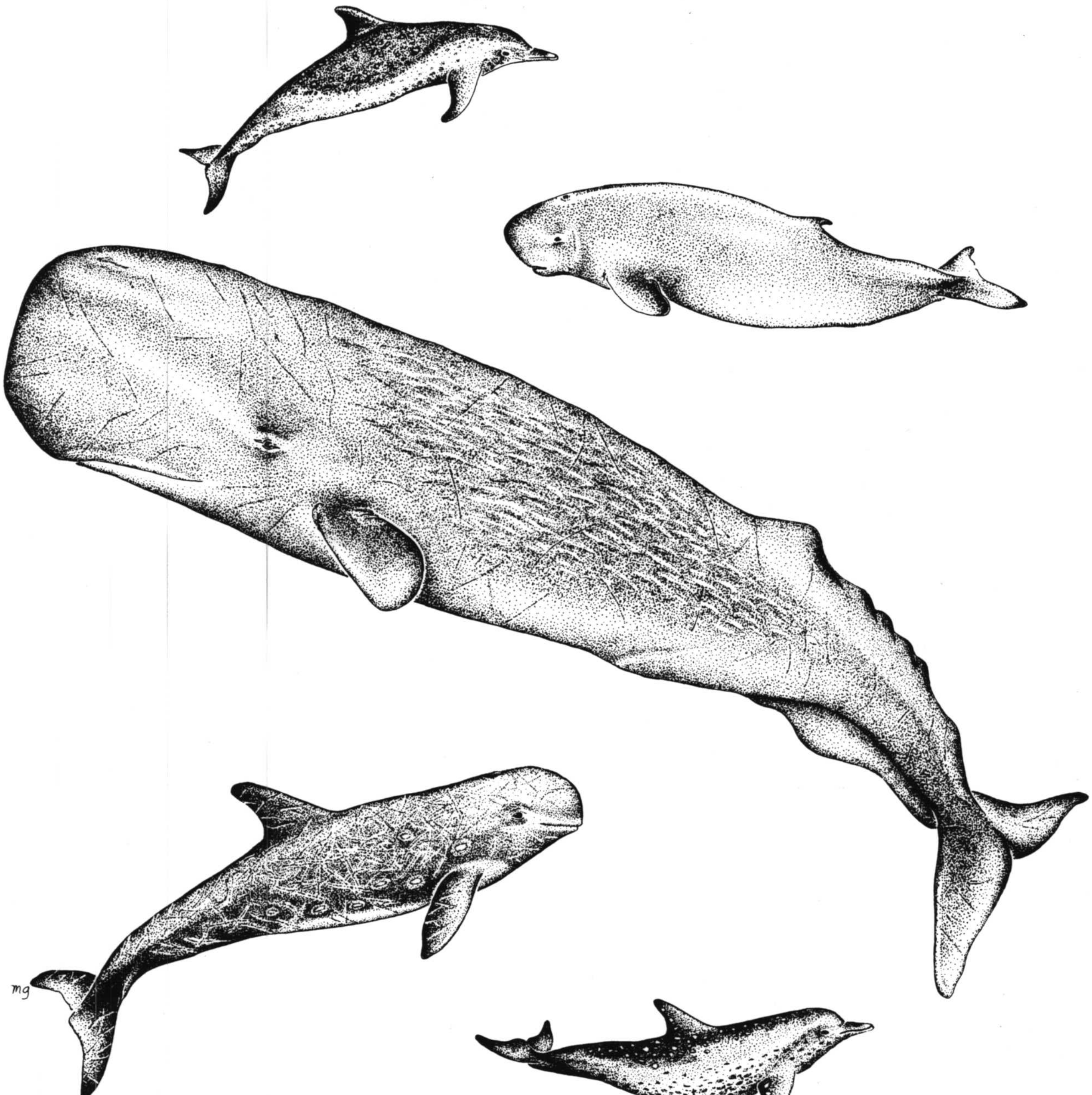
OCS Study
MMS 91-0027

Cetaceans on the Upper Continental Slope in the North-Central Gulf of Mexico



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

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Cetaceans on the Upper Continental Slope in the North-Central Gulf of Mexico

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ABSTRACT

At least 29 species of cetaceans occur or have occurred in the Gulf of Mexico (Gulf) including five species listed as endangered under the provisions of the Endangered Species Act. All cetaceans in U.S. waters are protected by the Marine Mammal Protection Act of 1972. Except for data from strandings, opportunistic sightings and limited aerial surveys, very little is known about cetaceans in the Gulf beyond the continental shelf. The continental shelf (<180 m deep) in the U.S. Gulf has been well studied compared to the deep waters (>180 m) and the bottlenose dolphin has been found to be the only species which commonly inhabits most shelf waters. Seaward of the shelf, water depths increase rapidly and the cetacean community becomes more diverse.

Minerals development has occurred widely in U.S. Gulf waters on the continental shelf west of Mobile Bay, Alabama (over 4,500 oil and gas platforms). Plans for development of the continental slope and central Gulf waters are in place and some exploratory activities have already occurred in these waters. Because of their protected status, information on cetacean diversity, abundance, and seasonality is needed in order to assess the potential impact of minerals development. In 1989, the Minerals Management Service and the National Marine Fisheries Service began cooperative aerial surveys of the upper continental slope with the following objectives: (1) determine the species diversity of cetaceans, (2) learn about the temporal and spatial distribution of each species and (3) estimate the relative abundance of each species.

From July 1989 through June 1990, we conducted aerial surveys each month (except December) in the north-central Gulf. The area studied was centered along the shelf break (180 m) south of the Mississippi River delta and extended from DeSoto Canyon (87°30.0' W) to west of the Mississippi Trough (90°30.0' W). The area studied was about 44 km wide. Water depths ranged from 18 to 2,000 m.

During the study, we sighted at least 15 species of cetaceans. Seven species accounted for 93% of the sightings of identified herds. These species included: Risso's dolphin (61 herd sightings), sperm whale (43), bottlenose dolphin (39), Atlantic spotted dolphin (36), dwarf/pygmy sperm whales (32), striped/spinner/Clymene dolphins (24) and pantropical spotted dolphin (23). Beaked whales (Cuvier's beaked whale and mesoplodonts) were sighted nine times and short-finned pilot whales five times. Herds of the following species were sighted once: melon-headed/pygmy killer whales, false killer whale, killer whale, rough-toothed dolphin, fin whale and sei/Bryde's whale.

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 species 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 the species sighted more than once were sighted throughout the length (east-west) of the study area.

For all cetacean herds sighted, and for each species, we tested the location data for preferences in intervals of water depth and sea floor topography. Cetaceans as a group did not prefer any water depth or topography interval on the upper continental slope. However, cetaceans that were sighted more than 20 times and could be identified to species were partitioned by these two factors. Bottlenose (<300 m) and Atlantic spotted dolphins (<600 m) preferred shallow waters over steep sea floor (a large relative change in water depth). Risso's dolphins preferred waters between 300-900 m over steep sea floor. Pantropical spotted dolphins (>900 m) and sperm whales (600-1,200 m) preferred deeper waters over less precipitous sea floor (a smaller relative change in water depth). Dwarf/pygmy sperm whales were found throughout the range of waters depths and topographies. Striped/spinner/Clymene dolphins may prefer deeper waters (>1,200 m) but showed no preference for topography. Of the species sighted more than once, beaked whales were sighted at the deepest mean water depth (966 m).

The overall density of cetaceans on the upper continental slope was 0.78 cetaceans/km^2. Because of large average herds sizes (88 dolphins/herd), striped/spinner/Clymene dolphins had the highest overall density (0.22 dolphins/km^2). Pantropical spotted dolphins averaged 72 dolphins/herd and had a density of 0.18 dolphins/km^2. Risso's dolphins, Atlantic spotted and bottlenose dolphins averaged much smaller herds (<30 dolphins/herd) and densities ranged from 0.05-0.08 dolphins/km^2. The physeterids only averaged about 2 whales/herd and the beaked whales only one, and their densities were much smaller (<0.006 whales/km^2).

Because of its extremely large size (about 20,000 kg), the sperm whale, an endangered species, is an important part of the cetacean community on the upper continental slope. Although they had a small overall density, we estimated that sperm whales made up between 21-44% of the total biomass of cetaceans. Sperm whales were found throughout the study area but were concentrated in the region near the Mississippi River delta.

On two days in June 1990, we conducted surveys in deeper waters south of the regular study area. During those two days, we sighted at least eight species of cetaceans including three that were sighted only one to five times during the regular surveys (false killer whale, melon-headed/pygmy killer whale and short-finned pilot whale). These species may be more numerous in the pelagic Gulf. Pantropical spotted dolphins were the most commonly sighted species. These surveys indicated that the Gulf, beyond the upper continental slope, is also an area of high cetacean diversity and abundance.

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ACKNOWLEDGEMENTS

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INTRODUCTION

Except for data from strandings (Schmidly 1981) and from aerial surveys by Fritts et al. (1983), virtually nothing is known about cetaceans in the Gulf of Mexico (Gulf) in waters beyond the continental shelf. The continental shelf in the U.S. Gulf has been relatively well studied. The bottlenose dolphin has been found to be the only species which commonly inhabits most shelf waters. The continental shelf in the Gulf extends out to the 180 m isobath. The shelf is very wide in most parts of the northern Gulf. It is up to 280 km wide off Florida and as wide as 200 km off Louisiana and Texas. Seaward of the 180 m isobath, on the continental slope, water depths increase rapidly and the cetacean community becomes more diverse.

At least 29 species of whales and dolphins occur or have occurred in the Gulf (Table 1). Schmidly (1981) presents a comprehensive review of strandings and sightings of marine mammals in the Gulf. He reviewed all available sources, published and unpublished, for information on strandings and sightings in the southeastern U.S. For each species, he presented information on the original source, the locations, dates and, in many cases, the numbers of animals involved in a stranding or sighting.

Minerals Management Service (MMS) supported aerial surveys conducted by the U.S. Fish and Wildlife Service for birds, turtles, and cetaceans in the Gulf from 1981 to 1982 (Fritts et al. 1983). These surveys sampled nearly 75,000 km^2 of the Gulf, including approximately 20,000 km^2 of waters deeper than 180 m offshore of western Louisiana and southern Texas (Fritts et al. 1983). In these two areas, they made 237 sightings of cetacean herds. Most of these sightings (205) were of bottlenose dolphin herds in waters less than 180 m. The 32 non-bottlenose dolphin sightings consisted of eight cetacean species. Twenty-two of these sightings were in waters deeper than 180 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, and 14% were dolphins of the genus Stenella. These surveys also included a Gulf study area (25,000 km^2) in which the entire area was less than 180 m deep offshore of southwestern Florida. Bottlenose dolphins were the most frequently sighted cetacean (322 herds) in this area, followed by dolphins of the genus Stenella (49 herds), and one sperm whale.

From 1983 to 1986, the National Marine Fisheries Service (NMFS) conducted a study designed to investigate the distribution, abundance, and diversity of cetaceans on the continental shelf in U.S. Gulf waters (Scott et al. 1989). In these waters, bottlenose dolphins were the most commonly sighted cetacean species and had an estimated abundance of 35,000-45,000 animals. Nine other species of cetaceans were also observed during these surveys, but they accounted for only 2.4% of the cetacean sightings (1,271 total sightings). During 1986 and 1987, the NMFS conducted aerial surveys

TABLE 1. CETACEANS OF THE GULF OF MEXICO.

Balaenidae	
Right whale	_Eubalaena glacialis_*
Balaenopteridae	
Blue whale	_Balaenoptera musculus_*
Fin whale	_B. physalus_*
Sei whale	_B. borealis_*
Bryde's whale	_B. edeni_
Minke whale	_B. acutorostrata_
Humpback whale	_Megaptera novaeangliae_*
Physeteridae	
Sperm whale	_Physeter macrocephalus_*
Pygmy sperm whale	_Kogia breviceps_
Dwarf sperm whale	_K. simus_
Ziphiidae	
Cuvier's beaked whale	_Ziphius cavirostris_
Blainville's beaked whale	_Mesoplodon densirostris_
Sowerby's beaked whale	_M. bidens_
Gervais' beaked whale	_M. europaeus_
Delphinidae	
Melon-headed whale	_Peponocephala electra_
Pygmy killer whale	_Feresa attenuata_
False killer whale	_Pseudorca crassidens_
Killer whale	_Orcinus orca_
Short-finned pilot whale	_Globicephala macrorhynchus_
Rough-toothed dolphin	_Steno bredanensis_
Fraser's dolphin	_Lagenodelphis hosei_
Common dolphin	_Delphinus delphis_
Bottlenose dolphin	_Tursiops truncatus_
Risso's dolphin	_Grampus griseus_
Atlantic spotted dolphin	_Stenella frontalis_
Pantropical spotted dolphin	_S. attenuata_
Striped dolphin	_S. coeruleoalba_
Spinner dolphin	_S. longirostris_
Clymene dolphin	_S. clymene_

* - endangered

designed to estimate the relative abundance of red drum (Sciaenops ocellatus) in the shallow U.S. Gulf waters. Sightings of cetaceans were also recorded during these surveys (Mullin et al. 1990). Bottlenose dolphin herds (1,042 sightings) made up over 99% of the cetacean herds sighted.

All marine mammals in U.S. waters are protected by the Marine Mammal Protection Act of 1972 (MMPA). The Act, except under special circumstances, places a moratorium on taking (killing, capturing, harassing or hunting) marine mammals in U.S. waters (Hofman 1989). The Act further specifies that marine mammal populations should be maintained at optimum sustainable levels in U.S. waters. Six species (Table 1) which occur or have occurred in the Gulf are also listed as endangered under the provisions of the Endangered Species Act of 1973 (ESA) as amended (FWS 1989). Section 7 of the ESA requires federal agencies to confer when the actions of one agency may impact or jeopardize a threatened or endangered species. The NMFS has jurisdiction over marine mammals in U.S. waters and it is their responsibility to see that the provisions of the MMPA and the ESA are carried out. The MMS oversees minerals development in U.S. waters. Therefore, the MMS consults with the NMFS prior to minerals development activities in the Gulf which may potentially impact marine mammals.

Minerals development has occurred widely in U.S. Gulf waters on the continental shelf west of Mobile, Alabama. In 1988, there were over 4,500 structures in the Gulf used for oil and gas production. Plans for development on the continental slope (>180 m) and in central Gulf waters in the western Gulf are in place and some exploratory activities have already occurred. Because of their protected status, before an area is developed, the first questions asked concern which cetacean species occur in the area, how many individuals are there and when do they occur. Except for the limited studies on slope waters conducted by Fritts et al. (1983), no studies have been carried out to answer these questions for Gulf waters beyond the continental shelf. Therefore, beginning July 1989 the MMS and the NMFS began cooperative aerial surveys of upper continental slope waters in the north-central Gulf. The primary objectives of the study were to (1) determine the species diversity of cetaceans, (2) learn about the temporal and spatial distribution of each species and (3) to estimate the relative abundance of each species.

METHODS

Study Areas

It has been demonstrated that areas of high sea floor relief may concentrate cetaceans (Hui 1979, Payne et al. 1986, Kenney and Winn 1986, Selzer and Payne 1988). The upper continental slope in the north-central Gulf is an area of high sea floor relief. From July through November 1989, we conducted a pilot study during which we surveyed four study areas along the upper continental slope in the north-central Gulf (Figure 1, Table 2).

Area 7 was over the steep escarpment south of the Mississippi River delta and covered part of the Upper Mississippi Fan. [Areas 1-6 were part of a sea turtle study on the continental shelf (Lohoefener et al. 1990a).] Area 8 covered most of the Mississippi Trough just west of the delta. Because of the large number of sperm whale sightings near the 900 m isobath during September in Area 7, Area 8 was shifted to the southeast in October and November to include the 900 m isobath to determine if this distribution of sperm whales continued beyond the delta area. Because sperm whales are listed as an endangered species, they were given special consideration in our study. Area 9 was over an area of very uneven bottom topography caused by the crests of salt domes. The dome crests were in the northwest and southwest portions of the area and rose up to 450 m from the surrounding bottom. After we completed work for a related study in August (Lohoefener et al. 1990a), additional fight time was available and Area 10 was added in September. Area 10 was selected to survey a steep escarpment of DeSoto Canyon south of the Alabama-Florida border.

The pilot study indicated that a wide variety of cetaceans were present along the continental slope and that aerial survey was an efficient method of studying them. A total of 171 herds of 10 species or species groups were sighted. In order to better define the distribution, relative abundance and seasonality of cetaceans in the north-central Gulf, the study was expanded and included the waters between, and most of the waters in, the original four study areas (Figure 1, Table 2). The northern boundary of the area surveyed was the 180 m isobath. The southern boundary was 44 km south of the 180 m isobath. For logistical reasons, this area was divided into seven study areas (B1-B7, Figure 1). These areas were surveyed from January 1990 through June 1990.

Because of an interest in cetaceans in deeper Gulf waters, after the completion of the regularly scheduled surveys in June 1990, two surveys were conducted over waters south of the study area. These surveys were conducted on 20 and 21 June 1990 (see Figure 7). These surveys are referred to as the "mid-Gulf surveys."

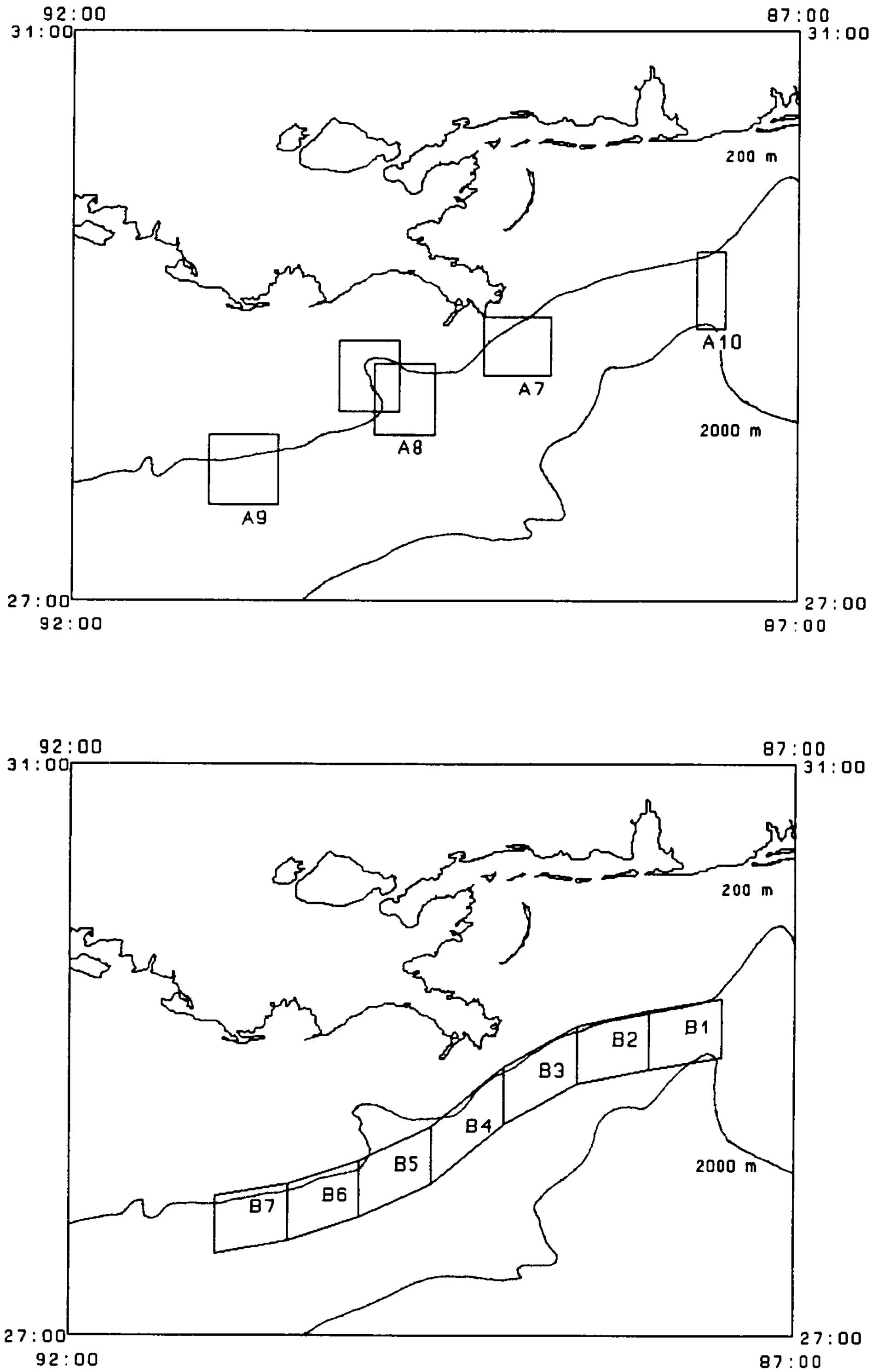


FIGURE 1. LOCATIONS OF THE STUDY AREAS IN THE NORTH-CENTRAL GULF.

TABLE 2. STUDY PERIOD, LOCATION, AREA AND WATER DEPTHS IN EACH STUDY AREA (* - 1 = July-November 1989, 2 = January-June 1990).

Area	Study Period*	Area (km²)	Range of Water Depths (m)	Transect Length (km)	Corners (latitude over longitude)			
					NE	SE	SW	NW
A7	1	2,099	18-1,317	46.3	29°00.0' 89°10.0'	28°35.0' 89°10.0'	28°35.0' 88°42.0'	29°00.0' 88°42.0'
A8a	1	2,255	29- 573	55.5	28°50.0' 89°45.0'	28°20.0' 89°45.0'	28°20.0' 90°10.0'	28°50.0' 90°10.0'
A8b	1	2,255	134- 966	55.5	28°40.0' 89°30.0'	28°10.0' 89°30.0'	28°10.0' 89°55.0'	28°40.0' 89°55.0'
A9	1	2,640	104-1,152	55.5	28°10.0' 90°35.0'	27°40.0' 90°35.0'	27°40.0' 91°04.0'	28°10.0' 91°04.0'
A10	1	1,180	66-2,003	59.2	29°27.0' 87°42.0'	28°55.0' 87°42.0'	28°55.0' 87°30.0'	29°27.0' 87°30.0'
B1	2	2,160	168-1,792	44.1	29°21.0' 87°30.0'	28°57.0' 87°30.0'	28°52.0' 88°00.0'	29°16.0' 88°00.0'
B2	2	2,160	139-1,710	44.1	29°16.0' 88°00.0'	28°52.0' 88°00.0'	28°46.0' 88°30.0'	29°10.0' 88°30.0'

TABLE 2. CONTINUED (* - 1 = July-November 1989, 2 = January-June 1990).

Area	Study Period*	Area (km^2)	Range of Water Depths (m)	Transect Length (km)	Corners (latitude over longitude) NE	SE	SW	NW
B3	2	2,160	163-1,070	44.4	29°10.0' 88°30.0'	28°46.0' 88°30.0'	28°29.0' 89°00.0'	28°53.0' 89°00.0'
B4	2	2,160	183-1,125	44.4	28°53.0' 89°00.0'	28°29.0' 89°00.0'	28°04.0' 89°30.0'	28°28.0' 89°30.0'
B5	2	2,160	230- 979	44.4	28°28.0' 89°30.0'	28°04.0' 89°30.0'	27°50.0' 90°00.0'	28°14.0' 90°00.0'
B6	2	2,160	152- 933	44.4	28°14.0' 90°00.0'	27°50.0' 90°00.0'	27°40.0' 90°30.0'	28°04.0' 90°30.0'
B7	2	2,160	176-1,098	44.4	28°04.0' 90°30.0'	27°40.0' 90°30.0'	27°35.0' 91°00.0'	27°59.0' 91°00.0'

Study Platform

The study platform was a DeHavilland (DHC-6) Twin-Otter aircraft maintained and operated by the NOAA Aircraft Operation Center, Miami, Florida. The Twin-Otter was flown by a NOAA pilot and copilot. The Twin-Otter is equipped with a large plexiglass bubble window on each side of the aircraft. Each bubble window gave an observer forward, lateral, rear, and downward visibility. Downward visibility was such that each observer could easily view an area on both sides of the transect line. The aircraft is equipped with an auxiliary fuel tank which allowed for extended flight time. The Twin-Otter is a highly maneuverable aircraft which can be flown slow and in tight circles which was invaluable for observing cetaceans. The Twin-Otter has a belly camera port and removable side window which also served as a camera port.

Sampling Methods

Sampling Design

The study was designed to survey Areas A7-A10 three times each month (July-November 1989) and Areas B1-B7 two times each month (January-June 1990). A 15-day survey window was available each month to complete the surveys. On a typical survey day two study areas were surveyed and the total flight time was usually 6.0-6.5 hours. (We were conducting surveys for a sea turtle study in one to two study areas on the continental shelf on each survey day.) Surveys were usually completed in 6-8 flight days. Windy weather was the greatest hindrance to conducting successful surveys. Surveys were only conducted when seas were a Beaufort 3 or less and visibility was good. Surveys were usually conducted from about 0900-1600 hours. The standard survey altitude was 229 m (750 ft). Rarely (<1%), low clouds required a survey altitude of 152 m (500 ft). The standard survey speed was 204 km/h (110 NM/hr).

To sample each study area, systematic transects from a single random starting location were used. Depending on the study area, the area was divided into 3, 4, or 5 equally-sized blocks. On each study day a random starting corner for each study area was selected. A random distance, to the nearest 0.01 minute, from that corner was then selected as the starting point for the first transect. Subsequent transects in the study area were the random distance from the edge of each block. Transect orientation was north-south. Three transects were surveyed per study day in Areas A8, A9 and A10, five in Area A7, and four in Areas B1-B7. Primarily because of logistics and later, our interest in sperm whales in Area 7, the study effort in each area was not equal (Table 3).

TABLE 3. SURVEY EFFORT IN EACH MONTH AND STUDY AREA.

Month	Days Surveyed	Study Area (effort in transect km) A7	A8	A9	A10	B1	B2	B3	B4	B5	B6	B7	TOTAL
1989													
July	6	934	440	394	-	-	-	-	-	-	-	-	1,768
August	6	677	447	489	-	-	-	-	-	-	-	-	1,613
September	7	956	396	412	176	-	-	-	-	-	-	-	1,940
October	7	634	499	0	356	-	-	-	-	-	-	-	1,489
November	9	920	167	164	535	-	-	-	-	-	-	-	1,786
December	(no survey)												
1990													
January	6	-	-	-	-	0	178	357	231	128	312	356	1,562
February	2	-	-	-	-	179	178	176	0	0	0	0	533
March	6	-	-	-	-	362	223	631	355	358	178	180	2,287
April	6	-	-	-	-	362	178	360	357	360	273	361	2,251
May	6	-	-	-	-	269	352	445	170	361	358	354	2,309
June	8	-	-	-	-	265	717	449	544	361	357	362	3,055
TOTAL		4,121	1,949	1,459	1,067	1,437	1,826	2,418	1,657	1,568	1,478	1,613	20,593

Data Collection

Three or four observers participated in each flight. Two observers, one on each side of the aircraft, observed the transect line and adjacent waters through the plexiglas bubbles. One observer was stationed at a microcomputer and entered observer supplied data via a data acquisition program written in BASIC. If onboard, the fourth observer was at a rest station. Observers rotated stations about every 30 minutes. Observers, pilots, and the computer operator communicated via an intercom system equipped with voice activated headsets. A super high resolution video camera was mounted in the belly port of the aircraft. While sea turtle study areas were surveyed, the camera continuously recorded the transect line and adjacent waters. For the cetacean surveys, it was usually turned off, however, as soon as cetaceans were sighted it was turned on to record all audio communications between observers. The recordings were used to supplement written notes concerning each sighting.

In addition to cetaceans, data on sea turtles, fish, human activity, and pollution were recorded. Data records were used to describe the transects and a number of variables were used to describe the environmental conditions (water color, turbidity, etc.) (see Appendix 1).

We divided each plexiglass bubble into seven sighting intervals which were 10° apart (0-10°, 11-20°, ... 61-70°) using a digital inclinometer and marked each interval on the bubble with a thin strip of tape. The sighting interval of each sighting was recorded. Sightings intervals corresponded to perpendicular distances from the transect line of 40, 83, 132, 192, 273, 397 and 629 m. Observers concentrated their sighting effort near the transect line and scanned periodically out to 70°. If a sighting cue beyond 70° was observed, they were ignored unless the observer was positive that it was a cetacean. These sightings were usually blowing or breaching sperm whales.

A II Morrow LORAN-C navigation receiver was directly interfaced to a Toshiba 1100+ laptop computer. Output from the receiver was constantly stored in one of the computer's storage buffers. The LORAN receiver output cycled at about 0.015 to 0.02 minutes of latitude and/or longitude. When a LORAN latitude and longitude position was recorded in the data base, the last latitude and longitude in the buffer was used. Therefore, these latitudes and longitudes should be within about 0.02 minutes of the aircraft's actual location. At the latitudes of our study areas, 0.01 minute of latitude or longitude should be about 16 to 19 m of actual distance.

