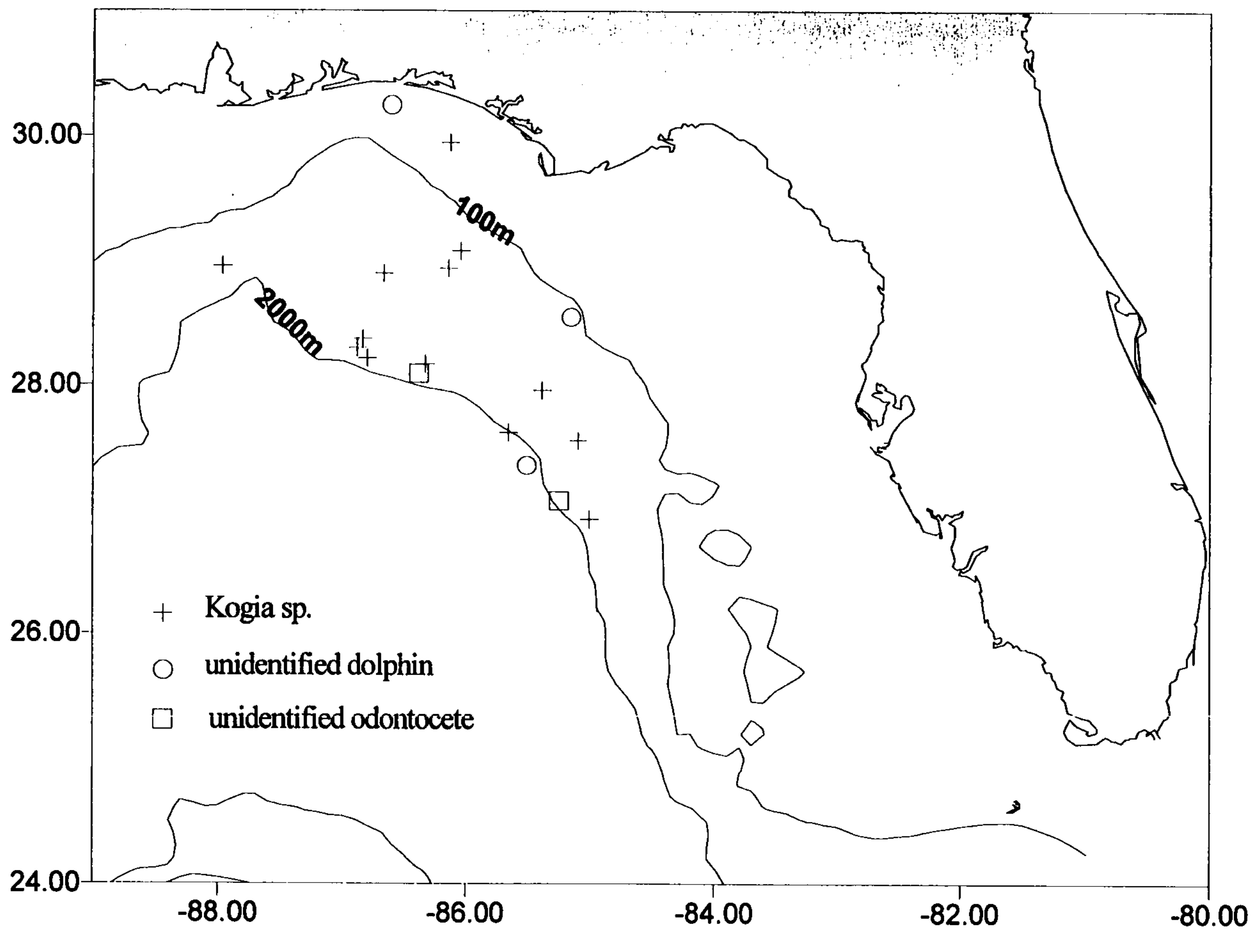


Figure 2.16. Location of *Kogia* sp. (n=13), unidentified dolphin (n=4), and unidentified odontocete (n=2) sightings during the GulfCet II Summer 1996 aerial survey.

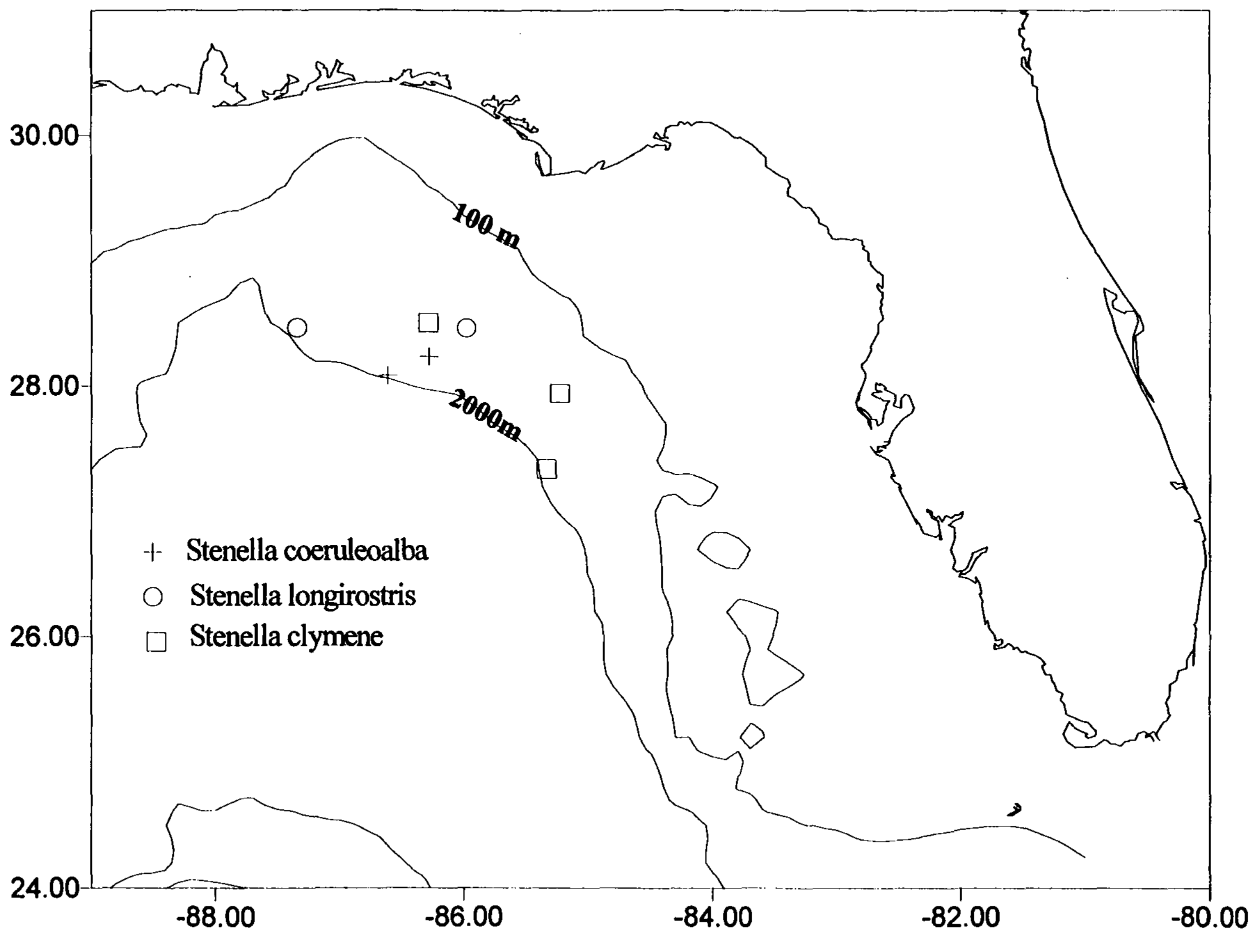


Figure 2.17. Location of *Stenella coeruleoalba* (n=2), *S. longirostris* (n=2), and *S. clymene* (n=3) sightings during the GulfCet II Summer 1996 aerial survey.

A group of three Bryde's whales were sighted 21 July in waters with a depth of 237 m. Because results from our vessel surveys indicate that balaenopterid whales are seen almost exclusively in the northeastern Gulf, at the time of the sighting we widened the search area around the initial sighting location. This search yielded four more Bryde's whales. During the transit back to the airport after the 22 July survey, the aircraft returned to the Bryde's whale sighting location. Seven Bryde's whales were sighted within 10 km of the previous sighting location. On 27 July, rough sea conditions prevented completion of the remaining transects in the southern portion of the study area. Suitable conditions to the north allowed for an intensive line-transect survey of the Bryde's whale sighting area. No whales were sighted.

Sea turtles were sighted 42 times. Continental shelf sightings consisted of loggerheads 18 times, unidentified chelonids four times, and leatherbacks four times (Figure 2.18, Tables 2.8-7). Conversely, slope sightings consisted of 15 leatherback sightings and one chelonid. Leatherback sightings were generally made in the northern half of the study area.

Table 2.7. Summary of sea turtle sightings on the continental slope during the Summer 1996 GulfCet II aerial survey.

Date	Species	Group size	Position		Depth (meters)	Effort status
13 July 1996	Leatherback sea turtle	1	29°37.19'	86°50.83'	219	on
13 July 1996	Leatherback sea turtle	1	29°08.04'	87°00.69'	709	on
13 July 1996	Leatherback sea turtle	1	28°42.76'	87°01.02'	726	on
13 July 1996	Leatherback sea turtle	1	28°47.04'	86°59.41'	682	on
13 July 1996	Unidentified chelonid	1	29°21.88'	86°45.80'	405	on
14 July 1996	Leatherback sea turtle	1	29°45.45'	86°25.20'	96	on
14 July 1996	Leatherback sea turtle	1	28°16.31'	87°05.82'	1400	on
15 July 1996	Leatherback sea turtle	1	29°13.88'	86°08.86'	204	on
15 July 1996	Leatherback sea turtle	1	28°47.45'	86°15.10'	331	on
19 July 1996	Leatherback sea turtle	1	28°40.79'	85°50.19'	239	on
19 July 1996	Leatherback sea turtle	1	28°33.95'	85°45.46'	239	on
19 July 1996	Leatherback sea turtle	1	28°16.90'	85°45.80'	363	on
20 July 1996	Leatherback sea turtle	2	28°15.97'	85°26.91'	259	on
20 July 1996	Leatherback sea turtle	1	28°14.37'	85°16.99'	217	on
23 July 1996	Leatherback sea turtle	1	27°02.44'	84°10.70'	104	on
30 July 1996	Leatherback sea turtle	1	26°45.25'	84°12.75'	129	on

Table 2.8. Summary of sea turtle sightings on the continental shelf during the Summer 1996 GulfCet II aerial survey.

Date	Species	Group size	Position		Depth (meters)	Effort status
11 July 1996	Loggerhead sea turtle	1	29°41.74'	87°23.96'	67	on
11 July 1996	Loggerhead sea turtle	1	29°57.86'	87°23.96'	29	on
11 July 1996	Leatherback sea turtle	1	29°58.50'	87°23.90'	29	off
11 July 1996	Leatherback sea turtle	1	29°50.90'	87°39.90'	31	on
12 July 1996	Loggerhead sea turtle	1	29°29.37'	87°49.00'	51	on
12 July 1996	Loggerhead sea turtle	1	29°41.52'	87°58.08'	36	on
12 July 1996	Unidentified chelonid	1	29°54.60'	88°05.98'	29	on
12 July 1996	Leatherback sea turtle	1	29°56.47'	88°05.95'	27	on
12 July 1996	Unidentified chelonid	1	30°00.16'	88°05.91'	21	on
13 July 1996	Loggerhead sea turtle	1	30°11.53'	86°49.96'	25	on
13 July 1996	Loggerhead sea turtle	1	30°10.57'	86°58.10'	25	on
13 July 1996	Loggerhead sea turtle	1	30°04.85'	87°05.93'	27	on
14 July 1996	Loggerhead sea turtle	1	29°49.15'	86°15.71'	58	on
15 July 1996	Loggerhead sea turtle	1	29°28.73'	85°59.94'	49	on
15 July 1996	Loggerhead sea turtle	1	29°42.63'	85°59.91'	40	on
15 July 1996	Loggerhead sea turtle	1	29°58.51'	85°59.87'	31	on
15 July 1996	Loggerhead sea turtle	1	30°01.90'	85°59.93'	29	on
19 July 1996	Loggerhead sea turtle	1	29°44.54'	86°07.92'	43	on
19 July 1996	Loggerhead sea turtle	1	29°52.65'	86°07.92'	38	on
19 July 1996	Unidentified chelonid	1	30°11.67'	86°24.07'	29	on
19 July 1996	Loggerhead sea turtle	4	30°08.88'	86°24.05'	32	on
19 July 1996	Loggerhead sea turtle	2	30°07.58'	86°24.13'	32	on
19 July 1996	Unidentified chelonid	1	30°01.55'	86°24.05'	43	on
19 July 1996	Loggerhead sea turtle	1	29°53.10'	86°24.01'	69	on
19 July 1996	Leatherback sea turtle	1	29°53.95'	86°24.05'	67	on
20 July 1996	Loggerhead sea turtle	1	30°08.35'	86°23.91'	32	on

2.3 DENSITY ESTIMATION

The objectives of density estimation are to: (1) estimate the minimum numbers of cetaceans of each species in the study area, (2) determine when these species are present in the study area, (3) establish repeatable baseline estimates of cetacean abundance to compare with future estimates, and (4) determine how these species are distributed in the study area. Density estimates for each cetacean species sighted will be made for the entire study area using line transect methods (Buckled et al. 1993).

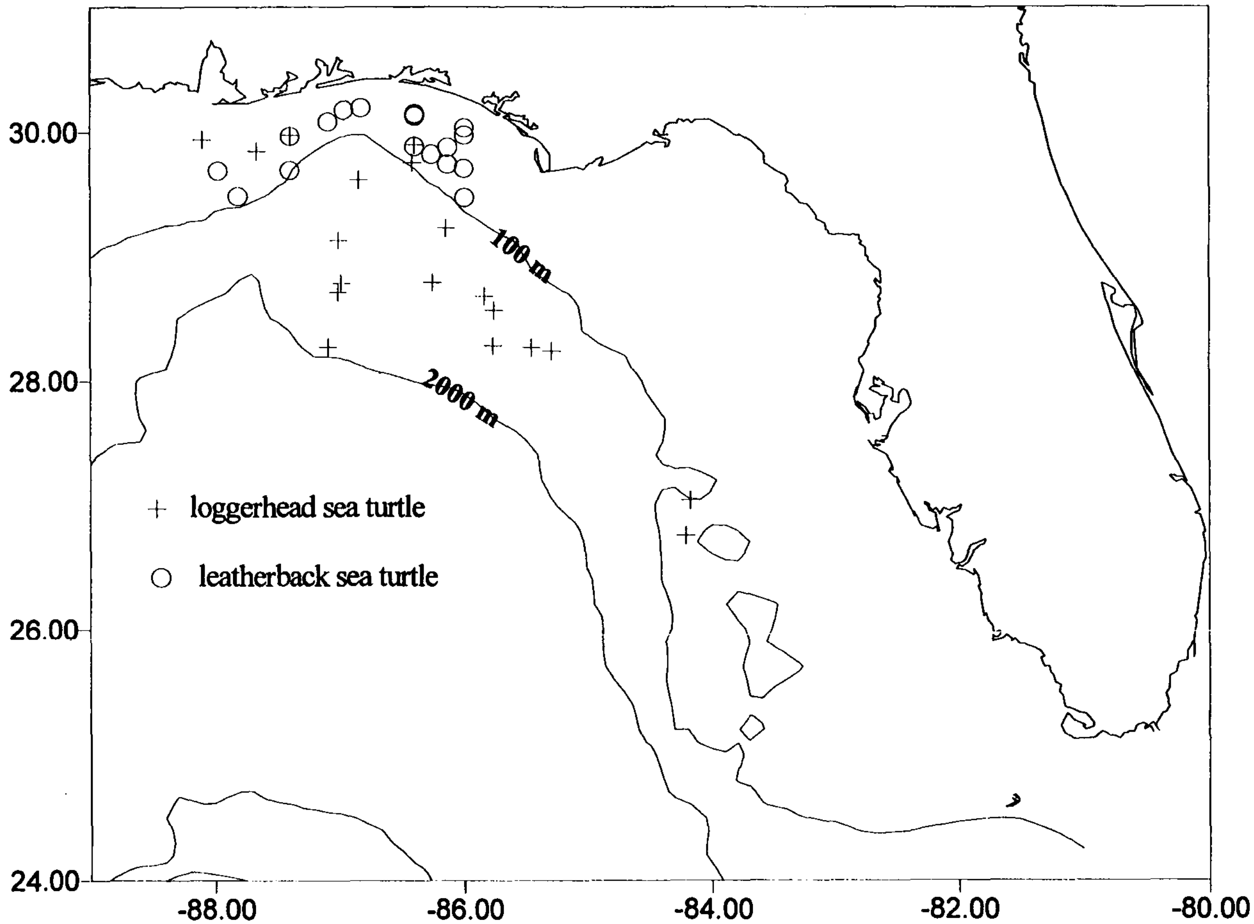


Figure 2.18. Location of leatherback (n=19) and loggerhead (n=19) sea turtles during the Summer 1996 GulfCet II aerial survey in the northeastern Gulf of Mexico.

At the completion of all GulfCet II field activities, we will use line transect methods to estimate the density of each species or species group for the entire study area, for each year, and for each season. For each estimate, we will calculate the animal density (D) for each species or species group using the method of Buckland et al. (1993):

$$D = \frac{n \cdot f(0) \cdot \bar{S}}{2L}$$

where D = animal density,

- n = number of groups sighted each season,
- $\bar{S}$ = size-biased adjusted mean group size,
- L = total number of transect meters surveyed each replicate (day or transect line), and
- f(0) = the probability density function for sightings evaluated at zero perpendicular distance.

