Abstract.—Little is known about cetaceans in the oceanic Gulf of Mexico (depths >200 m). From July 1989 to June 1990, we conducted aerial surveys in the oceanic north-central Gulf (long. 87.5°W–90.5°W) with the following objectives: 1) to determine which cetacean species were present; 2) to document temporal and spatial distribution for each species; and 3) to estimate relative abundance for each species. We surveyed a total of 20,593 transect km and sighted at least 18 species. Of 278 identified herds (6,084 animals), 94% of the herds and 98% of the animals represented seven species or species groups: Risso's dolphin, *Grampus griseus* (22% of the herds, 13% of the animals); sperm whale, *Physeter macrocephalus* (16%, 1%); bottlenose dolphin, *Tursiops truncatus* 14%, 7%); Atlantic spotted dolphin, *Stenella frontalis* (13%, 15%); pygmy sperm whale, *Kogia breviceps*, and dwarf sperm whale, *Kogia simus* (12%, 1%); striped dolphin, *Stenella coeruleoalba*, spinner dolphin, *S. longirostris*, and clymene dolphin, *S. clymene* (9%, 34%); and pantropical spotted dolphin, *S. attenuata* (8%, 27%). Each of these species or species groups was sighted throughout the area surveyed in at least three seasons. Mean water depths of bottlenose dolphin and Atlantic spotted dolphin sightings were less than 400 m; mean water depths of Risso's dolphins and pygmy and dwarf sperm whales were between 400-600 m; and mean water depths of striped, spinner, and clymene dolphins, sperm whales, and pantropical spotted dolphins were greater than 700 m. Mean herd sizes varied by species and species groups and ranged from 1.9 animals for pygmy and dwarf sperm whales to 87.8 animals for striped, spinner, and clymene dolphins.

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Cetaceans on the upper continental slope in the north-central Gulf of Mexico

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The Gulf of Mexico encompasses an area of over 1,500,000 km^2 and has an average depth of 1,700 m (Gore, 1992). The continental shelf (depths <200 m) is wide (up to 260 km) in most parts of the northern Gulf (Fig. 1). Directed studies (Fritts et al., 1983; Scott et al.[1]) and opportunistic sightings (Schmidly, 1981; Rademacher[2]) have suggested that only the bottlenose dolphin, *Tursiops truncatus*, and the Atlantic spotted dolphin, *Stenella frontalis*, are common in most continental shelf waters of the U.S. Gulf. However, there are records (primarily from strandings) of 29 cetacean species from the Gulf (Schmidly, 1981; Perrin et al., 1981; Hersh and Odell, 1986; Perrin et al., 1987; Bonde and O'Shea, 1989; Barron and Jefferson, 1993). Therefore, if species other than the bottlenose dolphin and the Atlantic spotted dolphin are represented in substantial numbers, their distributions must be primarily oceanic (depths >200 m).

Mineral deposits have been mined widely in U.S. Gulf shelf waters west of Mobile, Alabama, and as of 1988, over 4,500 drilling structures have been in use for oil and gas production. Mineral development on the continental slope (depths 200–2,000 m) in the central and western Gulf has begun and additional exploratory drilling is being planned. Before large-scale exploration, development, and production can take place, an assessment of cetacean diversity, distribution, and abundance is required to satisfy the intent of the U.S. Marine Mammal Protection Act and the U.S. Endangered Species Act. Both acts mandate that federal agencies take appropriate actions to ensure that their activities do not

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[1] Scott, G. P., D. M. Burn, L. J. Hansen, and R. E. Owen. 1989. Estimates of bottlenose dolphin abundance in the Gulf of Mexico from regional aerial surveys. U.S. Dep. Commer., NOAA, Nat. Mar. Fish. Serv., Southeast Fish. Sci. Cent., Miami Laboratory, 75 Virginia Beach Drive, Miami, FL 33149. Admin. Rep. CRD-88/89-07, 24 p.