The LORAN receiver monitored the quality of the signals it was receiving from the three LORAN stations. Poor quality signals could lead to an erroneous latitude and longitude. If any of the signals were of poor quality, a flag was placed in the data recorded to indicate that the recorded position might not be accurate. However, no flagged cetacean locations were recorded. [Three signal to noise ratios (SNRs) were used to monitor the reliability of the latitudes and longitudes. A poor quality signal occurred if the SNR was 64 or less.]

At the beginning of the study we tested the accuracy and precision of the reported LORAN locations by accessing the reported latitude and longitude of the aircraft as it flew over a specific point with a known latitude and longitude. The recorded position averaged within 200 m of the reported true location (se = 54.4).

When a cetacean herd was sighted, the belly video camera was turned on, the aircraft was diverted from the transect line and the herd was circled. Our primary objectives were to identify the species in the herd, document the sighting with still and video cameras, and make a reasonable estimate of herd size. Each observer usually performed one of these tasks. The identifying characteristics of each species, any associated species, and the response of the herd to the aircraft were noted.

Data Analyses

<u>Contour Index</u>

To determine if variations in sea floor topography affected the distribution of cetacean species on the continental slope, a contour index was used (see Hui 1979 or Selzer and Payne 1988). Each study area was divided into equal-area quadrants. A contour index (CI) was estimated for each quadrant as

$$CI = 100\frac{M-m}{M}$$

where M was the maximum depth and m was the minimum depth in the quadrant. The CI is a dimensionless number between 0.01 and 99.99 and represents the percent change in depth in the area sampled. Each quadrant was assigned to one of four CI intervals as follows: 20-39, 40-59, 60-79, 80-99. The CI interval of each sighting was determined. The survey effort in transect kilometers in each CI interval was estimated.

The null hypothesis was that each species was distributed at random with respect to CI intervals. The null hypothesis was tested for species or species groups sighted at least 20 times by comparing the observed distribution of sightings with respect to CI intervals to the expected distribution (based on level of effort) using the Chi-square test. When testing hypotheses, we used an alpha of 0.05 as the level of significance. The expected (E) number of sightings in each class (i) was estimated as

$$E_i = O_t \frac{L_i}{L_t}$$

where O_t was the total number of sightings of each species, L_i was the transect length in each CI interval and L_t was the total transect length.

Water Depth

The null hypothesis that cetaceans were randomly distributed with respect to water depth was tested for each species or species group sighted 20 or more times. Each study area was divided into nine equal-area parts and the average water depth in each part was estimated based on a random sample of 15 depths. Average water depths were divided into five intervals as follows: 0-300, 301-600, 601-900, 901-1,200 and > 1,200 m. The water depth interval was determined for each sighting. The amount of survey effort in transect kilometers was estimated for each water depth interval. The null hypothesis was tested by comparing the observed distribution of sightings with respect to water depth to the expected distribution using the Chi-square test. The expected number of sightings in each water depth interval was estimated in the same manner as the expected number for each CI interval.

For species or species groups sighted 20 or more times, the null hypothesis that water depths do not vary among species was tested with one-way analysis of variance (ANOVA). If the null hypothesis was rejected, Duncan's multiple range test was used to determine between which species differences in mean water depths occurred. These tests were made with the aid of the SAS computer program.

Plots

For each species or species group, the location of each sighting was plotted on maps of the study areas by season. Seasons consisted of winter (January-February), spring (March-May), summer (June-August) and fall (September-November).

Seasonal Herd Sizes and Water Depths

For each species or species group the mean herd size and the mean water depth were estimated for each season.

Sighting Rates

For each species or species group, as a measure of relative of abundance, we estimated the sighting rate of herds and the sighting rate of individual cetaceans for each study area and month. The sighting rate of herds was calculated as the number of herds per 100 km of transect effort for each month and for each study area. The sighting rate of individuals was estimated as the total number of whales or dolphins sighted per 100 km of transect effort for each month and for each study area.

Density Estimation

We used line transect methods (Burnham et al. 1980) to estimate the density of each species or species group for three time periods: (1) July-November 1989, (2) January-June 1990, (3) and both periods combined. For each time period, we estimated the herd density ($\hat{D}_h$) and its variance for each species as (Burnham et al. 1980:52)

$$\hat{D}_{hi}=\frac{n_i\hat{f}(0)}{2l_i}\,,\,\hat{D}_h=\frac{\sum l_i\hat{D}_{hi}}{\sum l_i}$$

$$v\hat{a}r(\hat{D}_h)=\frac{\sum l_i(\hat{D}_{hi}-\hat{D}_h)}{\sum l_i(R-1)}$$

where n_i was the number of herds sighted within 629 m of the transect line in a study area each day, l_i was the total number of transect meters surveyed in a study area each day and R was the total number of study areas surveyed during the time period (summations were made from i = 1, 2, 3, ...R). The parameter $\hat{f}(0)$ is the probability density function for sightings evaluated at zero perpendicular distance.

One way to estimate $\hat{f}(0)$ is to construct a sighting histogram using the number of sightings at increasing distance intervals from the transect line and to fit a model (probability density function) to the histogram. The value of the probability density function evaluated at the transect line is $\hat{f}(0)$. For each species, we constructed a sighting histogram by counting the total number of sightings in each of the seven perpendicular distance categories calculated from angle increments of 10° (i.e., 0-40, 41-83, 84-132, 133-192, 193-273, 274-397, 398-629 m). Burnham et al. (1980) recommended that sighting functions be based on a minimum of 40 sightings, but stated 60-80 sightings were preferable. The largest number of sightings for any single species or species group in our study was 61. We examined the sighting histograms for the seven species or species groups that were sighted more than 20 times but, except for sperm whales, we could see no pattern related to animal size or mean herd size. Because of the lack of pattern and because a sufficient number of sightings were not made for most species or species groups to estimate $\hat{f}(0)$, we pooled all non-sperm whale and non-baleen whale sightings (see below) to form an overall sighting histogram. To estimate $\hat{f}(0)$, a hazard-rate model (Buckland 1985, 1988) was fitted to the histogram. We selected the hazard-rate model for two reasons: (1) the number of parameters to be estimated in the model is fixed at two and therefore, there was no subjective decision making regarding the number of parameters on our part (In some models, such as the Fourier, a variable number of parameters can be used to improve the fit of the model to the data.), and (2) the model always has a shoulder near the transect line (distance zero). Using a hazard-rate model, we estimated $\hat{f}(0) = 0.00438$ (se = 0.00057). The model had an acceptable fit to the sighting histogram (Chi-square = 1.86, df = 5, $P < 0.05$, Figure 2).

Because there was a relatively large sample size for sperm whales (43 sightings) and the sighting histogram for sperm whales was relatively flat (Figure 3) compared to those of other species (i.e., the probability of sighting a sperm whale was apparently constant out to 629 m), we used a different procedure to estimate sperm whale density. Because of the flat shape of the sighting histogram, we used a strip transect procedure with the strip width equal to 629 m (i.e., $\hat{f}(0) = 1/629$ or 0.00158) to estimate the density of sperm whales and baleen whales. The shape of the histogram was probably due to the large size of sperm whales compared to the other species, their conspicuous blows and their breaching behavior. (We included baleen whales because their size is of the same magnitude as that of the sperm whale.)

The mean herd size of each species or species group was estimated as the arithmetic mean of herds sighted during 1989, 1990, and both years combined. The mean herd sizes may have been overestimated because larger herds may have had a higher probability of being sighted away from the transect line. Estimates of the density of individuals for each species ($\hat{D}_d$) were a product of the herd density and the mean herd size ($\bar{H}$) as $\hat{D}_d = \hat{D}_h\bar{H}$. The variance of this product was estimated as (Goodman 1960):

$$v\hat{a}r(\hat{D}_d) = \frac{\hat{D}_d^2 v\hat{a}r(H)}{n} + \bar{H}^2 v\hat{a}r(\hat{D}_h) - \frac{v\hat{a}r(\hat{D}_h)\, v\hat{a}r(H)}{n}$$

Our density estimates only apply to cetaceans at or near the surface (i.e., visible). The central assumption of line transect theory is that all herds on or very near the transect line are sighted (Burnham et al. 1980). Because cetaceans submerge to depths where they are not visible, some herds of every species on the transect line were certainly missed. Therefore, our density estimates underestimated the true density of cetaceans. Also,

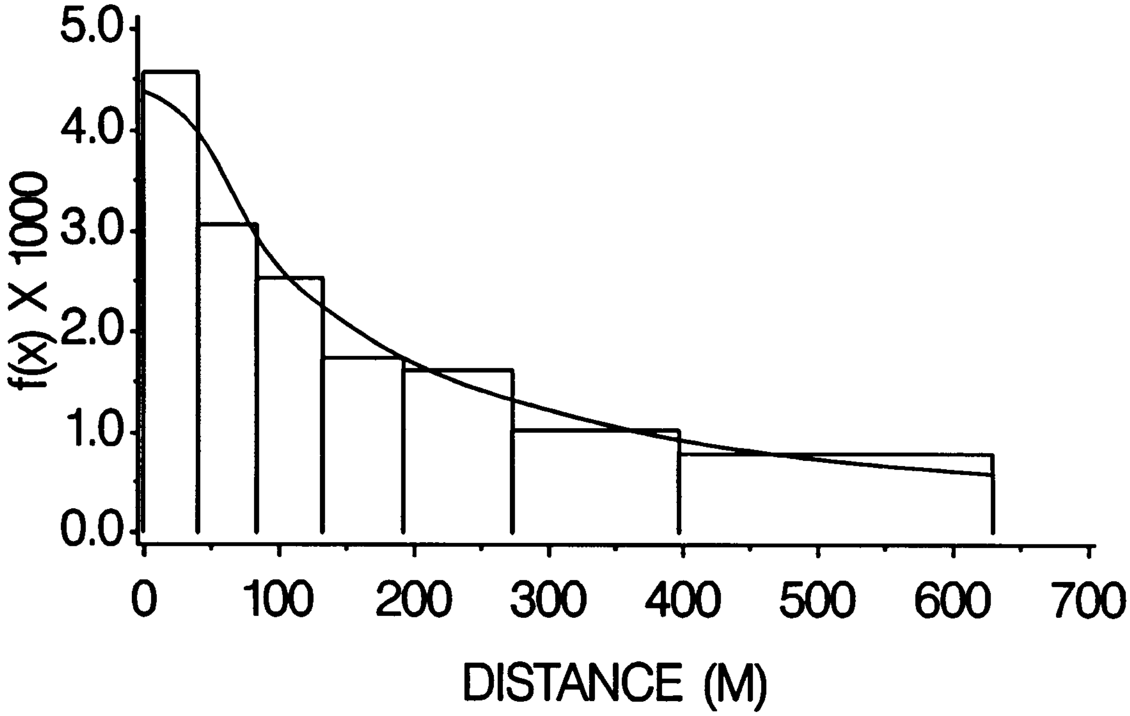


FIGURE 2. HAZARD-RATE MODEL FIT TO THE SIGHTING DISTANCE HISTOGRAM FOR ALL DOLPHINS AND SMALLER WHALES (f(x) - probability density, distance - meters from the transect line).

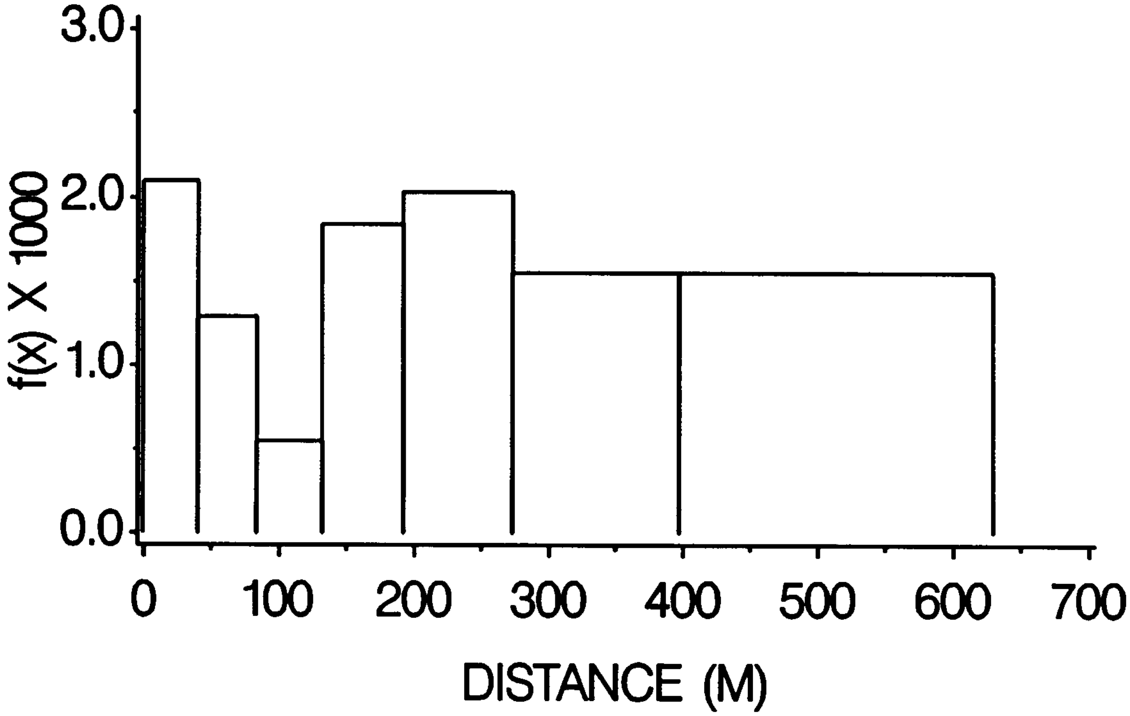


FIGURE 3. SIGHTING DISTANCE HISTOGRAM FOR SPERM AND BALEEN WHALES (f(x) - probability density, distance - meters from the transect line).

because $\hat{f}(0)$ was estimated by pooling all the sightings for smaller whales and dolphins, the densities may not represent the true relative abundance among the different species. Species that form small herds, are deep diving and/or are not active on the surface may be under-represented, whereas species with large herds that typically remain near the surface and/or are active at the surface may be over-represented in a relative sense.

Identification of Cetacean Species from Aircraft in the Gulf

Species of cetaceans were identified to the lowest taxonomic level possible. Specific identifying characteristics for each species or species group are summarized below. Our ability to make an identification of each sighting was dependant on many factors including visibility, water clarity, sea state and animal behavior. Species of some genera were impossible to separate from the air. Some species were easily identified. When a herd could not be identified beyond a reasonable doubt, we classified them as Stenella sp., unidentified large cetaceans (>7 m) or unidentified small cetaceans (≤7 m).

We included this section on the identification of cetaceans because this is an area of potential confusion and we do not want to include repetitious material under each species account. As has been stated, the distribution and relative abundance of whales and dolphins in the Gulf is poorly known. However, based on the work that had been done, we had some misimpressions going into this study concerning which species would occur more frequently and how to identify them from the air. However, there is the possibility that the species of marine mammals in the Gulf and their relative abundance has changed over the years. What we present here are, to our current knowledge, the best characteristics to use in identifying cetaceans from the air in the northern Gulf and some of the problems we encountered making the identifications. We were greatly benefitted in this by some fortuitous ground-truth data from the Gulf. We also include a general description of each species or species group. These descriptions are, unless indicated otherwise, drawn from Leatherwood et al. (1976) and Leatherwood and Reeves (1983).

Baleen whales

We sighted a baleen whale on two separate occasions. We identified one whale as a fin whale and the other as either a sei or Bryde's whale. Fin whales grow to be as long as 24 m, have a V-shaped rostrum, and are dark gray to brownish black on the back. The dorsal fin is located about one-third the body length from the flukes and is usually angled at <40°. Sei whales can be as long as 18.6 m, are dark gray on the back and have a strongly falcate dorsal fin which is located more than one-third the body length from the flukes. The rostrum may not be as pointed as in the fin whale. Bryde's whales reach 14 m in length, are dark gray and have a strongly falcate dorsal fin located one-third the body length from the flukes. They have three prominent ridges on their rostrum. Although we found absolute size very difficult to estimate from the air, we identified the fin whale based on its extremely pointed rostrum and its size which we estimated to be >20 m. The sei/Bryde's whale had a strongly falcate dorsal fin and we estimated its size to be 13-15 m. We were unable to determine whether the whale had three ridges on its rostrum.

Sperm whale

Male sperm whales average about 15 m in length and females reach about 12 m. Sperm whales have a huge squarish head and large triangular shaped flukes. The blow is distinctly forward and to the left. These characteristics make sperm whales very easy to identify from aircraft.

Dwarf/pygmy sperm whales

Adult dwarf sperm whales range in length from 2.1-2.7 m and adult pygmy sperm whales are somewhat larger ranging from 2.7-3.4 m. Both species are very robust anteriorly with a blunt sometimes squarish head. They are dark gray on the dorsal side and become progressively lighter toward the ventral side (Leatherwood and Reeves 1983, Nagorsen 1985). The relatively small flippers are place well forward on the body, just behind the head. On the animals we observed, the flippers were usually extended perpendicularly from the body and appeared to be squared off at the end. Their size, body shape, and the shape and position of the flippers made dwarf/pygmy sperm whales easy to identify from the air. We did not attempt to separate the species from the air.

Beaked whales

Cuvier's beaked whale ranges from 5.5-7.0 m in length, the body shape is very robust, the dorsal fin is on the posterior half of the body and the flippers are very small (Heyning 1989). Cuvier's beaked whale is reported to be dark gray to various shades of brown. The beak or rostrum is poorly defined. The head can be light gray or white and this lighter coloration in males may extend to the dorsal fin.

Mesoplodonts have a maximum length of 6.5 m and the body is generally very streamlined. The beak is well defined. Descriptions of body colors of beaked whales in most instances are based on stranded species and may not be reliable. We identified beaked whales with a robust body, light brown coloration and whitish head as Cuvier's beaked whale and all others as unidentified beaked whales.

Melon-headed/pygmy killer whales

Melon-headed whales grow to a maximum of 2.7 m. They have a very small beak and long pointed flippers. The color is generally black. Many times the areas around the mouth, anus and genitals are white. Pygmy killer whales also grow to a length of 2.7 m and are similar to melon-headed whales in most respects. However, the flippers are rounded and the color is usually various shades of gray. From the air, the long flippers, lack of prominent beak, and the white on the lips enabled us to identify herds as one of the two species but we could not separate them.

False killer whale

The males of this species grow to 5.5 m whereas females only grow to a maximum of 4.9 m. The body is long and slender and the head is rounded (no beak). The flippers are relatively long and rounded. The back is generally black. The slender body, the tapered and rounded head, and the size and shape of the flippers were used to identify this species from the air.

Killer whale

Killer whales are sexually dimorphic. Males can be as long as 9.5 m and females about 7.0 m. The dorsal fin is exceptionally large in males can be as tall as 1.8 m. The body colors are black and white. The body is robust. The size, shape and colors of these whales make them easy to identify from the air.

Short-finned pilot whale

Short-finned pilot whales are sexually dimorphic with mature males larger than females. Males can reach 5.3 m in length and females, 4.0 m. They are shades of very dark gray to dark brown. The head is blunt and bulbous. The dorsal fin is set well forward on the body. Many pilot whales have a pale or white chevron behind the dorsal fin. The large size, color and shape of the body, the white chevon, and position of the dorsal fin make this whale easy to identify from the air.

The short-finned and long-finned pilot whale (Globicephala melaena) cannot be distinguished from the air. We assumed the pilot whales we saw were short-finned because there have been, to our knowledge, no strandings of long-finned pilot whales in the Gulf, whereas strandings of short-finned pilot whales have been numerous (Schmidly 1981).

Rough-toothed dolphin

The length is reported to be 2.8 m. Some individuals are robust but most are more streamlined. The head tapers into the snout without a pronounced melon and the lips and lower jaw are often white. Their backs are dark gray to a purplish black. We only identified this species once. We sighted a herd of dolphins whose members had a purple hue and spent a considerable amount of time taking photographs. On the animals in the photographs, the heads were without a distinct melon and the lips were white.

Bottlenose dolphin

The bottlenose dolphin can reach a length of 3.9 m but most are less than 2.6 m (see Meade and Potter 1990). They usually have a very robust body shape. They have a distinct melon and a stocky snout. The color on the sides and back is generally a shade of gray that blends into a white or pinkish belly. The dorsal fin is falcate. There is a lack of distinct and consistent markings on the body. From the air bottlenose dolphins can be confused with Atlantic spotted dolphins (see below).

Risso's dolphin

Adult Risso's dolphins have a blunt snout with no beak and grow to 3.6-4.0 m in length. As juveniles, they are gray to brown, but as they age the pigment pales. Extensive scarring is often evident on the flanks of adults. Adults have a stout shape, with a blunt, often pure white head. The tall, sickle-shaped dorsal fin and body adjacent to it remain dark, as do the flippers and flukes, with the flanks and tail stock appearing much lighter. These characteristics make them easy to identify from the air.

Atlantic spotted dolphin

Adult Atlantic spotted dolphins grow to about 2.4 m and are very robust. They are generally born without spots and the spotting increases with age both dorsally and ventrally. The dorsal ground color varies with age from gray to purple. The ventral side is generally more pale. The dorsal fin is strongly falcate. These dolphins look very much like bottlenose dolphins in terms of body shape, melon and snout. From the air, we separated these dolphins from bottlenose dolphins by their white tail stock, a strong blaze near the blowhole and generally mottled appearance. These characteristics are caused by spotting and the effect is amplified by the amount of spotting. A herd of Atlantic spotted dolphins, especially a herd of young animals, could be easy to misidentify as bottlenose dolphins from the air. A mixed herd of bottlenose and Atlantic spotted dolphins could be difficult to recognize from the air.

Pantropical spotted dolphin

This species has only been recognized as distinct in the Atlantic, Caribbean and Gulf since the revision of the spotted dolphins by Perrin et al. (1987). Prior to this, pantropical spotted dolphins (Stenella attenuata) were part of the complex of the Atlantic spotted dolphin (formerly S. plagidon and now S. frontalis) and the bridled dolphin. (The common name, bridled dolphin, is no longer used. The scientific name of the bridled dolphin was S. frontalis. All dolphins formerly called the bridled dolphin were grouped into the Atlantic spotted dolphin or the pantropical spotted dolphin.)

Fritts et al. (1983:325) stated that the different forms of spotted dolphins could not be separated from the air. However, in the Gulf, we believe that the pantropical spotted dolphin and the Atlantic spotted dolphin are so differently shaped, colored and spotted that they should not be confused at all. We base this on our aerial survey observations, shipboard observations by two of us (W. Hoggard, C. Roden), conversations with our sea-going coworkers, and accompanying photographs and video tape from the Gulf (see below). We believe, when viewing living animals, that the old Atlantic spotted dolphin (see the photographs in Leatherwood et al. 1976:104-107) is essentially the new Atlantic spotted dolphin, and the bridled dolphin is the pantropical spotted dolphin (see Caldwell et al. 1971, Figure 3 or Leatherwood et al. 1976, Figure 121). The descriptions of the bridled dolphin by Fraser (1950, as reported by Lowery 1974) and Caldwell et al. (1971) for the most part correspond to our observations and photographs (both aerial and shipboard) of the dolphin we identified as the pantropical spotted dolphin in the Gulf.

Pantropical spotted dolphins are 2.2-2.5 m in length and were easily identified from the air by their slender body shape, white-tipped snout which was so pronounced that it almost seemed to glow and their distinct lobed saddle or cape which was very dark in contrast to the rest of the body. Also, when an animal was swimming on its side, the black stripe between the gape of the mouth and the flippers was sometimes visible. The spotting on these dolphins was light and more like flecks, and was not visible from the air. Our observations to date indicate that the spotting does not obscure the saddle as it apparently does on pantropical spotted dolphins in some areas of the Pacific. The Atlantic spotted dolphin is robust, and the spots are large and tend to overlap on some animals. While the sample size is still relatively small, we did not observe any dolphin which we thought had the characteristics of both species and could be confused between the Atlantic spotted dolphin and the pantropical spotted dolphin nor did we observe any herd which consisted of members of both species.

We initially misidentified pantropical spotted dolphins. We believed going into the study that pantropical and Atlantic spotted dolphins would be indistinguishable from the air. Schmidly (1981) reported eight sightings at sea and one stranding of the common dolphin (Delphinus delphis) in the Gulf. Fritts and Reynolds (1981) reported several common dolphin sightings in the Gulf during aerial surveys. Therefore, we believed that the common dolphin could be a relatively common species in the Gulf. During our initial aerial surveys we identified dolphins with distinct capes and white-tipped snouts as common dolphins. We thought that the point on the cape below the dorsal fin in common dolphins was obscured by the altitude of the aircraft. However, in December 1989 we obtained video footage of pantropical spotted dolphins bowriding a fishing vessel in the northern Gulf. This footage, and subsequent video and photographs from NOAA Ship Oregon II, convinced us that we had consistently misidentified pantropical spotted dolphins as common dolphins. During 1990, the first (ever) marine mammal cruise was conducted in deep northern Gulf waters by the NMFS-Southeast Fisheries Center (SEFC) and the pantropical spotted dolphin was the most commonly sighted cetacean (18 sightings). It was our sixth most common sighting. [The inclusion of the common dolphin in Lohoefener et al. (1990b) was an error.] Given this, it is remarkable that this species has not been sighted and reported in the Gulf prior to 1990. Either the distribution of the pantropical spotted dolphin has been extremely irruptive in the Gulf, this species has not been encountered by opportunistic observers (which is difficult to believe given its apparent proclivity towards bowriding) or it has also been misidentified by other observers (perhaps as common dolphins).

Striped/spinner/Clymene dolphins

Striped dolphins reach about 2.7 m in length. They have a dark rostrum and a moderately falcate dorsal fin. Their coloration is complex. Dorsally they can be various shade of gray. They are lighter on the sides with a light belly. They have a black stripe from the eye to the anus and a black stripe from the eye to the flipper. They also have a shoulder blaze or what Fritts et al. (1983) called a "feather blaze" and this is the most distinctive characteristic of the species. This blaze starts just above and posterior to the flippers and sweeps dorsally and posteriorly to the base of the dorsal fin.

The spinner dolphin grows to about 2.1 m. This dolphin species is very slender. The snout is very long and slender, and is dark on top. The body is a two-toned gray color which has a distinct margin laterally. The dorsal fin is not falcate and looks triangular.

Clymene dolphins grow to about 2.1 m. The color pattern is similar to that of the spinner dolphin. However, the Clymene dolphin appears to have a saddle and there is white on each side of the beak (see Perrin et al. 1981, Figures 1 and 2). The beak is also shorter than that of the spinner dolphin. Johnson et al. (in prep. a) indicated that some individuals sighted in the Gulf during the 1990 SEFC cruise had a lateral stripe very similar to that of the striped dolphin. They commented that the short beak, the black stripe and the robust appearance of the Clymene dolphin could cause it to be easily confused with striped dolphin. The dorsal fin, however, was not distinctly falcate.

Although we saw herds from the air that we were reasonably confident were of each species, we saw many more that had mixed characteristics. Given the problems of separating the species from ships, we decided to be conservative and lump them into a species group.

RESULTS AND DISCUSSION

Species Accounts

During the 11 months of aerial surveys we sighted 15 species or species groups of cetaceans (Table 4). Species which have been reported in the Gulf but which we did not encounter were the right whale, blue whale, minke whale, humpback whale, Fraser's dolphin and the common dolphin. Records of the right whale in the Gulf consist of a stranding record from Texas and a sighting of two right whales off the western coast of Florida (Moore and Clark 1963, Schmidly 1981). Right whales are known to regularly inhabit Atlantic waters off New England in summer. While a portion of the population spends the winter in the Atlantic off the Georgia and Florida coasts, the wintering grounds for the majority of the population remains unknown (Kraus et al. 1988). Records of the of the blue whale in the Gulf consist of two strandings on the Texas coast. The surviving population of blue whales in the entire North Atlantic is thought to only be a few hundred (Leatherwood and Reeves 1983). The minke whale may be more common in the Gulf. Four minke whales have stranded along Gulf shores (three on the Louisiana coast) and there are five stranding records from the Florida Keys (Schmidly 1981). Schmidly (1981) reported three humpback whale sightings in the Gulf, one near Tampa Bay, Florida and two in DeSoto Canyon near the eastern edge of the area we surveyed. The only record of Fraser's dolphin in the Gulf is from a mass stranding on the Marquesas Keys west of Key West, Florida (Hersh and Odell 1986).

Accounts of the species or species groups we encountered during our survey are given below. For each species, we summarize its general distribution, give a brief history of its known Gulf occurrence, and from our study, present data on the density, herd sizes, water depths, and spatial and temporal distribution. Since our survey effort was not equal among study areas (see Table 3), the distribution plots (see Figures 4-20) may give false impressions of the relative distribution of each species. However, the effort was equal from a north to south perspective (shallow water to deep water) and comparisons in this direction should be valid. Sighting rates (see Tables 6 and 7) provide more valid comparisons between study areas (east to west). The sample sizes were generally too small to draw conclusions about seasonal effects on average depths, average herd sizes and locations of herds sighted. Also, the study areas in 1989 (two months of summer and fall), in general, were over more shallow waters than the 1990 study areas (winter, spring and one month of summer). In 1989, 25% of the survey effort was over waters <180 m while none of the 1990 effort was <180 m. Therefore, differences in species composition and relative abundance between 1989 and 1990 may merely reflect this change in water depth and not represent a seasonal effect. This may also be true for the seasonal average water depths for some species. Results from the mid-Gulf surveys are presented

TABLE 4. SPECIES OF CETACEAN SIGHTED, MEAN HERD SIZES AND MEAN WATER DEPTHS.