We will estimate f(0) by constructing a sighting histogram using the number of sightings at distance intervals from the transect line and fitting a model (probability density function) to the histogram. The value of the probability density function evaluated at the transect line is f(0). Depending on results, we will construct a sighting histogram for each species or species group. Burnham et al. (1980) recommended that sighting functions be based on a minimum of 40 sightings, with 60-80 sightings preferred. Therefore, it may be necessary to pool data for species with similar sighting characteristics to construct an overall sighting function. A number of models will be fitted to the sighting distance distribution to estimate the sighting function at the transect [f(0)]. These models include the hazard-rate and hermite models (Buckland 1985, 1988), and the Fourier, half-normal, exponential, and negative exponential models (Laake et al. 1993). The appropriate model will be selected based on its overall fit to the sighting histogram and its shape [i.e., the presence of a shoulder near the transect line (distance = 0).]

The mean group size for each species or species group will be estimated as the arithmetic mean of groups sighted during each season. However, seasonal variation in group size will be examined using appropriately transformed values. The mean group sizes could be over-estimated because larger groups may have had a higher probability of being sighted away from the transect line. Correlation between sighting distance and group size will be tested and the mean group size adjusted accordingly (Drummer and McDonald 1987, Laake et al. 1993).

The variance of average density (D) will be estimated as:

$$\mathrm{var}(D) = D^2\left[\frac{\mathrm{var}(n)}{n^2} + \frac{\mathrm{var}(\bar{S})}{\bar{S}^2} + \frac{\mathrm{var}(f(0))}{f(0)^2}\right]$$

Density estimates will only apply to cetaceans at or near the surface (i.e., those visible). The central assumption of line transect theory is that all groups on or very near the transect line are sighted (Buckland et al. 1993). Because cetaceans are not visible when submerged, some groups of every species on the transect line will certainly be missed. Therefore, our density estimates will underestimate the true density of cetaceans.

III. ACOUSTIC SURVEYS

3.1 ACOUSTIC SURVEYS

3.1.1 The Linear Towed Array

Acoustic surveys will be conducted during the TAMUG visual and habitat surveys.

A new linear towed hydrophone array was designed and ordered from Innovative Transducers, Inc., Fort Worth, Texas. It has been received and will be tested prior to the Autumn 1996 cruise aboard R/V *Gyre*. The array is 535 m long with eight hydrophones (Figure 3.1). Its design will permit beamforming so that the localization of vocalizing animals will be possible. During the GulfCet II cruises we will be using equipment that permits real time beamforming, so that we will know the location of vocalizing animals as we receive them. This should permit us to estimate sperm whale group size, which is necessary for abundance estimation.

The array is most sensitive along its length (i.e., perpendicular to the long axis), with little sensitivity to the front and back of the array (Figure 3.2). The array will detect sounds from 6 Hz to 15 kHz and will be considerably more sensitive than the GulfCet I array, which will result in a greater detection range and more acoustic contacts. A larger sample size, as measured by contact number, is the simplest method to reduce population estimate variance and increase estimate precision. The new array is also smaller, quieter, and can be towed at faster speeds (i.e., 10 knots).

The hydrophones are made from polyvinylidene fluoride (PVDF). This piezo film sensor has superior bandwidth, lower distortion, and increased durability compared with other array hydrophones. The array is a solid core, as opposed to an oil-filled hose. Each hydrophone is housed in a hydrodynamic shell and coated with a hydrophilic compound resulting in reduced flow noise.

An eight channel Racal V-Store analog tape recorder will be used to record the acoustic data. This recorder has seven recording speeds, ranging from 15/32 to 30 inches per second (ips) and three bandwidth settings for each channel. The 3-3/4 ips recording speed has a 12.5 kHz bandwidth. At this speed, approximately 40 minutes of recording time are possible on a T-120 VHS tape. The 3-3/4 ips recording speed will be used in order to minimize the

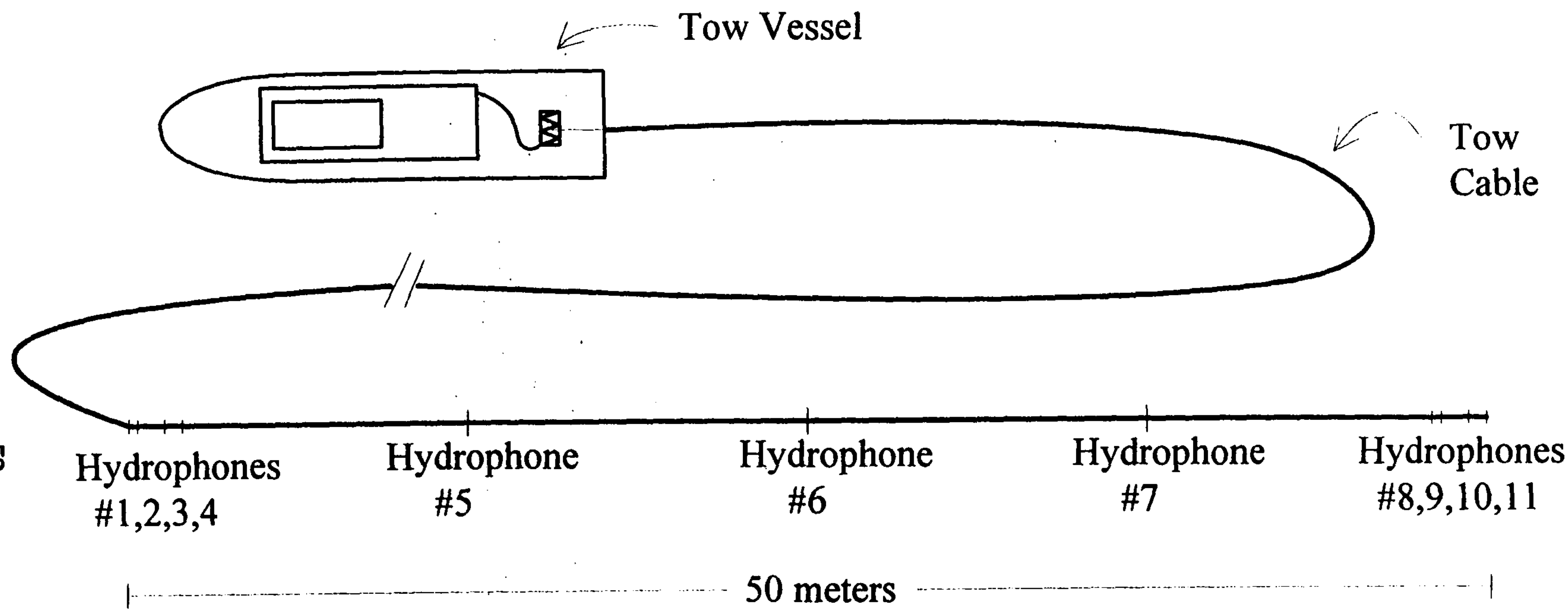


Figure 3.1. The configuration of the linear towed hydrophone array.

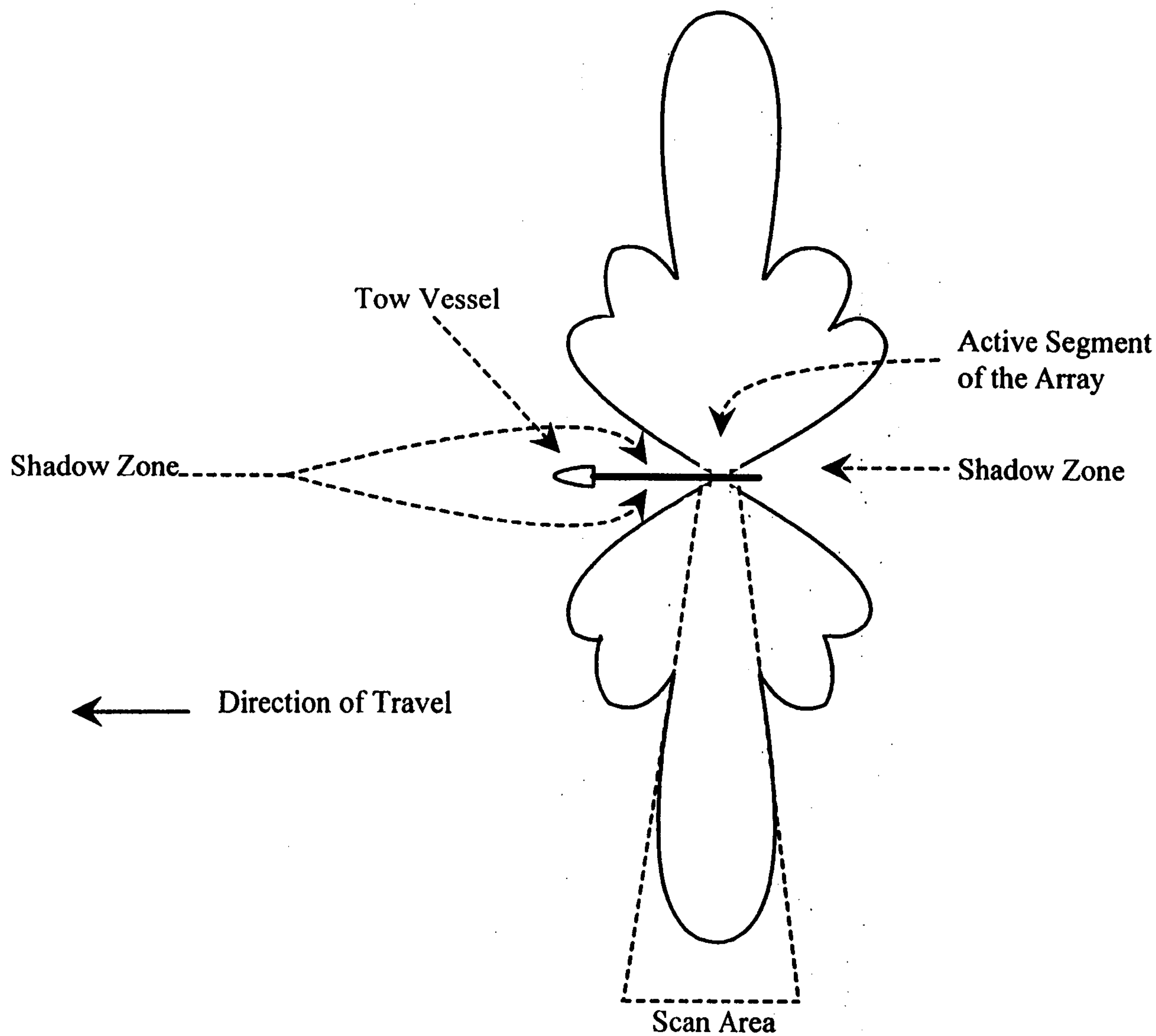


Figure 3.2. The directivity pattern of the hydrophone array.

number of tapes used per cruise, while a 7-1/2 ips recording speed will often be used when good signal-to-noise ratios are available. The 7-1/2 ips recording speed has 25 kHz bandwidth.

While at sea, acoustic signal processing will be conducted on a GulfCoast™ 486 microcomputer utilizing Signal™ software. This software contains a subroutine providing real time spectrograms displayed on the computer. The signals will also be auditorially monitored with either speakers or headphones concurrently with the spectrogram display. The acoustic operator will all acoustic events.

The primary analytical tools will be Signal™ and Canary™ software running on the appropriate computers (see Section 4.3.4). Both programs produce the spectrograms (frequency versus time displays with relative amplitude signified by shades of gray), oscillograms (time versus amplitude), and spectra (frequency versus amplitude). Statistica™ will be used for statistical analyses.

3.1.2 Data Analysis Methods

Encounter Analyses

Location. The location of acoustic contacts will be determined using the ship's GPS system. The location of all acoustic contacts will be downloaded automatically into the acoustic contact data file. This file will be similar to that used by the visual censusing team and will be produced by a computer program developed by the NMFS for their visual censusing. Information will include the time and location of all contacts as well as the tape, tape revolution, source identity, and any other pertinent information regarding the contact.

Species identification. Dolphin vocalizations have been extensively studied, but because of their variability they have been difficult to quickly and accurately identify to species (Wang Ding 1993, Wang Ding et al. 1995, Fristrup and Watkins 1992). One common dolphin vocalization type, whistles, although different from species to species, are difficult to identify to the species level without considerable analysis. Evans (1967) noted that most of the smaller pelagic species, including the common dolphin and the pantropical spotted dolphin, are distinctive from bottlenose dolphins and other larger species because their whistles are of higher frequencies. This was verified by Wang Ding (1993) who found a 0.931 correlation between maximum frequency of vocalization and body length for nine species of dolphin.

In GulfCet I, we used analytic procedures similar to those used by Wang Ding (1993). A total of 191 recordings were used to characterize the whistles of bottlenose dolphins, clymene dolphins, pantropical spotted dolphins, and striped dolphins. Analysis of these whistles, based on frequency and duration, using D^2 canonical correlation tests, significantly separated all four species. The relationship however between the clymene dolphin and pantropical spotted dolphin was closer than for the other two species. All frequency and duration comparisons between bottlenose dolphins and the three stenellid species showed significant differences. Single frequency parameters, such as beginning or minimum frequency, differentiate the three stenellid species. Minimum frequency differentiated clymene dolphin from pantropical spotted dolphin, while for clymene dolphin vs. striped dolphin it was maximum frequency. Beginning frequency differentiated pantropical spotted dolphin from striped dolphin. There was no significant difference between the whistle durations. A display of two canonical variables showed that the whistles of the bottlenose dolphins, which are more coastal in their distribution, were significantly different from those of the more pelagic stenellids.

Although based on small sample sizes, it is apparent that these techniques can be used to discriminate pelagic from coastal dolphins. With a larger sample size, it may be possible to discriminate between at least three of the five stenellids in the Gulf as well as bottlenose dolphins, rough-toothed dolphins, pilot whales, killer whales, false killer whales, and possibly Risso's dolphins. Besides these delphinids, sperm and baleen whales will also be acoustically differentiated.

Signal spectral analysis and statistical analysis procedures will be the same as those used in GulfCet I. Analytic effort will be expanded to examine recordings of all species. All recordings will be analyzed with Signal™ software. Ten variables will be measured for whistles: beginning frequency, end frequency, minimum frequency, maximum frequency, duration, number of inflection points (a change in the slope of the frequency contour from negative to positive or vice versa), beginning sweep and end sweep (up or down), harmonics, and contour break. Multivariate discriminant analysis will be used to compare overall whistle structures to determine if any significant variations exist between the species.

Canonical variables, which are computed from the linear combination of quantitative variables entered into the discriminant function, are a multivariate measure of the differences in overall whistle structures between different species. Each canonical variable is a linear combination of a subset of the acoustic variables, with each canonical variable minimizing the variance within its particular subset of variables. When the first two canonical variables of each species are plotted on an X-Y coordinate plot, the relative distance between the positions of each species is proportional to the relative differences between their whistles.

Density and Abundance Estimation

Acoustic effort. Acoustic effort will be defined as occurring when the survey vessel is traversing a track-line while recording. Off-effort events will occur when recording off the track-line. For example, at the request of the visual survey team, we will on occasion leave the track-line to verify identification of animals. We will also cease effort for CTD hydrographic stations, and during high noise conditions caused by ship traffic or heavy rain. Acoustic effort will differ from shipboard visual effort in that it will continue at night and during all Beaufort sea states in which the ship can remain at sea.

Detection range. Estimates of cetacean abundance will use strip census methods, where the strip width is defined as twice the detection range of the array. This range is dependent on the amplitude of the signal, the ambient noise level and the sensitivity of the array. Once a detection range is defined, a detection function is needed to determine what percentage of the available acoustic events are actually perceived. A natural source of variance of the detection range estimate will be the amplitude variance of the signals as well as the variance in ambient noise level. Array sensitivity is fixed.

Detection range will be measured in a manner similar to that used in GulfCet I. The hydrophone array will be calibrated by projecting signals from measured distances perpendicular to the array. Distances between the array and the signal projector will be determined using two GPS receivers; one at the projector and another aboard the tow vessel. The projected signal will be recorded at the array from a known distance. Representative noise samples are used to adjust the transmission loss model to the average noise level during GulfCet cruises. Sound pressure levels (SPL) will be measured at one minute intervals throughout the duration of the cruises by storing the output of a SPL meter in the data storage program. Based on the results of the play back, it will be determined at what level a particular signal must be received to be detected. A transmission loss (TL) model will be used with the form:

$$TL = 20 \log r + ar$$

where r = source range, a = an attenuation coefficient. Based on the transmission loss model, an average maximum detection range for the pertinent species will be calculated.

Detection threshold. The detection function describes how many animals will be detected as a function of distance from the vessel. Above, the method to define detection range was described. Signals may, however, go undetected for reasons associated with the psychoacoustics of listening. This is analogous to the problem of determining the visual detection function for standard line transect. A proportion of otherwise detectable signals are lost due to human factors dealing with attentiveness to low amplitude signals mixed with background noise. The detection function determines the proportion of missed signals so that the density calculations can be adjusted for these missed detections. For example, in GulfCet I, we determined that only 3.8% of the sperm whale clicks within 11.1 km of the array were missed and that the unadjusted density estimate should be multiplied by a correction factor of 1.038.

The detection function will be measured for both sperm whales and dolphins in the same manner as during GulfCet I. It is necessary to measure a new detection function because we will be using a different array, which has less flow noise and is more sensitive. Based on the performance of a statistically reasonable number of respondents, a detection threshold representing the probability density function for detecting signals will be generated.

Groups size estimates. The various species likely to be encountered in the Gulf of Mexico may be solitary or in groups of various sizes. Most of the beaked whales and the dwarf/pygmy sperm whales are solitary. Sperm whales and all delphinids and are social. Determining the number of animals in a group can be accomplished using both visual and acoustic methods. Determining the group size using acoustic methods involves localizing each vocalizing animal. Acoustic localization can be done using two techniques. One technique, near-field localization, uses difference in time of arrival for the same signal arriving at multiple hydrophones which defines a set of hyperbolas whose intersection describes the location of the vocalizer. This system is accurate to approximately five times the maximum distance between hydrophones. The other method is the far-field technique which utilizes signal processing to define narrow reception beams for the array. This permits resolution of a narrow receiving beam which can then be steered to determine the direction from which the signal originated. Assuming that there is only one vocalizing animal in that particular direction, the number of vocalizing animals can be estimated. Unfortunately, both of these techniques have problems dealing with resolution. For dolphins, sperm whales, and baleen whales, it is likely that animals will be detected considerably beyond the near-field localization limits, namely beyond 1 km. Therefore localization of all vocalizing animals cannot reliably be accomplished with this technique. Similarly for far-field localization of sperm whale signals, the width of even a narrow (3.75°) beam will be approximately 1 km at the estimated 15 km detection range of the new array. That is, when detecting sperm whales 15 km away, it will be impossible to resolve multiple animals vocalizing within 1 km of each other. Even at a detection distance of 5 km, it would be impossible to resolve animals gathered closer than 333 m. Therefore, neither localization strategy can be adequately used to count the number of vocalizing animals in a group.