[2] Rademacher, K. R. 1991. Opportunistic sightings of cetaceans in the Gulf of Mexico from NOAA Ship *Chapman*, 1989–90. U.S. Dep. Commer., NOAA, Nat. Mar. Fish. Serv., Southeast Fish. Sci. Cent., Pascagoula Facility, P.O. Drawer 1207, Pascagoula, MS 39568. Unpubl. data.

contribute to the demise of endangered species or to the depletion of marine mammal populations. To assess potential impacts of oil and gas activities on marine mammal populations, it is imperative that we know when, where, and how many marine mammals may be vulnerable to such activities.

Only limited data from strandings, opportunistic sightings (Schmidly, 1981; Mead[3]), and aerial surveys (Fritts et al., 1983) are currently available to assess these parameters for oceanic cetaceans in the Gulf. In July 1989, the U.S. Minerals Management Service and the Southeast Fisheries Science Center (SEFSC) began aerial surveys of cetaceans on the upper continental slope in the north-central Gulf. The objectives of the surveys were 1) to determine which species were present; 2) to document temporal and spatial distribution for each species; and 3) to estimate relative abundance for each species.

[3] Mead, J. G. 1992. Marine mammal strandings. National Museum of Natural History, Smithsonian Institution, Washington, D.C. 20560. Unpubl. data.

Methods

The study was conducted in two phases. Phase 1 was a five-month pilot study carried out from July through November 1989. The primary objective of Phase 1 was to determine which species of cetaceans,