		Mean Herd Size ($\bar{H}$)			Mean Water Depth ($\bar{W}$) (meters)		
Species or Type	n	$\bar{H}$	se(H)	range	$\bar{W}$	se(W)	range
Risso's dolphin	61	12.8	1.5	1- 48	440	25.5	97-1,079
Sperm whale	43	2.1	0.3	1- 9	877	35.5	199-1,573
Bottlenose dolphin	39	11.9	2.2	1- 60	257	41.0	20- 973
Atlantic spotted dolphin	36	26.6	5.2	2-137	363	39.4	91-1,152
Pygmy/dwarf sperm whale	32	1.9	0.2	1- 4	544	63.8	96-1,780
Striped/spinner/ Clymene dolphin	24	87.8	20.4	8-325	712	76.3	93-1,567
Pantropical spotted dolphin	23	71.8	8.8	7-186	905	76.6	65-1,566
Beaked whales	9	1.2	0.4	1- 2	966	468.8	205-1,811
Short-finned pilot whale	5	18.2	3.7	5- 28	605	71.3	364- 781
Pygmy killer/ melon-headed whale	1	25.0	-	-	318	-	-
False killer whale	1	3.0	-	-	1,107	-	-
Killer whale	1	8.0	-	-	964	-	-
Rough-toothed dolphin	1	4.0	-	-	933	-	-
Fin whale	1	1.0	-	-	148	-	-
Sei/Bryde's whale	1	1.0	-	-	342	-	-
Stenella spp.	12	20.3	12.1	2-152	257	41.0	20- 973
Unidentified large cetacean	5	2.0	0.6	1- 3	857	288.2	316-1,673
Unidentified small cetacean	25	19.7	9.4	1-212	603	85.7	88-1,780

separately within each species account. All other results only include data collected in the study areas (A7-A10, B1-B7). In many cases, we compare the results of our study to the study conducted by Fritts et al. (1983) and to the Cetacean and Turtle Assessment Program study (CETAP 1982). The Fritts et al. (1983) study was conducted in the Gulf and in the Atlantic off Florida and was described in the Introduction. The CETAP (1982) study was conducted from 1978-1982 in waters bounded by the U.S. coastline and the 2,000 m isobath from Cape Hatteras, North Carolina to Nova Scotia, Canada.

Baleen whales

During our 11 month survey we sighted two baleen whales. Both were sighted in DeSoto Canyon in the eastern portion of the area we surveyed (Figure 4). We sighted a fin whale (an endangered species) in November 1989. In about the same area during June 1990, we sighted a whale that was either a sei (an endangered species) or a Bryde's whale.

Sightings and strandings of balaenopterid whales in the Gulf of Mexico are not particularly common. However, balaenopterid whales may be, compared to other areas in the Gulf, more common in the north-central Gulf. Except for minke whales strandings in the Florida Keys, most of the balaenopterid strandings and sightings reported by Schmidly (1981) in the Gulf were in the north-central Gulf. Records of minke and humpback whales have already been discussed (see above). There are records of six fin whale strandings in the Gulf. Four of the strandings were found on the Louisiana coast north of the area we surveyed. Two of three fin whale sightings in the Gulf were near DeSoto Canyon. Additionally, a fin whale was sighted during NMFS aerial surveys of the continental shelf just seaward of the 180 m isobath near DeSoto Canyon in July 1985 (L. Hansen pers. comm., NMFS, Miami).

The two sei whale strandings and two of four Bryde's whale strandings in the Gulf reported by Schmidly (1981) were located near the Mississippi River delta. Other records include a live stranding of a Bryde's whale on the Louisiana coast in January 1990 (New Orleans Times Picayune, 10 January 1990) and a sei whale stranding on the Louisiana coast in 1990 (D. Odell, pers. comm., Sea World of Florida). Three of us (K. Mullin, R. Lohoefener, W. Hoggard) examined the ventral side a baleen whale in shallow water in the same vicinity during November 1985. This whale was probably a Bryde's whale. No baleen whale sightings in the Gulf were reported by Fritts et al. (1983).

Balaenopterid whale species are distributed throughout the world and most baleen whales migrate toward the poles in summer and toward the warmer southern waters in winter, although Bryde's whales in warm waters may not migrate (Leatherwood and Reeves 1983). Except possibly for the Bryde's whale, it would seem that

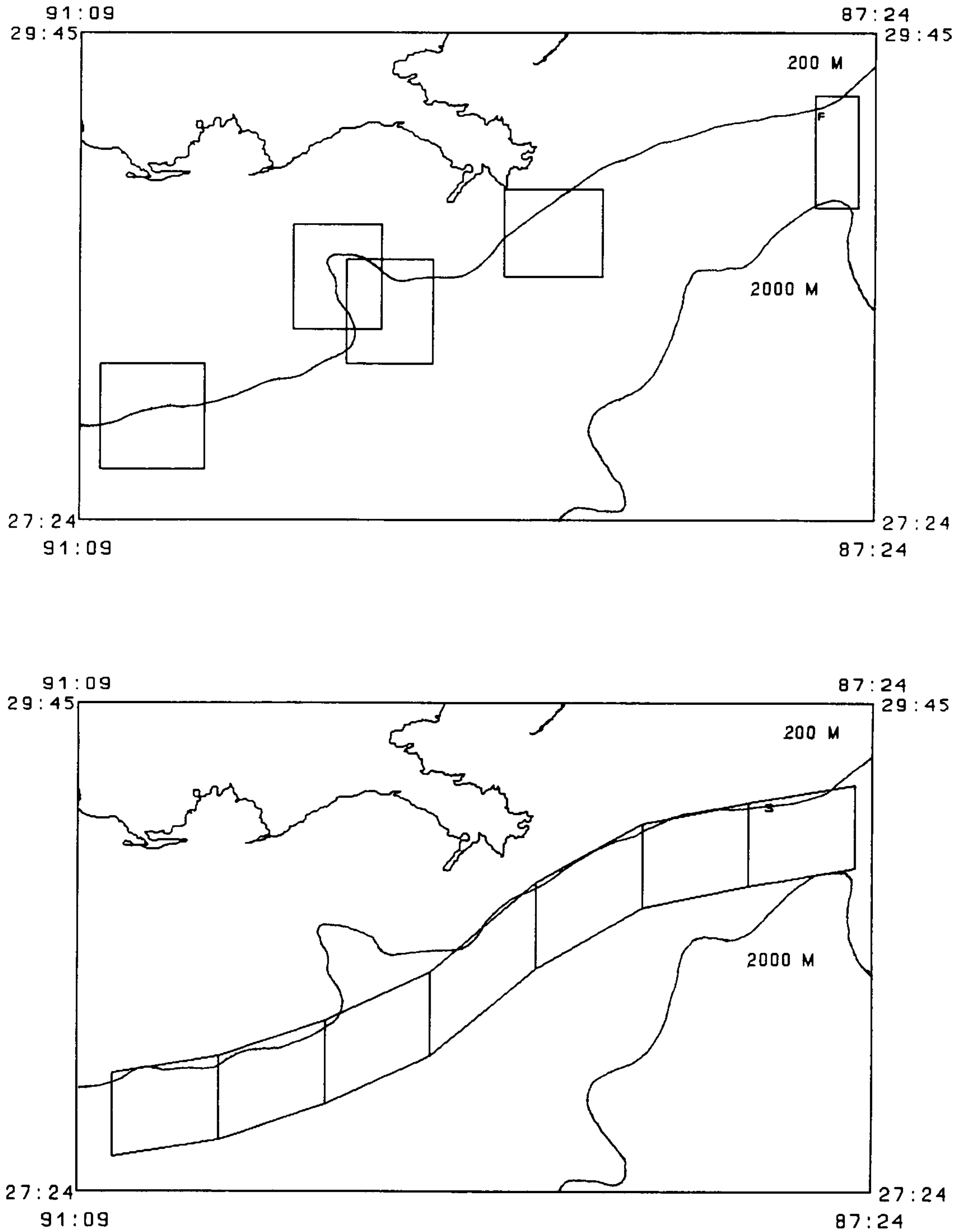


FIGURE 4. LOCATIONS OF BALEEN WHALE HERDS SIGHTED DURING 1989 (upper panel) AND 1990 (lower panel) (W - winter, R - spring, S - summer, F - fall).

baleen whales would inhabit the Gulf with higher frequency in the winter. Although the relative frequency of the limited number of strandings is increased in winter, there are stranding records of baleen whales (especially fin whales) in the Gulf throughout the year (Schmidly 1981). Poor weather in January and February 1990 reduced our survey effort during the winter months. Only 10% of our total effort was in winter. Therefore, our study was probably not adequate to determine whether there is a greater frequency of balaenopterids in the north-central Gulf in winter.

Sperm whale

The sperm whale is listed as an endangered species under the provisions of the U.S. Endangered Species Act of 1973. Prior to modern whaling the worldwide sperm whale population was about 3 million and is currently thought to be about 2 million. The male portion of the population was reduced about 45% by whaling and the female portion about 17% (Rice 1989). The sperm whale is the largest toothed whale. Family Physeteridae, to which it belongs, includes only two other species, the pygmy sperm whale and the dwarf sperm whale.

Sperm whales have cosmopolitan distribution in deep waters of all seas (Evans 1987). In most areas, sperm whales are seldom found in waters less than about 180 m. Otherwise they may be encountered almost anywhere on the high seas. Their distribution, however, is not random, but shows a preference for continental margins, sea mounts and, in general, areas of upwelling where food is abundant (Leatherwood and Reeves 1982, 1983).

Sperm whales are highly gregarious and aggregations of as many as 1,000 individuals have been recorded (Lowery 1974). The basic unit of sperm whale social organization is the breeding or mixed herd, consisting of mature females, juveniles of both sexes, and calves. Females become mature when they are between 7-13 years old. Mixed herds are reported to average 20-40 individuals (Rice 1989).

Male sperm whales leave the mixed herds between 15 and 21 years of age to form bachelor herds. Herd sizes of bachelor herds vary according to age. Younger and smaller males form herds that average about 20 whales but older more mature males are usually never in herds of more than 6 (Best 1979, Rice 1989). The maturing process is prolonged in male sperm whales. They begin to sexually mature at age 7-11 but do not become fully mature until they are 25-28 (Rice 1989). The proportion of sexually mature males to sexually mature females is 1:2.6, and only 10%-25% of the mature males are thought to be involved in breeding activity. This leaves many sexually idle males and predisposes formation of all-male groupings (Best 1979).

Social cohesion seems to exist in sperm whale herds and they appear to have stability over time (Evans 1987). Best (1979) reported that the female component of mixed herds are stable units with very little permanent subdivision and the females may maintain close association throughout their lives. Whitehead and Arnbom (1987) reported that herd members were usually seen associating in subgroups of 2-10 individuals but that while the composition of the subgroups changed from hour to hour, the larger herd did seem to have a more stable membership.

Breeding strategy in sperm whales is still not clearly defined. The long-standing belief was that a solitary, large bull took control of a mixed herd for the breeding season, often by battling competing males. Evans (1987) reported that older males were solitary or in small groups except during breeding when they may compete to gain control of a mixed herd. Best et al. (1984) reported that evidence suggested that the association with a mixed herd may be extremely brief, possibly only a matter of days, and that male sperm whales might maximize their mating opportunities if they moved between female groups within one breeding season. There is still debate among researchers as to whether most successful breeding is accomplished by the larger, seasonally present bulls, or by younger males present in the herd throughout the year (Leatherwood and Reeves 1983, Evans 1987).

The historical presence of sperm whales in the Gulf was documented by whalers. Sperm whales were once numerous enough in the Gulf to support whaling operations. Townsend (1935) compiled location data of sperm whale kills in the Gulf from logbooks of Yankee whalers from the mid-1700's through the early 1900's. North of 24° north latitude and west of 84° west longitude, 42 kill locations were reported in the Gulf. All of the whaling occurred from March through July. Most of the kills were made between the Mississippi River delta and the western end of Cuba. Apparently whalers did not hunt sperm whales in the western Gulf.

Lowery (1974) stated that sperm whales once occurred in numbers in the Gulf, including Louisiana's offshore waters, but were now rare anywhere in the Gulf. However, Schmidly (1981) reported 16 strandings scattered throughout the Gulf and three strandings in the Florida Keys. Schmidly (1981) also reported seven at-sea sightings, most (5) near the Mississippi River delta. Collum and Fritts (1985) reported that aerial surveys and opportunistic sightings from ships from 1979-1981 (also see Fritts and Reynolds 1981 and Fritts et al. 1983) resulted in 17 sightings of a total of 47 adult and 12 calf sperm whales. Most (12) of the sightings were off Texas, two were off the coast of Mexico, two were offshore of Louisiana, and one sighting was off the Florida coast.

Sperm whale herds were our second most common sighting (Table 4). However, because we used strip transects to estimate herd density for sperm whales (see Methods), the overall herd density was estimated to be near the middle of the herd densities for other species (Table 5). Of the species sighted more than once, only dwarf/pygmy sperm whales and beaked whales had smaller herd sizes. Because of the small herd sizes, the density of sperm whales only exceeded that of beaked whales for species sighted more than once (Table 5). The combined density we estimated for 1989 and 1990 was similar to the peak density reported from the shelf edge region during the CETAP (1982) study (about 0.003 whales/km^2). The estimated sperm whale density for 1989 was five times the 1990 estimate.

Our sperm whale density estimates were undoubtedly negatively biased because some whales were submerged. Sperm whales dive to great depths to feed. Dives of up to 90 minutes have been reported but most dives are probably less than 30 minutes. There has been no consensus reached among researchers concerning peak feeding times. Sperm whales probably feed throughout the 24 hour day but dive times apparently vary by time of day (Rice 1989).

The 1989 density was predominately a result of sperm whale sightings in Area 7 (Table 5, Figures 5 and 6). The density of sperm whales in Area 7 was twice the 1989 density for all study areas combined and 10 times the 1990 density. Over one-half of all the sightings of sperm whale herds made during the entire study were made during 1989 in Area 7 but nearly half (48%) of our effort in 1989 was in Area 7. However, the herd sighting rate in Area 7 was still the highest of any study area but only two times the next highest rate (Table 6). Area 7 was near the Mississippi River delta. During the 1990 portion of the study, sighting rates of sperm whales were the highest in the study areas near the River delta (B2-B4) (Tables 6 and 7). There was also a relatively high herd sighting rate near DeSoto Canyon during 1989 (A10) but no herds were sighted in that area during 1990 (B1). Although the sightings were concentrated near the River delta, sperm whale herds were widely distributed east to west (Figure 5).

Sperm whale sightings were also widely distributed in time. The only month a sperm whale herd was not sighted was May 1990. By far, the most sperm whales were sighted during the fall months and the highest sighting rates occurred during fall (Tables 8 and 9). Twenty-four of the sightings were in fall and 19 of those sightings were in Area 7.

Most sperm whales of either sex and all age classes are thought to shift poleward in the spring and summer, returning to temperate and tropical portions of their range in the fall (Leatherwood and Reeves 1983). Females and young undergo less extensive seasonal migrations than males and generally remain between 40° N and 40° S. Males range more poleward and are regularly found from 65° N to 70° S (Evans 1987). (The maximum

TABLE 5. HERD DENSITY, MEAN HERD SIZE, DENSITY AND NUMBERS OF CETACEANS (C - data from 1989 and 1990 combined, $\hat{D}_h$ - herds/km^2, R - replicate transects, $\bar{H}$ - mean herd size, n - number of herds sighted, $\hat{D}_d$ - individuals/km^2, $\hat{N}$ - numbers of individuals, se - standard error).

Year	$\hat{D}_h$	se($\hat{D}_h$)	R	$\bar{H}$	se(H)	n	$\hat{D}_d$	se($\hat{D}_d$)	$\hat{N}$	se($\hat{N}$)
					Species or Type					
					"Baleen" whales					
C	.0001	.0001	130	1.0	-	2	.00+	-		
89	.0001	.0001	55	1.0	-	1	.00+	-	1	-
90	.0001	.0001	75	1.0	-	1	.00+	-	1	-
					Sperm whale					
C	.0014	.0003	130	2.1	.3	43	.003	.001		
89	.0021	.0007	55	2.3	.4	27	.005	.002	39	14
Area 7	.0038	.0012	21	2.5	.5	23	.010	.003	20	7
90	.0009	.0003	75	1.7	.5	16	.001	.001	22	9
					Pygmy/dwarf sperm whale					
C	.0033	.0006	130	1.9	.2	32	.006	.001		
89	.0046	.0012	55	2.1	.3	18	.010	.003	78	24
90	.0023	.0006	75	1.7	.2	14	.004	.001	61	17
					"Beaked" whales					
C	.0010	.0003	130	1.2	.4	9	.001	.001		
89	.0013	.0006	55	1.3	.3	5	.002	.001	14	5
90	.0007	.0003	75	1.3	.3	4	.001	.001	14	7

TABLE 5. CONTINUED.

Year	$\hat{D}_h$	se($\hat{D}_h$)	R	$\bar{H}$	se(H)	n	$\hat{D}_d$	se($\hat{D}_d$)	$\hat{N}$	se($\hat{N}$)
				Melon-headed/pygmy killer whale						
C	.0001	.0001	130	25.0	-	1	.003	-		
89	.0003	.0003	55	25.0	-	1	.007	-	53	-
				False killer whale						
C	.0001	.0001	130	3.0	-	1	.00+	.00+		
89	.0003	.0002	55	3.0	-	1	.001	.001	6	5
				Killer whale						
C	.0001	.0001	130	8.0	-	1	.001	-		
90	.0002	.0002	75	8.0	-	1	.001	-	22	-
				Short-finned pilot whale						
C	.0005	.0004	130	18.2	3.7	5	.010	.007		
89	.0013	.0009	55	18.2	3.7	5	.024	.017	192	141
				Rough-toothed dolphin						
C	.0001	.0001	130	4.0	-	1	.00+	-		
90	.0002	.0002	75	4.0	-	1	.001	-	11	-

Species or Type

TABLE 5. CONTINUED

					Species or Type					
Year	$\hat{D}_h$	se($\hat{D}_h$)	R	$\bar{H}$	se(H)	n	$\hat{D}_d$	se($\hat{D}_d$)	$\hat{N}$	se($\hat{N}$)
					Bottlenose dolphin					
C	.0041	.0011	130	11.9	2.2	39	.049	.016		
89	.0082	.0025	55	11.5	2.7	32	.095	.035	772	287
90	.0013	.0005	75	13.7	3.1	7	.017	.008	261	117
					Risso's dolphin					
C	.0065	.0011	130	12.8	1.5	61	.083	.017		
89	.0036	.0009	55	11.9	2.5	14	.043	.014	350	113
90	.0085	.0017	75	13.1	1.8	47	.111	.027	1,679	404
					Atlantic spotted dolphin					
C	.0038	.0007	130	26.6	5.2	36	.102	.027		
89	.0059	.0015	55	45.2	14.7	23	.267	.107	2,186	873
90	.0023	.0006	75	16.8	4.3	13	.039	.014	593	212
					Pantropical spotted dolphin					
C	.0025	.0005	130	71.8	8.8	23	.176	.042		
89	.0021	.0008	55	75.1	17.2	8	.155	.071	1,265	580
90	.0027	.0007	75	69.9	10.1	15	.189	.057	2,853	868

TABLE 5. CONTINUED

Year	$\hat{D}_h$	se($\hat{D}_h$)	R	$\bar{H}$	se(H)	n	$\hat{D}_d$	se($\hat{D}_d$)	$\hat{N}$	se($\hat{N}$)
					Species or Type					
				Striped/spinner/Clymene dolphin						
C	.0025	.0006	130	87.8	20.4	24	.223	.074		
89	.0033	.0012	55	53.0	21.3	13	.178	.093	1,451	746
90	.0020	.0006	75	128.8	33.8	11	.255	.101	3,856	1,528
					Stenella sp.					
C	.0014	.0006	130	20.3	12.1	12	.028	.019		
89	.0023	.0012	55	9.0	2.2	9	.021	.012	170	96
90	.0007	.0004	75	54.0	49.0	3	.039	.037	588	552
				Unidentified small cetaceans						
C	.0026	.0006	130	19.7	9.4	25	.052	.027		
89	.0036	.0012	55	11.1	5.9	13	.040	.024	326	197
90	.0020	.0007	75	29.0	18.5	12	.058	.039	873	598

TABLE 5. CONTINUED

Year	$\hat{D}_h$	se($\hat{D}_h$)	R	$\bar{H}$	se(H)	n	$\hat{D}_d$	se($\hat{D}_d$)	$\hat{N}$	se($\hat{N}$)
					Species or Type					
					Unidentified large cetaceans					
C	.0005	.0002	130	2.0	.6	5	.001	.001		
89	.0003	.0002	55	3.0	-	1	.001	-	7	-
90	.0007	.0004	75	1.7	.7	4	.001	.001	19	11
					All nonendangered cetaceans					
C	.0290	.0026	130	26.8	3.0	275	.778	.111		
89	.0359	.0045	55	23.4	3.8	143	.841	.173	6,865	1,414
90	.0233	.0029	75	30.5	4.8	132	.711	.144	10,769	2,170

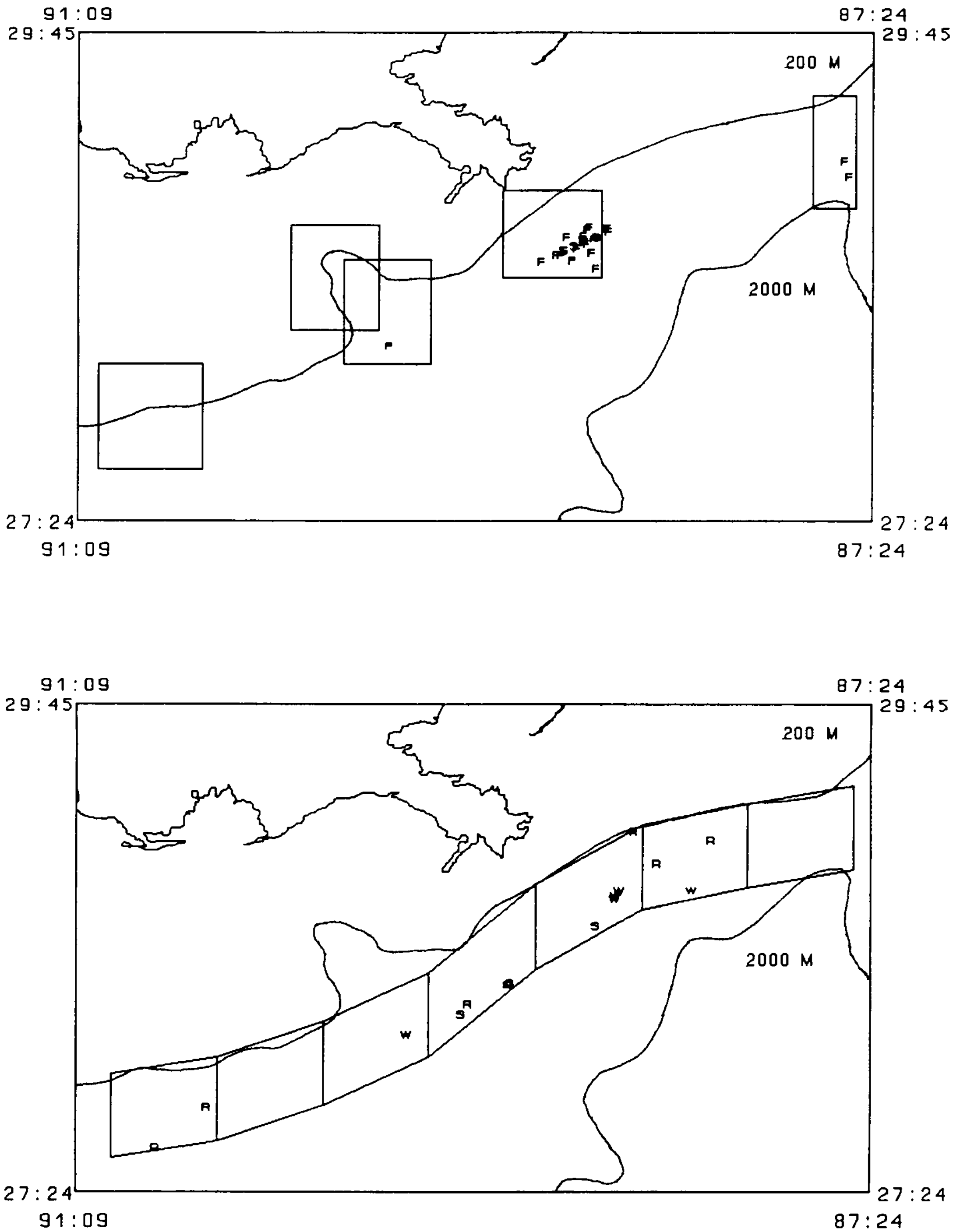


FIGURE 5. LOCATIONS OF SPERM WHALE HERDS SIGHTED DURING 1989 (upper panel) AND 1990 (lower panel) (W - winter, R - spring, S - summer, F - fall).

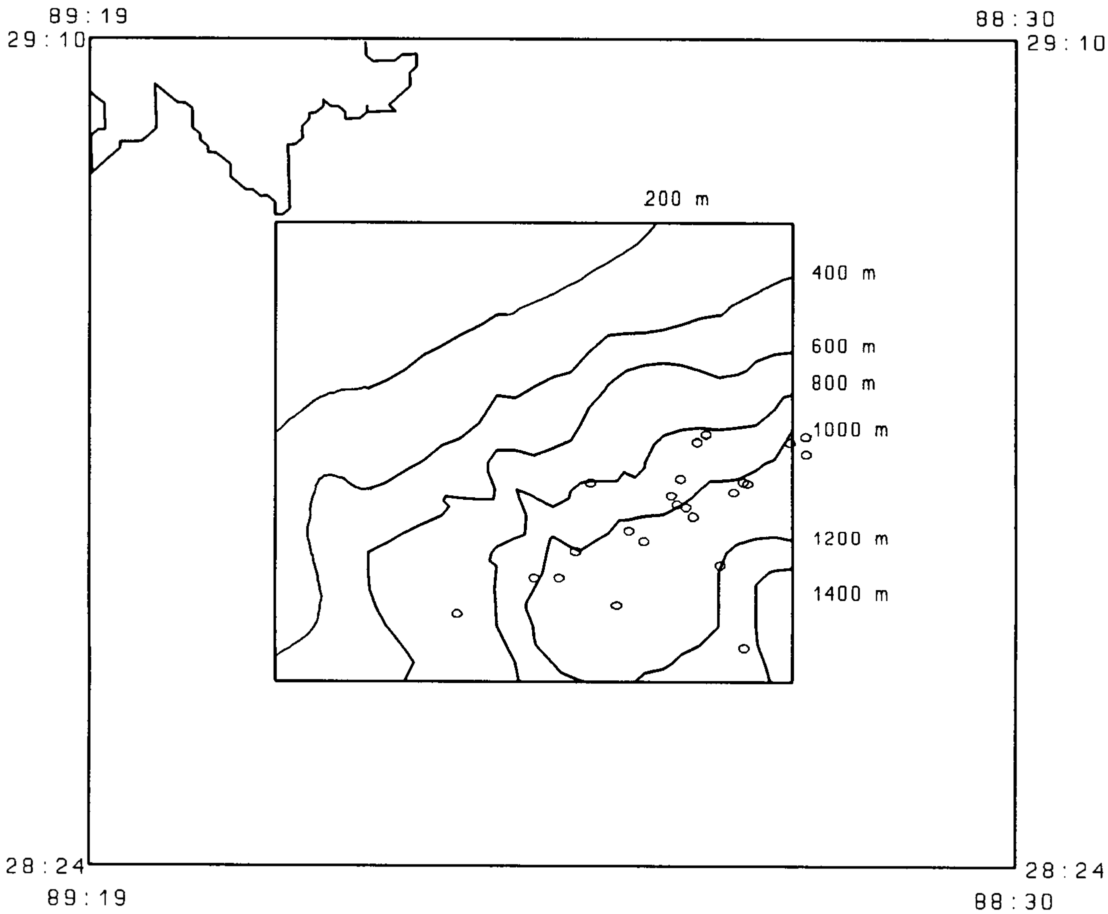


FIGURE 6. LOCATIONS (o) OF SPERM WHALE HERDS IN AREA 7
(m - meters).

TABLE 6. SIGHTING RATES OF CETACEAN HERDS BY AREA.