An alternative strategy is to use the group sizes observed during the concurrent visual census. For animals such as dolphins that travel reasonably close together, there is little difficulty in using this technique. For animals such as sperm whales and baleen whales that spread out over considerable areas while maintaining contact acoustically, it is difficult to interpret the visual sighting data relative to actual group size. As was the case for sperm whales in GulfCet I, there is a question as to what level of social organization is enumerated by acoustic vs. visual censusing. Following the methods used in GulfCet I, all acoustic contacts made within the detection range of the array will be assumed to be within the same group. That is, all contacts within, for example, 15 km will be considered to be coming from the same sperm whale group. This assumes that sperm whale groups are generally acoustically isolated from each other, and that a sperm whale's auditory sensitivity is no greater than the array sensitivity, that is, that the whale's detection range is no better than that of the acoustic array.

The group size used in the final population estimates will be determined by clustering all visual contacts within the acoustic detection range. For example, in GulfCet I, the concurrent visual survey team had 48 sperm whale contacts (both on- and off-effort). Of those 48 contacts, 43 were concurrent with acoustic contacts. On seven occasions there were multiple visual contacts within the space of a single acoustic contact; that is, on seven occasions the latitudinal extent of a single acoustic contact encompassed multiple visual contacts. The mean group size for the 48 visual sightings was 3.8 animals/visual contact. When the multiple visual contacts within the space of the seven acoustic contacts were summed, the overall mean was 7.3 animals per acoustic contact (n = 7). Alternatively stated, 43 visual sightings averaging 3.9 animals/contact were reduced to 23 acoustic contacts averaging 7.3 animals per contact. Based on this logic, the appropriate sperm whale group size for the acoustic census was 7.3 animals.

Using a group size of 7.3 sperm whales, the acoustic and visual population estimates were nearly identical, 316 and 313 animals, respectively. This similarity in population estimate suggests that this method for determining group size is reasonable.

Density estimates. The estimated mean contact density, $\overline{D}$, will be calculated, using a detection function-modified strip transect method, as follows:

$$\overline{D} = f(d_{max}) \cdot \left(\left(\sum_{L=1}^{k} \frac{n_L}{l_L d} \right) k^{-1} \right)$$

where $\overline{D}$ = corrected mean contact density for transect lines 1 to k,
$f(d_{max})$ = detection function perpendicular to the array,
k = number of transect lines,
n_L = number of on-effort acoustic contacts on transect line L,
l_L = on-effort length on transect line L, and
d = detection width x 2.

Abundance estimates. The estimated abundance, N, in the study area will be calculated as follows:

$$N = AS\overline{D}$$

where N = estimated sperm whale or dolphin abundance,
A = total census area,
S = group size, and
$\overline{D}$ = mean density.

The log-normal 95% confidence intervals for population estimates will be calculated as follows:

$$\text{Lower 95\% CI} = \frac{N}{\exp\left(\sqrt{1.96 \cdot \left(\ln\left(1 + (cvN)^2\right)\right)}\right)}$$

$$\text{Upper 95\% CI} = N \cdot \exp\left(\sqrt{1.96 \cdot \left(\ln\left(1 + (cvN)^2\right)\right)}\right)$$

where CVN = coefficient of variation of N.

Variance of D will be estimated as:

$$\mathrm{var}(D) = D^2\left[\frac{\mathrm{var}(n)}{n^2}+\frac{\mathrm{var}(S)}{S^2}+\frac{\mathrm{var}\left(f(d_{max})\right)}{f(d_{max})^2}\right]$$

and the coefficient of variation for the density estimate will be estimated as:

$$CV(D) = \frac{\sqrt{\mathrm{var}(D)}}{D}$$

The sampling unit for the acoustic survey will be a transect line. The variance of n, the number of on-effort acoustic contacts, will be estimated based on the variance in the number of on-effort acoustic contacts within each sampling unit. The estimated variance of S, the mean group size, will be based on the variance of the visual census' group size estimates. The estimate of the variance of the detection function, f(0), will be based on the variance of its component elements, namely, variance in signal strength and noise levels. Variance in noise levels will be estimated based on the variance in sound pressure level measured throughout the cruise.

3.2 IDENTIFICATION OF DOLPHIN SIGNALS RECORDED IN THE GULF OF MEXICO

3.2.1 Introduction

The acoustic analysis team is now concentrating on the data set of unidentified signals from GulfCet I. We have analyzed 277 more signals since the Final Report for the Pre-contract Costs Award (Norris et al. 1996b). An additional 351 signals have been digitized and await analysis. The goal of this work is to further develop the dolphin whistle classification procedures. This will permit identification of the unidentified signals recorded during GulfCet II, which will in turn enable us to make independent estimations of dolphin abundance based on the acoustic data.

We have obtained recordings from additional species that will be used to develop identification cues. In particular, we have access to recordings and analysis of Atlantic spotted dolphins whistles from the Bahamas. We have no recordings of this species in the GulfCet I data set and therefore had no measurements of their acoustic parameters. The analyses of these whistles will be added to the data set from the other identified species.

Fourteen delphinid species are found in the northern Gulf of Mexico (see Table 1.1). Relative to our ability to identify their vocalizations, these fourteen species can be divided into three groups according to the size of their recorded whistle repertoire: (1) those species with adequate recordings or with sufficiently distinctive vocalizations, (2) those species for which we do not currently have representative samples, and (3) those species for which there are few or no recordings. Recordings during GulfCet I were made day and night and during all weather conditions. Because there was significant acoustic effort when it was impossible to visually confirm the identity of the sound source, there remains a need to develop procedures to identify the source of marine mammal signals. The problem addressed here is that of identifying the signals of animals recorded in the absence of visual sighting. For example, 331 of the 487 acoustic contacts made during GulfCet I were of unidentified dolphins, while we do have 124 contacts from 11 visually identified species.

The overall goal of the identification procedures described below is to use acoustical and other data to identify acoustic contacts. Rather than to develop a machine-based identification system, the objective is to determine what is needed to aid a human in making species classifications. Information available to those making the species identification includes the location and the time of year of the recording, audio playback of the signals, spectrograms of individual signals, and the acoustical analyses of all signals, including composition of the recorded repertoire. Parametric acoustical measures are made as are descriptions of the repertoire of the contact. Descriptors of dolphin repertoire include, for example, the percent of the repertoire that is burst pulses. Species specific patterns will determined from these data and used to identify the source of the unidentified signals.

Characterizing the acoustic features of marine mammal signals has been attempted by a number of workers. Fristrup and Watkins (1992) adopted a strategy using a large set of parameters to characterize a wide variety of signals, from groups as diverse as pinnipeds, whales and dolphins. The goal of that work appeared to be automatic, machine-based identification. Steiner (1981) and Wang Ding (1993) used a series of measured acoustical parameters to differentiate dolphin signals. The research reported below used many of the parameters adopted in the latter projects.

The level of difficulty in identifying the source of an acoustic contact varies. Some species are easily identified; killer whales and sperm whales, for example, have particularly distinctive vocalizations. Other species are less readily identified. In the Gulf of Mexico there are, for example, numbers of closely related species, such as the five species in the genus *Stenella*, with signals that are to humans perceptually similar. There are also species for which there is little or nothing known of their vocalizations. For example, during GulfCet I, we made the first recordings of the Fraser's dolphin (Leatherwood et al. 1993). Unfortunately, the recordings were too brief to permit generalizations about their overall vocal system. Most of the effort described below has been directed toward describing the acoustic patterns for the more commonly recorded animals in the GulfCet study area, in order to develop a classification schema for those species.

This research was conducted by students at the Marine Acoustics Laboratory at Texas A&M University at Galveston under the guidance of Drs. Jeffrey Norris and William Evans. The acoustic measurements were done by students during the Fall 1995 and Spring 1996 academic semesters.

3.2.2 Methodology

Recordings

Acoustical analyses were conducted on two groups of GulfCet recordings: identified and unidentified contacts. While cataloging the recordings from identified sources, copies of all high quality whistles and burst pulses were made on a tape recorder. These recordings were ordered by species. The second group of recordings was from the unidentified sources. All recordings were cataloged into a spreadsheet such that the tape number and tape counter number was known for relocation of the signal.

Acoustic Analysis

Analysis of all signals was done using Canary™, bioacoustics software developed by Cornell University, Ithaca, New York. Signals were digitized at a 44.1 kHz sampling rate. Spectrograms were made using a 1024 point Fast Fourier Transform, resulting in a 5.805 ms framelength with a frequency resolution of 43 Hz. The filter bandwidth was 699.4 Hz. Signals were conditioned using a Hamming window. Following procedures described by Wang Ding (1993) and Steiner (1981), a series of parameters were described for each whistle: the frequency and time of the beginning and end of the signal, maximum and minimum frequency, center time, frequency change, duration, and peak time and frequency of maximum amplitude in the signal (Figure 3.3). Additionally, the following signal characteristics were described based on the appearance of the spectrogram: number of inflections; whether the beginning and end frequency swept up, down, or was constant; number of contour breaks; number of steps (abrupt frequency changes); and signal type (e.g. upsweep, downsweep, etc.).

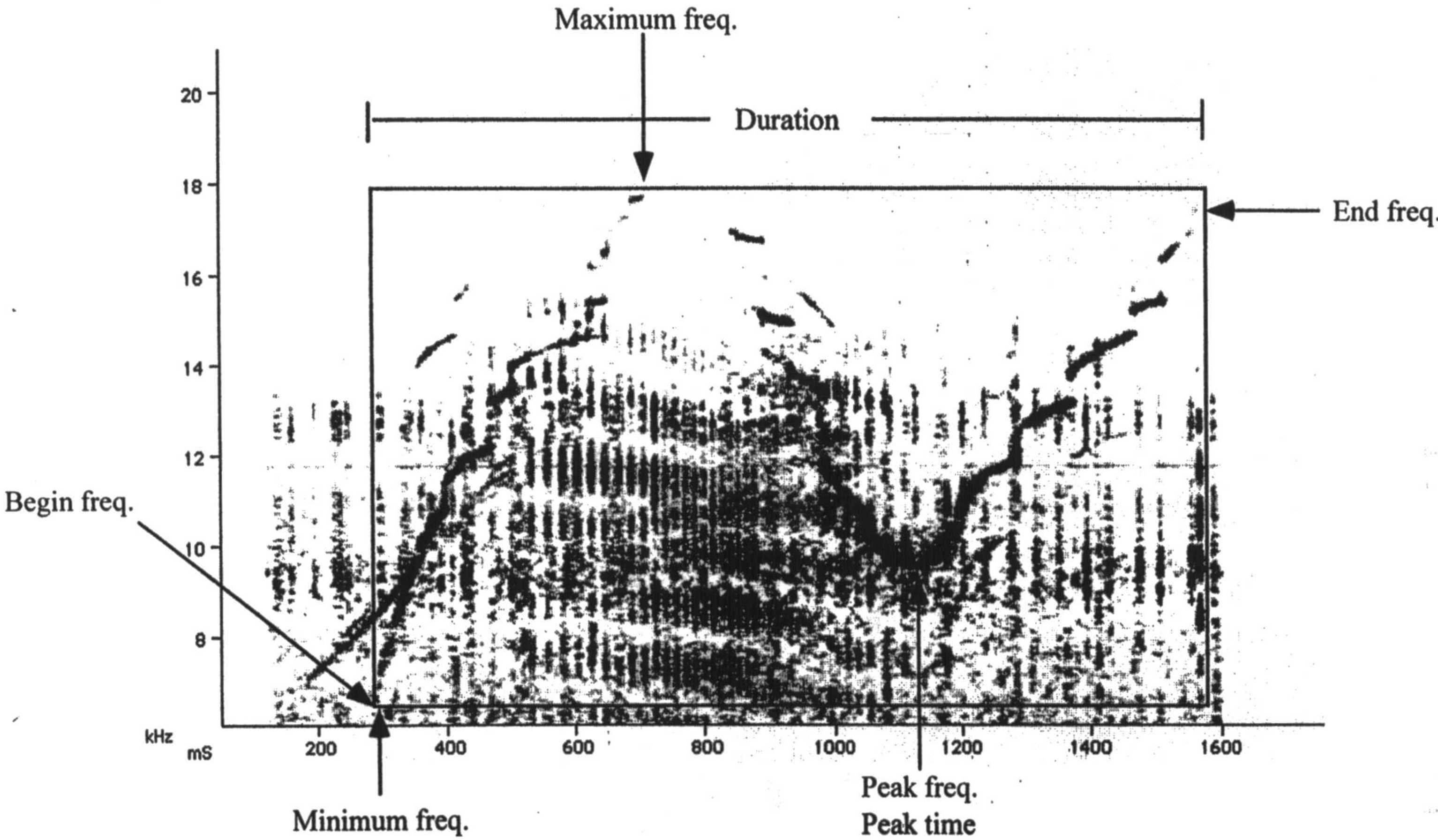


Figure 3.3 Spectrogram of a pantropical spotted dolphin stepped sine whistle illustrating the measured acoustic parameters. The box around the signal represents the area (selected by the user) from which Canary™ calculates values for the parameters of interest.

The measured acoustics data were then exported to a spreadsheet program from which the final parameters were calculated. Time parameters were: start and end time, duration, center time as a percentage of overall signal duration, and peak time as a percentage of overall signal duration. Frequency parameters were: beginning and end frequency and their bandwidth, high and low frequency and their bandwidth, and peak frequency. The signal characteristics described above were also used.

Statistical Procedures

Discriminant function analysis (DFA) was used to derive classification rules from the identified signals so that, given the same parameters from an unknown species, classification could be made. DFA is concerned with the relationship between membership in some class (for example, species x, y, or z) and a series of variables describing some common features contained by members of all classes (for example, frequency variables of their vocalizations). DFA was done using the Statistica™ software package (Statsoft, Tulsa, OK). The central premise was that each species' calls would be sufficiently distinctive to be correctly classified above a 75% correct classification rate. Relatively simple acoustic parameters were used to classify these signals following the notion that there would acoustical correlates to gross morphometric differences between species. For example, based on our experience with both marine and terrestrial animals, including humans, larger animals produce lower frequency signals than smaller animals. According to this theory, bottlenose dolphins should, in general, produce lower frequency whistles than the smaller *Stenella* species. In addition, we expect that sympatric species of similar sizes should also encode their signals with acoustic differences that should allow them, and hopefully us, to differentiate between species.

Personnel Training

Each analyst trained on a standard set of training vocalizations and their results were compared. Once it was shown that the analysts could accurately describe the acoustics of a signal, they began analyzing the recordings of the identified sources.

3.2.3 Results

Acoustic Analysis

A total of 381 signals from six species were analyzed. These six species represent 73% of the total estimated dolphin population in the GulfCet study area (Hansen et al. 1996). The whistles were classified into six types based on the configuration of the spectrogram (Figure 3.4). For some species, sample size was an analytical limitation. There were 17 and 11 whistles from the false killer whale and the striped dolphin, respectively, so these species were dropped from further classifications. The most common whistle type was a sine whistle, with the constant frequency whistle being the least common (Table 3.1). There was appreciable inter-specific variability in whistle repertoire. There was also significant inter-specific overlap in the values for each acoustic parameters (Figure 3.5). This inter-specific overlap prevented satisfactory classification of the combined data set using discriminant function analysis. The inability to classify these signals was not unexpected because initial comparisons were between all whistles for all recorded species. There was likely to be greater intra-specific variability between whistle types (e.g., pantropical spotted dolphin upsweeps vs. downsweeps) than inter-specific variability within whistle types (e.g., pantropical spotted dolphin sine whistles vs. clymene dolphin sine whistles). The final data set, determined by sample size, included upsweep whistles for pantropical spotted, clymene, and rough toothed dolphins, as well as concave and sine whistles for pantropical spotted, clymene, and bottlenose dolphins (Table 3.1).

Discriminant function analysis was performed on sine whistles of pantropical spotted dolphins (n = 25), clymene dolphin (n = 30), and bottlenose dolphins (n = 32). The goal of this analysis was to discriminate between bottlenose dolphins and the two stenellid species. Nine parameters were used to determine a classification system. There was significant inter-specific variability for these parameters, particularly low frequency and number of steps (Table 3.2). A canonical analysis was used to compute the actual discriminant functions. The first of two discriminant function roots explained 60% of the variability between the three species. The first root was most heavily weighted on low frequency and number of steps, while for the second root, low frequency and number of inflections were most heavily weighted. The DFA accurately separated the 87 whistles of these three species, with the first root separating bottlenose dolphins from the two stenellids, and the second root separating clymene dolphins from pantropical spotted dolphins (Figure 3.6). Sine whistles of pantropical spotted dolphins were correctly classified 84% of the time, with the errors evenly split between the other two species, while 83% of the clymene dolphin whistles were correctly classified, with 4 of 5 errors falsely identifying them as pantropical spotted dolphins (Table 3.3). The sine whistles of bottlenose dolphins were correctly classified 87.5% (28/32), with 3 of 4 erroneous classifications as clymene dolphin whistles.