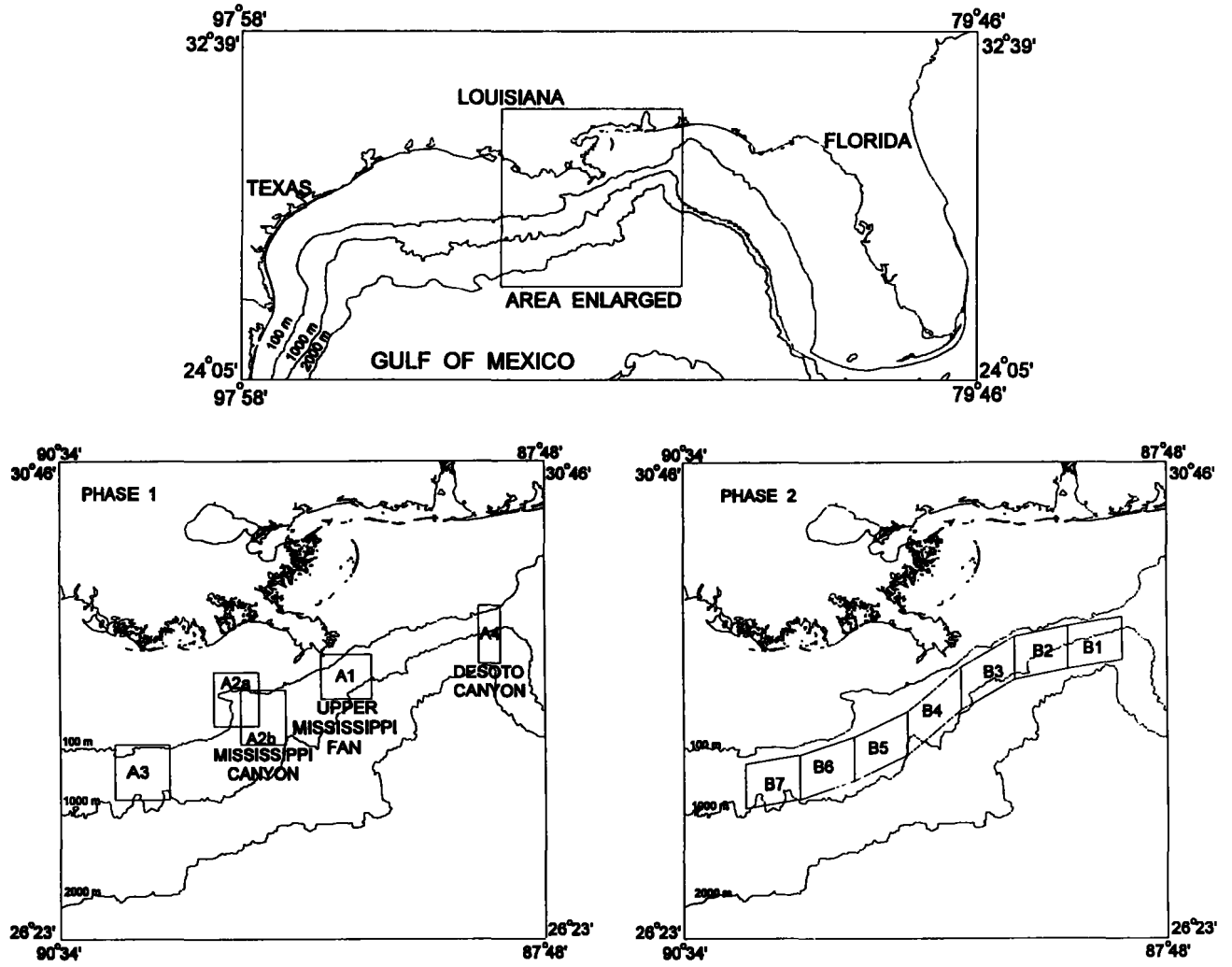

Figure 1

Location of the area surveyed for cetaceans in the north-central Gulf of Mexico (top panel). The locations of the survey blocks for Phase 1 (July–November 1989) are shown in the lower left panel and for Phase 2 (January–June 1990), in the lower right panel.

if any, inhabited the upper continental slope in the north-central Gulf. Since studies elsewhere indicated that cetaceans may concentrate in areas of high seafloor relief (Hui, 1979; Payne et al., 1986; Kenney and Winn, 1986; Selzer and Payne, 1988), three survey blocks were initially selected on the upper continental slope (Fig. 1, Blocks A1–A3; Table 1): 1) the Upper Mississippi Fan, 2) the Mississippi Canyon, and 3) an area of submarine salt domes. The DeSoto Canyon survey block (Block A4) was added in September when additional flight time was available.

The Mississippi Canyon survey block was shifted southeast to include deeper waters for the October and November surveys. This was done because sperm whales, *Physeter macrocephalus*, were sighted near the 1,000-m isobath during September in the Upper Mississippi Fan survey block. The sperm whale is listed as an endangered species under the U.S. Endangered Species Act (USFWS, 1989), and we were interested in defining its distribution.

The results of Phase 1 indicated that a variety of cetaceans were relatively abundant on the upper continental slope; ten species and 171 herds were sighted. Therefore, Phase 2 was implemented and monthly surveys, except for December, were continued to complete a full year period.

Phase 2 was conducted from January through June 1990. The study area selected for Phase 2 consisted of seven adjacent blocks 30 minutes wide (48.7 km) that extended from long. 87.5'W to long. 90.5'W (Fig. 1, Blocks B1–B7). The northern border of the study area, except near the Mississippi Canyon, generally followed the 200-m isobath. Each block extended 44.1 km south of its northern border.

The Mississippi Canyon was not surveyed because we wanted to focus on oceanic waters. Because of the shape of the canyon, surveys of oceanic waters would have been logistically inefficient. We also believed that the results of Phase 1 established the canyon as important cetacean habitat; eight species were identified in 54 sightings.

Aerial surveys were conducted when the sea state was Beaufort 0–4 and visibility was good and were designed to sample blocks A1–A4 at least twice each month during Phase 1, and blocks B1–B7 twice each month during Phase 2. Line transect sampling methods were used (Buckland et al., 1993) although line transect analyses are not presented here.

The survey aircraft, a DeHavilland Twin Otter with a large plexiglass bubble window on each side that allowed observers to view an area on both side of the transect line, was flown at an altitude of 750 feet (229 m) and a speed of 110 knots (204 km/h). Transects that were uniformly spaced from a random starting point were surveyed in each block (Table 1). Transects ran north-south, perpendicular to the bathymetry. One observer was stationed at each bubble window and one at a computer station. Observers rotated every 30 minutes to avoid fatigue. The bubble windows were divided into seven 10'

Table 1

Summary of area, water depth, transect length, number of transects, and effort per month for each survey block in the Gulf of Mexico.