Species or Type	Sighting Rate (herds/100 km)										
	A7	A8	A9	A10	B1	B2	B3	B4	B5	B6	B7
Fin whale	0	0	0	.09	0	0	0	0	0	0	0
Sei/Bryde's whale	0	0	0	0	.07	0	0	0	0	0	0
Sperm whale	.56	.05	0	.28	0	.19	.25	.24	.06	0	.12
Pygmy/dwarf sperm whale	.15	.46	.07	.17	.21	.05	.04	.24	.13	.20	0
"Beaked" whales	.05	.21	0	.09	.07	.11	0	0	0	0	.06
Melon-headed/ pygmy killer whale	0	.05	0	0	0	0	0	0	0	0	0
False killer whale	.02	0	0	0	0	0	0	0	0	0	0
Killer whale	0	0	0	0	0	0	0	.06	0	0	0
Short-finned pilot whale	.10	0	.07	0	0	0	0	0	0	0	0
Rough-toothed dolphin	0	0	0	0	0	0	0	0	.06	0	0
Bottlenose dolphin	.24	1.03	.07	.09	0	.11	0	.18	.06	.07	0
Risso's dolphin	.19	.15	.14	.09	.56	.71	.12	.60	.32	.27	.25
Atlantic spotted dolphin	.19	.46	.27	.19	.21	0	.04	.24	.06	.20	.06
Pantropical spotted dolphin	.15	0	0	.28	.07	.27	0	.18	.06	.27	.12
Striped/spinner/ Clymene dolphin	.14	.15	.14	.19	.35	.05	.04	.18	0	.07	0
<u>Stenella</u> spp.	0	.21	.34	0	.07	0	0	0	.13	0	0
Unidentified small cetacean	.17	.15	.14	.09	.14	.05	.04	.18	.13	0	.19
Unidentified large cetacean	0	0	0	.09	0	.05	.04	0	0	.07	0
TOTAL	1.94	2.92	1.23	1.69	1.74	1.57	.57	2.11	1.02	1.15	.81
TOTAL NUMBER OF SPECIES	11	9	7	9	8	7	5	8	7	6	5

TABLE 7. SIGHTING RATES OF INDIVIDUAL CETACEANS BY AREA.

Species or Type	Sighting Rate (individuals/100 km)										
	A7	A8	A9	A10	B1	B2	B3	B4	B5	B6	B7
Fin whale	0	0	0	.1	0	0	0	0	0	0	0
Sei/Bryde's whale	0	0	0	0	.1	0	0	0	0	0	0
Sperm whale	1.4	.1	0	.5	0	.2	.3	.8	.1	0	.1
Pygmy/dwarf sperm whale	.3	.8	.1	.7	.3	.1	+	.5	.2	.4	0
Beaked whales	.1	.1	0	.1	.1	.1	0	0	0	0	0
Melon-headed/ pygmy killer whale	0	1.3	0	0	0	0	0	0	0	0	0
False killer whale	.1	0	0	0	0	0	0	0	0	0	0
Killer whale	0	0	0	0	0	0	0	.5	0	0	0
Short-finned pilot whale	2.1	0	.3	0	0	0	0	0	0	0	0
Rough-toothed dolphin	0	0	0	0	0	0	0	0	.3	0	0
Bottlenose dolphin	3.1	9.4	2.7	1.5	0	2.4	0	1.3	.8	1.2	0
Risso's dolphin	3.1	1.0	1.1	.1	7.4	11.6	1.5	5.7	4.9	4.7	1.3
Atlantic spotted dolphin	3.8	18.0	4.8	43.3	3.5	0	.5	5.1	.3	1.2	3.0
Pantropical spotted dolphin	13.1	0	0	12.6	3.7	14.9	0	10.3	1.7	29.9	9.7
Striped/spinner/ Clymene dolphin	4.4	14.0	1.3	20.1	38.6	12.3	2.7	30.8	0	4.2	0
<u>Stenella</u> spp.	0	3.0	1.6	0	.4	0	0	0	10.0	0	0
Unidentified small cetacean	1.2	.6	.6	7.0	7.0	1.0	.1	13.1	.4	0	.2
Unidentified large cetacean	0	0	0	.3	0	.1	+	0	0	.2	0
TOTAL	32.7	48.2	12.4	86.2	61.2	42.6	5.1	68.0	18.6	41.8	14.3
TOTAL NUMBER OF SPECIES	11	9	7	9	8	7	5	8	7	6	5

TABLE 8. SIGHTING RATES OF CETACEAN HERDS BY MONTH.

Species or Type	Sighting Rate (herds/100 km)											
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
Fin whale	0	0	0	0	.06	-	0	0	0	0	0	0
Sei/Bryde's whale	0	0	0	0	0	-	0	0	0	0	0	.03
Sperm whale	.11	.06	.61	.53	.22	-	.32	.19	.17	.09	0	.13
Pygmy/dwarf sperm whale	.23	.12	.31	.34	.06	-	0	0	.13	.18	.04	.20
Beaked whales	.11	.06	.05	0	.06	-	0	.19	.09	.04	0	.03
Melon-headed/ pygmy killer whale	0	.06	0	0	0	-	0	0	0	0	0	0
False killer whale	0	.06	0	0	0	-	0	0	0	0	0	0
Killer whale	0	0	0	0	0	-	0	0	0	0	.04	0
Short-finned pilot whale	0	.06	0	0	.22	-	0	0	0	0	0	0
Rough-toothed dolphin	0	0	0	0	0	-	0	0	0	.04	0	0
Bottlenose dolphin	.79	.06	.57	.34	.06	-	.12	0	.04	.04	0	.09
Risso's dolphin	.33	.31	.05	0	.11	-	.13	0	.43	1.11	.17	.20
Atlantic spotted dolphin	.17	.19	.31	.54	.17	-	0	.38	.26	.13	0	.07
Pantropical spotted dolphin	0	.06	.21	.13	.11	-	0	0	.13	.18	.22	.13
Striped/spinner/ Clymene dolphin	0	.43	.05	.07	.22	-	.19	0	.09	.08	.13	.03
Stenella spp.	.34	0	.15	0	0	-	0	0	.09	.04	0	0
Unidentified small cetacean	0	.37	.21	.07	.11	-	.13	0	.09	.27	.04	.03
Unidentified large cetacean	0	0	0	.07	0	-	0	.19	0	.09	0	0
TOTAL	1.98	1.86	2.52	2.08	1.40	-	.90	.93	1.49	2.31	.65	.95
TOTAL NUMBER OF SPECIES	6	12	8	6	10	-	4	2	8	10	7	10

TABLE 9. SIGHTING RATES OF INDIVIDUAL CETACEANS BY MONTH.

Species or Type	Sighting Rate (individuals/100 km)											
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
Fin whale	0	0	0	0	.1	-	0	0	0	0	0	0
Sei/Bryde's whale	0	0	0	0	0	-	0	0	0	0	0	+
Sperm whale	.5	.1	1.3	1.5	.3	-	.4	.2	.2	.1	0	.5
Pygmy/dwarf sperm whale	.5	.2	.6	.6	.2	-	0	0	.3	.3	.1	.4
Beaked whales	.1	.1	.1	0	.1	-	0	.2	.1	+	0	+
Melon-headed/ pygmy killer whale	0	1.5	0	0	0	-	0	0	0	0	0	0
False killer whale	0	.2	0	0	0	-	0	0	0	0	0	0
Killer whale	0	0	0	0	0	-	0	0	0	0	.3	0
Short-finned pilot whale	0	.3	0	0	4.8	-	0	0	0	0	0	0
Rough-toothed dolphin	0	0	0	0	0	-	0	0	0	.2	0	0
Bottlenose dolphin	5.8	.5	4.9	9.7	.9	-	2.8	0	.1	.2	1.5	1.5
Risso's dolphin	3.5	3.2	1.2	0	1.6	-	2.0	0	4.5	16.8	2.0	1.8
Atlantic spotted dolphin	3.8	4.5	26.8	21.5	3.3	-	0	8.3	5.6	1.3	0	.5
Pantropical spotted dolphin	0	2.5	18.9	15.2	2.2	-	0	0	11.1	13.3	14.2	7.7
Striped/spinner/ Clymene dolphin	0	5.7	.4	11.4	23.4	-	34.6	0	4.8	17.2	13.7	2.0
Stenella spp.	4.0	0	.5	0	0	-	0	0	6.8	.3	0	0
Unidentified small cetacean	0	.9	6.3	.1	.3	-	.3	0	.2	14.2	.8	+
Unidentified large cetacean	0	0	0	.2	0	-	0	.2	0	.2	0	0
TOTAL	18.0	19.9	61.1	60.2	37.4	-	40.1	8.6	33.8	64.1	31.1	14.4
TOTAL NUMBER OF SPECIES	6	12	8	6	10	-	4	2	8	10	7	10

latitude in the Gulf is less than 31° N.) Leatherwood and Reeves (1982) thought that this distribution was a result of the large size of males. Since they have greater metabolic requirements, in order to find enough prey, they may need to migrate to higher latitudes to waters with higher prey densities. This distribution would also reduce competition with females at lower latitudes.

Of the species we sighted more than once, only beaked whales and pantropical spotted dolphins were sighted at greater mean water depths (Table 4). Seasonally, we sighted sperm whales at mean water depths that were generally similar but herd sightings in winter and spring were in waters that were on average 100-200 m more shallow than those in summer and fall (Table 10). Sperm whales preferred water depths >600 m and distinctly preferred the depth range from 900-1,200 m (Table 11). Sperm whale sightings in Area 7 were concentrated near the 900 m isobath (Figure 6). Sperm whales on the upper continental slope preferred deeper waters away from the shelf break with a mid-range relative change in water depth (CI = 40-79) (Table 12). The southern half of Area 7 had a CI of 60-79 (Figure 6). When Area 7 was eliminated from the analysis, 17 of 20 herds were sighted at a CI of <59.

The sperm whale sightings reported by Collum and Fritts (1985) were generally in deeper water than our sightings. Their sightings were at an average depth of 1,228 m (range 104-2,742 m). CETAP (1982) reported a mean depth of 1,804 m for sperm whale sightings. In general, our surveys did not cover waters as deep as the CETAP surveys. Also, the south Texas study area surveyed by Fritts et al. (1983) extended into deeper waters than most of our survey area. [Most of sightings reported by Collum and Fritts (1985) occurred in this area.] Therefore, our surveys may not have covered the seaward concentration of sperm whales on the continental slope. One sperm whale was sighted during the mid-Gulf surveys at a depth of 2,392 m (Table 13, Figure 7).

The concentration of sperm whales near the Mississippi River delta (particularly in fall) was probably due to an abundance of squid in that area. Squid are the principal food of sperm whales (Clarke 1986). Voss and Brakoniecki (1985) report concentrations of longfin squid (<u>Loligo</u> <u>pealei</u>) east and west of the Mississippi River delta. However, the primary depth range of this species in the northern Gulf is thought to be in waters more shallow than we sighted sperm whales (40-250 m, Hixon 1980). Two species which occur in deeper Gulf waters that are thought to exist in "commercial quantities" are the shortfin squid (<u>Illex</u> <u>illecebrosus</u>) and the orange back squid (<u>Ommastrephes</u> <u>pteropus</u>) (Voss 1971). These two squid belong to the family Ommastrephidae. Squid in this family are medium (.15-.70 m) and large (>.7 m) sized squid (Clarke 1986) and this family is one of about seven squid families that make up the bulk of the diet of sperm whales worldwide (Rice 1989). In general, very little is known about the abundance and distribution of squid in deep Gulf waters but the shortfin squid is

TABLE 10. SEASONAL MEAN HERD SIZES AND WATER DEPTHS ($\bar{H}$ - mean herd size, $\bar{W}$ - mean water depth in meters, se - standard error, n - sample size).

Season	$\bar{H}$	se(H)	$\bar{W}$	se(W)	n
			Species or type		
			Baleen whales		
Winter	-	-	-	-	0
Spring	-	-	-	-	0
Summer	1.0	-	324	-	1
Fall	1.0	-	148	-	1
			Sperm whale		
Winter	1.2	.20	764	14	5
Spring	1.0	0	707	111	7
Summer	3.1	1.03	869	57	7
Fall	2.3	.41	945	49	24
			Dwarf/pygmy sperm whale		
Winter	-	-	-	-	0
Spring	1.6	.26	707	191	8
Summer	2.0	.33	560	88	12
Fall	2.0	.39	420	60	12
			Beaked whales		
Winter	1.0	-	925	-	1
Spring	1.5	.50	1,035	42	2
Summer	1.3	.50	876	7	4
Fall	1.0	0	1,007	803	2
			Melon-headed/pygmy killer whale		
Winter	-	-	-	-	0
Spring	-	-	-	-	0
Summer	25	-	318	-	1
Fall	-	-	-	-	0

TABLE 10. CONTINUED

Season	$\bar{H}$	se(H)	$\bar{W}$	se(W)	n
			Species or type		
			False killer whale		
Winter	-	-	-	-	0
Spring	-	-	-	-	0
Summer	3.0	-	1,107	-	1
Fall	-	-	-	-	0
			Killer whale		
Winter	-	-	-	-	0
Spring	8.0	-	963	-	1
Summer	-	-	-	-	0
Fall	-	-	-	-	0
			Short-finned pilot whale		
Winter	-	-	-	-	0
Spring	-	-	-	-	0
Summer	5.0	-	364	-	1
Fall	21.5	2.25	665	49	4
			Rough-toothed dolphin		
Winter	-	-	-	-	0
Spring	4.0	-	932	-	1
Summer	-	-	-	-	0
Fall	-	-	-	-	0
			Bottlenose dolphin		
Winter	22.0	4.00	472	406	2
Spring	3.5	.50	374	180	2
Summer	8.6	.62	271	69	18
Fall	15.1	4.08	202	42	17
			Risso's dolphin		
Winter	16.0	9.00	475	38	2
Spring	13.6	1.96	425	33	39
Summer	9.4	2.19	465	53	17
Fall	17.3	8.29	470	71	3

TABLE 10. CONTINUED

Season	$\bar{H}$	se(H)	$\bar{W}$	se(W)	n
			Species or type		
		Atlantic spotted dolphin			
Winter	22.0	10.00	188	26	2
Spring	17.6	5.78	310	41	9
Summer	19.4	3.98	386	121	8
Fall	52.9	19.60	400	57	17
		Pantropical spotted dolphin			
Winter	-	-	-	-	0
Spring	73.6	13.10	839	112	11
Summer	55.2	8.99	947	101	5
Fall	79.4	18.89	984	155	7
		Striped/spinner/Clymene dolphin			
Winter	180.0	76.53	805	13	3
Spring	116.3	42.89	1,081	133	7
Summer	99.5	6.57	455	91	8
Fall	99.3	39.53	578	114	6

TABLE 11. DEPTH PREFERENCES OF CETACEAN HERDS (OBS - herds observed, EXP - herds expected, ns - nonsignificant, * - $P<0.05$, ** - $P<0.01$, *** - $P<0.001$).

All cetaceans

Depth (m)	OBS	EXP
18- 300	72	76.5
301- 600	97	92.7
601- 900	62	66.8
901-1,200	62	61.3
>1,200	27	22.6

Chi-square = 1.7^{ns}

Bottlenose dolphin

Depth (m)	OBS	EXP
18- 300	23	9.6
301- 600	10	10.6
601- 900	3	8.4
901-1,200	3	7.6
>1,200	0	2.8

Chi-square = 27.8^{***}

Atlantic spotted dolphin

Depth (m)	OBS	EXP
18- 300	15	8.6
301- 600	16	10.4
601- 900	3	7.6
901-1,200	1	6.8
>1,200	1	2.5

Chi-square = 16.3^{**}

Striped/spinner/ Clymene dolphin

Depth (m)	OBS	EXP
18- 300	1	5.8
301- 600	8	7.0
601- 900	5	5.0
901-1,200	5	4.6
>1,200	5	1.7

Chi-square = 10.7^{*}

Dwarf/pygmy sperm whale

Depth (m)	OBS	EXP
18- 300	8	7.7
301- 600	12	9.3
601- 900	6	6.7
901-1,200	4	6.1
>1,200	2	2.2

Chi-square = 1.6^{ns}

Risso's dolphin

Depth (m)	OBS	EXP
18- 300	10	14.4
301- 600	32	17.7
601- 900	16	12.8
901-1,200	3	11.6
>1,200	0	4.3

Chi-square = 24.5^{***}

TABLE 11. CONTINUED.

Pantropical spotted dolphin			Sperm whale		
Depth (m)	OBS	EXP	Depth (m)	OBS	EXP
18- 300	1	5.0	18- 300	0	10.3
301- 600	1	7.3	301- 600	0	12.5
601- 900	6	5.3	601- 900	11	9.0
901-1,200	10	4.8	901-1,200	28	8.2
>1,200	5	1.8	>1,200	4	3.0
Chi-square = 20.5^{***}			Chi-square = 71.7^{***}		

TABLE 12. CONTOUR INDEX PREFERENCES OF CETACEAN HERDS (OBS - herds observed, EXP - herds expected, ns - nonsignificant, * - P<0.05, ** - P<0.01, *** - P<0.001).

All cetaceans

CI	OBS	EXP
20-39	33	41.0
40-59	64	63.6
60-79	100	109.8
80-99	123	105.6

Chi-square = 5.2^{ns}

Bottlenose dolphin

CI	OBS	EXP
20-39	2	5.2
40-59	3	8.0
60-79	6	13.6
80-99	29	13.2

Chi-square = 28.3^{***}

Atlantic spotted

CI	OBS	EXP
20-39	0	4.7
40-59	2	7.2
60-79	15	12.2
80-99	19	11.9

Chi-square = 13.3^{**}

Striped/spinner/ Clymene dolphin

CI	OBS	EXP
20-39	3	3.1
40-59	5	4.8
60-79	5	8.2
80-99	11	7.9

Chi-square = 2.4^{ns}

Dwarf/pygmy sperm

CI	OBS	EXP
20-39	5	4.2
40-59	7	6.4
60-79	7	10.9
80-99	13	10.6

Chi-square = 2.2^{ns}

Risso's dolphin

CI	OBS	EXP
20-39	3	7.9
40-59	14	12.2
60-79	12	20.7
80-99	32	20.1

Chi-square = 14.0^{**}

Pantropical spotted

CI	OBS	EXP
20-39	8	3.3
40-59	9	5.0
60-79	5	8.5
80-99	3	8.3

Chi-square = 14.9^{**}

Sperm whale

CI	OBS	EXP
20-39	5	5.6
40-59	12	8.6
60-79	21	14.6
80-99	5	14.2

Chi-square = 10.1^{*}

TABLE 13. CETACEAN HERDS SIGHTED DURING MID-GULF SURVEYS.

Species	Adults	Calves	Water Depth (m)
20 June 1990			
Beaked whale	1	0	2,762
Pantropical spotted dolphin	9	0	1,814
Stenella spp.	26	0	2,548
	34	0	1,282
21 June 1990			
Sperm whale	1	0	2,392
Dwarf/pygmy sperm whale	1	1	867
	1	0	1,006
Melon-headed/ pygmy killer whale	6	3	651
False killer whale	2	0	2,332
Short-finned pilot whale	54	10	2,418
Pantropical spotted dolphin	6	1	711
	67	0	3,184
	33	0	2,956
	95	0	2,835
	5	0	2,120
Striped/spinner/ Clymene dolphin	63	0	673
	82	0	748
	75	0	3,029
	80	3	2,288

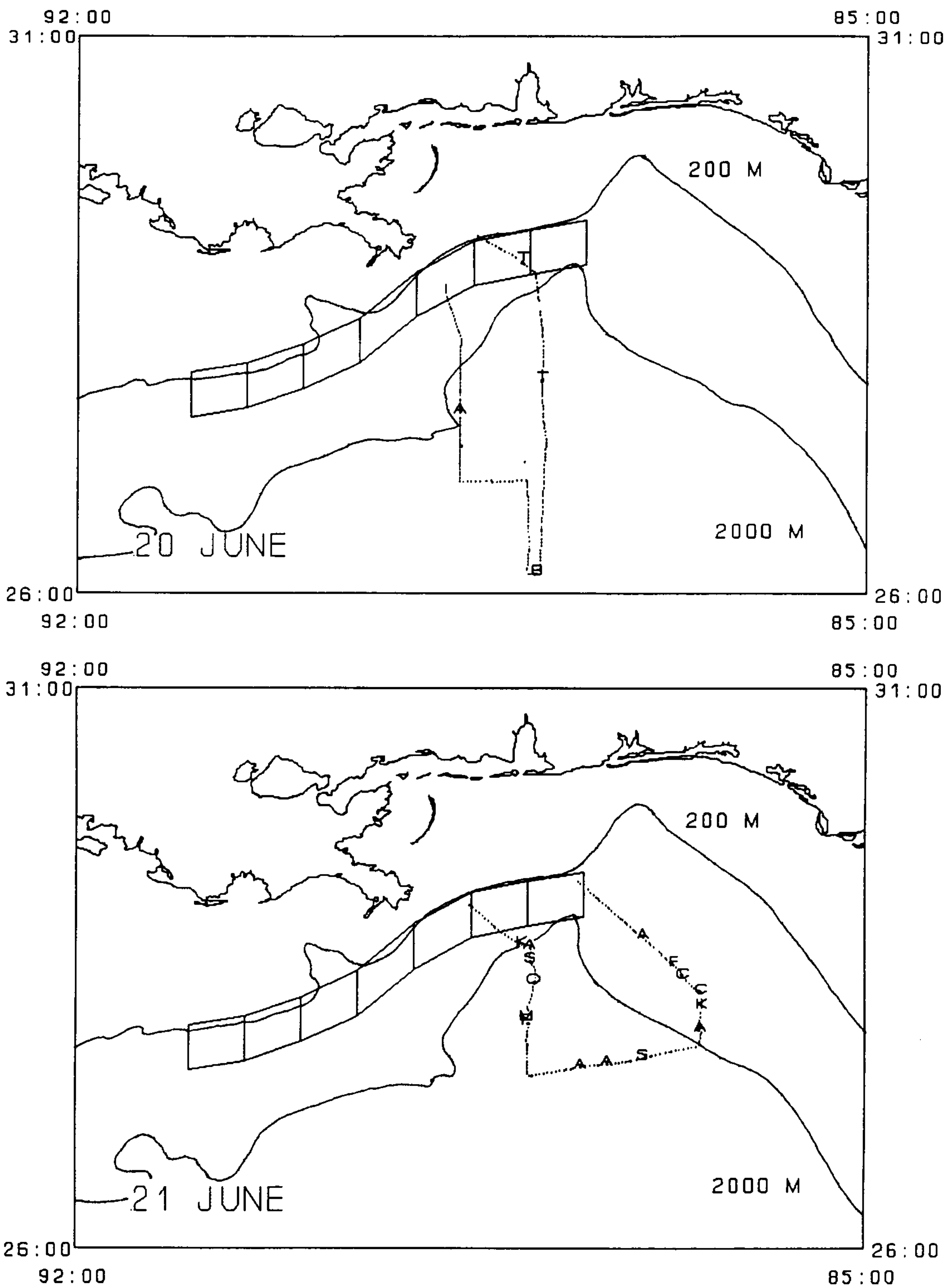


FIGURE 7. LOCATIONS OF CETACEAN HERDS SIGHTED DURING MID-GULF SURVEYS (A - pantropical spotted dolphins, F - pygmy killer whales, C or S - striped/spinner/Clymene dolphins, K - dwarf or pygmy sperm whales, P - pilot whale, M - sperm whale, O - false killer whale, B - beaked whale, T - Stenella spp. The dotted line is the survey route.)

thought to inhabit the upper continental slope and the orange back is thought to be more pelagic (Voss 1971).

The 43 herds we sighted had a total of 91 whales. Herd sizes ranged from one to 11 whales with a mean of 2.1. Most sightings (26) consisted of one whale and eight had two whales. Although the sample size was small, winter and spring mean herd sizes were smaller (about 1) than those from summer and fall (2-3) (Table 10). The mean size of sperm whale herds we sighted was slightly smaller than the mean of 3.5 (range 1-14) reported by Collum and Fritts (1985) and the mean of 3.0 (range 1-100) reported by CETAP (1982).

The range and frequencies of herd sizes we observed does not fit with observations from other areas. Herd sizes reported from other areas for mixed groups and bachelor herds were much larger and ranged from about 20-40 (Rice 1989). The sperm whale herd sizes we observed may be more in line with the sizes of subgroups consisting of 2-10 animals observed by Whitehead and Arnbom (1987).

Our small herd sizes may have been an artifact of aerial surveys and perhaps non-synchronous feeding by members of the sperm whale herd or subgroup. Our observation time, when a sperm whale herd was sighted, was less than 10 minutes, so it is possible that other members of the herd or subgroup were below the surface. Also, sperm whales may be able to communicate over long distances (Caldwell et al. 1966). Sperm whales in a herd could have been spread out over such a large area that we may not have sighted all the members in a herd. However, mixed sperm whale herds are thought to be more cohesive spatially than this but bachelor herds may be more loosely aggregated. The sperm whales concentrated in Area 7 along the 900 m isobath could have been members of one or two herds in the same vicinity. We estimated the size of the sperm whale "population" in Area 7 to be 39 whales. Although this estimate is undoubtedly negatively biased, it is more in line with the sizes of mixed groups and bachelor herds (Rice 1989). Most of the herds sighted by Collum and Fritts (1985) and during the CETAP (1982) surveys were also from aerial surveys.

The only other explanation that would account for the small sizes of sperm whale herds and the number of solitary animals we observed would be that they primarily consisted of older sexual and socially mature males. This explanation makes very little sense, however. At the latitudes in the Gulf, if the solitary animals were mature males, we should have sighted a commensurate number of larger mixed herds. We did not observe this. Physically mature males can be one and one-half times as long and three times as heavy as physically mature females (Evans 1987). Collum and Fritts (1985) reported that of 17 sperm whale herds they sighted in the Gulf, six were solitary animals. They estimated the solitary animals to be larger than adults in mixed groups and speculated that the large solitary animals could be mature males. We did not see any individuals that we recognized as being particularly large.

We found absolute size very difficult to estimate from the air without some kind of known reference object. Large male sperm whales could make up a relatively small part of the Gulf population at any given time during the year. Whitehead and Arnbom (1987) speculated, based on the low numbers of large males observed near the Galapagos Islands during breeding season, that perhaps because of energetic or other limitations, males might not breed every year, remaining instead in the colder waters at higher latitudes where they normally feed.

We observed calves on only two occasions and they made up <3% of the sperm whales we observed. One calf was sighted with two adults in October 1989 in Area 7. The calf was swimming underneath the posterior half of one of the adults. The calf would surface briefly to breath and quickly returned to that position. The second calf was observed in a herd of eight adults during June 1990 in Area B4. Collum and Fritts (1985) reported many more calves from their Gulf sperm whale sightings. They reported 20% of the whales they observed were calves.

Sperm whales have a low productivity rate. The calving interval for sperm whales averages five years and thus, in any given year, only about 20% of the females are receptive to breeding and young of the year comprised about 6% of the total sperm whale population. A female sperm whale might produce an average 4.1 calves during her lifetime (Best 1979, Best et al. 1984). Breeding periods are generally April-June in the northern hemisphere and births occur mainly in August (Evans 1987).

Depending on the depth and duration of a dive, Leatherwood and Reeves (1983) reported that a sperm whale may remain on the surface for more than an hour and blow more than 50 times before beginning the next dive. They stated that shorter surface times and fewer blows are more common and that females may have shorter dives and surface intervals than males. Most of the sperm whale herds we observed (22) were resting at the surface blowing at regular intervals. We observed sperm whales breaching in the distance five times but the whales stopped breaching as the aircraft approached. We sighted one sperm whale engaged in a most unusual behavior on 13 September 1989. This whale was completely vertical in the water column with flukes down and its head about 5 m below the surface. We circled the whale for 12 minutes and it never moved from this position. We could only find one reference to a similar posture in a sperm whale. Best et al. (1984), in describing the behavior of herd members during the birth of a calf, noted that the occasions were sometimes characterized by "...unusual postures of one or more animals (often head-up in vertical position)...". The sperm whale we observed was the only one we sighted that day. We thought the other herds we observed during the study were traveling.

The reaction of sperm whales to our aircraft was not consistent. Some would remain on or near the surface the entire time we were in the vicinity. Others would immediately throw flukes up and sound, and some would dive a few minutes after the sighting.

Dwarf/pygmy sperm whales

The dwarf and the pygmy sperm whales are probably distributed throughout temperate, subtropical and tropical waters worldwide. However, the dwarf sperm whale may inhabit warmer waters than the pygmy sperm whale (Caldwell and Caldwell 1989). Both species apparently inhabit waters near the edge of the continental shelf and beyond. Ross (1978) suggested that the dwarf sperm whale may live on or near the edge of the continental shelf, whereas the pygmy sperm whale may inhabit deeper waters. He later updated this hypothesis and suggested that immature animals and mother/calf pairs of both species (but primarily the dwarf sperm whale) inhabit more shallow water near the continental shelf and adults of both species inhabit pelagic waters (Ross 1984).

In the Gulf, prior to this study both species were known only from strandings. Schmidly (1981) reported 18 strandings of the pygmy sperm whale and six strandings of the dwarf sperm whale. While strandings have been predominately pygmy sperm whales, Johnson et al. (in prep. b) reported that seven of 11 Kogia sightings from the 1990 SEFC ship survey in the Gulf were identified as dwarf sperm whales and the remainder as only dwarf/pygmy sperm whales.

Sightings of dwarf/pygmy sperm whale herds were our fifth most common sighting (Table 4). However, because of the small average herd sizes, the densities of dwarf/pygmy sperm whales were generally less than those of the species of Stenella, Risso's dolphin and the bottlenose dolphin (Table 5). Caldwell and Caldwell (1989:241) stated that because of the lack of sightings at sea, "there are no real estimates of abundance for either species," therefore, ours may be one of the first for dwarf/pygmy sperm whales.