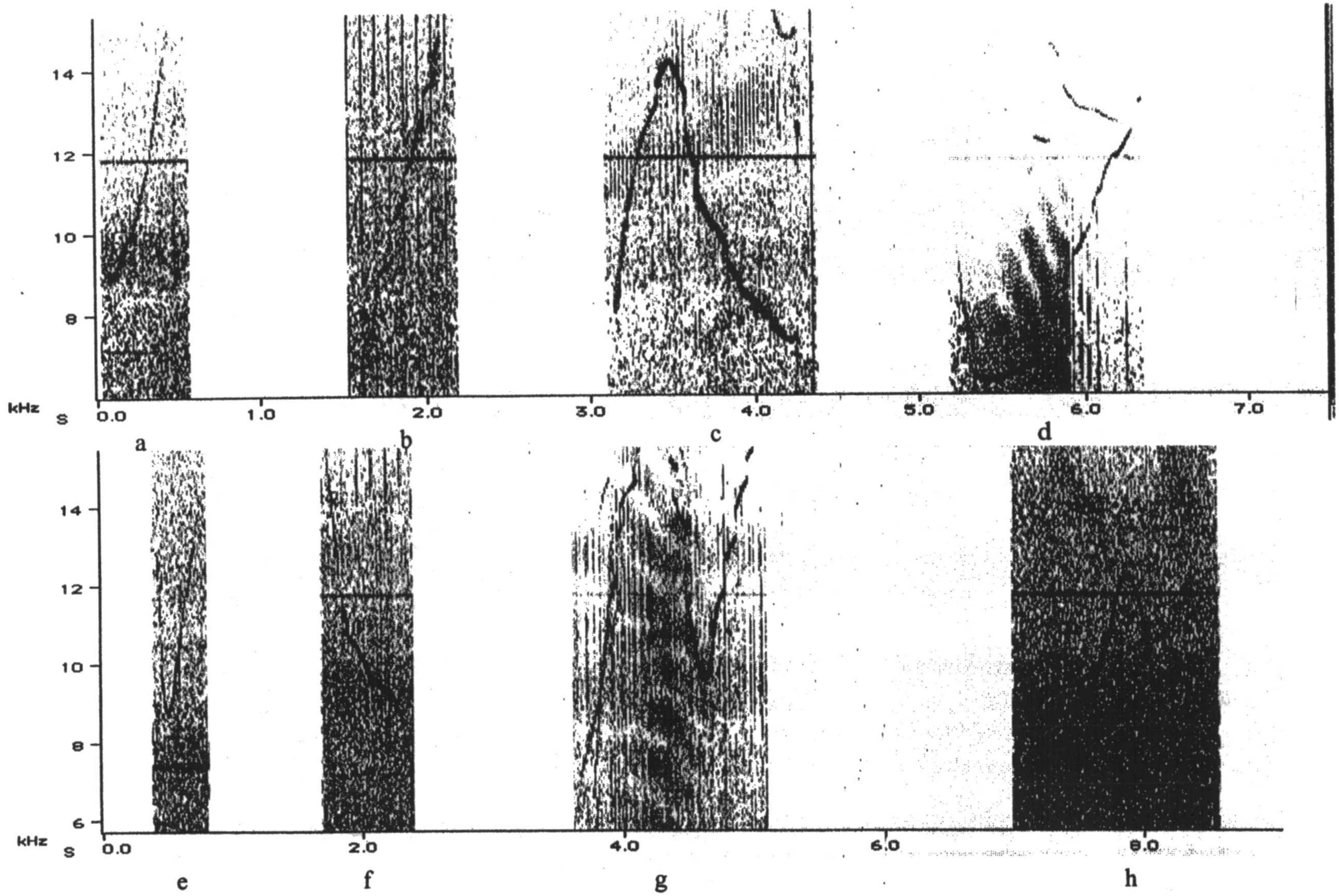


Figure 3.4 Spectrograms of whistle types: (a) linear upsweep, (b) stepped upsweep, (c) stepped convex, (d) stepped concave, (e) linear concave, (f) stepped downsweep, (g) stepped sine, and (h) linear sine. All examples were produced by pantropical spotted dolphins except (h), by a bottlenose dolphin.

Table 3.1. Numbers of different types of whistles used by dolphins recorded during GulfCet I. SA = pantropical spotted dolphin, SY = clymene dolphin, SO= striped dolphin, PC = false killer whale, TT = bottlenose dolphin, SB= rough toothed dolphin. CF= constant frequency whistle.

	CF	%	Up	%	Down	%	Concave	%	Convex	%	Sine	%	Total
SA	0	0.0	27	23.1	17	14.5	25	21.4	23	19.7	25	21.4	117
SY	1	0.8	29	22.8	3	2.4	48	37.8	16	12.6	30	23.6	127
SO	0	0.0	0	0.0	2	18.2	0	0.0	6	54.5	3	27.3	11
PC	0	0.0	0	0.0	1	5.9	3	17.6	0	0.0	13	76.5	17
TT	2	2.6	5	6.5	11	14.3	22	28.6	5	6.5	32	41.6	77
SB	3	9.4	23	71.9	2	6.3	3	9.4	0	0.0	1	3.1	32
Total	6	1.6	84	22.0	36	9.4	101	26.5	50	13.1	104	27.3	381

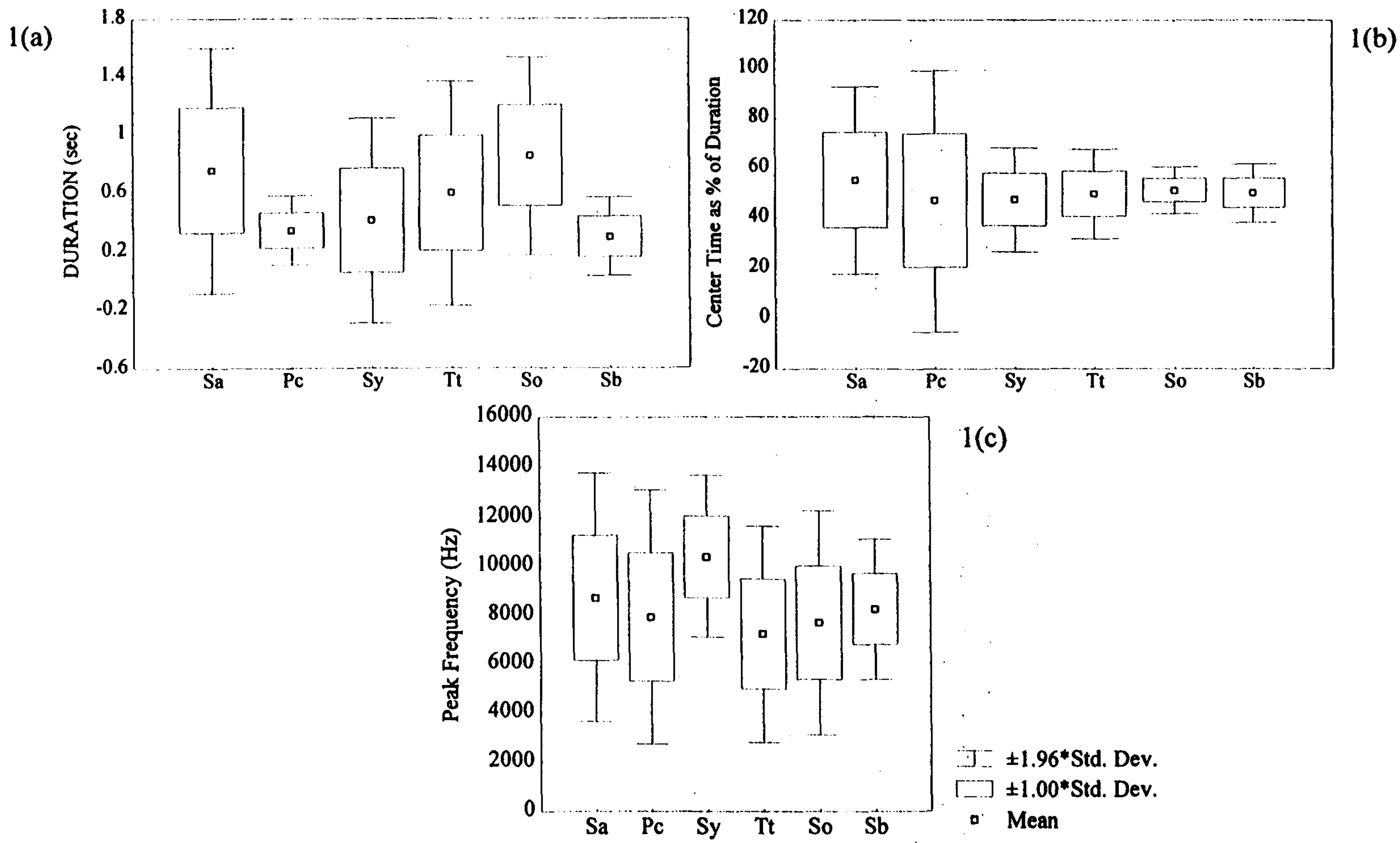


Figure 3.5. Box plots of (a) duration, (b) center time as percent of duration, (c) peak frequency, (d) beginning frequency, (e) end frequency, (f)high frequency, and (g) low frequency. Sa = pantropical spotted dolphin, Pc = false killer whale, Sc = clymene dolphins, Tt = bottlenose dolphin, So = striped dolphin and Sb = rough-toothed dolphins.

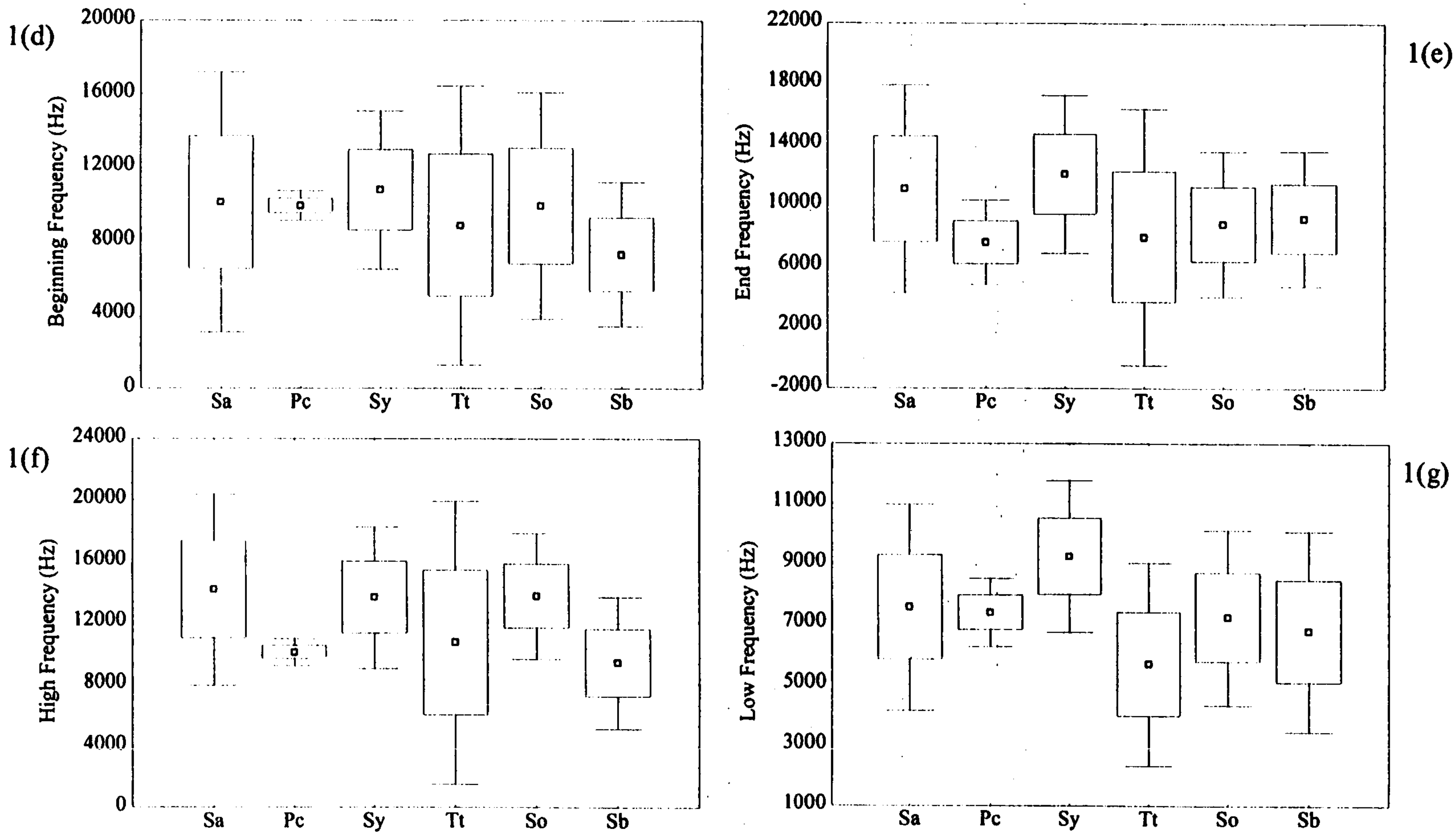


Figure 3.5, continued.

Table 3.2. Means values for nine acoustic variables measured for (a) sine whistles from pantropical spotted, clymene, and bottlenose dolphins and (b) upsweep whistles from both stenellids and rough toothed dolphins.

	Time variables		Frequency variables (Hz)					Signal characteristics		
Species	Duration (sec)	Center time (% of duration)	Beginning	End	High	Low	Peak	No. of inflections	No. of steps	n
(a) Sine Whistles										
Pantropical spotted dolphin	1.007	55.6	10113	12630	16324	7780	9930	2.6	2.6	25
Clymene dolphin	0.873	52.2	11255	11112	14384	9098	10549	3.6	1.1	30
Bottlenose dolphin	0.831	49.5	8546	7100	10705	5427	7277	3.3	0.4	32
All three species	0.896	52.2	9931	10073	13588	7369	9168	3.2	1.3	87
(b) Upsweep Whistles										
Pantropical spotted dolphin	0.514	42.7	7174	12855	13050	6997	8854	0.1	1.3	27
Clymene dolphin	0.262	39.7	8885	14368	14502	8673	9982	0.3	0.2	29
Roght-toothed dolphin	0.325	49.1	7074	9313	9576	6604	8355	1.0	2.3	23
All three species	0.366	43.5	7773	12379	12571	7498	9123	0.4	1.2	79

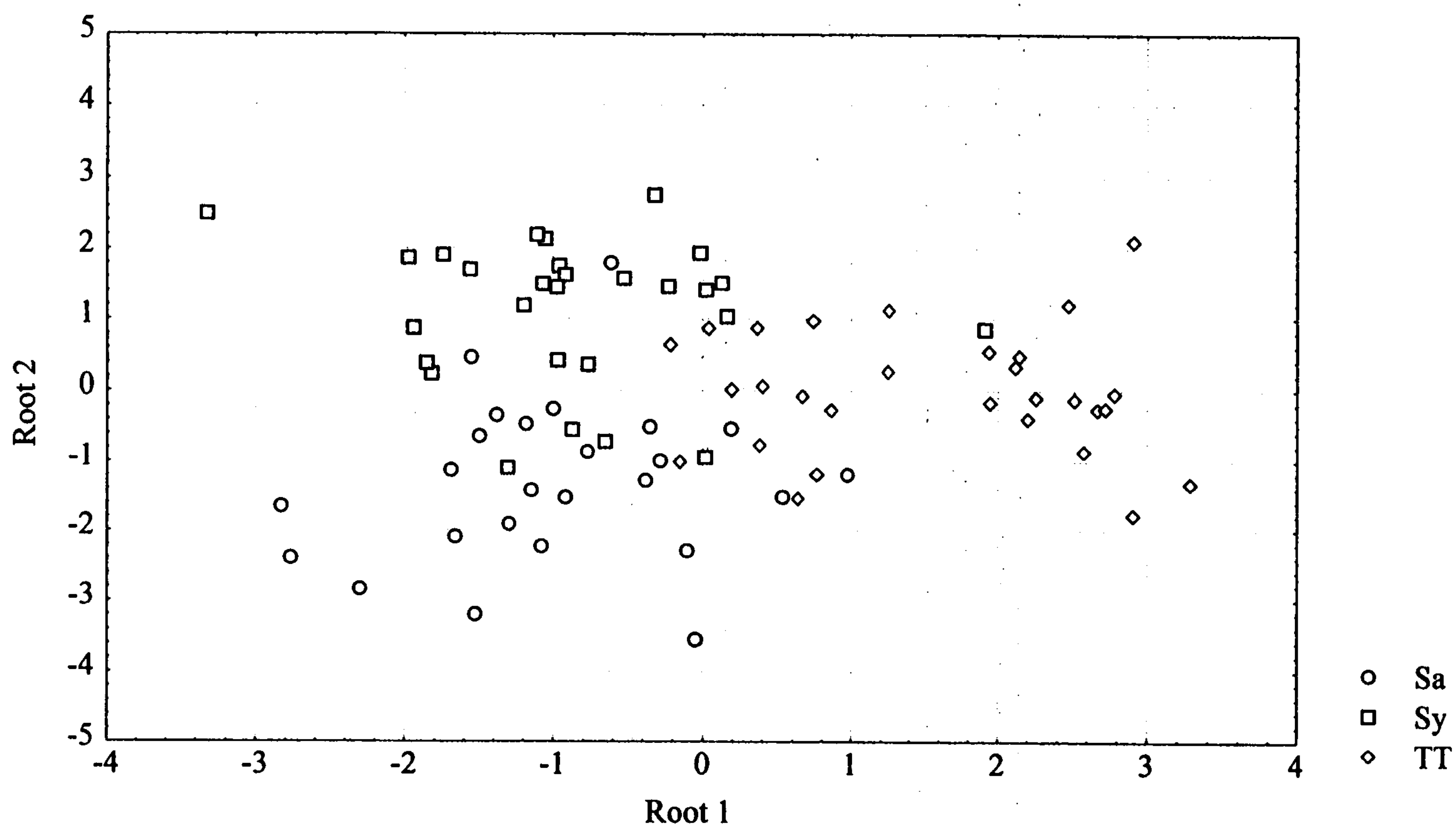


Figure 3.6. Plot of the first two discriminant function roots for sine whistles. The first root discriminates bottlenose dolphins from the two *Stenella* spp., the second, the two *Stenella* spp. Sa = pantropical spotted dolphin, Sy = clymene dolphin, Tt = bottlenose dolphin.

Table 3.3. Classification matrix for (a) sine whistles from pantropical spotted dolphin, clymene dolphin, and bottlenose dolphin and (b) upsweep whistles from both stenellids and rough toothed dolphin. Rows are observed classifications and columns are predicted classifications. For example, 21 of 25 (84%) pantropical spotted dolphin sine whistles were correctly classified. "p" = proportion of total data set derived from each species.