Block	Area (km^2)	Range of water depths (m)	Transect length (km)	Number of transects[1]	Transect kilometers of effort per month and block											
					1989					1990						
					Jul	Aug	Sep	Oct	Nov	Jan	Feb	Mar	Apr	May	Jun	Total
A1	2,099	18–1,317	46.3	5	934	677	956	634	920	—	—	—	—	—	—	4,121
A2a	2,255	29–573	55.5	3	440	447	396	—	—	—	—	—	—	—	—	1,283
A2b	2,255	134–966	55.5	3	—	—	—	499	167	—	—	—	—	—	—	666
A3	2,640	104–1,152	55.5	3	394	489	412	0	164	—	—	—	—	—	—	1,459
A4	1,180	66–2,003	59.2	3	—	—	176	356	535	—	—	—	—	—	—	1,067
B1	2,160	168–1,792	44.1	4	—	—	—	—	—	0	179	362	362	269	265	1,437
B2	2,160	139–1,710	44.1	4	—	—	—	—	—	178	178	223	178	352	717	1,826
B3	2,160	163–1,070	44.1	4	—	—	—	—	—	357	176	631	360	445	449	2,418
B4	2,160	183–1,125	44.1	4	—	—	—	—	—	231	0	355	357	170	544	1,657
B5	2,160	230–979	44.1	4	—	—	—	—	—	128	0	358	360	361	361	1,568
B6	2,160	152–933	44.1	4	—	—	—	—	—	312	0	178	273	358	357	1,478
B7	2,160	176–1,098	44.1	4	—	—	—	—	—	356	0	180	361	354	362	1,613
				Total	1,768	1,613	1,940	1,489	1,786	1,562	533	2,287	2,251	2,309	3,055	20,593

[1] Number of planned transects each time the block was surveyed.

sighting intervals corresponding to perpendicular distances from the transect line of 40, 83, 132, 192, 273, 397, and 629 m. Observers searched on and near the transect line and scanned periodically out to 629 m. Sighting cues beyond 629 m were ignored unless the observer was certain it was a cetacean.

When cetaceans were encountered, the sighting interval was noted and the herd was circled. Before continuing on the transect, the herd was identified and its size estimated. The identifying characteristics of each cetacean species were noted. Data were entered on a computer interfaced with a LORAN-C navigation receiver. Latitude, longitude, and heading were automatically recorded with each data record.

Cetaceans were identified to the lowest taxonomic level possible from descriptions in field guides by Leatherwood et al. (1976) and Leatherwood and Reeves (1983). Our ability to make an identification was dependent on water clarity, sea state, and animal behavior. We were not able to distinguish species of some genera or groups of species. These groups included 1) the species of *Mesoplodon*; 2) the melon-headed whale, *Peponocephala electra*, and pygmy killer whale, *Feresa attenuata*; 3) the dwarf sperm whale, *Kogia simus*, and pygmy sperm whale, *K. breviceps*; and 4) the short-finned pilot whale, *Globicephala macrorhynchus*, and long-finned pilot whale,[4] *G. melaena*. Cuvier's beaked whale, *Ziphius cavirostris*, and *Mesoplodon* spp. could not always be distinguished and these sightings were classified as unidentified ziphiids. While we did make positive identifications of striped dolphins, *S. coeruloealba*, spinner dolphins, *S. longirostris*, and clymene dolphins, *S. clymene*, from photographs, they were usually difficult to distinguish in the field and were grouped together for analyses. In some cases, animals could only be identified as large cetaceans (greater than about 7 m) or small cetaceans (less than about 7 m).

For species or species groups sighted 20 or more times, the null hypothesis that water depth did not vary among species or species groups was tested with one-way analysis of variance. If the null hypothesis was rejected, Duncan's multiple-range test was used to determine where significant differences in mean water depths occurred.