The shape and position of the mouth, and the diet of dwarf/pygmy sperm whales (i.e., squid, crustaceans and some fish) suggest that they feed at or near the bottom in deep water (Ross 1978, Gaskin 1982, Nagorsen 1985). Their deep and probably extended dives could cause our abundance estimates to be greatly underestimated if feeding occurred regularly during the daylight hours. Also, dwarf/pygmy sperm whales were always observed to be relatively quiet at the surface and this, along with their small herd sizes, could cause herds to be missed more than other species (see below).

The small mean herd size (<2) we found for these species generally supports previously reported herd sizes. From limited observations at sea, the herd sizes have been reported to range from 2-10 (Yamada 1954, Ross 1978). Vidal et al. (1987) report sightings of two single pygmy sperm whales and a group of three in the Gulf of California. Scott and Cordaro (1987) described the behavior of a herd consisting of a mother and calf in a tuna purse seine. The largest herd we sighted consisted of three adults and a calf. Johnson et al. (in prep. b) reported 11 herds in the Gulf ranged in size from 1-7 with a mean of 2.1.

The temporal distribution of dwarf/pygmy sperm whales we sighted was variable. The highest sighting rates of herds occurred in the early fall (September, October) and no herds were sighted in the winter (Table 8). Spatially, herds were found throughout the study area although only one herd was sighted in the extreme western part of the study area. There was a concentration of sightings along the western wall of the Mississippi Trough (Figure 8). This concentration resulted in a sighting rate for these species in Area A8 which was more than twice that for any other area (Table 6). This portion of A8 was not surveyed in 1990. Because of the small herd sizes, the spatial and temporal sighting rates of individuals were very similar to those for herds (Tables 7 and 9).

As stated earlier, dwarf/pygmy sperm whales inhabit waters of the continental shelf edge and beyond. Dwarf/pygmy sperm whales were sighted in a great range of water depths (Table 4). If the two species of _Kogia_ partition themselves by water depth or proximity to the edge of the continental shelf, as suggested by Ross (1978), this could account for the wide range of water depths we found them in on the upper continental slope. Seasonally, the average water depth varied greatly (Table 10). Dwarf/pygmy sperm whales were observed in more shallow water in the fall and deeper water in the spring. Johnson et al. (in prep. b) reported a mean depth of 1,552 m (range 364-3,150) for _Kogia_ sightings from the SEFC ship survey. The ship survey covered deeper waters in the central Gulf as well as continental slope waters.

In the range of water depths sampled in our study, dwarf/pygmy sperm whales apparently did not prefer any particular water depth interval (Table 11). Also, bottom topography did not significantly influence their distribution (Table 12). Again, if the two species are partitioned by water depth according to species, age class or maternal status, our inability to separate the two species may have masked potential differences.

We did not sight dwarf/pygmy sperm whales in association with any other species. We sighted two herds of dwarf/pygmy sperm whales during mid-Gulf surveys (Table 13, Figure 7). The response of dwarf/pygmy sperm whales to the aircraft was consistent and predictable. They usually dove within several orbits of the aircraft. Sometimes they would remain at the surface longer if we climbed to 300-450 m as soon as the sighting was made. When they

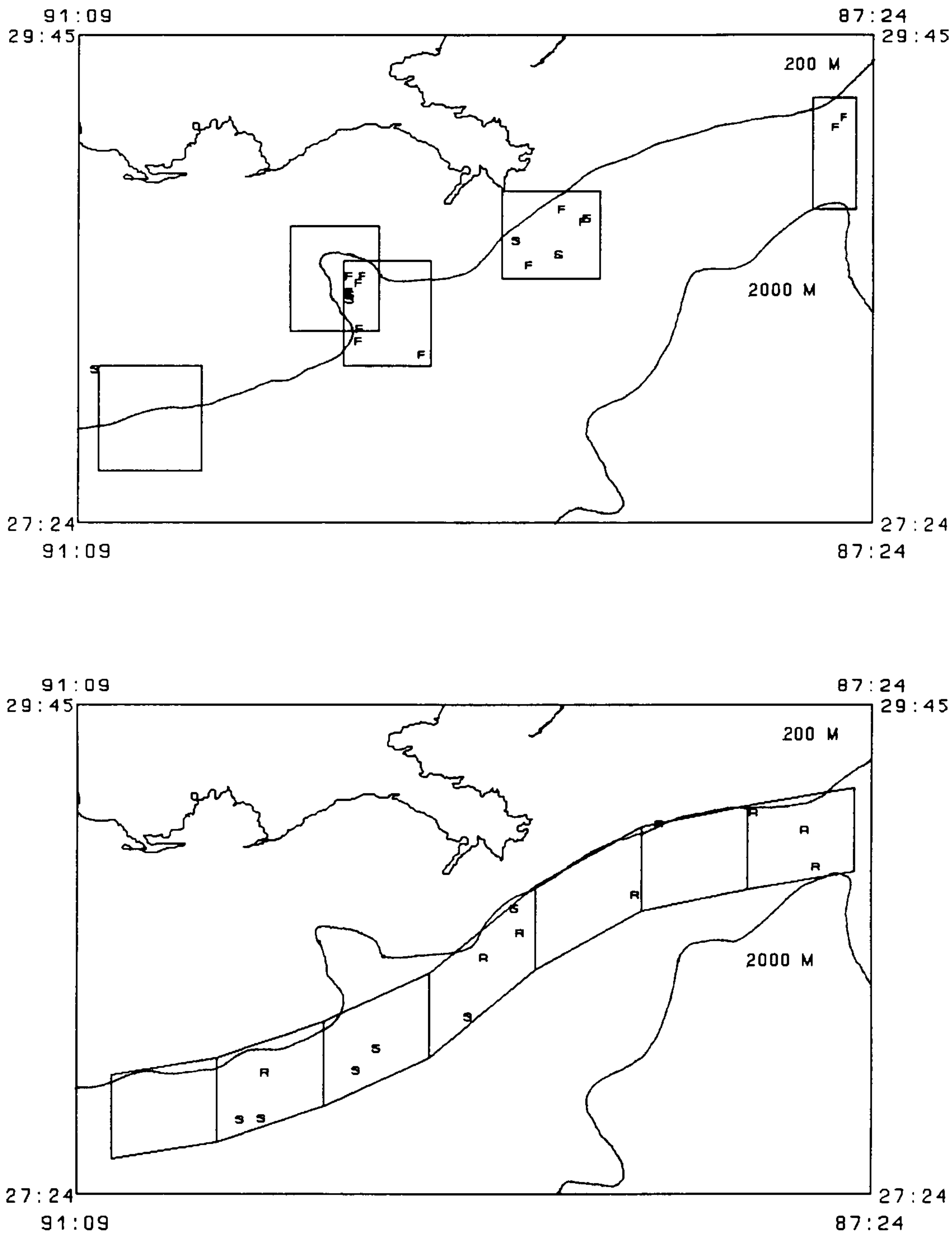


FIGURE 8. LOCATIONS OF DWARF/PYGMY SPERM WHALE HERDS SIGHTED DURING 1989 (upper panel) AND 1990 (lower panel) (W - winter, R - spring, S - summer, F - fall).

dove they did not throw flukes or create any visible surface disturbance. They usually dropped below the surface and swam out of sight with several very pronounced fluke beats. Apparently the aircraft did not overly agitate the animals because we did not observe the cloud of intestinal fluid that is emitted when an animal is agitated. However, this "startled response" has only been observed for pygmy sperm whales (Caldwell and Caldwell 1989). For the few moments we could observe these species, they usually were very still, rafting at the surface. We did not observe a visible blow. In contrast to the very reserved behavior of the dwarf/pygmy sperm whales we observed, Johnson et al. (in prep. b) report on the breaching behavior of a dwarf sperm whale observed during the 1990 SEFC cruise.

The 32 sightings of dwarf/pygmy sperm whales made here constitute the largest data base of at-sea sightings of this species group in the Gulf. This portion of the eastern Gulf and the Atlantic south of Cape Hatteras may be an important part of the range of these two species. Fritts et al. (1983) did not sight any dwarf/pygmy sperm whales in their Texas or Louisiana study areas but did sight one herd in their Atlantic study area. (Their Gulf study area off Florida was entirely on the continental shelf.) Strandings of dwarf and pygmy sperm whales are numerous on the Atlantic coast south of Cape Hatteras. In contrast, during extensive surveys north of Cape Hatteras, only one herd of dwarf/pygmy sperm whales was sighted (CETAP 1982).

Beaked whales

Members of the beaked whale family (Ziphiidae) are distributed throughout the world. Of the 19 species in the family, 13 belong to the genus Mesoplodon (Leatherwood and Reeves 1983, Reyes et al. 1991). Species known from the Gulf include three mesoplodonts and only one non-mesoplodont, Cuvier's beaked whale (also known as the goosebeaked whale) (Table 1).

Data on beaked whales in the Gulf are limited. Sowerby's beaked whale is known from only one stranding on the Florida panhandle (Bonde and O'Shea 1989). In the Gulf, Schmidly (1981) reported one stranding of Blainville's beaked whale on the Louisiana coast, six strandings of Gervais' beaked whale and seven strandings of Cuvier's beaked whale. Fritts et al. (1983) reported the first sightings of living beaked whales in the Gulf. They reported five sightings of 12 mesoplodonts in the Gulf.

During our surveys we sighted 11 beaked whales. Seven single animals were sighted and 2 pairs. We are confident that two of the single animals and one of the pairs were Cuvier's beaked whale. Four of the sightings were either mesoplodonts or Cuvier's beaked whales. We believe that the beaked whale sighted during the mid-Gulf surveys was Cuvier's (Table 13, Figure 7). Beaked whales responded to aircraft almost immediately by diving. In many cases our observations consisted of the initial glance by the observer. In other cases, the animal would dive after two or three orbits. Similar behavior was observed during the CETAP (1982) surveys.

One beaked whale sighted in June 1990 in Area B7 was very interesting. This beaked whale remained at the surface long enough for photographs and video tape to be taken. (The pilots increased the altitude in an attempt to extend the observation time.) It was long, relatively streamlined (nonrobust), the dorsal fin was about two-thirds of the way back from the head and it had a well defined elongate beak. This beaked whale's color pattern was different than any we had seen. The anterior two-thirds dorsally were white or very light gray. The posterior third was black or olive in color. The posterior dark coloration invaded the anterior white at an angle ventrally for about one-third the body length. We are reasonably confident that the animal was a mesoplodont. However, the coloration does not match that of any known mesoplodont species. The color pattern does match that of some older male Cuvier's beaked whale. In those animals, the dorsal surface becomes white or pale from the head to the dorsal fin. However, the beak on Cuvier's whale is not as well defined as that of a Mesoplodon and the beak that does exist becomes less distinct as the animal ages (Leatherwood and Reeves 1983). The color pattern looked similar to the unidentified Mesoplodon described by Pitman et al. (1987) except that on the animals they sighted in the eastern tropical Pacific, the posterior dark coloration invaded the anterior white color dorsally. Assuming we correctly identified it as a Mesoplodon, it could be a species in which the color pattern is not known, it could be a color variant or aberrant of a species that is better known, or it could be a new species. Each conclusion is reasonable. The coloration of the known species of Mesoplodon are generally based on dead strandings and colors may change quickly after death. The genus has the most species in the order cetacea, many of which are very obscure and there may still be unknown species.

The herd sizes we observed of beaked whales (1-2) were the smallest of any species we sighted more than once and were similar to other reported observations. However, as many as seven Cuvier's beaked whales have been reported in one herd (Heyning 1989) and Meade (1989) reported that a mass stranding of mesoplodonts had 28 animals. Six sightings of unidentified beaked whales by Fritts et al. (1983) averaged 2.5 animals per herd. In the Atlantic, 13 sightings of Mesoplodon sp. averaged 3.0 whales and six herds of Cuvier's beaked whale averaged 2.7 whales (CETAP 1982).

We sighted beaked whales throughout the year but none were sighted in October, January and May (Table 8). East to west, sightings were made throughout length of the area studied (Figure 9). Of species sighted more than once, beaked whale sightings on average were made in the deepest water (Table 4). All beaked whale sightings were in the middle to southern portions of the study

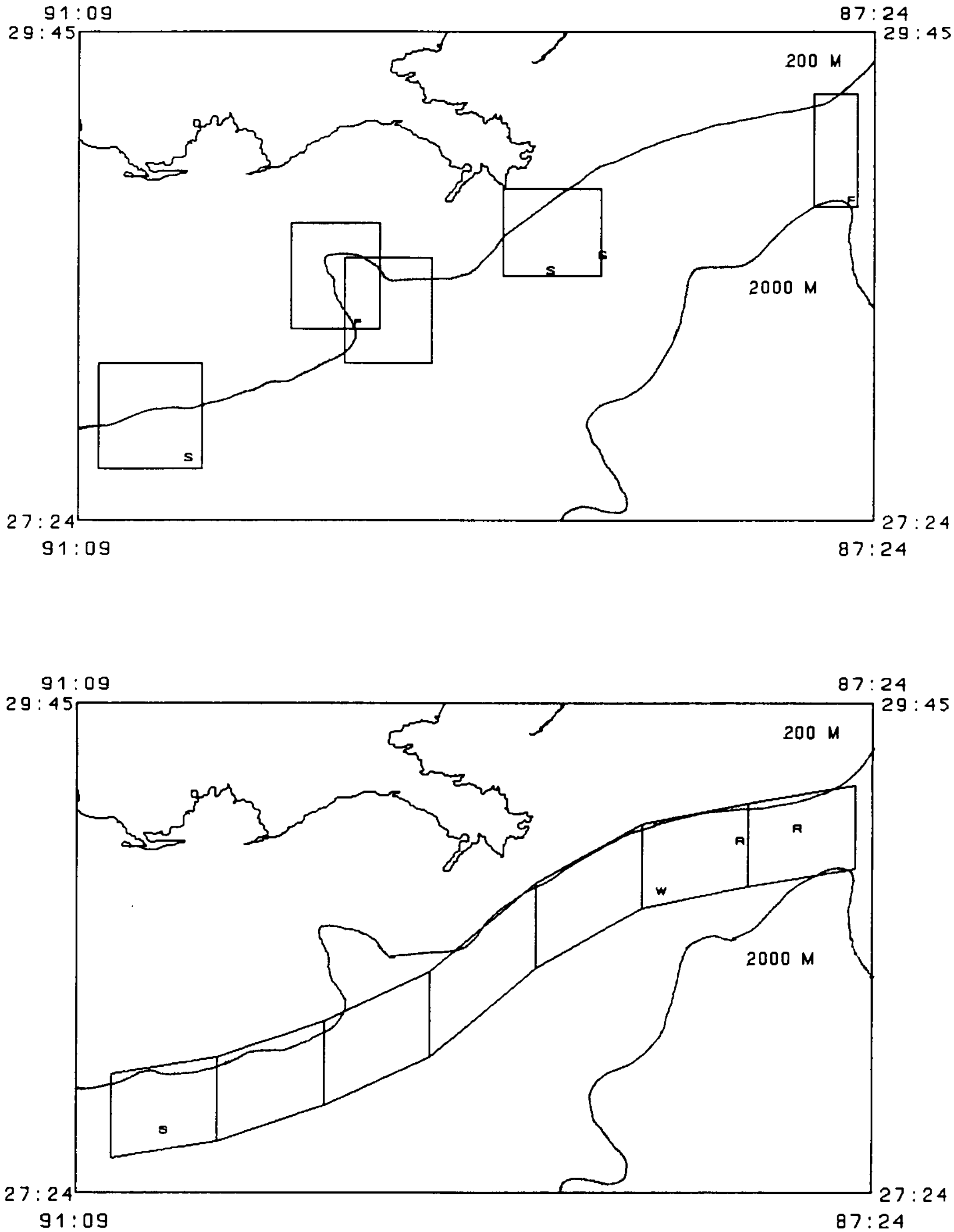


FIGURE 9. LOCATIONS OF BEAKED WHALE HERDS SIGHTED DURING 1989 (upper panel) AND 1990 (lower panel) (W - winter, R - spring, S - summer, F - fall).

area. Fritts et al. (1983) reported four of their six sightings in waters >900 m. All of the beaked whale sightings reported by CETAP (1982) were near the 2,000 m isobath. The beaked whale sighted during the mid-Gulf survey was almost halfway between Mobile, Alabama and the Yucatan Peninsula. Beaked whales are probably difficult to sight from aircraft. They average small herds, dive very quickly in response to the aircraft and of the animals we observed, none were creating surface disturbances which would cue observers to their presence. However, Leatherwood et al. (1976) show a photograph of a beaked whale jumping clear of the surface. We did not observe beaked whales associated with any other species.

Melon-headed/pygmy killer whales

Melon-headed whales and pygmy killer whales occur in warm waters throughout the world. However, the pygmy killer whale may be restricted to tropical waters. Very little is known about either species. Melon-headed whales have been reported to form large herds of up to 1,500 animals. Observations of pygmy killer whales suggest herds generally contain fewer than 50 whales. Both species have been sighted associated with other cetaceans including Fraser's dolphin (Leatherwood and Reeves 1983).

Schmidly (1981) reported only two strandings of pygmy killer whales in the Gulf. The first Gulf stranding of the melon-headed whale occurred on the Texas coast in 1990 (D. Odell, pers. comm., Sea World of Florida). We sighted one herd of 25 melon-headed/ pygmy killer whales during our regular surveys. The herd was sighted in Area A8 during August 1989 in water 318 m deep (Figure 10). We also sighted a herd of nine melon-headed/pygmy killer whales while conducting a mid-Gulf survey during June 1990 (Figure 7). The water depth of the sighting was 651 m. Fritts et al. (1983) sighted one herd of 20-25 pygmy killer whales during November in their Texas study area in water 659 m deep. Both herds sighted during our study remained near the surface while the aircraft circled overhead.

False killer whale

Like so many Gulf cetaceans, false killer whales are distributed in warm temperate to tropical waters throughout the world. This whale is not known to be abundant anywhere and thought to be an oceanic species. They are known to form herds of over 100 animals and associate with other cetaceans (Leatherwood and Reeves 1983). Seven Gulf records reported by Schmidly (1981) include strandings, sightings and captures. A mass stranding of 19 was reported from the Florida Keys (Odell et al. 1980). We sighted one herd of three false killer whales during our regular surveys in August 1989 in Area A7 (Figure 11). The water depth was 1,107 m. During a mid-Gulf survey in June 1990 we sighted a herd of two animals at a water depth of 2,332 m (Figure 7). Fritts et al.

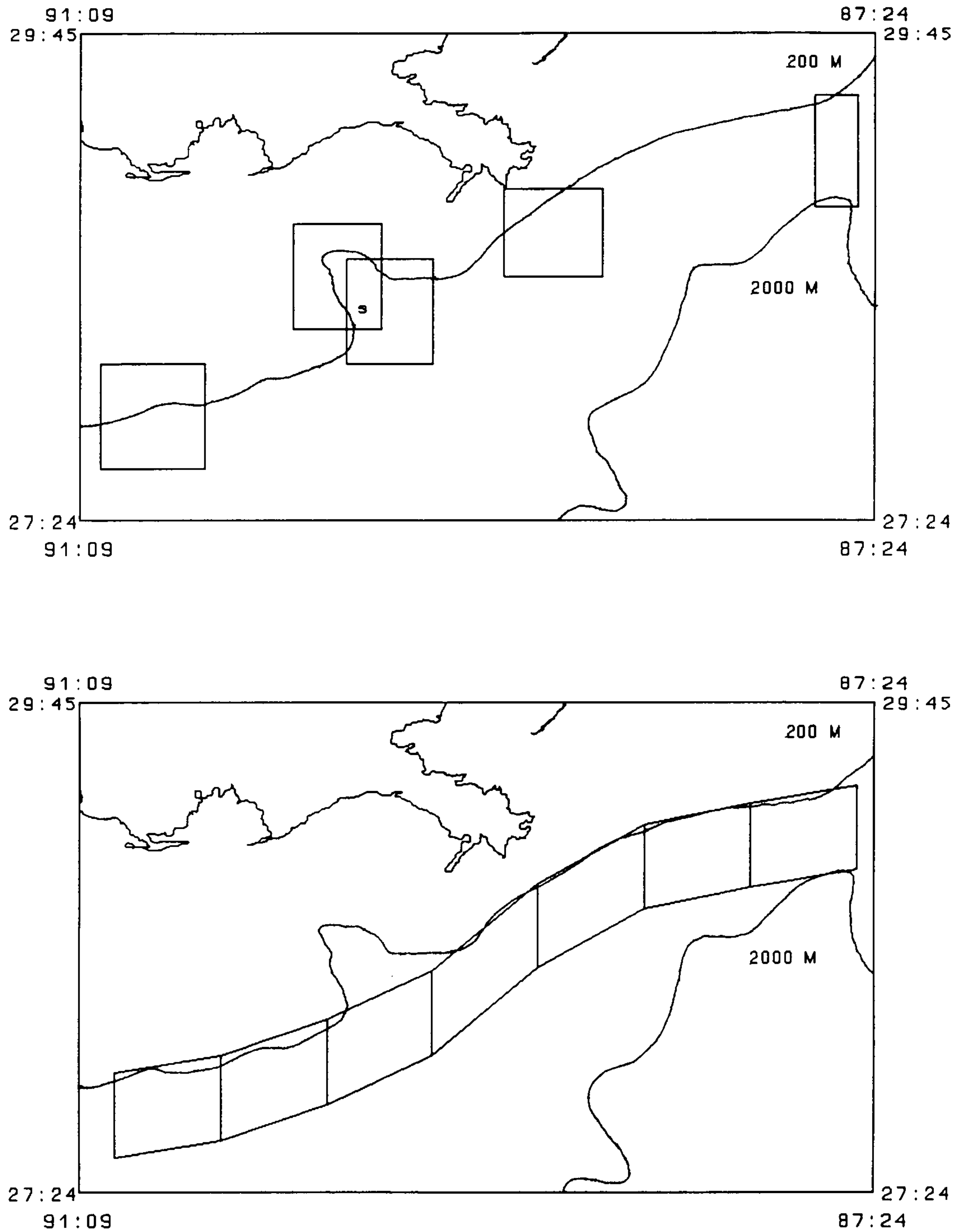


FIGURE 10. LOCATIONS OF MELON-HEADED/PYGMY KILLER WHALE HERDS SIGHTED DURING 1989 (upper panel) AND 1990 (lower panel) (W - winter, R - spring, S - summer, F - fall).

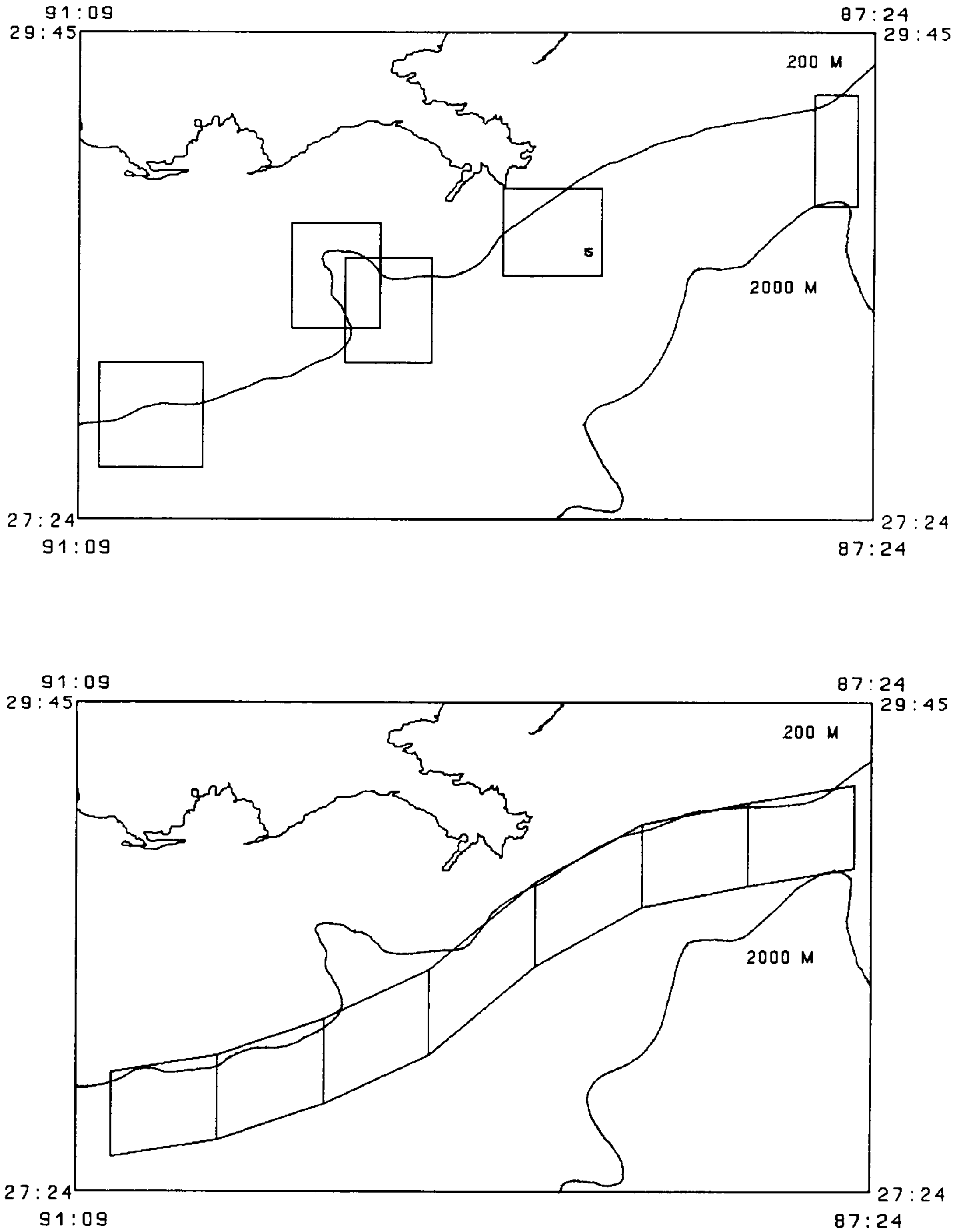


FIGURE 11. LOCATIONS OF FALSE KILLER WHALE HERDS SIGHTED DURING 1989 (upper panel) AND 1990 (lower panel) (W - winter, R - spring, S - summer, F - fall).

(1983) did not sight false killer whales in the Gulf. However, they sighted five herds in the Atlantic at water depths from 640-741 m. Their herds ranged in size from 2-8 and averaged 2.2 whales. One herd of seven false killer whales was sighted during the CETAP (1982) surveys.

The two herds we sighted reacted very differently to the aircraft. One herd rafted at the surface during the entire observation time but the other dove almost immediately.

Killer whale

Killer whales are found throughout the world in both coastal waters and pelagic habitat. Schmidly (1981) reported four strandings and two sightings of killer whales in the Gulf. There have been at least two other recent sightings of killer whales in the Gulf. In 1985, fishermen photographed a pod of about 15 that was made up of bulls, cows and calves off Texas (Corpus Christi Caller, 6 September 1985). In 1989, a pod was videotaped in deep water south of the Alabama-Florida border (R. Shipp, pers. comm., Univ. South Alabama). This sighting was near the southeastern corner of our Area B1 or A10.

We sighted a pod of eight killer whales on 14 May 1990 in Area B4 at a depth of 964 m (Figure 12). The pod consisted of a mature male, a very small calf and six whales of intermediate sizes. The mature male was identified by its extremely large size compared to the other whales in the pod and the size and shape of its dorsal fin. The individuals, except for the mother and calf pair, were spread out with more than 30-50 m between them and were generally milling about. For the most part, the whales remained near the surface the entire time we observed them.

Killer whales will feed on other marine mammals and many species of fish. In the Gulf of Maine, bluefin tuna (*Thunnus thynnus*) may be a major prey of killer whales. The annual peaks in both killer whale sightings and bluefin tuna catches coincide in the Gulf of Maine (Gormley 1990). The Gulf of Mexico (Gulf) is a major spawning ground of bluefin tuna. Yellowfin tuna (*T. albacares*) and blackfin tuna (*T. atlanticus*) also occur in the Gulf. Bluefin tuna are migratory and are thought to be gone from the north-central Gulf by early June, but yellowfin and blackfin tuna are in the Gulf throughout the year. The major Gulf fishing grounds for bluefin and yellowfin tuna are from DeSoto Canyon to about 92° W longitude, similar to the area we surveyed (USDOC 1985). Killer whales may be in the Gulf feeding on tuna.