Species	% Correct classification	Pantropical spotted dolphin	Clymene dolphin	Bottlenose dolphin
(a) Sine whistles		p = 0.29	0.34	0.37
Pantropical spotted dolphin	84.0	21	2	2
Clymene dolphin	83.3	4	25	1
Bottlenose dolphin	87.5	1	3	28
All three species	85.1	26	30	31
(b) Upsweep whistles		p=0.34	0.37	0.29
Pantropical spotted dolphin	81.5	22	4	1
Clymene dolphin	96.6	1	28	0
Rough-toothed dolphin	100.0	0	0	23
All three species	92.4	23	32	24

A second discriminant function analysis was performed on upsweep whistles from two stenellids (pantropical spotted dolphin (n = 27), clymene dolphin (n = 29)), and rough toothed dolphin (n = 23). The goal of this analysis was to discriminate rough-toothed dolphin from the two stenellids. Inter-specific variability was significant and centered mostly on duration, number of steps, and low frequency (Table 3.2). A DFA was used to compute the actual discriminant functions. The first of two discriminant function roots explained 87% of the variability between the three species. The first root was most heavily weighted on frequency variables, while the second root, which explained considerably less of the inter-specific variability, was most heavily weighted on duration differences. Number of steps was the single most expressive parameter in differentiating these species, followed by duration differences. These two discriminant function roots separated the three species, with the first root differentiating rough-toothed dolphin from the stenellids, and the second root differentiating the two stenellids (Figure 3.7). Upsweep whistles of pantropical spotted dolphins were correctly classified 82% of the time, with most classification errors mistaking the two stenellids. Clymene dolphin whistles were correctly classified 97% of the time, the only error being a misclassification to pantropical spotted dolphins (Table 3.3). All of the rough-toothed dolphin upsweeps were correctly classified.

The final dolphin whistle identification procedure was a step-wise key (Table 3.4). This key identifies the vocalizations of six dolphin species: killer whale, pilot whale, pantropical spotted dolphin, clymene dolphin, rough toothed dolphin, and bottlenose dolphin. The key uses percentage of the repertoire for particular signal types (burst pulses and constant frequency signals) as well as the results of discriminant function analysis for upsweep and sine whistles. Using this key, vocalizations of pantropical spotted, clymene, and bottlenose dolphins should be identifiable. Additionally, signals from killer whales, pilot whales, and rough-toothed dolphins should be identifiable.

3.2.4 Discussion

The signal identification procedures described above should accurately identify signals produced by six dolphin species, representing most of the dolphins found in the GulfCet study area. Increasing the reliability and scope of these procedures necessitates increasing the sample sizes for those species for which we have limited recordings. We can reliably identify the vocalizations of six species: pantropical spotted dolphins, clymene dolphins, bottlenose dolphins, rough-toothed dolphins, killer whales, and pilot whales. These represent 65% of the animals in the study area. Three species alone,

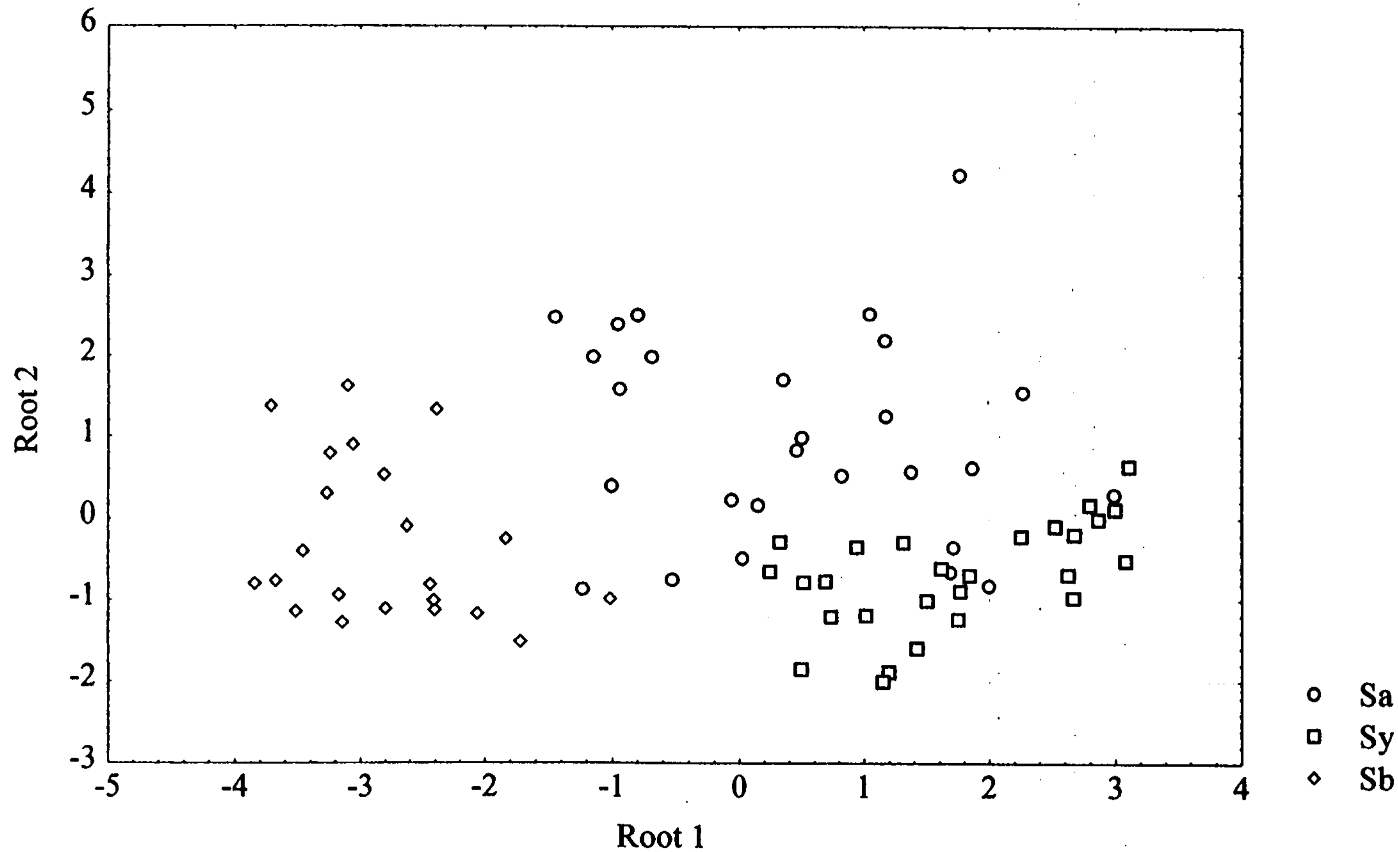


Figure 3.7 Plot of the first two discriminant functions for upsweep whistles. The first root discriminates rough-toothed dolphins from the two *Stenella* spp., the second, the two *Stenella* spp. Sa = pantropical spotted dolphin, Sy = clymene dolphin, Sb = rough-toothed dolphin.

Table 3.4. Key to identification procedures used to identify six species of dolphins based on repertoire and signal characteristics. The last two steps involve discriminant function analysis (DFA) classification of whistles.

1. Recordings contain only burst pulses:
   Killer whales

2. Recordings are primarily burst pulses, with whistles below 10 kHz:
   Pilot whales

3. Vocal repertoire is mixed whistles and some burst pulses:

   3.1. At least 75% of repertoire is constant frequency whistles:

      3.1.1. DFA classify Upsweep Whistles:
         Pantropical spotted dolphin,
         Clymene dolphin,
         Rough toothed dolphin

   3.2. DFA classify Sine Whistles:
      Pantropical spotted dolphin,
      Clymene dolphin,
      Bottlenose dolphin

bottlenose dolphin, clymene dolphin, and pantropical spotted dolphin, represent over 61% of all the dolphins in the study area. The other three species are rare in the Gulf of Mexico and represent approximately 3% of Gulf delphinids (Hansen et al. 1996). Recordings of vocalizations from other locales exist for an additional five species, representing an additional 25% of the animals in the study area. These are Risso's dolphin, Atlantic spotted dolphin, spinner dolphin, striped dolphin, and false killer whale. There are few if any recordings for three species: pygmy killer whale, Fraser's dolphin, and melon headed whales. These species represent 11% of the animals in the study area.

A high priority in the near future will be to obtain new recordings, particularly for those species for which there are large recording sets from other locations. In particular, we have access to numerous recordings from Atlantic spotted dolphin recorded in the Bahamas. Lacking recordings from the Gulf of Mexico, recordings from the Bahamas represent the geographically closest population. Another tactic to increase recording samples will be to group recordings made of multiple species swimming together. For example, we have an excellent recording of a mixed school of melon headed whales and Fraser's dolphins. Lacking recordings of either species alone, we will do discriminant function analysis on these combined signals and attempt to derive classification functions for a combined melon headed whale/Fraser's dolphin class. Inter-specific variability however may mask our ability to derive accurate classification rules.

Assessing the classification error rate is an important step in devising a classification system. The classification error rate assesses the discriminatory performance of a fitted model. Classification validation will be done by calculating the classification error rate using a jackknife approach (McLachlan 1992). The classification error rate for sine whistles will be calculated using the 87 examples of sine whistles from bottlenose dolphins, pantropical spotted dolphins, and clymene dolphin. The jackknife procedure involves removing one sample from the data set, running the discriminant function analysis and obtaining the classification rule from those remaining 86 signals. The classification rule is then used to classify the single removed sample. Since the identity of this removed sample is known, the classification rate will be determined. This jackknife procedure will be repeated 87 times, and the mean classification rate will be measured. The classification error rates based on discriminant function analysis results are typically biased to indicate higher than actual correct classifications. We will estimate the unbiased apparent error rate for the discriminant function analysis results using the techniques described by McLachlan (1992).

The overall goal of the procedures described above is to classify those signals for which there was no identity. This is needed in order to determine the source for all dolphin contacts so that we can parse the total estimated dolphin population into it component species. This will permit a more accurate dolphin population estimate. In GulfCet I, the dolphin abundance estimates from the acoustic survey were 1.98 times those of the shipboard visual survey (36,760 and 18,584, respectively) (Norris et al. 1996a). Based on overlap of the 95% confidence intervals, these estimates were not significantly different. The acoustic survey population estimate is based on more contacts (369) than from the visual contacts (315), even though the visual census used the combined visual contacts from both Texas Institute of Oceanography and National Marine Fisheries Service vessels. The density of acoustic contacts per kilometer was more than double than that from the visual survey. Once the identity of each contact is known, the resulting dolphin population estimate should have a smaller coefficient of variation, which should result in a better ability to detect population trends.

IV. BIOLOGICAL OCEANOGRAPHY

Pre-cruise planning continues for the second GulfCet II cruise, which is slated to be at sea 11-28 October. Biological oceanography habitat studies are an integral part of the fieldwork being planned. Since the cruise has not yet been conducted, this chapter presents the goals and methods of the biological oceanography component of the GulfCet II Program.

4.1 PURPOSE

A primary objective of the GulfCet II Program is to identify possible associations between cetacean high-use habitats and the ocean environment, and attempt to explain any relationships which appear to be important to cetacean distribution.

The GulfCet I Program (Davis and Fargion 1996) obtained limited information on cetacean habitat preference. A strong correlation was identified between species distribution and ocean depth. However, the study failed to establish strong correlations with other oceanographic variables such as sea surface temperature, salinity, water column structure and distinctive features such as warm-core and cold-core eddies. This may have resulted from the fact that: (1) the oceanography of the Gulf of Mexico is very dynamic with the periodic intrusion of the Loop Current from the southeast and the formation of warm-core eddies that move across the northern Gulf and (2) cetaceans are large, warm-blooded mammals whose wide-ranging movements are not physiologically constrained by water temperature or other hydrographic features. The distribution and spatial dynamics of cetaceans in relation to their environment may be more productively investigated by testing hypotheses in relation to well defined oceanographic features during dedicated, focal habitat cruises than by correlation with physical measurements made during line transect surveys designed to estimate abundance.

The distribution of cetaceans is probably better explained by the availability of prey, which may secondarily be influenced by oceanographic features. As a result, we will use models of dynamic height (determined by satellite altimetry) to monitor the weekly locations of the Loop Current and eddy systems and gather data on nekton distribution and biomass during focal studies to assess cetacean distribution and habitat. For example, we hypothesize that the concentration of cetaceans, especially sperm whales, found offshore from the Mississippi River delta results from the nutrientenriched waters that support a large biomass of prey. Likewise, cold-core eddies or the edge of warm-core eddies may concentrate nekton that is preyed upon by cetaceans. Based on our experience during GulfCet I, a better understanding of cetacean habitat preference can only be achieved by examining both the physical and biological components of the marine environment using a multidisciplinary approach during focal shipboard surveys.

4.2 APPROACH

In order to test our hypothesis that the distribution and abundance of cetaceans in the northern Gulf are positively correlated with spatial and temporal variations in regional food stocks of zooplankton and micronekton, we propose a two fold approach: (1) acoustic estimation of nekton biomass and direct net sampling to both ground truth the acoustics and to provide specimens of cephalopods and midwater fishes for identification and biomass calibration and (2) identification of oceanographic features (i.e., eddies and the Loop Current) using satellite sea surface altimetry obtained from the Center for Astrodynamic Research at the University of Colorado and *in situ* hydrographic measurements during shipboard surveys (described in Chapter 5).

4.2.1 Acoustic Estimation of Nekton Biomass

To test this hypothesis requires monitoring techniques suitable for stock biomass assessment. A recent international symposium on Fisheries and Plankton Acoustics (Aberdeen Scotland, June 1995) reviewed the ways in which active hydroacoustic sampling of the ocean can be a useful technique to study the biomass and structure of fisheries stocks, including zooplankton. A principal conclusion from that symposium was that the use of acoustic echo integration techniques for distribution and biomass estimates now constitutes the major field technique for assessing fisheries and plankton biomass.

To relate the distribution and abundance of marine mammals in the northern Gulf of Mexico to nekton standing stocks, we will acoustically estimate nekton stocks with an existing narrowband 153 kHz Acoustic Doppler Current Profiler (ADCP) that is available as shipboard scientific equipment on R/V *Gyre*. Murphy et al. (1992) have described how this ADCP is through-the-hull mounted on R/V *Gyre*; Zimmerman (1993) has reviewed previous use of shipboard ADCPs to estimate nekton biomass and described how this 153 kHz ADCP is calibrated quantitatively for the underway collection of volume backscattering data. Volume backscattering data collection using the ADCP will be supplemented by towing a dual frequency Datasonics TTV-170 profiler: the two transducers of this system emit sound an octave lower in frequency (22 kHz) and 2x higher (300 kHz) in frequency than the ADCP. Numerous reports in the literature verify that the 22 kHz frequency is useful for surveying for the presence of Deep Scattering Layers and of aggregations of nekton with air-filled swimbladders; the 300 kHz frequency will be used for side-by-side comparison with the ADCP to study the volume backscattering from nekton.

The dual frequency Datasonics system is available as common use equipment from the Department of Oceanography at TAMU by arrangement with Dr. Aubrey Anderson. Dr. Anderson has agreed to its use in support of the pair of 10-day GulfCet cruises which we are proposing will be fielded by R/V *Gyre* in Autumn of both field years (1996 and 1997). For validation of the volume backscattering from the 22/300 kHz dual frequency system (and for the ADCP), the dual frequency system will be towed concurrently with the MOCNESS (Multiple Opening Closing Net and Environmental Sampling System). These tows will be made from depth specific strata for comparison with the acoustics data.

Our expectation is that high frequency acoustic estimation of nekton stock abundance will complement and extend the stocks data using MOCNESS tows. Moreover, since ADCP backscatter data will be collected continuously in time, it offers the potential for correlation with habitat parameters on spatial scales ranging from 1 km (for a 5 minute temporal ensemble average) to 102 km (mesoscale eddy scales). We plan to collect ADCP volume backscattering data on both the Autumn Eastern Planning Area surveys and on the focal habitat cruises, both while the vessel is underway as well as when it is slowed for MOCNESS trawls. The 153 kHz ADCP collects data in 40 vertical bins, each with 4 m or 8 m vertical resolution. From previous work by Zimmerman (1993), we know an ADCP that is through-the-hull mounted and configured for 8 m vertical resolution can give quantitative backscatter intensity information down to a depth of about 220 m while the vessel is underway at 9-10 knots and somewhat deeper (i.e., to about 280 m) when the vessel slows for trawls and/or other station activities. This ADCP acoustic estimation of nekton stocks will not interfere with or compete for ship time with other tasks.

Investigating the relationships between nekton patchiness and ocean physics ideally requires that both are sampled on the same space and time scales. The ADCP provides information on both biological and physical parameters. It uses the Doppler shift to measure the currents and the acoustic backscatter strength may be used to estimate animal distribution and provide information on their behavior. Concurrent CTD/XBT surveys should provide additional hydrographic data at the mesoscale time and space scales we hypothesize will contain the principal variability in the local circulation. Moreover, the continuity in space or time of the ADCP backscattered return and current shear can be used for allocation of direct stratified sampling effort for the layers and nekton species of interest (Lyons and Smith 1995).

Because the spatial and temporal resolution of an ADCP is limited by the 5 minute long averaging times needed to measure currents accurately (these 5 minute ensembles are manufacturer's standard), we anticipate that intercomparison of the backscatter strength measurements of the ADCP with that of the dual frequency Datasonics echosounder will be useful. For example, in a recent study of the calibration of a 153 kHz ADCP against the 200 kHz channel of a Simrad EK500, over a range of Mean Volume Backscattering Strength of -88 to -68 dB (relative to a scattering cross section of 1 m^{-1}) from 10 to 90 m depth, the data from the two instruments were correlated but with a slope error of about 10% and an offset error of + 3 dB (Griffiths and Diaz 1995). After correction for these systematic errors, the residual differences between the ADCP and the EK500 were less than 1 dB.