Sighting rates of herds and individuals were used as measures of overall, temporal, and spatial relative abundance. Seasons were defined as summer (June–August), fall (September–November), winter (January–February), and spring (March–May). To summarize spatial relative abundance, the area surveyed was divided into an eastern zone (Blocks A4, B1, and B2), a central zone (Blocks A1, A2, B3, B4, and B5), and a western zone (Blocks A3, B6, and B7). All sightings from each season and zone were pooled. For each season and for each zone, the sighting rate of herds (herds/100 transect km) and animals (animals/100 transect km) of each species or species group was calculated.

We also compared the relative abundance of individuals of each species or species group from our surveys to those from the Gulf stranding database (Mead[3]). The database of Gulf strandings contained 2,321 records identified to species. Only 516 records (22%) were not those of bottlenose dolphins. To compare our results with these data, we excluded bottlenose dolphins and unidentified cetaceans from both data sets. We used our species or species-group categories and calculated the relative abundance of each within each data set as a percentage of the total number of animals.

Results

In total, we sighted 320 herds (7,438 animals) and identified 18 species of cetaceans (Table 2); 45 herds (14%) could not be identified. Of the 275 identified herds (6,084 animals), 93.5% of the herds and 97.7% of the animals consisted of seven species or species groups: Risso's dolphins (herds, 22.2%; animals, 12.6%); sperm whales (15.6%, 1.4%); bottlenose dolphins (14.2%, 7.4%); Atlantic spotted dolphins (12.8%, 15.0%); pygmy and dwarf sperm whales (11.6%, 1.0%); striped, spinner, and clymene dolphins (8.7%, 33.8%); and pantropical spotted dolphins (8.4%, 26.5%).

Mean herd sizes of species or species groups sighted more than 20 times ranged from 1.9 to 87.8 animals (Table 2). The largest herd consisted of 325 striped, spinner, or clymene dolphins (SSC dolphins). Dolphins of the genus *Stenella* had the largest mean herd sizes and the largest ranges of herd sizes. However, the mean herd sizes of pantropical spotted dolphins and SSC dolphins were each about three times that of the Atlantic spotted dolphin. The mean herd sizes of sperm whales and pygmy and dwarf sperm whales were close to two, and they exhibited the smallest ranges of herd sizes. Bottlenose dolphins and Risso's dolphins had similar means and ranges of herd sizes.

Mean water depths of species or species groups sighted 20 or more times ranged from 257 to 905 m (Table 2). Differences between these means were statistically significant (Table 3). Mean water depths of pantropical spotted dolphin, sperm whale, and SSC dolphin sightings were the largest (>700 m). Each of

[4] Only the short-finned pilot whale is known to inhabit the Gulf of Mexico (Schmidly, 1981).

Table 2

Cetaceans sighted, mean herd size ($\overline{H}$) and mean water depth ($\overline{W}$; n = number of herds) from aerial surveys conducted in the Gulf of Mexico from July 1989 to June 1990 (%CV=percent coefficient of variation).

		Herd size (animals)			Water depth (meters)			
Species or species group	n	$\overline{H}$	SE	Range	$\overline{W}$	SE	Range	%CV
Risso's dolphin (*Grampus griseus*)	61	12.8	1.46	1–48	440	25.5	97–1,079	46
Sperm whale (*Physeter macrocephalus*)	43	2.1	0.30	1–9	877	35.5	199–1,573	27
Bottlenose dolphin (*Tursiops truncatus*)	39	11.9	2.23	1–60	257	41.0	20–973	100
Atlantic spotted dolphin (*Stenella frontalis*)	35	26.6	5.15	2–137	367	40.3	91–1,152	65
Pygmy/dwarf sperm whales (*Kogia breviceps/simus*)	32	1.9	0.20	1–4	544	63.8	96–1,780	65
SSC dolphins[1] (*S. coeruleoalba/longirostris/clymene*)	24	87.8	20.44	8–325	712	76.3	93–1,567	53
Pantropical spotted dolphin (*S. attenuata*)	23	71.8	9.38	7–186	905	76.6	65–1,566	39
Pilot whale (*Globicephala* sp.)	5	18.2	3.73	5–28	605	71.3	364–781	28
Cuvier's beaked whale (*Ziphius cavirostris*)	3	1.3	0.33	1–2	1,268	275.1	916–1,810	38
Mesoplodon sp.	1	1.0	—	—	910	—	—	—
Unidentified ziphiids (*Mesoplodon/Ziphius*)	3	1.3	0.33	1–2	668	238.2	204–993	62
Pygmy killer/melon-headed whales (*Feresa/Peponocephala*)	1	25.0	—	—	318	—	—	—
False killer whale (*Pseudorca crassidens*)	1	3.0	—	—	1,107	—	—	—
Killer whale (*Orcinus orca*)	1	8.0	—	—	964	—	—	—
Rough-toothed dolphin (*Steno bredanensis*)	1	4.0	—	—	933	—	—	—
Fin whale (*Balaenoptera physalus*)	1	1.0	—	—	148	—	—	—
Bryde's whale (*B. edeni*)	1	1.0	—	—	342	—	—	—
Unidentified small cetacean	40	30.1	10.38	1–325	530	68.3	87–1,779	82
Unidentified large cetacean	5	1.8	0.45	1–3	857	288.2	316–1,673	57