Short-finned pilot whale

The short-finned pilot whale (pilot whale) also inhabits warm temperate to tropical waters throughout the world. Pilot whales are generally found on the continental slope and beyond. However,

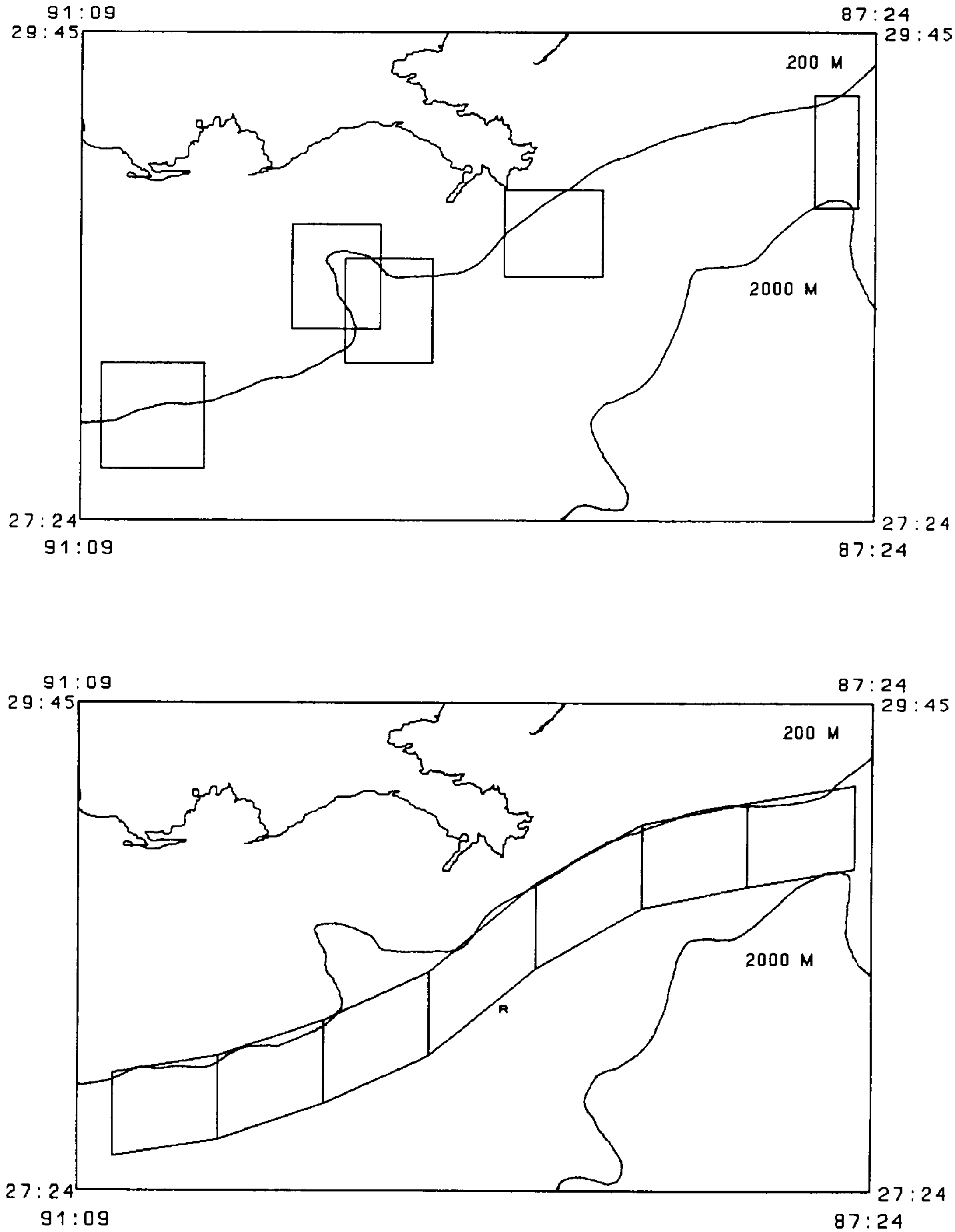


FIGURE 12. LOCATIONS OF KILLER WHALE HERDS SIGHTED DURING 1989 (upper panel) AND 1990 (lower panel) (W - winter, R - spring, S - summer, F - fall).

they will come inshore off southern California and Japan seasonally (Leatherwood and Reeves 1983).

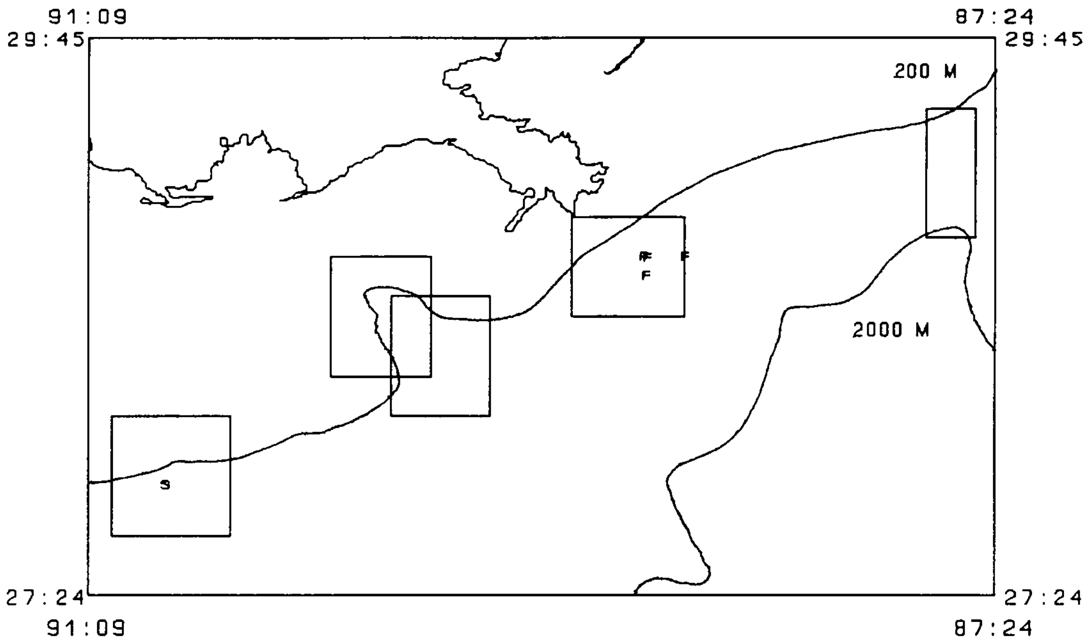
Strandings of pilot whales are numerous in the Gulf (Schmidly 1981). Fritts et al. (1983) reported sightings of four herds during their aerial surveys in the Gulf.

We sighted five herds of pilot whales. One herd of five was sighted in Area A9 during August 1989 associated with a group of Risso's dolphins. The other four herds were sighted on 4 November 1989 in Area A7. The sightings were aggregated (Figure 13) and may have been part of one large herd totaling 86 whales. Each sighting consisted of animals of various sizes. Some extremely large animals were obviously mature males with squared-off heads and large rounded dorsal fins. There were also mother-calf pairs and animals of intermediate sizes. In each instance, they were in groups of 1-5 that were spread out. The whales were very active, frequently diving and surfacing. An additional herd of 64 was sighted during a mid-Gulf survey (Table 13, Figure 7). Members of this herd were rafting at the surface in groups of 3-7. The aircraft apparently did not disturb them to a large degree. They would sink just below the surface when the aircraft was overhead, and would rise to the surface again after it passed.

Fritts et al. (1983) sighted 144 pilot whales in four herds in the Gulf and 680 in 69 herds in the Atlantic. All the herds were sighted well offshore in water depths ranging from 618-1,143 m. Two of the herds were mixed with _Stenella_ sp. Pilot whales (_Globicephala_ sp.) were the second most numerous species sighted during the CETAP (1982) study. The peak (spring) pilot whale density in that study in the shelf edge region was about 10 times our combined density estimate. (The shelf edge in the CETAP study was defined as the waters between 91-2,000 m and of the areas covered by their study, is probably most comparable to the area we studied.)

Pilot whales are thought to feed almost exclusively on squid (Clarke 1986). While a wide variety of squid species occur in the Gulf, only five species are thought to occur in commercial quantities. Three of those species occur primarily on the continental shelf. While much is to be learned about squid in the Gulf, apparently the short-finned squid (_I. illecebrosus_) inhabits slope waters and the orange-backed squid (_O. pteropus_) is distributed primarily beyond the slope in the pelagic Gulf (Voss 1971). Since the pilot whales in the Gulf rarely occur in shelf waters, perhaps Gulf pilot whales feed on one or both of these species.

We only sighted pilot whales along the upper continental slope on two days during 11 months of surveys. However, we sighted pilot whales during one of two mid-Gulf surveys. Unless this sighting was strictly fortuitous, it may indicate that pilot whales in the



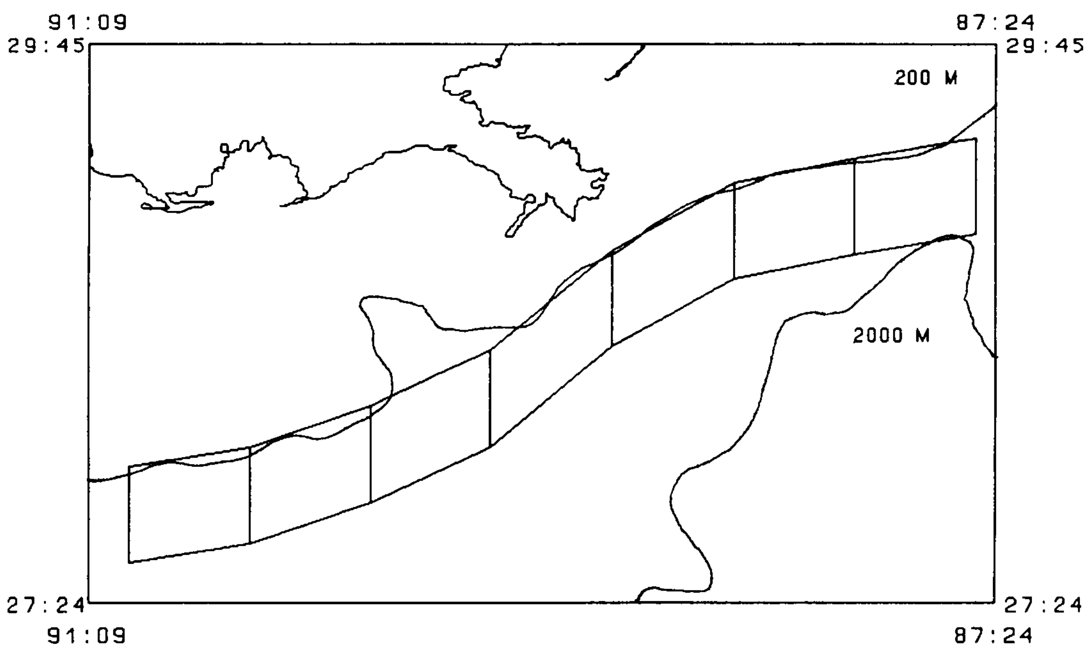


FIGURE 13. LOCATIONS OF SHORT-FINNED PILOT WHALE HERDS SIGHTED DURING 1989 (upper panel) AND 1990 (lower panel) (W - winter, R - spring, S - summer, F - fall).

Gulf occur more frequently beyond the upper continental slope. Their primary prey there may be orange-backed squid. Voss (1971) commented that this species reaches a large size and is very abundant. Long-finned pilot whales near Newfoundland move near shore to feed on short-finned squid as the squid migrate inshore (Mercer 1975). However, short-finned squid prefer cooler waters (Whitaker 1980) and shoreward migrations beyond deep slope waters probably never occur in the Gulf.

Rough-toothed dolphin

Rough-toothed dolphins are distributed in pelagic warm temperate to tropical waters throughout the world but are not thought to be abundant anywhere (Leatherwood and Reeves 1983). Schmidly (1981) reported five Gulf strandings and one sighting of this species. One of these strandings was a group of 16 on the Florida Gulf coast (Layne 1965). The sighting was reported near DeSoto Canyon along the 2,000 m isobath. The natural history of this species is very poorly known. However, they are thought to feed on octopi and squid with herd sizes generally <50. Fritts et al. (1983) did not report any rough-toothed dolphin sightings. We sighted one herd of four rough-toothed dolphins during April 1990 in Area B5 in water 933 m deep (Figure 14). One herd of 45 animals was report seaward of the 2,000 m isobath during the CETAP (1982) surveys. The herd we sighted remained near the surface.

Bottlenose dolphin

Bottlenose dolphins are distributed throughout the world in all but the coldest of waters (Leatherwood and Reeves 1983). Bottlenose dolphins inhabit nearly all marine environments including bays, sounds, river inlets, marshes, the continental shelf and pelagic waters.

The bottlenose dolphin is found in nearly all continental shelf marine environments in the Gulf. There are numerous stranding records of bottlenose dolphins throughout the Gulf (Schmidly 1981). Many studies of bottlenose dolphins in coastal Gulf waters have been conducted (see Leatherwood and Reeves 1982 and Shane et al. 1986 for a review, and Wells et al. 1980, 1987).

During our surveys, only Risso's dolphin and sperm whale herds were sighted more often than herds of bottlenose dolphins. Of the delphinids sighted more than once, bottlenose dolphins had the smallest overall mean herd size but it was similar to that of Risso's dolphin (Table 4). Herd sizes were variable seasonally (Table 10). The herd sizes we found were within the range of those reported from other studies conducted in shelf waters (see Leatherwood and Reeves 1982:379). Within the shelf zone, habitat apparently affects herd size. Mullin (1988) compared seasonal mean herd sizes from a salt marsh (range of means, 3-5), a sound (5-8) and adjacent Gulf waters (6-15). The mean herd sizes he reported

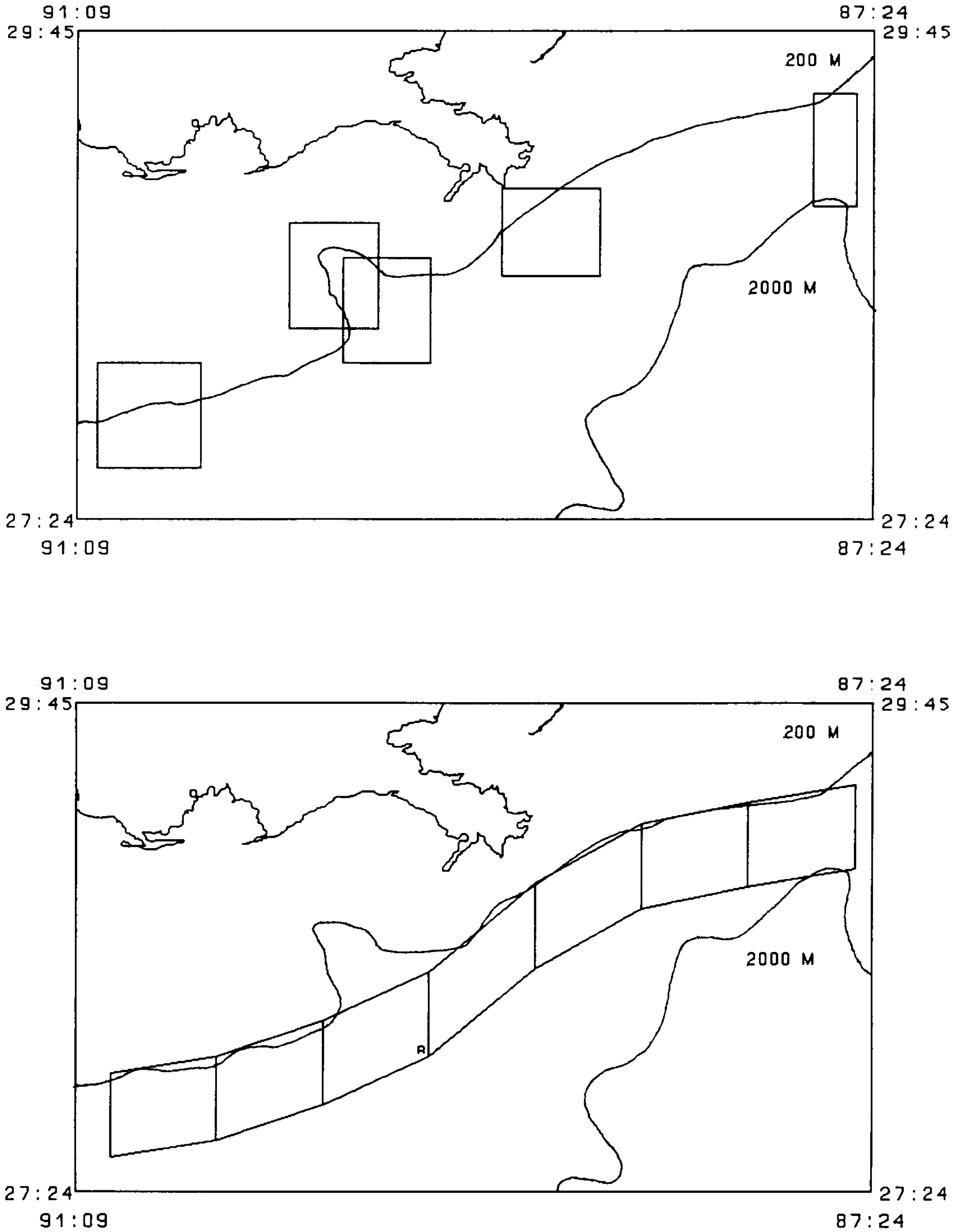


FIGURE 14. LOCATIONS OF ROUGH-TOOTHED DOLPHIN HERDS SIGHTED DURING 1989 (upper panel) AND 1990 (lower panel) (W - winter, R - spring, S - summer, F - fall).

from Gulf waters on the shelf were similar in size to those found during our study. CETAP (1982) reported bottlenose dolphin herds averaged 14.8 (range 1-350). However, Scott and Chivers (1990) reported average herd sizes in the Pacific ranged from 40-94 dolphins but median sizes were on the order of 9-20.

The density of bottlenose dolphins in 1989 was more than five times greater than the 1990 estimate (Table 5). If there was not a seasonal effect, this decrease in 1990 was likely caused by the shift of the area studied to deeper waters. Most of the bottlenose dolphin sightings were concentrated in shallower portions of Areas A8 and A7 during 1989 (Figure 15). Estimates of bottlenose dolphin densities on the continental shelf are generally much larger than the overall density we estimated for the upper continental slope (see Shane et al. 1986:37 or Mullin et al. 1990:119). Spring estimates of bottlenose dolphin density on the shelf edge along the northeastern U.S. coast were generally about twice our overall estimate (CETAP 1982).

Bottlenose dolphin herds were sighted in every survey month except February and May (Tables 8 and 9). Bottlenose dolphins were distributed throughout the area surveyed but few herds were sighted in the extreme eastern and western part of the study area (Tables 6 and 7, Figure 15). The reported effect of water depth on the distribution of bottlenose dolphins is not consistent between different studies. In the Pacific, Scott and Chivers (1990) report bottlenose dolphin herds well over 1,000 km from shore. We found more herds than expected in water <300 m and fewer herds in waters >600 m (Table 11) and we sighted no bottlenose dolphin herds in deeper waters during the two mid-Gulf surveys. Scott et al. (1989) reported bottlenose herds were sighted in all shelf waters (<180 m) surveyed in the northern Gulf. However, Fritts et al. (1983) found that bottlenose dolphins herds were generally confined to waters <50 m with almost no sightings beyond the 100 m isobath. Along the northeastern U.S. coast, bottlenose dolphins have a disjunct distribution. One group of dolphins is confined to the immediate coastal waters and the other group is distributed in the shelf edge area near the 1,000 m isobath (CETAP 1982). The differences in species composition in shelf waters of the Atlantic and the Gulf could affect the distributions. The bottlenose dolphin and, to a lesser extent, the Atlantic spotted dolphin, are the only cetaceans that inhabit the shelf with frequency in the Gulf whereas in the Northeast, as many as seven species may inhabit the shelf consistently.

In our study, many more bottlenose dolphin herds than expected were sighted over waters with the greatest relative change in water depth (CI = 80-99, Table 12). In our study, this relative change occurred in the shallowest water we surveyed near the continental shelf break. The bottlenose dolphin is generally abundant in Gulf shelf waters and this distribution may reflect a preference of bottlenose dolphins for shallower waters in the Gulf rather than a

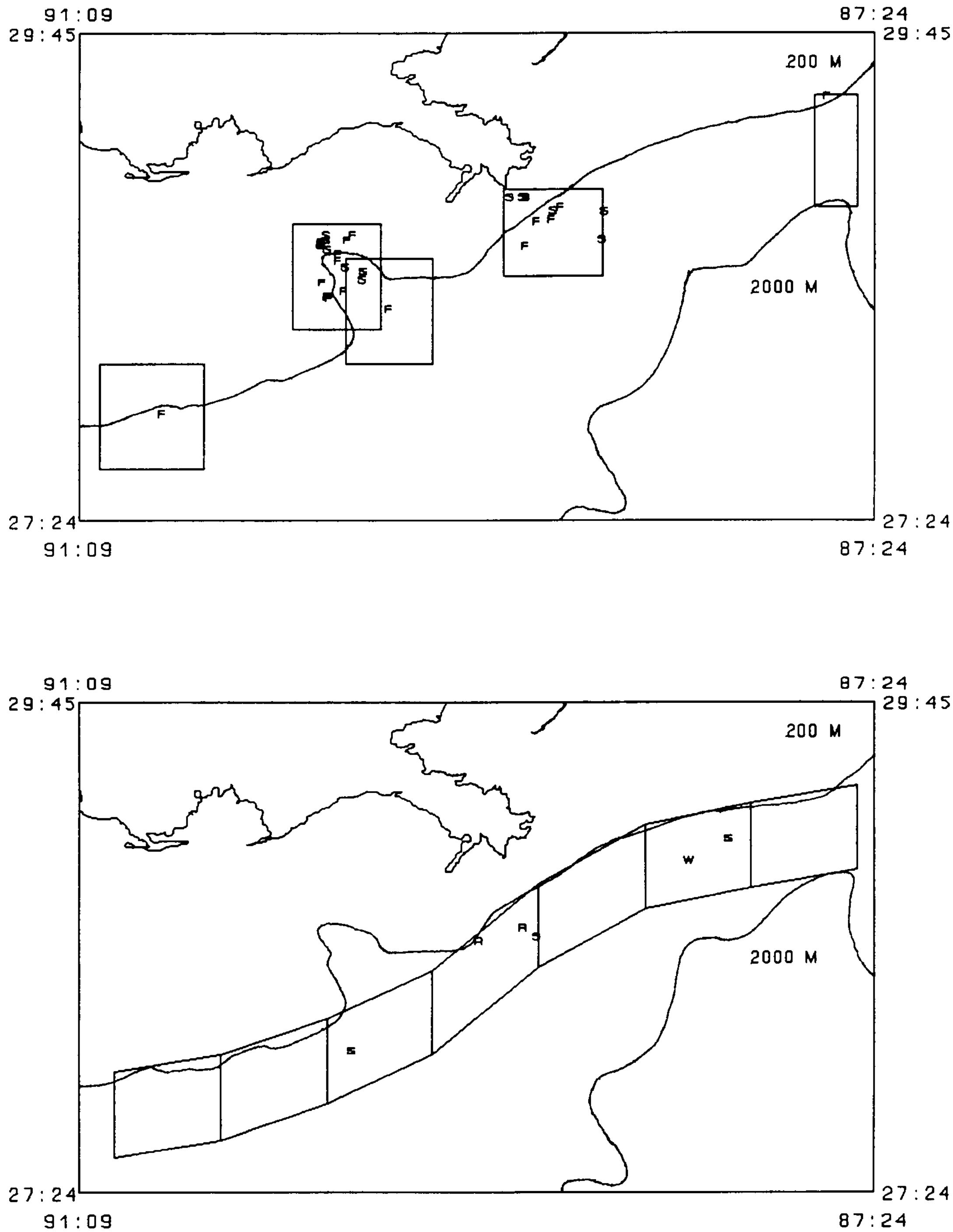


FIGURE 15. LOCATIONS OF BOTTLENOSE DOLPHIN HERDS SIGHTED DURING 1989 (upper panel) AND 1990 (lower panel) (W - winter, R - spring, S - summer, F - fall).

particular affinity for waters over steep escarpments. Bottlenose dolphins did not appear to have an adverse reaction to the aircraft except when its shadow passed over. When this happened, they reacted by making a startled dive. All the small cetaceans we observed reacted in a similar manner.

Risso's dolphin

Risso's dolphins (or grampus) inhabit tropical and temperate waters throughout the world (Leatherwood et al. 1980). While Risso's dolphins are thought to occur primarily in deep-water (>180 m) (Leatherwood and Reeves 1983), they are also widely distributed in some coastal Atlantic waters (Evans 1987). Risso's dolphins prey primarily upon squid (Clarke 1986).

Historical data on Risso's dolphins in the Gulf is very limited. Gunter (1954) stated that this species was not recorded from the Gulf but may be expected because of its general distribution. The first record from the Gulf was reported by Paul (1968). An animal live-stranded near Tarpon Springs, Florida in 1966 and subsequently died during rescue efforts. In addition to that account, Schmidly (1981) reported only two other Gulf strandings. Jennings (1982) reported on five sightings of Risso's dolphins from aerial surveys in the Gulf (see Fritts et al. 1983). These sightings provided the first record of Risso's dolphins in the western Gulf (1 sighting) and the first pelagic sightings off of western Florida.

During our aerial surveys, herds of Risso's dolphins were our most common sighting (Table 4). However, in terms of overall density of individuals, all species of Stenella were more abundant (Table 5). The densities we estimated for Risso's dolphins were generally larger than those reported by CETAP (1982) for the shelf edge region (0.006-0.057 dolphins/km^2).

Risso's dolphin herds ranged in size from 1-48 individuals, with a mean of 12.8 (Table 4). Mean herd sizes varied from 9.9 in summer to 17.3 in fall (Table 10). Leatherwood et al. (1980) compiled information available on Risso's dolphins from the eastern Pacific through 1975. They reported that herds consisted of 1-220 animals with a geometric mean of 10.7. They estimated that 76.4% of the herds contained fewer than 20 animals. Leatherwood and Reeves (1983) stated that although occasionally seen singly or in pairs, Risso's dolphins usually live in herds of 25 to several hundred. Kruse (1989), who conducted a two year study of Risso's dolphins in Monterey Bay, California, observed 59 herds ranging in size from 3 to over 500 with a mean herd size of 63. Herd sizes remained stable seasonally in Monterey Bay. Fritts et al. (1983) reported that 12 sightings made in the Gulf and Atlantic Ocean ranged in size from 3-157 dolphins and averaged 22.8. In surveys conducted north of Cape Hatteras, 478 Risso's dolphin herds were sighted. The mean herd size was 17.2 with a range from 1-400 (CETAP 1982). Evans (1987) noted that Risso's dolphins appear to live in groups of more stable composition than other pelagic dolphins. In his studies off Scotland, a typical herd consisted of one male, 4-6 females and young probably of both sexes. He stated that recognizable individuals have been observed in the same group over a period of several weeks and from one year to the next.

Sighting rates of Risso's dolphin herds varied greatly among months and ranged from a high of 1.11 herds/100 km in April to a low of no herds observed in October and February (Table 8). The sighting rates of the total number of Risso's dolphins had a similar pattern (Table 9). Sighting rates were generally highest in spring months and lowest in the fall and winter. The sighting rate of Risso's dolphin herds in April was the highest monthly herd sighting rate of any species we encountered. Of all the Risso's dolphin herds sighted during the study, we sighted 41% during April. As with sperm whales and pilot whales, the distribution of Risso's dolphins is probably related to the abundance of squid. Kruse (1989) noted that the number of Risso's dolphins was lowest in the winter and peaked in the fall in Monterey Bay. Kruse (1989) correlated the seasonal abundance of Risso's dolphins with landings of the squid, L. opalescens, from Monterey Bay and found that the peak abundance of the dolphins was about a month prior to the peak landings. She speculated that the dolphins may have been attracted to squid aggregating along thermal fronts characteristic of high relief areas prior to spawning before the squid were available to the fishery. Leatherwood et al. (1980) believed that the movement of Risso's dolphins north and onto the continental shelf in the eastern Pacific was related to warming surface temperatures. Paul (1968) speculated, based on observations in the Atlantic, that Risso's dolphins appeared to winter in warmer southern waters and move northward in the summer months.

Risso's dolphins had a wide spatial distribution during our study. Of the cetaceans identified in our study, Risso's dolphin was the only species that was sighted in each of the 11 study areas. The central to eastern study areas (B1-B4) in 1990 generally had the highest sighting rates of herds and numbers of Risso's dolphins (Tables 6 and 7). The lowest sighting rate was in area A10 but this may have been a seasonal effect because B1 overlapped A10. (A10 was surveyed only in the fall.)

The herds we observed were in water depths ranging from 97-1,079 m, with a mean water depth of 440 m (Table 4). We did not sight Risso's dolphins during the mid-Gulf surveys. Seasonally, the water depths were very similar (Table 10). Kruse (1989) found Risso's dolphin herds in depths ranging from 73-2,195 m. Season did not appear to affect the depth at which animals were seen in Monterey Bay. Jennings (1982) reported that the 12 herds sighted from aerial surveys conducted in the Gulf and the Atlantic were in water depths from 200-1,530 m.

Risso's dolphin herds in the north-central Gulf preferred water depths from 300-900 m. More herds than expected under the random hypothesis were found in the 300-900 m depth range (Table 11). Fewer than expected were found in waters <300 m deep and in waters >901 m deep. Kruse (1989) reported significantly more Risso's dolphins than expected between 180-914 m and fewer than expected in <180 m.