We hypothesize that there will be marked spatial and temporal differences in standing stocks of zooplankton and nekton across frontal zones associated with the Loop Current and its associated eddies. In March 1993, zooplankton were collected at 3 stations within and 5 outside a cold-core ring (CCR) that was centered near 26°N, 91°W in the western Gulf of Mexico (Biggs et al. in prep.). This mesoscale cyclonic circulation, which was visible in TOPEX and ERS-1 altimetry as an elliptical shaped local depression in the sea surface topography (-10 to -20 dyne cm SSH anomaly, with dimensions 550 km x 150 km), had surface temperatures 1-2°C cooler than the adjacent oceanic surface waters. Since nutrient-rich midwater (10-12 µM nitrate L^{-1}) domed to < 30 m of the base of the 70-75 m deep mixed layer within this cyclone, Biggs et al. hypothesized it would be a region of locally high primary productivity and sought to determine whether the cyclone might have elevated stocks of zooplankton. It did, averaging 50% greater biomass than adjacent slope and was twice as rich in species composition of euphausiids, pteropods, and siphonophores than was the adjacent slope. Macrozooplankton stocks collected within the upper 100 m with an open net of 333-µm mesh were well correlated with the acoustic backscatter intensity integrated 0-100 m from R/V *Gyre*'s vessel-mounted 153 kHz Acoustic Doppler Current Profiler ($r^2 = 0.80$). We believe this correlation might have been even higher, however, if on this cruise we had been able to make depth-discrete tows with a MOCNESS trawl system instead of open net tows that integrated the entire upper 100 m of the water column.

Another important reason for making MOCNESS trawls for validation of the acoustic backscattering data is that there are large differences in the acoustic scattering properties of zooplankton and nekton of different taxa. For example, during recent GLOBEC fieldwork it was found that volume backscattering levels from two physically distinct areas (a well-mixed area on top of Georges Bank and a stratified area on the southern flank of the Bank) differed by 4-7 fold, even though these areas were separated by only a few tens of kilometers in space and they were sampled just hours apart in time (Wiebe et al. 1995). There was no significant difference in MOCNESS sampled biomass between these two locations and the regression between volume backscattering and total biovolume was not significant. Instead, the difference in volume backscattering was due to differences in the acoustic scattering properties of the zooplankton taxa and the fact that the taxonomic composition of the plankton differed between the two sites. Only when taxa-specific model predictions of acoustic backscattering cross-section were used with field size and abundance data to predict measured volume backscattering was a highly significant relationship obtained between observed and predicted volume backscattering (Wiebe et al. 1995).

4.2.2 MOCNESS Nekton Trawls

The main prey group for sperm whales in the study area is cephalopods (Clarke 1977). Their diet shows spatial variability and, most likely, temporal variability as well. Our knowledge of sperm whale diet comes from an analysis of the cephalopod beaks in the stomachs in those caught by whalers. These are necessarily adults and our knowledge of juvenile sperm whales is totally lacking. The diets of some other Gulf cetaceans also include cephalopods as well as midwater fishes.

Cephalopods are found throughout the water column as well as on or in association with the bottom. The most common families represented in sperm whale stomachs are: Histioteuthidae, Ommastrephidae, Architeuthidae, Cranchiidae, Enoploteuthidae and Thysanoteuthidae. The Histioteuthidae live below about 200 m. The Ommastrephidae and Thysanoteuthidae migrate up to the surface waters at night, but migrate to 600 m or deeper during the day (Nakamura 1991). The Architeuthidae, or giant squids, are thought to live near the bottom along the base of the continental slope (Clarke and MacLeod 1974, 1976, 1982; Okutani and Satake 1978; Clarke 1962).

The majority of our knowledge of oceanic cephalopod vertical and horizontal distributions comes from towing nets. These nets vary from the 3 m Isaacs Kidd Midwater Trawl (IKMT, 7.8 m^2 mouth area) to the Engels Trawl (EMT, 242 m^2 mouth area). Each end of the size spectrum has its own bias. The smaller IKMT is more easily avoided due to its smaller mouth opening while the EMT has much larger mesh openings and therefore underrepresents the smaller cephalopods. There are also significant differences in ship requirements for launch and recovery.

We will use a 4 m^2 MOCNESS (Wiebe et al. 1976) on focal habitat cruises to collect midwater fish and squid. This net is instrumented with a CTD and gives real time data on depth, flow rate, net angle, and net speed, as well as temperature and salinity. The nets will be made of 4-mm bar mesh netting and each will have a 0.5 m plankton net suspended inside the mouth to sample zooplankton at the same time. It can be launched and recovered under most sea states that would be encountered. It will require the addition of a removable roller on the stern. We have contacted T.L. Hopkins at the University of South Florida who uses this system and he has made available his experience on field operations, and will loan us the 4 m^2 MOCNESS system. We have operated a much larger IKMT (mouth area 15 m^2) on the R/V *Gyre*. The launch and recovery time is somewhat greater, but the catches are proportionately much better. These data will allow us to determine the amount of available prey and its depth distribution. We can supplement these data with data collected on various Department of Oceanography cruises in the area over the past 15 years. The trawls will be most effective if taken at night because those species that migrate vertically will be closer to the surface and the amount of net avoidance will be much lower than during daylight.

We propose to spend some limited time on each focal habitat cruise collecting squid at the surface under a night-light using squid jigs and fishing poles. Specimens collected will provide data on seasonal availability and reproductive state. Since many squid species die following spawning and attract many predators at that time, squid abundance and reproductive state could aid in explaining seasonal sperm whale movements.

The squid and specimens collected during the trawls will be preserved in 10% buffered formalin. In the laboratory, trawl specimens will be sorted, separating midwater fishes and cephalopods. Taxonomic identifications will be made to the lowest possible level. Biomass will be calculated from measurements taken on each specimen. Zooplankton biomass will be measured and correlated with the ADCP data. All data will be plotted and compared to hydrography and marine mammal distributions. Nonparametric statistical tests will be used initially to quantify temporal and spatial relationships. Other analyses, such as correspondence, will also be used to define relationships.

V. PHYSICAL OCEANOGRAPHY

5.1 PURPOSE AND APPROACH

The physical characteristics of the Gulf of Mexico are remarkable in their variability and intensity. Oceanographic features may influence the distribution of cetaceans and their prey. Therefore, a goal of the GulfCet II program is to characterize the physical habitat to reveal cetacean-habitat associations.

In the northwestern Gulf, anticyclonic warm eddies with their affiliated cold cyclonic eddies and the fresh water influx from the Mississippi River are the primary features which can enhance primary productivity and subsequently increase production at higher trophic levels. Biggs and Müller-Karger (1994) reported that the continental slope of the NW Gulf is a region where pelagic predators are abundant. Since these predators (such as skipjack, blackfin tuna, blue marlin, swordfish, and shark) require consistent food sources, they are not likely to be sustained by low primary productivity or infrequent episodes of enhanced primary productivity. Primary productivity, therefore, must be maintained relatively consistently. Particular areas where this level of production are likely to remain relatively constant are the Mississippi River plume vicinity and the area just peripheral to the eddy pathway from the Loop Current. It is suspected that cetacean food sources, as well, would most likely be concentrated in these areas of consistently higher primary productivity, and, therefore, cetacean foraging efficiency would be maximized when effort was concentrated in these areas. It would seem likely, then, that these areas would be preferred habitats for many marine mammals present in the Gulf.

GulfCet II ship surveys are designed to test a working hypothesis of the preferred cetacean habitat in the Gulf based on previously collected oceanographic data from the Gulf (Hamilton 1992; Walker et al. 1994; Fargion et al. 1994a; and Fargion et al. 1994b). During the GulfCet II program, shipboard surveys with supporting satellite altimetry will be used to monitor the general water circulation in the study area. Near-real-time altimetry will be used to assist in cruise planning. Two sampling strategies are being used: a large scale survey of the overall study area and a focal survey to focus on specific oceanographic features (e.g., eddies and Loop Current) and the fresh water fronts in the area of the Mississippi River.

Altimeter data from the NASA/CNES TOPEX/Poseidon and ESA ERS-2 missions are processed in near-real-time at the Colorado Center for Astrodynamics Research at the University of Colorado. Because a radar altimeter functions at microwave frequencies, nearly continuous coverage of the Gulf is possible. Conventional ocean remote sensing techinques which rely on visible or infrared observations are affected by cloud coverage.

GulfCet II utilizes the altimeter data in two ways: for a time evolution description of the oceanographic features in the Gulf and to determine geographical areas of cyclonic and anticyclonic eddies. Furthermore, ship data will be used to calibrate the altimeter data rather than using the ship itself in hydrographic survey mode as was done for GulfCet I. Because hydrographic survey mode necessitated stopping to make CTD casts every 10-20 nautical miles in order to resolve the mesoscale circulation, fewer stops for hydrographic stations allow more cost efficient use of ship time in GulfCet II. Moreover, by sampling a limited geographical area in the focal studies, our observations will be more synoptic in time as well as in space. We seek to use the ship time on focal cruises in particular to examine day-to-day temporal as well as mesoscale spatial variability. The GulfCet II ship surveys also make use of continuous flow-through systems capable of resolving fine scale gradients and frontal zones in surface temperature, surface salinity, and surface chlorophyll. Moreover, the ship we will use for the focal surveys (R/V *Gyre*) will be outfitted with an Acoustic Doppler Current Profiler (ADCP) and so will be capable of fine scale (every 5 minutes) direct measurement of underway current velocity at depths of 0-200 m (this same active sonar system will also be used to estimate nekton biomass, described in Chapter 4).

Surface temperature and salinity will be monitored underway by sensing a flow pumped from a sea chest at a depth of 3 m in the after hull of *Gyre*. These data will be compared with geostrophic calculations of near surface current from the XBTs. To provide the T/S relationship needed to compute dynamic topography from the XBT survey, CTD casts will be made to 800 m depths on each cruise Leg. These CTD stations will be located at the center of features and/or in regions of greatest dynamic height gradient as determined by altimeter data. The location and spacing of the XBT hydrographic stations will be based on 10 nautical mile resolution and will be adjusted following the altimeter data.

The variability in certain environmental parameters will be used to delineate the mesoscale features in the northern Gulf. Differences in temperature and salinity (T-S) will be used to characterize water masses. Gulf Common Water (GCW) and Caribbean Subtropical Underwater (SUW) can both be found within the top 250 m of water depth, while Antarctic Intermediate Water (AAIW) is located deeper, at a depth of 600 to 1,000 m. In addition, temperature and salinity changes will be used to detect warm and cold water rings (eddies) as well as fresh water input. Dynamic height, as an indicator of geostrophic flow, and ADCP will be employed to detect general circulation patterns, including eddies. Chlorophyll a concentration will be used as a proxy for potential primary productivity. Standard hydrographic techniques will be used to measure these parameters.

5.2 RESULTS THUS FAR

5.2.1 Spring 1996 *Oregon II* Cruise

During Legs 1 and 2 at ichthyoplankton stations (located every 30 minutes of latitude and longitude) (see Chapter 2), vertical conductivity-temperature-depth (CTD) profiles were made to a depth of 200 m with a Seabird SBE 25-03 Sealogger CTD equipped with a fluorometer (Figures 5.1-2). Water samples were taken once per day at the surface, mid-depth and maximum depth for chlorophyll and salinity calibration. A continuous flow thermo-salinograph and fluorometer recorded the surface temperature, salinity and fluorescence 24 hr/day and data were downloaded to data file every 60 seconds. Expendable bathymetric probes (XBTs) were launched in the event of a CTD failure.

For Leg 3 (Figure 5.3), CTD casts to 500 m or maximum depth were made at the beginning and end of each transect line. Four CTD casts were made to 850 m, at the seaward ends of the 2nd, 5th, 7th, and 9th lines. For the longer transect lines, CTD casts were made at the one-third and two-thirds points of the line distance, and for the shorter lines, in the middle of the line. Water samples were taken once per day at the surface, mid-depth and maximum depth for chlorophyll and salinity calibration. XBTs were deployed every 18.5 km (10 NM) beginning at and seaward of the 100 m isobath. So that CTD salinity could be splined to XBT temperature profiles, three CTD casts were made to 850 m in the western, central, and eastern part of the survey area.

Contour maps of sea surface temperature and depth of the 15° isotherm have been produced from the Leg 3 XBT data (Figures 5.4-5). Dynamic height has also been computed for the Leg 3 XBT data, and geostrophic transport has been computed between station pairs and archived at the Data Management Office in Galveston. CCAR has provided Topex satellite altimetry maps of Sea Surface Height (SSH) for the Leg 3 field area (e.g., Figure 5.6), and Bob Leben and Doug Biggs are currently working on comparing these remotely-sensed SSH fields with the Leg 3 "seatruth" dynamic height. Louisiana State University has provided MCSST imagery of sea surface temperature for the Leg 3 field area, for two clear-sky periods on 5 June (1914Z, NOAA-14) (Figure 5.7) and on 6 June (0038Z, NOAA-12) (Figure 5.8). These remotely-sensed sea

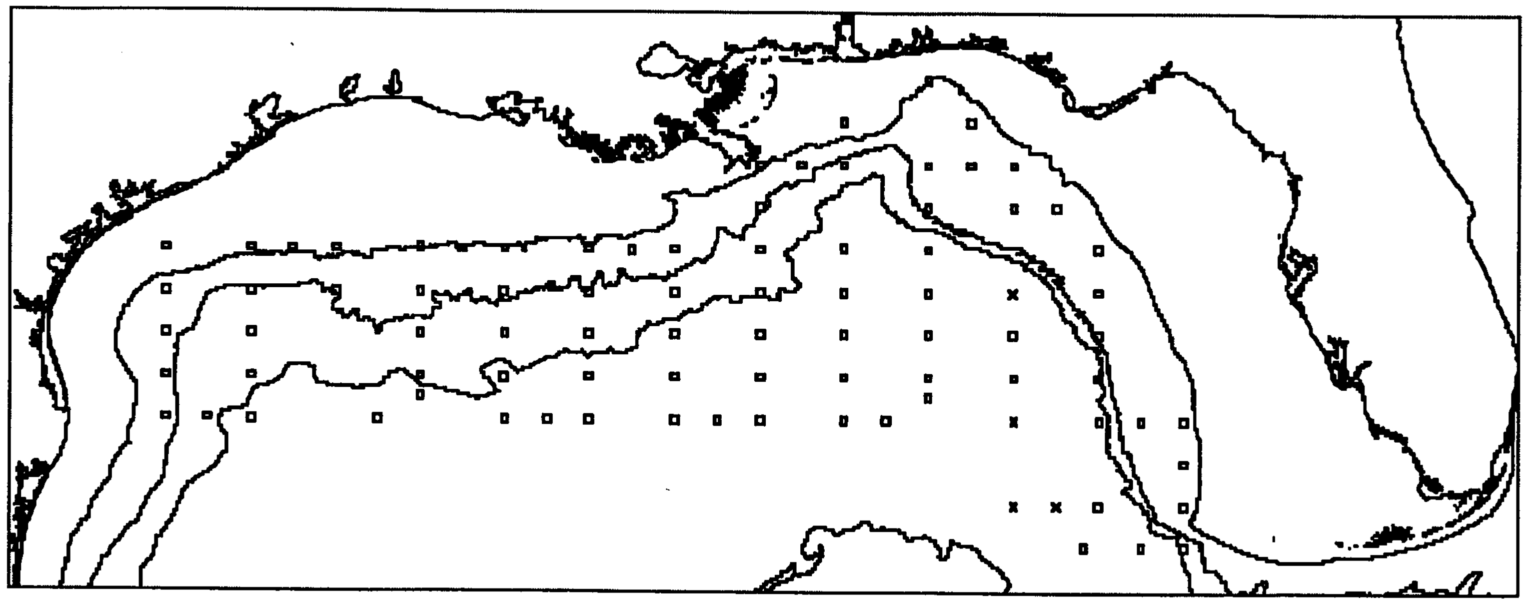


Figure 5.1. Locations of CTD stations (square, n = 84) and XBT stations (x, n = 4) from NOAA Ship *Oregon II* Cruise 220 Leg 1 (17 April-04 May 1996). The 100 m, 1000 m and 2000 m isobaths are shown.

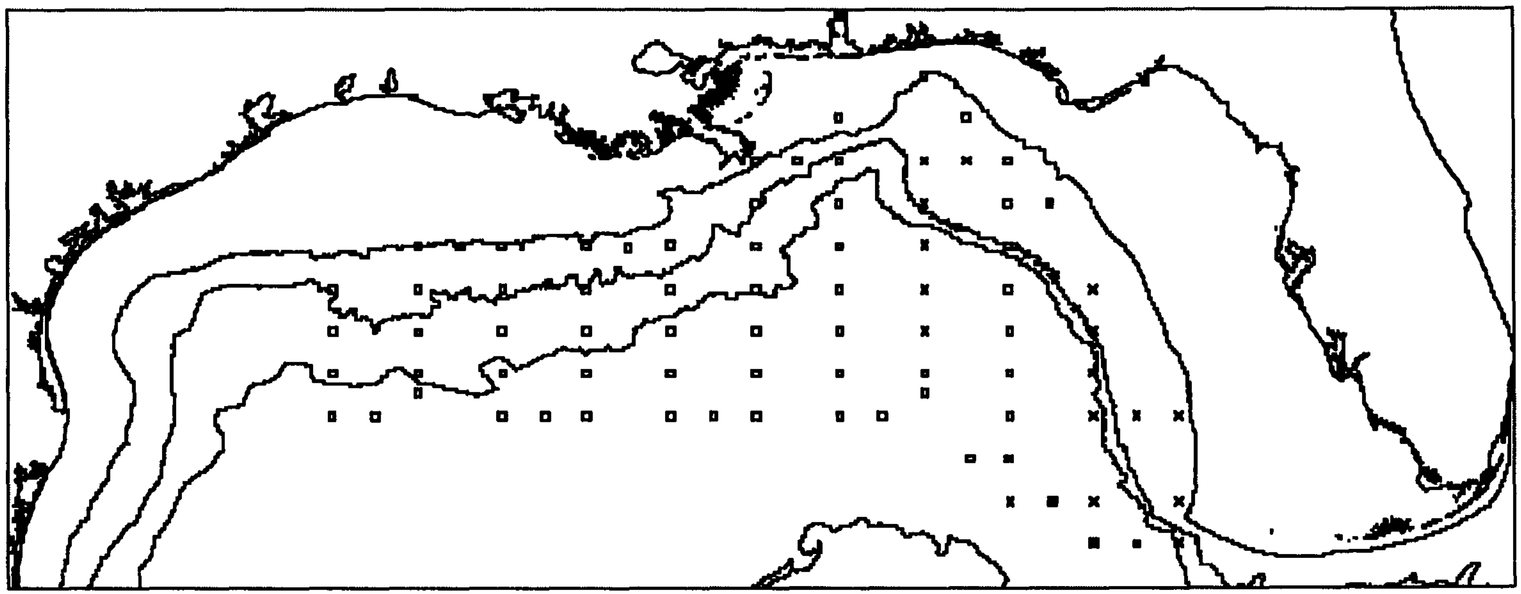


Figure 5.2. Locations of CTD stations (square, n = 62) and XBT stations (x, n = 23) from NOAA Ship *Oregon II* Cruise 220 Leg 2 (07-26 May 1996). The 100 m, 1000 m and 2000 m isobaths are shown.