[1] S. *coeruleoalba*, *S. longirostris*, and *S. clymene* were each positively identified at least once.

these species inhabited a range of water depths greater than 1,300 m. However, most sperm whales inhabited a very narrow range of water depths (Fig. 2). The mean depth of sperm whale sightings had a coefficient of variation of 0.27, the lowest of any species or species group (Table 3). Bottlenose dolphins, Atlantic spotted dolphins, and Risso's dolphins had the shallowest mean water depths (<450 m) and inhabited a range of water depths less than 1,100 m. Cuvier's beaked whales were only sighted at depths greater than 900 m.

Cetaceans were widely distributed between seasons (Table 4). Five species or species groups were sighted in every season of the year: sperm whales, bottlenose dolphins, Risso's dolphins, Atlantic spotted dolphins, and SSC dolphins. Pygmy and dwarf sperm whales and pantropical spotted dolphins were sighted in all seasons except winter and Cuvier's beaked whale,

Table 3

Duncan's multiple range test of mean water depths ($\overline{W}$) inhabited by cetacean species and species groups in the Gulf of Mexico during 1989–90 (ANOVA: F=29.3, P<0.05; species or species groups sighted more than 20 times; n=number of herds).

Species or species group	n	$\overline{W}$ (meters)	Duncan grouping*
Pantropical spotted dolphin (*Stenella attenuata*)	23	905	A
Sperm whale (*Physeter macrocephalus*)	43	877	A
SSC dolphins (*S. coeruleoalba/ longirostris/clymene*)	24	712	B
Pygmy/dwarf sperm whales (*Kogia breviceps/simus*)	32	544	C
Risso's dolphin (*Grampus griseus*)	61	440	C D
Atlantic spotted dolphin (*S. frontalis*)	36	368	D E
Bottlenose dolphin (*Tursiops truncatus*)	39	257	E

* Means with the same letter are not significantly different, P>0.05.

in all seasons except summer. The number of species or species groups sighted in summer, fall, winter and spring was 12, 10, 6, and 10, respectively. Seasonal sighting rates of all cetacean herds ranged from 0.91 herds/100 km (winter) to 2.01 herds/100 km (fall) and those of all animals sighted ranged from 16.80 animals/100 km (summer) to 52.25 animals/100 km (fall).

The relative abundance of several species or species groups varied seasonally (Table 4). Sighting rates (herds and animals) of Risso's dolphins showed a distinct peak during spring. During April alone, 30% of the Risso's dolphin herds and 48% of the animals were sighted. Sighting rates of sperm whales and Atlantic spotted dolphins peaked in the fall. Sighting rates of bottlenose dolphins and pygmy and dwarf sperm whales were highest during summer and fall. SSC dolphins exhibited similar herd sighting rates in each season, but the animal sighting rate was much lower during summer. SSC dolphin herds averaged only about 20 animals in summer but near 100 or more during other seasons.