More Risso's dolphin herds than expected were sighted over the waters with the greatest relative change in water depth (CI = 80-99, Table 12). However, fewer herds than expected were found in the 60-79 CI interval and about the same number as expected were sighted in the 40-59 interval. Kruse (1989) noted that most of Risso's dolphins she observed in Monterey Bay were over the steepest bottom topography. However, note that many of the Risso's dolphin herds we sighted (Figure 16) were at the very northern boundary of the area surveyed, on the edge of the continental shelf. This distribution may indicate that our study areas did not include the shoreward distribution of Risso's dolphins in the north-central Gulf.

Risso's dolphins are often associated with other oceanic cetaceans (Leatherwood and Reeves 1983). Fritts et al. (1983) noted that one of the herds observed was associated with an unidentified whale. Dohl et al. (1983) [as cited in Kruse (1989)] reported that 20% of their observed herds were associated with other species. Kruse (1989) reported 57% of her sightings involved mixed cetacean species schools. The single association we observed was a herd of 15 Risso's dolphins within 200 m of five short-finned pilot whales during August in Area A9. Risso's dolphins were generally tolerant of the circling aircraft. For the most part, they remained at or near the surface while we observed them.

The historical data indicates that Risso's dolphin was probably not a common species in the Gulf. The number of strandings was low (Schmidly 1981) and aerial surveys over the continental slope resulted in few sightings (Fritts et al. 1983). However, in terms of herds sighted, Risso's dolphin was our most common sighting. This could have resulted from several factors: (1) Risso's dolphins have become more common in the Gulf recently, or (2) Risso's dolphins may be more common in the north-central and eastern Gulf where no deep-water survey effort had been expended prior to this study. However, Risso's dolphins may have always been relatively common in all or part of the Gulf. The number of strandings may be a very a poor indicator of the abundance of pelagic cetaceans in the Gulf because the continental shelf is wide and/or Risso's dolphin may not be a species which strands frequently for either physical or social reasons. Except for the

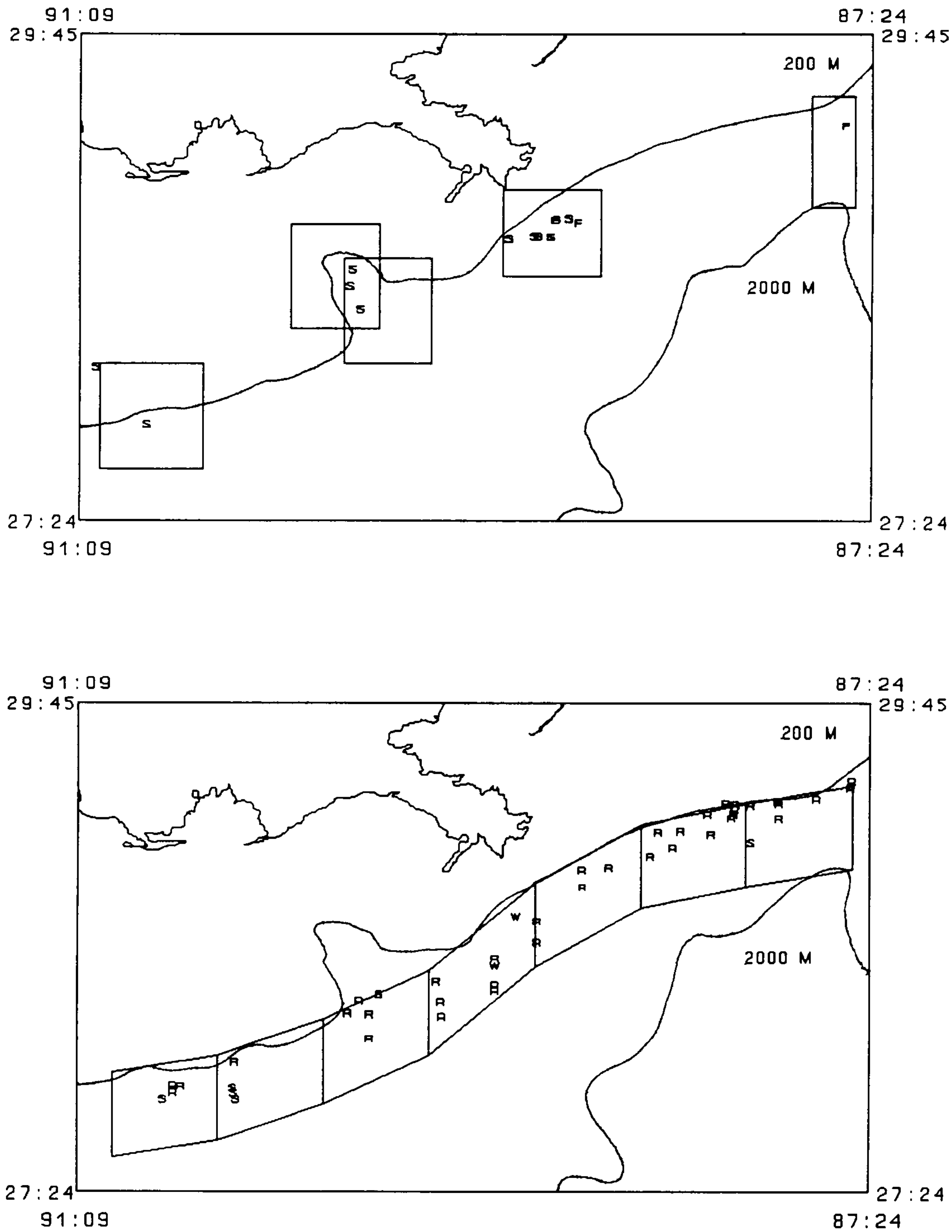


FIGURE 16. LOCATIONS OF RISSO'S DOLPHIN HERDS SIGHTED DURING 1989 (upper panel) AND 1990 (lower panel) (W - winter, R - spring, S - summer, F - fall).

Texas study area, very little of the on-transect effort by Fritts et al. (1983) was over the continental slope. Four of the five Risso's dolphin sightings in the Gulf by Fritts et al. (1983) were during a limited number of opportunistic surveys of slope waters in the eastern Gulf.

Atlantic spotted dolphin

The Atlantic spotted dolphin is distributed from warm temperate to tropical waters in the Atlantic Ocean (Perrin et al. 1987). Atlantic spotted dolphins are thought to be a deep-water species (>180 m) that may move onto the continental shelf in the Gulf of Mexico seasonally (Leatherwood et al. 1976).

Numerous strandings and at-sea sightings (most on the continental shelf) of Atlantic spotted dolphins were reported by Schmidly (1981) in the Gulf. Fritts et al. (1983) sighted spotted dolphins in all their Gulf and Atlantic study areas.

Herds of Atlantic spotted dolphins were our fourth most common sighting (Table 4). Of the identified *Stenella*, the Atlantic spotted dolphin had the smallest mean herd size and were about one-third the size of the other *Stenella*. Our observations concur with those of Leatherwood et al. (1976:104-105) that they occur "in herds of up to several hundred individuals, though groups of 50 or fewer (6-10) are more common." The average size of 50 herds observed by Fritts et al. (1983) was 13.9 animals. Mean herd sizes were similar for winter, spring and summer but the fall mean was much larger (Table 10).

During 1989, Atlantic spotted dolphins had the highest estimated density of any species (Table 5). The 1989 density estimate was over seven times the 1990 estimate and again, this may be due to the shift of the study areas to deeper waters. It has been speculated that spotted dolphins are the most abundant offshore species in the Gulf (Schmidly 1981, see Fritts et al. 1983:329). This may not be true. In 1990, striped/spinner/Clymene dolphins, pantropical spotted dolphins and Risso's dolphins were more abundant. Overall, pantropical spotted dolphins and striped/spinner/Clymene dolphins had higher estimated densities. Also, the offshore distribution of Atlantic spotted dolphins may not extend beyond the shelf break region. We sighted Atlantic spotted dolphins primarily in the northern regions of the study areas (Figure 17). No Atlantic spotted dolphins were identified during the two mid-Gulf surveys.

Sighting rates of Atlantic spotted dolphin herds were higher in early fall and in late winter to early spring. No herds were sighted in January and May (Table 8). By far, more individuals were sighted in September and October than in any other month and very few individuals were sighted in late spring and summer (Table 9).

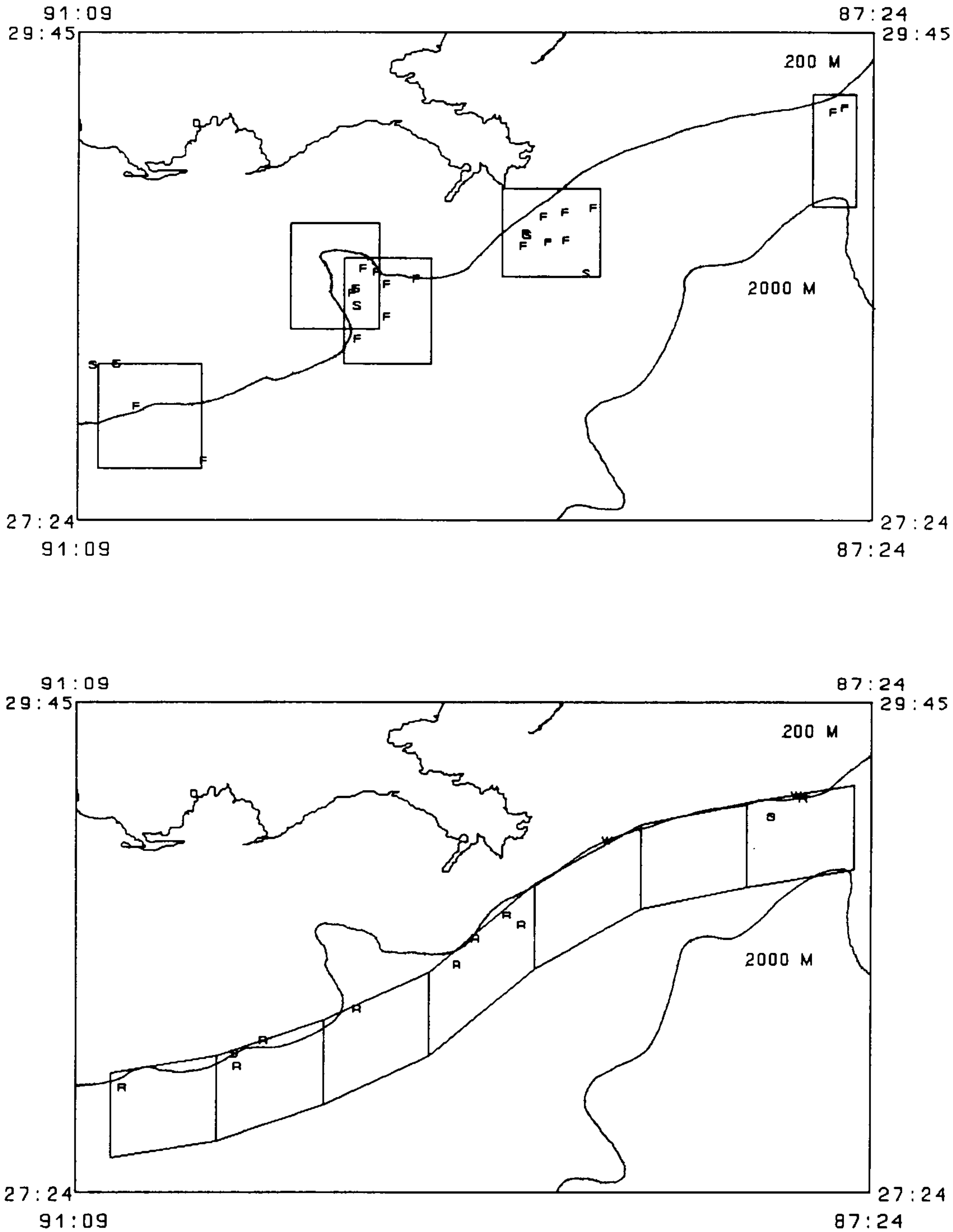


FIGURE 17. LOCATIONS OF ATLANTIC SPOTTED DOLPHIN HERDS SIGHTED DURING 1989 (upper panel) AND 1990 (lower panel) (W - winter, R - spring, S - summer, F - fall).

Atlantic spotted dolphins were distributed throughout the area studied and were sighted in every study area except Area B2 (Figure 17). The highest herd sighting rate was in Area A8, but two large herds (137 and 325) in Area A10 caused a very high individual sighting rate in that area (Table 7).

Of the whales and dolphins sighted more than once, only the bottlenose dolphin was sighted in more shallow water than the Atlantic spotted dolphin (Table 4). Except in winter, when two herds were sighted in very shallow water, the seasonal mean water depths were similar (Table 10). More Atlantic spotted dolphin herds than expected were sighted in waters <600 m (Table 11).

Atlantic spotted dolphins also showed a preference for waters nearest the continental shelf break with a high relative change in water depth. More herds than expected under the null hypothesis were sighted in areas where the CI was >60 (Table 12). Because so many sightings were along the more shallow northern boundary of the study areas, we probably did not survey the shoreward limits of their distribution. Atlantic spotted dolphins may be also distributed shoreward of shelf break in shallow waters with very little relative change in water depth and may not have a distinct preference for steep escarpments in the Gulf. Most of the sightings of spotted dolphins made by Fritts et al. (1983) were on the continental shelf (<180 m).

There has been much speculation concerning possible seasonal movement and migrations of Atlantic spotted dolphins (see Fritts et al. 1983:329-331). Although, these speculations are based on very limited data, inshore migrations would account for the relatively few sightings we made in summer, but the whereabouts of this species in winter would still be unaccounted for unless they move seaward of the upper continental slope. However, our sighting effort in the winter months was comparatively small (<10% of the total) and we probably did not obtain an adequate winter sample to draw conclusions.

<u>Pantropical spotted dolphin</u>

As the name implies, the pantropical spotted dolphin is distributed throughout the world in tropical and some subtropical waters (Perrin et al. 1987). This species has been studied in the Pacific because of its interaction with the yellowfin tuna purse-seine fishery. The records of this species in the Gulf were summarized in the Methods section.

Pantropical spotted dolphins (pantropicals) were our seventh most common sighting (Table 4). However, during the 1990 SEFC cruise, herds of pantropicals (18 of 90) were the most common sighting (L. Hansen pers. comm., NMFS, Miami). Except for herds identified as striped/spinner/Clymene dolphins, pantropicals had the largest mean herd size which averaged more than three times that of the Atlantic spotted dolphin. Mean herd sizes of pantropicals in the eastern tropical Pacific were generally much larger than our average and ranged from 150 to over 1,000 (Hammond and Laake 1983, Au and Perryman 1985). For the herds we sighted, average herd sizes were generally similar for all seasons (Table 10). Because of the large average herd size, the overall density of pantropicals in the Gulf was second only to striped/spinner/Clymene dolphins (Table 5).

We did not sight pantropicals in the winter. Sighting rates of herds were similar in the fall and spring but decreased in the late summer (Table 8). This pattern was more pronounced when the sighting rates of individuals were examined (Table 9). Herds were sighted in all study areas but Areas A8 and A9 and B3. The lack of sightings in A8 and A9 may have been related to water depth (see below). Herds were sighted throughout the area studied but sighting rates of herds and individuals were highly variable among areas (Tables 6 and 7).

Of the cetacean species sighted more than once, only beaked whales were sighted at a mean water depth greater than the mean for pantropicals (Table 4). Mean water depths were similar for spring, summer and fall (Table 10). Herds of pantropicals preferred deeper waters. They were distributed primarily along the southern border of the study areas and more herds than expected were sighted in the water depth intervals >900 m (Figure 18, Table 11). The relative change in water depth in the southern portions of the study areas was generally reduced. The pantropicals preferred waters with a CI <60 (Table 12).

During the mid-Gulf surveys, herds of pantropicals were the most commonly sighted species and were sighted throughout the waters surveyed (Table 13, Figure 7). Six herds sighted were in waters that averaged 2,270 m.

We did not sight pantropicals associated with other cetaceans. We did observe a herd of pantropicals vigorously pursuing flying fish (Exocoetidae) on one occasion and they were apparently feeding on them. Pantropicals did not react obviously to the aircraft.

<u>Striped/spinner/Clymene dolphins</u>

The striped dolphin is distributed in nonpolar seas throughout the world and is thought to inhabit waters well offshore but may move closer to shore seasonally in some areas. Spinner dolphins are widely distributed in subtropical and tropical pelagic waters. From what little is known about Clymene dolphins, the species seems to be confined to subtropical and tropical waters of the Atlantic (Leatherwood and Reeves 1983).

All three species are known from comparatively few strandings in the Gulf. Schmidly (1981) reported two strandings of striped

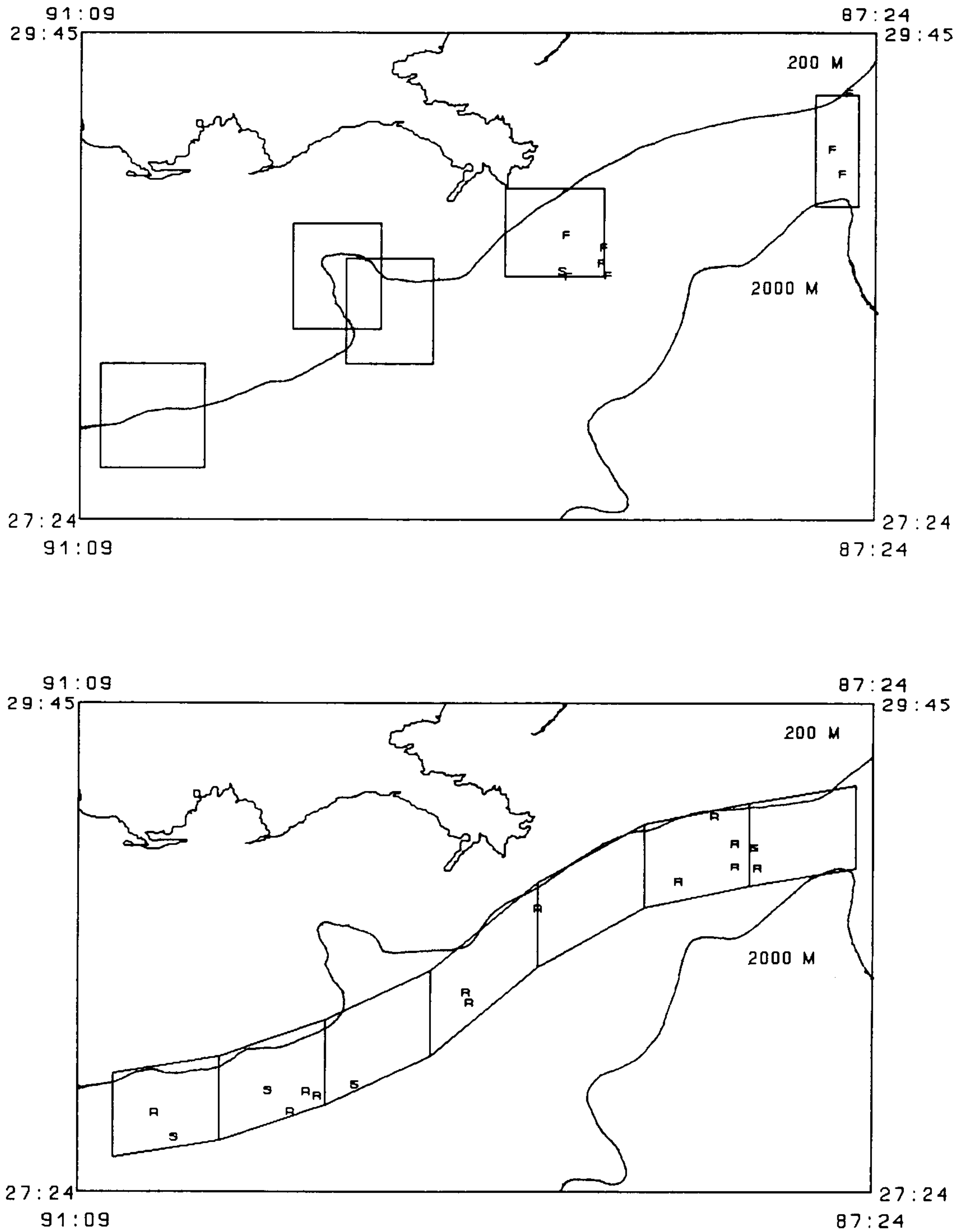


FIGURE 18. LOCATIONS OF PANTROPICAL SPOTTED DOLPHIN HERDS SIGHTED DURING 1989 (upper panel) AND 1990 (lower panel) (W - winter, R - spring, S - summer, F - fall).

dolphins, eight of spinner dolphins and two of Clymene dolphins in the Gulf. Two of the spinner dolphin strandings consisted of more than 25 animals each (Meade et al. 1980, Schmidly 1981). In both 1989 and 1990, a striped dolphin stranded on the Alabama coast (G.T. Regan, pers. comm., Springhill College, Mobile). In 1985, 47 Clymene dolphins were found stranded on the Louisiana coast after Hurricane Juan (see Harris 1986).

Examination of data from a group of species which probably have subtle to large differences in their ecological requirements among them may not be particularly revealing. However, for consistency we present the data for this species group in a similar manner as the other species.

As a group, these three species were our sixth most common sighting and had the largest overall average herd size (Table 4). Compared to other species sighted during our study, average herd sizes were very large in winter, spring and fall but the summer herd sizes were much smaller (Table 10). Because of large herd sizes, this group of dolphins had the highest density of any other species overall and in 1990 (Table 5). Only the Atlantic spotted dolphin had a larger density in 1989. Herds were sighted in every month except July and February (Table 8). East to west, herds were sighted throughout the area surveyed but no herds were sighted in Areas B5 and B7 (Table 6, Figure 19). Herd sighting rates were variable among areas but Area B1 had the highest rate. Fewer herds were sighted in the western areas overall. Because of large herds sizes and small sample sizes, sighting rates of individuals were extremely variable (Tables 7 and 9).

As a group, these species favored deeper waters (Tables 4). North to south, sightings of these species were generally in the middle to southern portions of the study areas. Sightings in winter and spring were in deeper waters than those in summer and fall (Table 10). More herds than expected were sighted in waters >1,200 m deep and fewer in waters <300 m deep (Table 11). They had no preference for contour intervals (Table 12). Four herds of this species group were sighted during the mid-Gulf surveys (Table 13, Figure 7).

Fritts et al. (1983) sighted striped dolphins in all their Gulf study areas. Of their Gulf areas, they made most of their sightings off Florida in water <100 m deep. In their Atlantic area, water depths of sightings averaged about 500 m. Herd sizes ranged from 1-130 and 55 herds averaged 15.7 dolphins. They found striped dolphins associated with pilot whales and spotted dolphins. Off the northeastern U.S. coast, striped dolphin herds ranged up to 500 dolphins and averaged 65. Almost all of the sightings were in water >1,000 m deep (CETAP 1982). Near Japan, striped dolphins are found frequently in herds of more than 500 dolphins and some herds contain over 2,000 animals (Nishiwaki 1975).

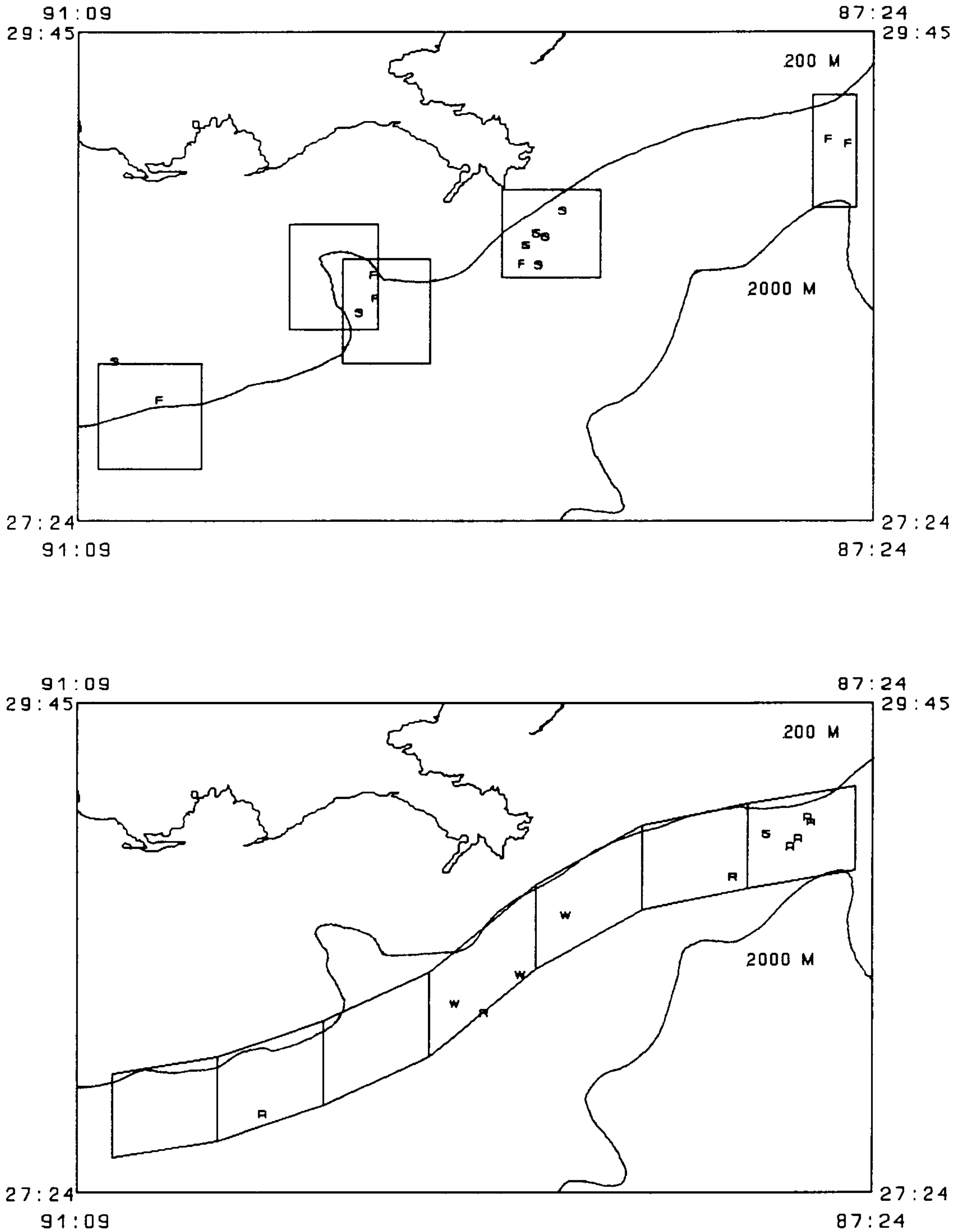


FIGURE 19. LOCATIONS OF STRIPED/SPINNER/CLYMENE DOLPHIN HERDS SIGHTED DURING 1989 (upper panel) AND 1990 (lower panel) (W - winter, R - spring, S - summer, F - fall).

Fritts et al. (1983) sighted five herds of spinner/Clymene dolphins on the continental shelf off Florida and one herd in their Texas area. They sighted bottlenose dolphins, spotted dolphins and short-finned pilot whales associated with spinner/Clymene dolphins. Herd sizes ranged from 3-85 dolphins. In waters north of Cape Hatteras, four spinner dolphin herds averaged 43 dolphins and were sighted in waters at or >2,000 m (CETAP 1982). Herds of spinner dolphins in the eastern tropical Pacific Ocean generally average well over 200 dolphins (Hammond and Laake 1983, Au and Perryman 1985). Herds are distributed throughout the pelagic eastern tropical Pacific. However, spinner dolphins near Hawaii often rest in waters <50 m (Norris and Dohl 1980 a).

Fritts et al. (1983:348) commented that "spinner dolphins remained at the surface more than the other Stenella spp. observed" and were not observed diving out of view. For the most part we had similar observations but on several occasions, our experience was quite different. These dolphins would sometimes dive as group, remain down for an extended period of time, and resurface. But as soon as we would circle overhead they would dive again. On at least three occasions, we thought that their reaction was so strong that we broke off observations because it appeared our activities were forcing them down.

OVERVIEW AND SUMMARY

Of the 29 species of cetaceans known to occur in the Gulf, during the entire study, we sighted at least 15. However, seven species (or species groups) accounted for 93% of the sightings of identified herds (Risso's dolphin, sperm whale, bottlenose dolphin, Atlantic spotted dolphin, pygmy/dwarf sperm whales, striped/spinner /Clymene dolphins and pantropical spotted dolphin). Six species were sighted only one time (see Table 4). Cetaceans were distributed widely over time. Six species were sighted in every season of the year (sperm whale, beaked whales, bottlenose dolphin, Risso's dolphin, Atlantic spotted dolphin, striped/spinner/Clymene dolphins). Two species were sighted in every season but winter (pygmy/dwarf sperm whales, pantropical spotted dolphin). Twelve species were sighted in summer, 10 in both spring and fall, but only six species were sighted in winter. Herd sighting rates in winter were lower than in the other seasons (summer - 1.46 herds/100 km, fall - 2.01, winter 0.91, spring - 1.48). However, the sighting rate of individuals was higher in winter than summer (summer - 16.8 cetaceans/100 km, fall - 52.7, winter - 32.1, spring - 42.9). The average herd size of all cetacean herds sighted in summer was much smaller than in the other seasons (summer - 12 cetaceans/herd, fall - 26, winter - 37, spring - 29). It is difficult for us to conclude that there were fewer species on the upper continental slope in the winter months. Only 10% of our total survey effort was in winter. We did not conduct surveys in December. Furthermore, conducting aerial surveys is notoriously difficult in the winter. Polar air masses intrude into the Gulf 15-30 times each winter bringing high winds with them that last for days (Weber et al. 1990). Fall and spring may have been a time of increased cetacean abundance on the upper continental slope; sighting rates of individual cetaceans were higher than the winter rates and much higher than the summer sighting rates.