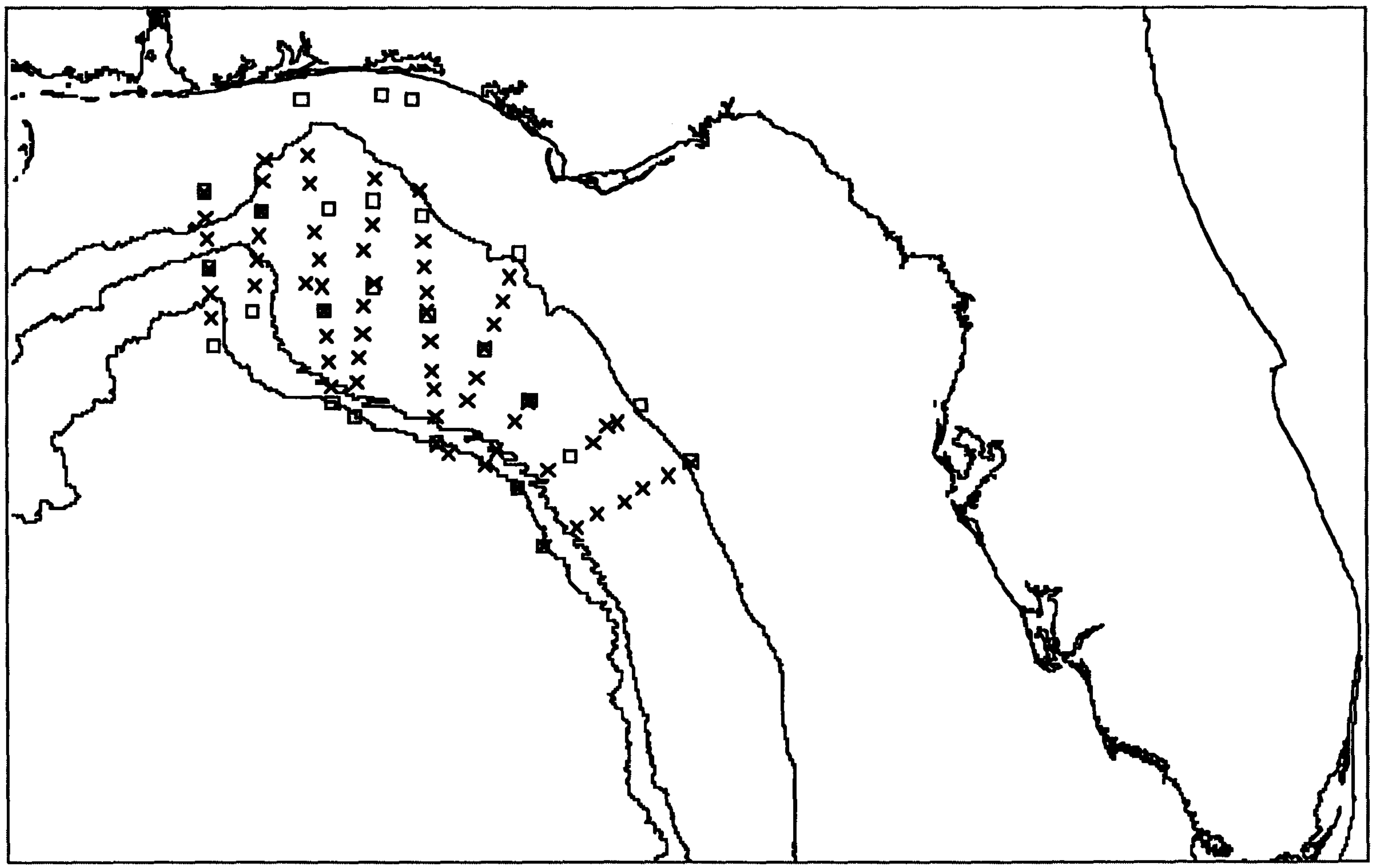


Figure 5.3. Locations of CTD stations (square, n = 26) and XBT stations (x, n = 65) from NOAA Ship *Oregon II* Cruise 220 Leg 3 (29 May-09 June 1996). The 100 m, 1000 m and 2000 m isobaths are shown.

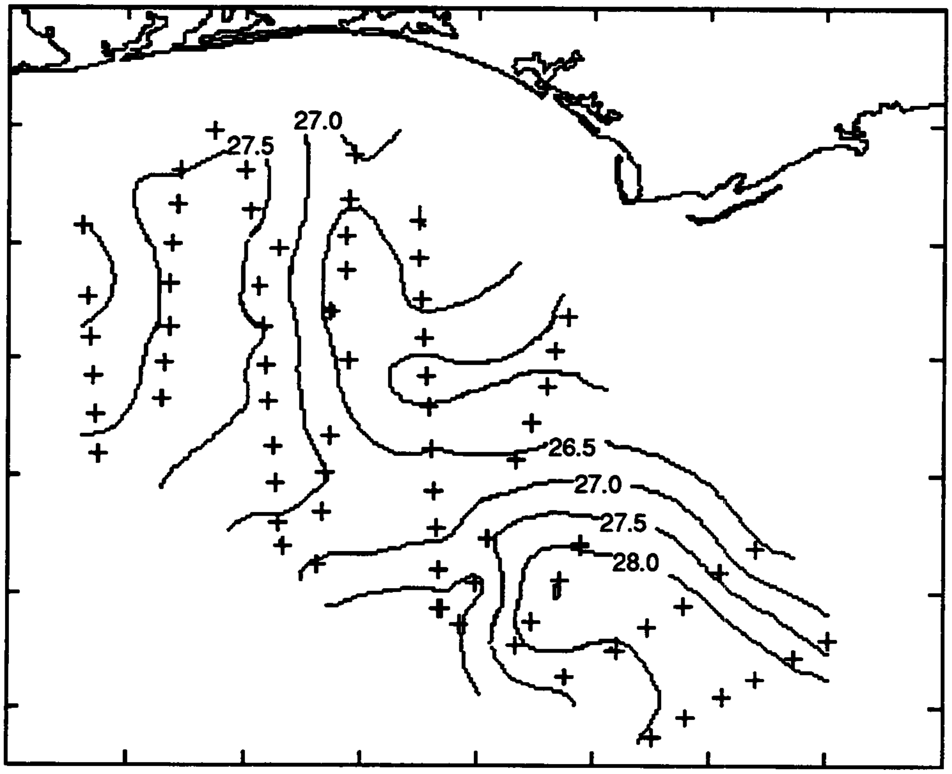


Figure 5.4. Sea surface temperature contours in the Eastern Planning Area, from the Spring 1996 Oregon II cruise. Data are from XBTs (stations shown as pluses).

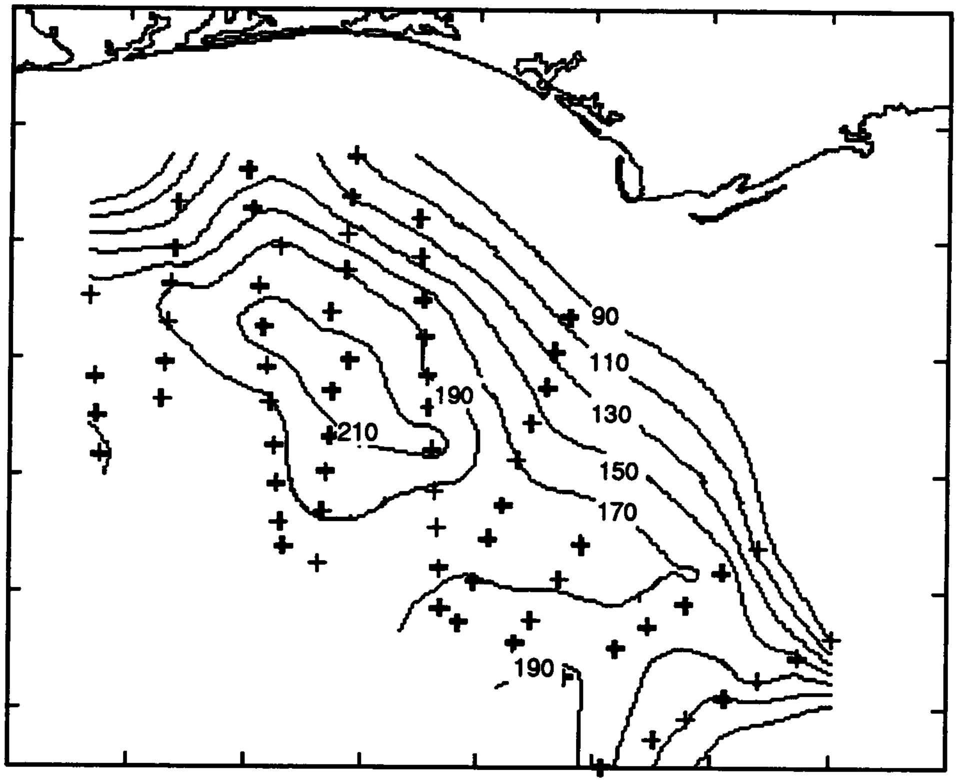


Figure 5.5. Depth of the 15 °C isotherm in the Eastern Planning Area, from the Spring 1996 *Oregon II* cruise. Data are from XBTs (stations shown as pluses).

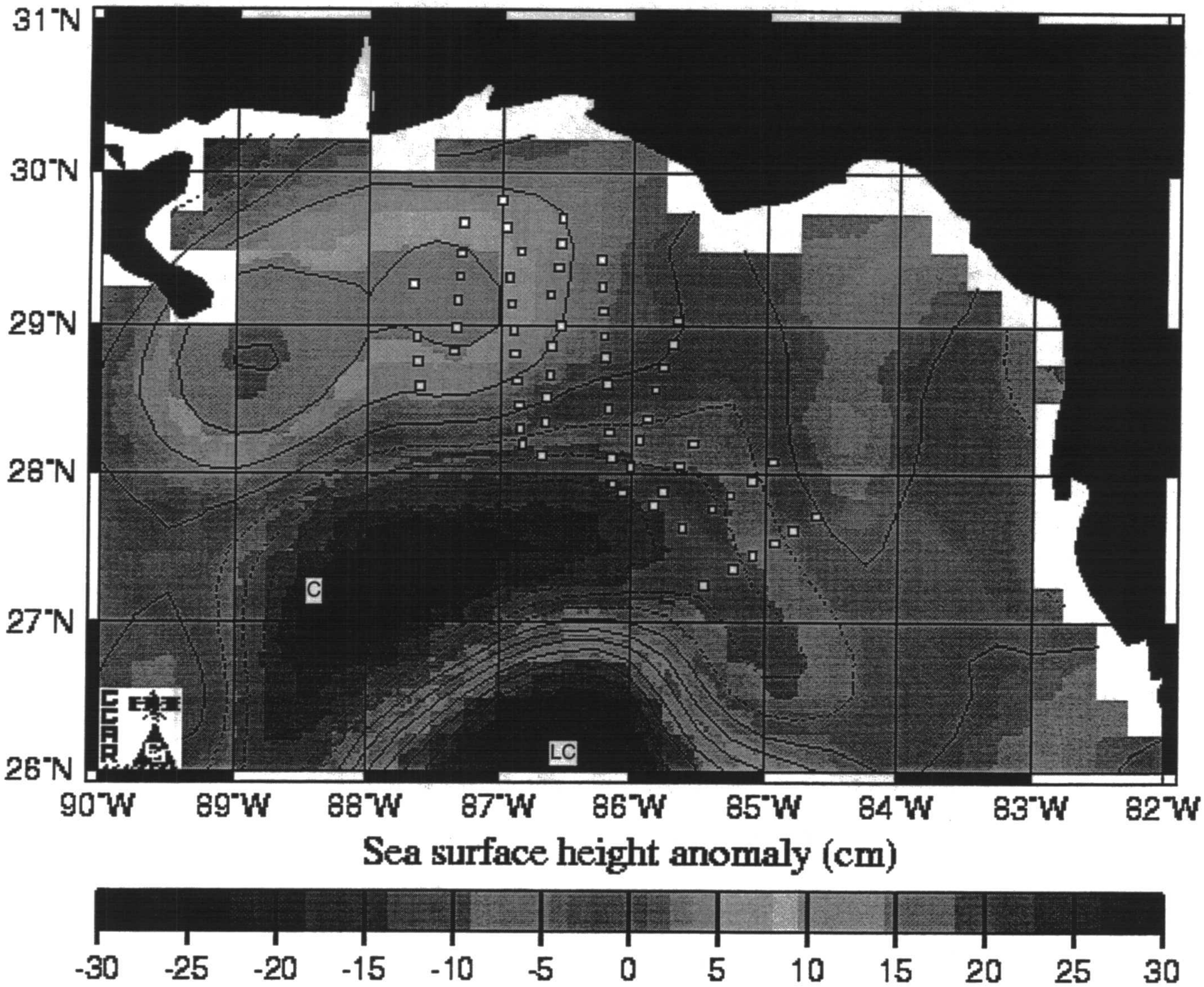
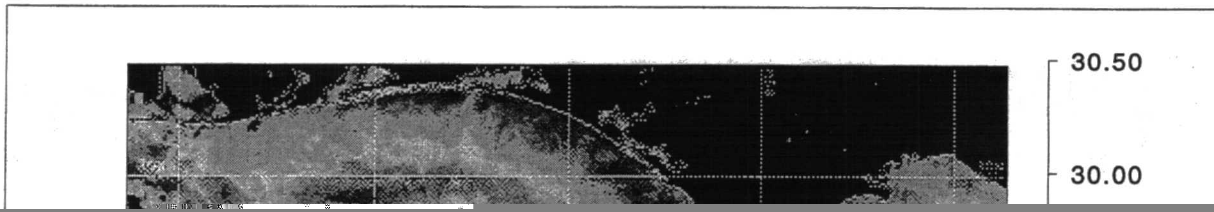


Figure 5.6. Oregon II Spring 1996 Leg 3 hydrographic stations overlay TOPEX/ERS-2 satellite altimetry (a 35 day average centered on 6 June 1996). Lables: C = cold core eddy "C", LC = Loop Current.


30.50
30.00

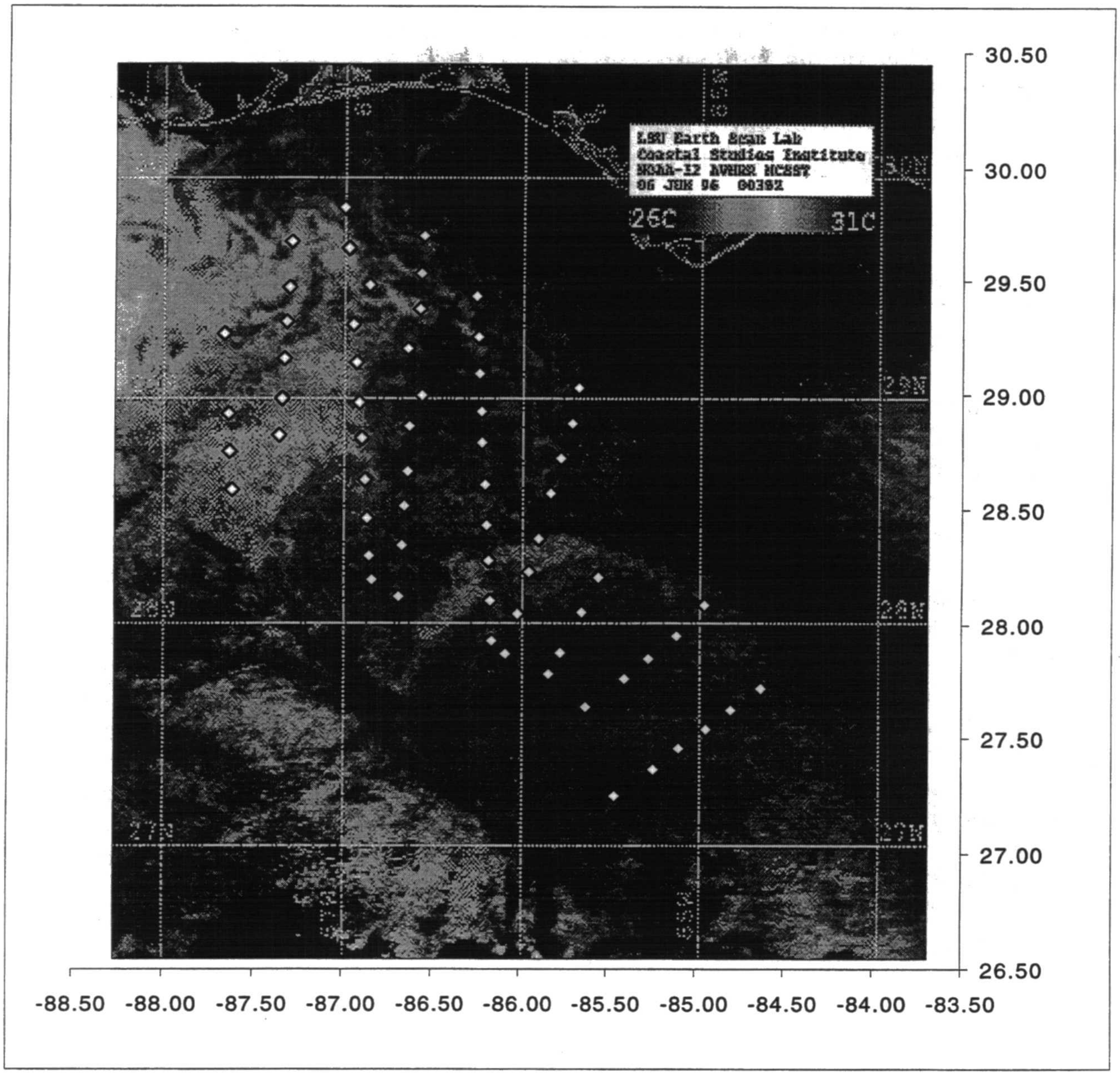


Figure 5.8. MCSST imagery of sea surface temperature for the Leg 3 field area (6 June 1996 0038Z, NOAA-12). Diamonds mark hydorgraphic stations. Image courtesy of Coastal Studies Institute, Louisianna State University.

surface temperature maps agree very well with Leg 3 "seatruth" SST and allow the along-track Leg 3 SST data to be seen in the context of regional mesoscale detail. For example, both remotely-sensed SST images show that a cyclonic eddy in the southern part of the Leg 3 field area was apparently interacting with the Loop Current to the South. They show a warm water filament of Loop Current origin being entrained cyclonically into the eastern and northern margin of the cyclone.