Cetaceans were sighted throughout the area surveyed (Fig. 2). Each species or species group sighted 20 or more times had a wide spatial distribution and was sighted in all three zones (Fig. 2, Table 5). Ten species were sighted in the eastern zone, 13 in the central zone, and nine in the western zone. Sighting rates of all herds sighted were generally similar in the eastern and central zones (1.67 and 1.71 herds/100 km, respectively) and a little lower in the western zone (1.05 herds/100 km). However, because the mean herd size of all cetaceans sighted from the eastern zone (35.8 animals) was larger than those of the central (19.2 animals) and western (21.5 animals) zones, the sighting rates of animals were more variable: 59.5 animals/100 km (eastern), 32.7 animals/100 km (central), and 22.6 animals/100 km (western).

Sighting rates of species or species groups sighted 20 or more times varied by zone (Table 5). Except for Atlantic spotted dolphins and pantropical spotted dolphins, herd sighting rates were lowest in the western zone. Except for pantropical spotted dolphins, the animal sighting rates were also lowest in the western zone. Sighting rates (herd and animal) of Risso's dolphins and SSC dolphins were highest in the eastern zone. In the central zone, sighting rates of sperm whales, bottlenose dolphins, Atlantic spotted dolphins, and pygmy and dwarf sperm whales were highest; those of pantropical spotted dolphins were lowest.

Risso's dolphin sightings in the eastern part of the study area were generally concentrated near the 200-m isobath. Most of the sperm whale sightings (65%) occurred southeast of the Mississippi River delta along the 1,000-m isobath. Of 39 bottlenose dolphin herds sighted, 19 were sighted in waters less than 100 m deep, at the head of the Mississippi Canyon and on the Upper Mississippi Fan. A concentration of pygmy and dwarf sperm whales occurred along the western Mississippi Canyon. Most of the SSC dolphin sightings occurred on the Upper Mississippi Fan and in DeSoto Canyon. Four of the five pilot whale herds sighted were encountered on the Upper Mississippi Fan on 4 November 1989. The only baleen whales sighted, one fin whale, *Balaenoptera physalus*, in the fall and one Bryde's whale, *B. edeni*, in the summer, were both sighted in waters about 200 m deep in the DeSoto Canyon (Fig. 2).

The relative abundance of many species or species groups was different from the Gulf stranding data (Table 6). Compared with the stranding database, the relative abundances of Risso's dolphins, pantropical spotted dolphins, and Atlantic spotted dolphins were greater in our study. The relative abundances of balaenopterid whales, ziphiids, pilot whales, and pygmy and dwarf sperm whales from the stranding data were larger than those observed during our surveys.

Discussion

This study was the first to focus on cetaceans in the oceanic Gulf of Mexico. We sighted at least 18 of the 29 cetacean species with one or more historical