Within the area we surveyed, cetaceans also had a wide spatial distribution (Figure 20). For the most part, cetaceans were sighted throughout the study area both east to west and north to south. We divided the area surveyed into a eastern zone (A10, B1, B2), a central zone (A7, A8, B3-B5), and a western zone (A9, B6, B7), to summarize the east-west species distribution. Except for the short-finned pilot whale, all the species sighted more than once were sighted in all three zones (Table 4). Thirteen species were sighted in the central zone, 10 in the eastern and nine in the western. Herd sighting rates were generally similar among zones but were lowest in the western zone (east - 1.7 herds/100 km, central - 1.7, west - 1.1). Sighting rates of individual cetaceans showed more variability with the highest rate in the east zone (east zone - 60 cetaceans/100 km, central - 33, west - 23). The mean herd size of all herds sighted in the east zone was the largest (east - 36, central - 19, west - 21). The low mean herd size in the central zone was a result of the number of physeterids sighted. Physeterid herds were sighted 75 times but they had mean

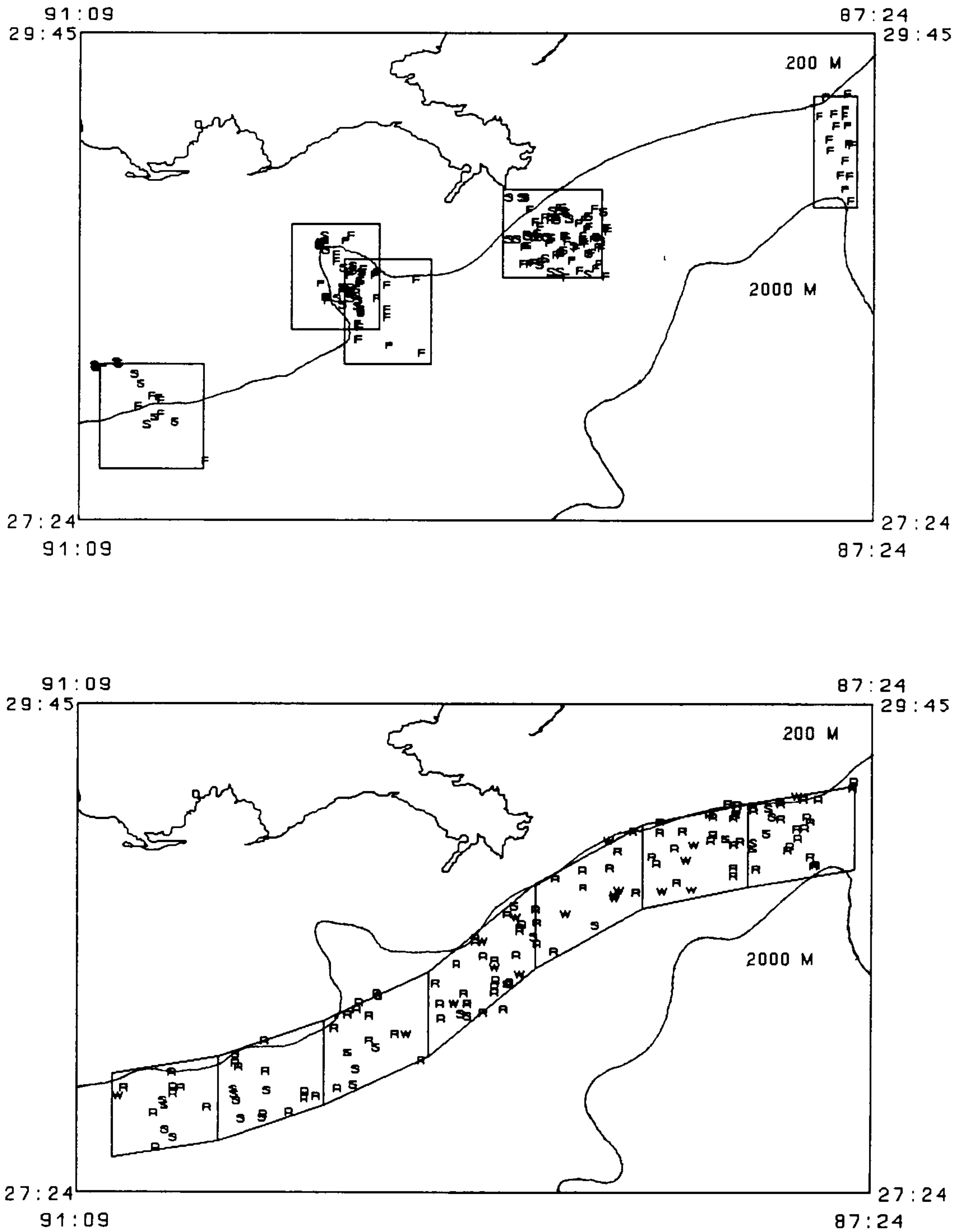


FIGURE 20. LOCATIONS OF ALL CETACEAN HERDS SIGHTED DURING 1989 (upper panel) AND 1990 (lower panel) (W - winter, R - spring, S - summer, F - fall).

herd sizes of only about 2 and 77% of the physeterid sightings were in the central zone. Striped/spinner/Clymene dolphins had the largest overall mean herd size. Eight herds of this species group were sighted in the east compared to only three in the west.

Overall, cetacean herds as a group did not show a preference for any water depth zone (Table 11). However, of the species that were sighted more than 20 times, except for dwarf/pygmy sperm whales, all showed a water depth zone preference. It is logical that ecological differences exist among species in a species group such as dwarf/pygmy sperm whales and water depth preferences could be masked by lumping them together. Comparison of the mean water depths of species sighted more than 20 times with ANOVA and a multiple range test further illustrates the partitioning of species by water depths (Table 14). Atlantic spotted and bottlenose dolphins were sighted at the shallowest mean depths, Risso's dolphins inhabited slightly deeper waters, dwarf/pygmy sperm whales and striped/spinner/Clymene dolphins were at intermediate depths, and sperm whales and pantropical spotted dolphins were sighted at the deepest mean depths. Beaked whales were not sighted enough times to be included in the ANOVA analysis but they would probably be grouped with the sperm whales and pantropicals.

Cetacean herds as a group also showed no preference for CI interval. However, cetacean herds that could be identified to species showed a CI interval preference, while the two species groups showed no preference (Table 12). Bottlenose, Atlantic spotted and Risso's dolphins preferred more shallow waters near the shelf break with the greatest relative change in water depth (CI ranging from 80-99). Sperm whales and pantropical spotted dolphins preferred deeper waters with a smaller relative change in depth (CI < 79).

Compared to the continental shelf and much of the central Gulf, the continental slope is an area of great bottom relief. Other studies of cetaceans have indicated bottom relief affects the distribution of cetaceans and cetaceans are concentrated near steep bottom (Hui 1979, 1985; Selzer and Payne 1988). Comparing CI intervals within the continental slope may not have as much meaning as comparing the slope to the central Gulf. Our results indicate that cetacean species were partitioned on the upper continental slope. For each species, whether this was wholly or in part related to water depth, bottom topography or a combination of both factors, is not clear.

The results of the two mid-Gulf surveys were very interesting (Table 13, Figure 7). On the first day (20 June), only four herds were sighted in about 715 km of effort (0.6 herds/100 km). The sighting rate was less than the typical rate for most study areas. The next day (21 June), however, the sighting rate was 2.6 herds/100 km, which was greater than the rates for most study areas. The major difference between the two days was probably

TABLE 14. ANOVA AND MULTIPLE RANGE TEST OF WATER DEPTHS.

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	P > F
Model	6	13,490,996	2,248,499	29.25	.0001
Error	250	19,221,097	76,884		
Total Corrected	256	32,712,094			

R^2	CV	Root MSE	Mean Depth
.412	50.01	277.28	554.45

Source	DF	ANOVA SS	Mean Square	F Value	P > F
Species	6	13,490,995	2,248,499	29.25	.0001

Duncan's Multiple Range Test

Species	n	Mean Depth (m)	Duncan Grouping*
Pantropical spotted dolphin	23	905	A
Sperm whale	43	877	A
Striped/spinner/ Clymene dolphin	24	712	B
Dwarf/pygmy sperm whale	32	544	C
Risso's dolphin	61	440	C D
Atlantic spotted dolphin	36	363	D E
Bottlenose dolphin	39	257	E

*-means with same letter are not significantly different, P>.05

weather. On the first day, the Gulf was choppy and the weather was very hazy. The second day was one of those extremely rare days when there was not a breath of wind and visibility was exceptional. The Gulf was literally like a mill pond and anything that disturbed the surface could be sighted. Also, on the second day, the outbound route was just landward of the northern end of the Florida Escarpment. The route turned to the west just after we crossed the Escarpment. At this point, there was a water depth change of 1,000 m in less than 9 km. Perhaps this area, with its great bottom relief, is an area of high cetacean abundance. For both days combined, we sighted at least eight species of cetaceans, more than half the total for the 11 month survey. We sighted two species we had only sighted one time before (melon-headed/pygmy killer whale, false killer whale) and a species we had only sighted on two previous days (short-finned pilot whale). Either these sightings were extremely fortuitous or these three species are more abundant in the pelagic Gulf. These results suggest that the Gulf beyond the upper continental slope is also an area of both high cetacean abundance and diversity. The results also indicate that pantropical spotted dolphins may be the most abundant species seaward of the upper continental slope.

We have examined the effects of static features such as water depth and contour index on the distribution of cetaceans in the north-central Gulf. However, there are dynamic features that have not been examined. The Mississippi River and its distributary, the Atchafalaya River, enter the Gulf north of the area we surveyed. These rivers, filled with nutrients and sediment, discharge an average of 20,000 m^3 of fresh water per second into the Gulf and account for nearly one-half of the total freshwater flow into the Gulf. The Loop Current, the major oceanographic feature in the eastern Gulf, carries 25-30 million m^3 of water per second into the Gulf. At times, the Loop Current extends as far north as the Mississippi River delta or DeSoto Canyon. As the Loop Current flows onto the continental slope it causes nutrient rich upwellings (Jones et al. 1973, Weber et al. 1990). All of these features, static and dynamic, combine and interact to make the north-central Gulf of Mexico an incredibly complex area. These features undoubtedly affect the distribution of cetacean prey species and ultimately the distribution of cetaceans. The abundance of prey species has been demonstrated to be positively correlated with the abundance of several species of cetaceans (see Kenney and Winn 1986, Payne et al. 1986, Selzer and Payne 1988). Very little is known about the distribution and abundance of potential prey species beyond the continental shelf in the Gulf. However, near the shelf break region of DeSoto Canyon, Herron et al. (1989) found Gulf butterfish (Perprilus burti), a potential prey species, to be correlated with Loop Current related thermal fronts.

The herd sizes of some of the species we sighted were much smaller than herds of the same species sighted in the eastern tropical Pacific (Leatherwood and Reeves 1983, Au and Perryman 1985). While the mean herd sizes of species we sighted that were also sighted in the CETAP (1982) study were generally similar, the range of herd sizes were much greater off the northeastern U.S. coast. The largest herd of any species we sighted was estimated to have 325 animals whereas herd sizes for five species in he CETAP study were estimated to exceed 500 animals in many cases. These differences may be related to prey and predator concentrations and distribution. Norris and Dohl (1980 b) and Wells et al. (1980) suggested that because the ocean environment is not as physiographically complex as some coastal habitats, changes in predation and the distribution of prey species should create conditions where larger herds are favored. [Scott and Chivers (1990) examined this hypothesis with bottlenose dolphin data from the Pacific Ocean and concluded that, while some very large herds of bottlenose dolphins were observed in the pelagic environment, most of the herds were no larger than coastal herds.]

We sighted very few herds with mixed cetacean species. Fritts et al. (1983) also reported very few mixed species herds. In the eastern tropical Pacific, spinner and pantropical spotted dolphins are commonly found in herds together. Bottlenose dolphins were estimated to be associated with other cetaceans in 20% of the herds sighted in the Pacific. Associations with pilot whales, a species we sighted very few herds of, were the most common association (Scott and Chivers 1990). During the CETAP (1982) study, baleen whales were found to be associated with other cetaceans in 13-28% of the herds. We only saw two baleen whales. Also, the species of odontocetes that were most commonly found in mixed herds in the CETAP study were pilot whales and white-sided dolphins (Lagenorhynchus obliquidens). White-sided dolphins do not occur in the Gulf. Clearly we did not commonly see some of the species that tend to form mixed species herds. However, from our aerial perspective, we could have easily missed mixed species herds. It would be very difficult to identify a few bottlenose dolphins mixed in with a herd of Atlantic spotted dolphins. Also, with large herds, we usually identified the entire herd based on a few "good looks" of several animals. If the other animals' appearance or behavior was not obviously different, we identified all the animals as one species. Therefore, a few spotted dolphins mixed with spinner or striped dolphins could be easily missed and vice versa.

How does the cetacean community on the upper continental slope in the Gulf compare to a similar region, the shelf edge region in the northeastern U.S. (CETAP 1982, Hain et al. 1985)? At least 20 species of cetaceans were sighted in the shelf edge region during the CETAP study. We sighted at least 15. Five species of baleen whales were sighted in the CETAP study while only two species were sighted in our study. Of the identified herd sightings, about 9% of the CETAP sightings were of baleen whales whereas <1% of our sightings were baleen whales. Common dolphins and pilot whales made up about 30% of the CETAP sightings. We identified no common dolphins and 2% of our herd sightings were pilot whales. Dwarf/pygmy sperm whales made up 12% of our sightings but none were sighted in the shelf edge region during the CETAP study.

The peak density of all cetaceans in the shelf edge region of the CETAP study was estimated to be about 0.77 cetaceans/km^2 (spring) and the low, about 0.42 cetaceans/km^2 (winter). We estimated the density of all cetaceans to be similar to the peak CETAP density. Densities ranged from 0.71 cetaceans/km^2 in 1990 to 0.85 cetaceans/km^2 in 1990. Hain et al. (1985) estimated the biomass of cetaceans in the shelf edge region in the Atlantic. They estimated the cetacean biomass to be about 0.43 metric tons/km^2 in spring and 0.12 metric tons/km^2 in winter. Kenney and Winn (1986) listed the biomass of each cetacean species used by Hain et al. (1985). Using the same biomass figures, we estimated the biomass in our study area to be 0.21 metric tons/km^2 in 1989 and 0.14 metric tons/km^2 in 1990. The major difference in cetacean biomass between the Gulf region we surveyed and the Atlantic shelf edge region is the number of sperm and baleen whales sighted. In the CETAP study, 2.7% of the cetacean abundance in spring was comprised of sperm and baleen whales. In our study, during 1989, sperm and baleen whales made up 0.6% of the estimated abundance. While these difference may seem small, if 2.7% of our abundance had been sperm whales in 1989, the estimated biomass would have been 0.40 metric tons/km^2. The major difference in biomass between 1989 and 1990 in our study was the reduced density of sperm whales and pilot whales. (A sperm whale is estimated to have a mass of 20,000 kg, a pilot whale 850 kg but the species of _Stenella_ only have a mass of 50-55 kg.)

This study added greatly to the knowledge of cetaceans in the Gulf and changed some perceptions about which species occur there and their relative abundance. Risso's dolphins were found to be much more common than previously thought. In 1990, Risso's dolphin had the second highest estimated density and the highest single species component (27%) of total estimated cetacean biomass. The Atlantic spotted dolphins may not be the most common offshore species in the Gulf. In fact, it may only inhabit waters near the shelf edge. Pantropical spotted dolphins are very common in the Gulf and may prove to be the most abundant species in the Gulf beyond the continental shelf. Dwarf and/or pygmy sperm whales are common in the north-central Gulf as are striped, spinner and/or Clymene dolphins. The sperm whale is a very important part of the cetacean community of the upper continental slope. In 1989, sperm whales comprised an estimated 44% of the total cetacean biomass and 21% of the total 1990 biomass. Sperm whale sightings were relatively common and the area just off the Mississippi delta may be an important habitat for them, at least seasonally. All of the species sighted more than 20 times were widely distributed both in space and time on the upper continental slope. A wide variety of other species including false killer whales, short-finned pilot whales and killer whales were either transients in the Gulf, live primarily seaward of the upper continental slope and occasionally came into shelf waters, and/or exist at much lower abundance levels in slope waters.

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APPENDIX 1

Data Base Description

1. DATA RECORDS

Each data record is 72 characters long. Blank fields complete the data record for records that contain less than 72 characters. Each data file has been named for the day , month, year, and "part number" for the date of the survey. The part number was used when the survey day was broken into 2 portions (because of refueling, etc.). A 3 character suffix (SUR) was added each file name to describe the data file as a raw survey data file. Example of survey data file names are "150789P1.SUR" or "230190P2.SUR." The following data types (variables) were used in the July 1989 through June 1990 surveys for marine animals, human activities, and pollution.

VARIABLE NAME	FIELD WIDTH	RECORD PLACEMENT	DATES AND NOTES
CARD	1	1	07/89 - 06/90
AREA	3	2-4	"
PART	2	5-6	"
DAY	2	7-8	"
MONTH	2	9-10	"
YEAR	2	11-12	"
HOUR	2	13-14	"
MINUTE	2	15-16	"
SECOND	2	17-18	"
LATITUDE	6	19-24	"
LONGITUDE	6	25-30	"
TRACK	3	31-33	"
SPEED	3	34-36	"
WARN	1	37	"
ALTITUDE	4	38-41	"
WEATHER	1	42	"
SEA STATE	1	43	"
TURBIDITY	1	44	"
SUNLIGHT	1	45	"
GLARE	1	46	"
WATER COLOR	1	47	"
(blank)	2	48-49	"
SPECIES 1	2	50-51	"
SPECIES 2	2	52-53	"
SPECIES 3	2	54-55	"
SPECIES 4	2	56-57	"

Data Base Description, Continued

VARIABLE NAME	FIELD WIDTH	RECORD PLACEMENT	DATES AND NOTES
OBSERVER	1	58	07/89 - 06/90
OBSERVATION ANGLE	2	59-60	"
HERD/SCHOOL SIZE	1	61	"
BEHAVIOR	1	62	"
(blank)		63-67	07/89 - 11/89
PHOTOGRAPHS TAKEN	1	63	01/90 - 06/90
WHALE COUNT	3	64-66	"
WHALE CALF COUNT	2	67-68	"

2. CARD TYPES

The first character of each data record is a card type. The card type defines what type of data record follows. Card types were:

A = BEGIN STUDY AREA
B = BEGIN TRANSECT
C = ENVIRONMENTAL CHANGE
D = SIGHTING
E = GOING OFF TRANSECT
F = no F records in the data base
G = BACK ON TRANSECT
H = END TRANSECT
I = END STUDY AREA
J = no J records in the data base
S = SPACE/TIME CHECK (We designed this record to document the aircraft's location at a specified time interval. We usually used 1 minute as the time interval and S cards would be recorded if no other record had been recorded in the preceding minute.)

3. DATA BASE COMPOSITION

The data contained in type of data record is indicated by an "X."

	RECORD TYPE								
DATA TYPE	A	B	C	D	E	G	H	I	S
AREA	X	X	X	X	X	X	X	X	X
PART	X	X	X	X	X	X	X	X	X
DAY	X	X	X	X	X	X	X	X	X
MONTH	X	X	X	X	X	X	X	X	X
YEAR	X	X	X	X	X	X	X	X	X
HOUR	X	X	X	X	X	X	X	X	X
MINUTE	X	X	X	X	X	X	X	X	X
SECOND	X	X	X	X	X	X	X	X	X
LATITUDE	X	X	X	X	X	X	X	X	X
LONGITUDE	X	X	X	X	X	X	X	X	X
TRACK	X	X	X	X	X	X	X	X	X
SPEED	X	X	X	X	X	X	X	X	X
WARN	X	X	X	X	X	X	X	X	X
ALTITUDE	X	X	X	X	X	X	X	X	X
WEATHER		X	X	X			X		X
SEA STATE		X	X	X			X		X
TURBIDITY		X	X	X			X		X
SUNLIGHT		X	X	X			X		X
GLARE		X	X	X			X		X
WATER COLOR		X	X	X			X		X
SPECIES 1				X					
SPECIES 2				X					
SPECIES 3				X					
SPECIES 4				X					
OBSERVER				X					
OBSERVATION ANGLE				X					
HERD/SCHOOL SIZE				X					
BEHAVIOR				X					
PHOTOGRAPHS TAKEN				X					
NUMBER OF CETACEANS				X					
NUMBER OF CALF CETACEANS				X					

4. VARIABLE DESCRIPTIONS

AREA

A 3 character code where "SA" stands for Study Area and the third character is either 1, 2, 3, 4, 5, 6, 7, 8, 9, 0, or A, which represent the study area being studied. A stood for DeSoto Canyon and 0 indicated a beach survey for stranded animals and turtle nests.

PART

A 2 character code where "P" stood for Part and the numeral indicated what segment (1,2,3,....9) of the day's surveys were included in the file.

DAY, MONTH, YEAR

A computer supplied variable, written without divisions between the parts (e.g., 021288 = December 2, 1988).

HOUR, MINUTE, SECOND

Again a computer supplied variable and written without divisions between the parts.

LATITUDE and LONGITUDE

Supplied by the LORAN-C receiver interfaced to the computer, each consists of degrees, minutes, and hundredths of a minute.

TRACK

Supplied by the LORAN-C receiver interfaced to the computer, the compass direction in degrees of the current heading of the aircraft.

SPEED

Supplied by the LORAN-C receiver interfaced to the computer, the ground speed was recorded from 0 to 999 NM/h.

WARN

Indirectly supplied by the LORAN-C receiver interfaced to the computer, if any of the 3 LORAN-C signal Signal to Noise Ratios were less than 64, then a flag was placed in the data recorded indicating the aircraft's location, track and speed might be suspect. The flag was:

0 = all SNRs above 64,
1 = Warning, 1 or more SNRs less than 64

ALTITUDE

Altitude was recorded as feet above sea level (0 to 9999 ft) and was supplied by the aircraft's instruments.

WEATHER

An observer supplied subjective rating where:

1 = CLEAR (0-10% CLOUD COVER)
2 = PARTLY CLOUDY (10-50% CLOUD COVER)
3 = CLOUDY (50-100% CLOUD COVER)
4 = LIGHT RAIN
5 = CLEAR BUT HAZY
6 = PARTLY CLOUDY AND HAZY
7 = CLOUDY AND HAZY
8 = FOG OR LOW CLOUDS

SEA STATE

An observer supplied subjective rating where:

0 = NO WHITECAPS
1 = SMALL WAVES, FEW WHITECAPS
2 = 0-33% WHITECAPS, WAVES 1-2 FEET
3 = 33%-50% WHITECAPS, WAVES 2-3 FEET
4 = > 50% WHITECAPS, WAVES > 3 FEET
5 = WORSE CONDITIONS THAN 4

WATER TURBIDITY

An observer supplied subjective rating where:

0 = GOOD
1 = FAIR
2 = POOR

SUNLIGHT QUALITY

An observer supplied subjective rating where:

0 = NONE
1 = POOR
2 = FAIR
3 = MODERATE
4 = GOOD
5 = EXCELLENT

GLARE

An observer supplied subjective rating where:

0 = NO HINDRANCE
1 = HINDRANCE ON ONE SIDE
2 = HINDRANCE ON BOTH SIDES

WATER COLOR

An observer supplied subjective rating where:

1 = BROWN
2 = GREEN
3 = GRAY
4 = BLUE
5 = BLUE/GREEN
6 = BROWN/GRAY
7 = GREEN/GRAY
8 = GREEN/BROWN
9 = DARK GREEN

SIGHTING CODES (SPECIES 1, 2, 3, AND 4)

Up to 4 individuals of a species or up to 4 species could have been recorded per sighting. Other codes (95 through 98) allowed us to record more numerous sightings - up to 151 per sighting record. Numeric codes representing marine animals, human activities, and pollution were:

1 Loggerhead Sea Turtle
2 Leatherback Sea Turtle
3 Unidentified Sea Turtle but not a Loggerhead or Leatherback
4 Green, Kemp's Ridley, or Hawksbill Sea Turtle (described in the audio log)
5 Unidentified Sea Turtle but not a Leatherback
6 Manatee
7 Bottlenose Dolphin
8 Stenella sp.
9 Unidentified small cetacean(s)
10 Unidentified large cetacean(s)
12 Spotted Dolphin
13 Striped Dolphin
14 Spinner Dolphin
15 Common Dolphin
16 Pygmy Killer Whale
17 Pygmy or Dwarf Sperm Whale
18 Risso's Dolphin
19 Pilot Whale
20 Human Activity
21 False Killer Whale
22 Beaked Whale
23 Killer Whale
24 Minke Whale
25 Bonito
26 Tuna
27 King Mackerel
28 Crevalle Jack
29 Unknown Ray School
30 Dolphin Fish
31 Tarpon
32 Red Drum
33 Black Drum
34 Cobia
35 Sunfish
36 Manta Ray
37 Cownose Rays
38 Unknown Ray (1 or 2)
39 Hammerhead Shark
40 Unknown, not Hammerhead, Shark
41 Whale Shark
42 Shark School

SIGHTING CODES (SPECIES 1, 2, 3, AND 4), Continued

44 Sperm Whale
45 Humpback Whale
46 Bryde's Whale
47 Right Whale
48 Sei Whale
49 Fin Whale
50 Unknown Large Fish
51 Blue Runners
52 Spadefish
53 Thread Herring
54 Spanish Mackerel
55 Menhaden
56 Mullet
57 Anchovies
58 Atlantic Bumpers
59 Catfish
60 Bluefish
61 Ground Mullet
62 Flying Fish
63 Either Drum or Jacks
64 Cannonball Jellyfish
65 Other Jellyfish
70 Unknown Small Fish
75 Other known cetacean
80 Anchored Shrimp Trawler
81 Trawling Shrimp Trawler
82 Longline Boat
83 Purse Seiner
84 Charter Fishing Boat
85 Recreational Fishing Boat
86 Fish Trawler
87 Seismographic Boat
88 Platform Service Boat
89 Other Boat (noted in audio log)
90 Plastic Rope
91 Longline Fishing Gear
92 Plastic
93 Oil Slick
94 Other Pollution (noted in audio log)
95 10 - 20 schools or sightings
96 21 - 30 schools or sightings
97 31 - 40 schools or sightings
98 41 - 50 schools or sightings

OBSERVER

Which observer made the sighting, where:

1 = LEFT
2 = RIGHT

OBSERVATION ANGLE

For all sea turtle sightings and for marine mammal sightings beginning in 1990 the observation angle was the digital inclinometer reading to the nearest degree. For other sightings the angle was one of 7 intervals, where each interval represent 10°from vertical (i.e., 1 = 0 to 10 degrees, 2 = 11 to 20 degrees, etc.). In addition, 0 was used to record a missing interval or angle. Except for sea turtles and marine mammals, no sightings were recorded when the sighting interval was greater than 7.

SIZE

When used to record number of cetaceans, the codes were:

1	1 to 5 cetaceans
2	6 to 12 cetaceans
3	13 to 20 cetaceans
4	20 to 50 cetaceans
5	> 50 cetaceans

When used to record the size of drum schools, the codes were:

1	< 5,000 lbs
2	5,000 - 20,000 lbs
3	20,000 - 60,000 lbs
4	60,000 - 100,000 lbs
5	> 100,000 lbs

BEHAVIOR

For sea turtle sightings, the behavior codes were:

1 - SWIMMING
2 - BASKING
3 - NEAR SURFACED
4 - COPULATING OR INTERSPECIFIC ACTIVITY
5 - DIVING
6 - OTHER BEHAVIOR (noted in the audio log)

BEHAVIOR, Continued

For cetacean sightings, the behavior codes were:

1 - TRAVELING
2 - RESTING
3 - FORAGING
4 - COMPLEX SOCIAL ACTIVITY
5 - MILLING
6 - UNKNOWN (noted in the audio log)

PHOTOGRAPHS TAKEN?

Used to record if special or unusual photographic records were recorded for a sighting, the code was:

0 - NO
1 - YES

NUMBER OF CETACEANS

This variable field was added to the data records in July 1989 and was used to largely replace the cetacean herd size classes (although these were still automatically recorded for the July through November 1989 data). The number includes both adults and calf cetaceans of a species or type per sighting. To derive only number of large or adult cetaceans, subtract numbers of calves from this variable.

NUMBER OF CETACEAN CALVES

This variable field was added to the data records in January 1990. The number of calves was also included in the number of cetaceans variable.

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. The includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, 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 assure that their development is in the best interest of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.