5.2.2 Ship-of-Opportunity

Concurrent with Leg 3 fieldwork aboard *Oregon II*, R/V *Gyre* and USTS *Texas Clipper II* dropped some 3 dozen XBTs in the western Gulf of Mexico as these two ships surveyed the remnants of Loop Current Eddy A (Figure 5.9). This warm-core ring, which had separated from the Loop Current in September 1995, had drifted slowly WSW since then and at eddy age 9 months had reached the western margin of the Gulf. The two-ship survey showed that this aging warm-core eddy was interacting with what remained of another, older warm core eddy in this "eddy graveyard" at the western margin of the Gulf. The XBT data from both ships have been shared with the GulfCet II Program as Ship-of-Opportunity cruises. Dynamic heights have been calculated for each of the XBT stations and are being used by Bob Leben as seatruth for ongoing attempts to enhance the forecasting capability of near real-time altimetry SSH mapping. Dr. Leben is experimenting with decorrelation time scales ranging from 6-17 days to determine how short a temporal average he can use to produce SSH maps from tandem T/P and ERS-2 data. For example, the present temporal average for mapping with a spatial resolution of 1/4 degree is 35 days. However, so that we may locate epicenters of warm-core eddies, cyclones, and other features whose geographic locations change on a time-scale of days-weeks during our upcoming October 1996 *Gyre* fieldwork, we seek to nowcast using data averaged over length scales of days-weeks, rather than weeks-months. Dr. Leben's determination of such decorrelation length scales is in progress.

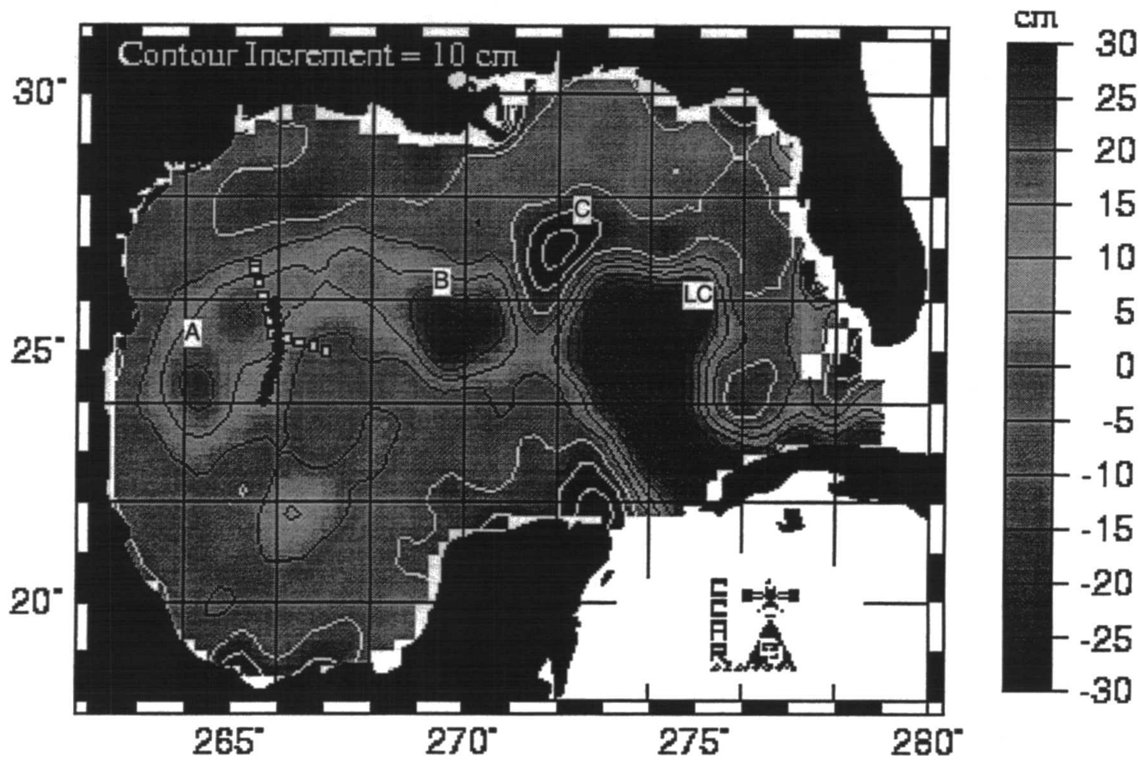


Figure 5.9. *Texas Clipper II* and *Gyre* Ship-of-Opportunity hydrographic stations overlay TOPEX/ERS-2 satellite altimetry (sea surface height anomaly plus model mean) (a 35 day average centered on 6 June 1996). Lables: A = warm core eddy "A", B = warm core eddy "B", C = cold core eddy "C", LC = Loop Current.

VI. THE GEOGRAPHICAL INFORMATION SYSTEM LABORATORY

6.1 OVERVIEW

This section describes the development and implementation of the Geographical Information System (GIS)/Computer modeling teaching laboratory at Texas A&M University, Galveston. Expenses for readying the lab have been cost-shared by Texas A&M University. Assembly of the lab began in January 1996. Equipment has been purchased and is being installed. The lab has been operational since April 1996.

The GIS lab will be an important part of the GulfCet Program's analytical capabilities. These facilities will be integral to realizing the Program's objective of identifying associations among cetacean abundance and distribution, and environmental features, such as sea surface temperature, ocean depth, warm-core and cold-core eddies, bottom topography, and spatial and temporal variations in regional food stocks of zooplankton and micronekton.

An important objective of the lab is to provide a teaching facility. Toward this end, the lab is structured around one central file/application server with seven workstations. This structure minimizes file distribution and system administration time and maximizes the accessibility of specialty software and file storage/backup capabilities. The facility was designed economically; it utilizes existing, slower equipment for jobs in which processing speed is not critical, such a print serving and map digitizing. New, faster computers are put to use as the workstations.

6.2 HARDWARE AND SOFTWARE COMPONENTS

Central file/application server. The server, the heart of the lab, is a 200 MHz Pentium Pro™ CPU running the Windows NT™ operating system, and its peripheral devices will provide the capacity to backup and manage the very large data files inevitable with graphical and database intensive GIS work. The system is configured to handle the demand of several users simultaneously.

Peripheral devices and specialty software on the server will be accessible from all workstations, eliminating the need to purchase multiple copies of these items. The peripheral devices include 20 GB of hard disk space, a CD-ROM drive, a CD-ROM writer, and a 4 GB tape streamer.

Workstations and digitizer. Five 133 MHz Pentium™ CPUs run MapIX™ GIS software in a Windows 95™ environment. Each system has 16 MB of RAM, a 1.2 GB hard disk, a CD-ROM drive, and a 17" monitors with graphics accelerator card. Two of the workstations (existing, upgraded computers) are configured to operate the map digitizer, and one the full page color scanner.

Print server and printers. One of the largest consumers of system resources, especially when large graphic files are involved, is printing. A computer (an existing Intel 80486™ CPU upgraded to a Pentium™) is dedicated to serving the three printers, removing the resource drain from the file server and workstations.

The lab's existing color map plotter has been augmented with two additional printers: one color inkjet and one laser writer.

Networking. The servers, workstations, and printers constitute a self-contained network with its own hub, independent of the overall TAMUG network, but in communication with it. Should the TAMUG network experience problems, work in the GIS lab will remain unaffected.

Uninterruptable power supply (UPS). All components in the facility are plugged into UPSs to protect against damage caused by brownouts and blackouts, allowing the systems to safely be left running continuously. Furthermore, continuous running reduces wear on hard disks caused by start-up and shut-down.

VII. LITERATURE CITED

Biggs, D.C. and F.E. Müller-Karger. 1994. Ship and satellite observations of chlorophyll stocks in interacting cyclone-anticyclone eddy pairs in the western Gulf of Mexico. J. Geophys. Res., 99:7371-7384.

Biggs, D.C., R.A. Zimmerman, R. Gasca, E. Suárez-Morales, I. Castellanos, and R.R. Leben. In prep. ADCP measurements of the distribution and abundance of plankton in a Cold-Core Ring in the Gulf of Mexico. Submitted 1/96 to Fish. Bull.; currently in revision to address reviewers' comments.

Buckland, S.T. 1985. Perpendicular distance models for line transect sampling. Biometrics 41:177-195.

Buckland, S.T. 1988 Programs for the implementation of the hazard-rate and Hermite polynomial line transect methods. Scottish Agricultural Statistics Service, Edinburgh, Scotland. 16 pp.

Buckland, S.T., D.R. Anderson, K.P. Burnham, and J.L. Laake. 1993. Distance Sampling: Estimating Abundance of Biological Populations. Chapman and Hall, London, 446 pp.

Burnham, K. P., D.R. Anderson, and J.L. Laake. 1980. Estimation of density from line transect sampling of biological populations. Wildlife Monographs 72:1-202.

Clarke, M.R. 1962. Stomach contents of a sperm whale caught off Madeira in 1959. Norsk Hvalfangst-Tidende, No. 5:173-191.

Clarke, M.R. 1977. Beaks, nets and numbers. Symp. Zool. Soc. Lond., No. 38:89-126.

Clarke, M.R. and N. MacLeod. 1974. Cephalopod remains from a sperm whale caught off Vigo, Spain. J. Mar. Biol. Ass. U.K., 54:959-968.

Clarke, M.R. and N. MacLeod. 1976. Cephalopod remains from sperm whales caught off Iceland. J. Mar. Biol. Ass. U.K., 56:733-749.

Clarke, M.R. and N. MacLeod. 1982. Cephalopod remains from stomachs of sperm whales caught in the Tasman Sea. Mem. Nat. Mus. Vict., 43:25-42.

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 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. 357 pp.

Drummer, T.D. and L.L. McDonald. 1987. Size bias in line transect sampling. Biometrics 43:13-21.

Evans, W.E. 1966. Vocalization among marine mammals. Pp. 159-186 *in* W.N. Tavolga, ed. Proceedings of the Second Conference on Marine Bio-acoustics. American Museum of Natural History, New York.

Fargion, G.S., D.C. Biggs, and P. Hamilton. 1994a. Dynamic topography of eddies U, V, and W in 1992-93 from GulfCet, aircraft, and Ship-Of-Opportunity surveys. *In* Proceedings: Thirteenth Annual Gulf of Mexico Information Transfer Meeting, December 1993. U.S. Dept. of the Interior. OCS Study MMS 94-0061, 399-408 pp.

Fargion, G.S., D.C. Biggs, P. Hamilton, R. Leben, L. Rouse, and N. Walker. 1994b. Ship, aircraft, and satellite observations of the Loop Current Eddies V and X and their interaction with the continental margin of the Northern Gulf of Mexico. EOS 75:212.

Fristrup, K.M. and W.A. Watkins 1992. Characterizing acoustic features of marine animal sounds. Technical Report, Woods Hole Oceanographic Institution, Woods Hole, MA 02543. 75 pp.

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. FWS/OBS-82/65. 455 pp.

Griffiths, G. and J.I. Diaz. 1995. Comparison of acoustic backscatter measurements from a ship-mounted ADCP and an EK500 scientific echosounder. P. 86 *in* Abstracts of the ICES International Symposium on Fisheries and Plankton Acoustics, Aberdeen, Scotland.

Hamilton, P. 1992. Lower continental slope cyclonic eddies in the central Gulf of Mexico. J. Geophys. Res., 97:2185-2200.

Hansen, L.J., K.D. Mullin, T.A. Jefferson, and G.P. Scott. 1996. Visual surveys aboard ships and aircraft. Pp. 55-132 *in* R.W. Davis and G.S. Fargion, eds. 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 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.

Holt, R.S. and S.N. Sexton. 1990. Monitoring trends in dolphin abundance in the eastern tropical Pacific using research vessel over a long sampling period: Analyses of the 1986 data, the first year. U.S. Fish. Bull. 88:105-111.

Jefferson, T.A., S. Leatherwood, L.K.M. Shoda, and R.L. Pitman. 1992. Marine mammals of the Gulf of Mexico: A field guide for aerial and shipboard observers. Texas A&M University Printing Center, College Station. 92 pp.

Laake, J.L., S.T. Buckland, D.R. Anderson, and K.P. Burnham. 1993. DISTANCE users guide version 2.0. Colorado Cooperative Fish and Wildlife Unit, Colorado State University. Fort Collins, CO. 72 pp.

Leatherwood, S., and R.R. Reeves. 1990. The bottlenose dolphin. Academic Press, San Diego, CA. 653 pp.

Leatherwood, S., T.A. Jefferson, J.C. Norris, W.E. Stevens, and L. Hansen, 1993. Occurrence and sounds of Fraser's dolphins (*Lagenodelphis hosei*) in the Gulf of Mexico, with a summary of Atlantic records. Texas Journal of Science., 45:301-303.

Lyons M.L.G., P.E. Smith. 1995. Zooplankton patchiness as estimated by oblique plankton net tows and ADCP backscattered return. P. 99 *in* Abstracts of the ICES International Symposium on Fisheries and Plankton Acoustics, Aberdeen, Scotland.

McLachlan, G.J, 1992. Discriminant Analysis and Statistical Pattern Recognition. John Wiley and Sons, New York. 526 pp.

Mullin, K., W. Hoggard, C. Roden, R. Lohoefener, C. Rogers, and B. Taggart. 1991. Cetaceans on the upper continental slope in the north-central Gulf of Mexico. OCS Study MMS 91-0027. U.S. Dept Of The Interior, Minerals Mgmt. Service, Gulf Of Mexico OCS Regional Office, New Orleans, La. 108 pp.

Murphy D.J., D.C. Biggs, M.L. Cooke. 1992. Mounting and calibrating an acoustic Doppler current profiler. MTS Journal, 26:34-38.

Nakamura, Y. 1991. Tracking of the mature female of flying squid, *Ommastrephes bartrami*, by an ultrasonic transmitter. Bull. Hokkaido Natl. Fish. Res. Inst., 55: 205-207.

Norris, J.C., W.E. Evans, R. Benson, and T.D. Sparks. 1996a. Acoustic surveys. Pp. 133-187 *in* R.W. Davis and G.S. Fargion, eds. 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 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.

Norris, J.C., W.E. Evans, S.O. Collier, S.K. Lynn, and R.W. Davis. 1996b. Final Report: Pre-contract costs award to Texas A&M University under National Biological Service Request for Proposal 1445-ORFP-95-005. Unpublished contract report, GulfCet Data Management Office, Texas A&M Univeristy at Galveston. 9 pp.

Okutani, T. and Y. Satake. 1978. Squids in the diet of 38 sperm whales caught in the Pacific waters off northeastern Honshu, Japan, February 1977. Bull. Tokai Reg. Fish. Res. Lab., 93:13-27.

Schmidly, D.J. 1981. Marine mammals of the southeastern United States coast and the Gulf of Mexico. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. FWS/OBS-80/41. 165 pp.

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. Unpubl. report. 70 pp.

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

Steiner, W. 1981. Species-specific differences in pure tonal whistle vocalizations of five north Atlantic dolphin species. Behavioral Ecology and Sociobiology, 9:241-246.

Thomas, J.A., S.R. Fisher, L.M. Ferm, and R.S. Holt. 1986. Acoustic detection of cetaceans using a towed array of hydrophones. Rep. Int. Whal. Comm., Spec. Iss. 8:139-148.

Walker, N.D., G.S. Fargion, L.J. Rouse, and D.C. Biggs. 1994. The Great Flood of Summer 1993: Mississippi River discharge studied. EOS 75: 414-415.

Wang Ding. 1993. Dolphin whistles: Comparison between populations and species. Ph.D. dissertation, Institute of Hydrobiology, The Chinese Academy of Sciences. Wuhan, P.R. China. 247 pp.

Wang Ding, B. Würsig, and W.E. Evans. 1995. Whistles of bottlenose dolphins: comparisons among populations. Aquatic Mammals 21:65-77.

Wiebe, P.H., K.H. Burt, S.H. Boyd and A.W. Morton, 1976. A multiple opening/closing net and environmental sampling system for sampling zooplankton. J. Mar. Res., 34:313-326.

Wiebe, P.H., T.K. Stanton, C.H. Greene, G. Lough, S. Kaartvedt, J.J. Dawson, N. Copley. 1995. Solving the forward problem by complex zooplankton assemblages and implications for solving the inverse problem. P. 49 *in* Abstracts of the ICES International Symposium on Fisheries and Plankton Acoustics, Aberdeen, Scotland.

Würsig, B., S.K. Lynn, and K.D. Mullin. 1996. Behavior of cetaceans relative to survey vessels. Pp. 189-205 *in* R.W. Davis and G.S. Fargion, eds. 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 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.

Würsig, B., S. K. Lynn, T. A. Jefferson, and K. D. Mullin. Submitted. Behavior of cetaceans in the northern Gulf of Mexico relative to survey ships and aircraft. Submitted to U.S. Fish. Bull.

Zimmerman, R.A. 1993. Bioacoustic surveys of planktonic sound scatterers and their diel and seasonal variability in the northwest Gulf of Mexico. M.Sc. thesis, Texas A&M University, College Station. 216 pp.

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 **Minerals Revenue Management** 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.