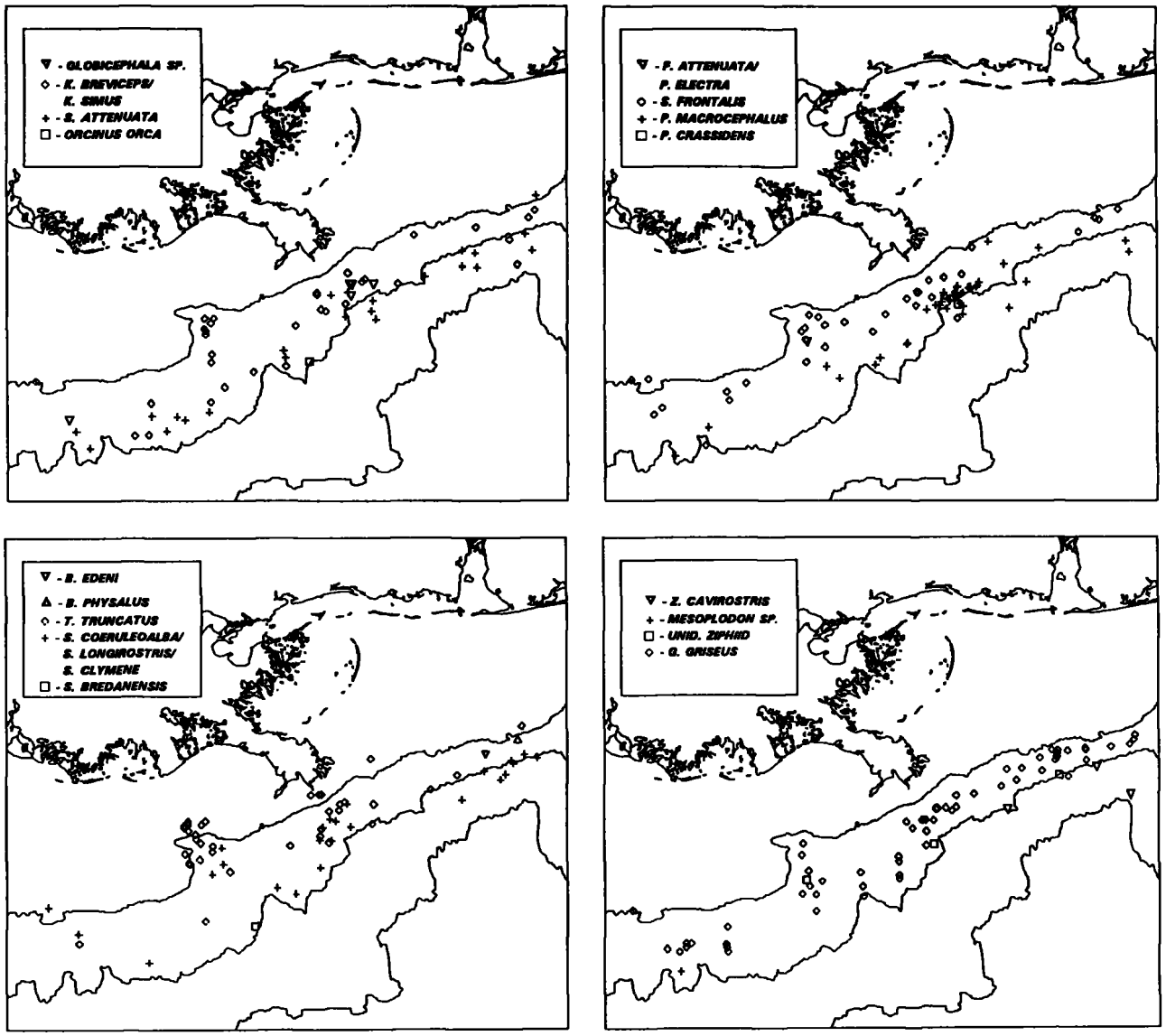

Figure 2

The locations of sightings of each cetacean species or species group in the Gulf of Mexico for the entire study (July 1989–June 1990).

records from the Gulf. The first at-sea identifications of Bryde's whale, pygmy and dwarf sperm whales, spinner dolphins, and Cuvier's beaked whales in the Gulf were recorded during this study. Prior to this study, species with five or fewer herd-sighting records (nonstranding) from the Gulf included pantropical spotted dolphin, clymene dolphin, Risso's dolphin, killer whale, false killer whale, rough-toothed dolphin, fin whale, pygmy killer whale, melon-headed whale, and *Mesoplodon* spp. (Schmidly, 1981; Jennings, 1982; Fritts et al., 1983; Rademacher[2]). Sperm whales were hunted commercially in the Gulf until the early 1900's (Townsend, 1935) but were recently thought to be rare (Lowery, 1974). However, our data and the 17 Gulf sperm whale sightings reported by Collum and Fritts (1985) indicate they may be more abundant than previously thought. Species known from the Gulf that could be distinguished from aircraft, but were not identified during our surveys, included the northern right whale, *Eubalaena glacialis*, the blue whale, *B. musculus*, the minke whale, *B. acutorostrata*, the humpback whale, *Megaptera novaeangliae*, and the Fraser's dolphin, *Lagenodelphis hosei*.

Table 4

Seasonal sighting rates of cetacean herds (herds/100 km) and individual animals (animals/100 km) in the Gulf of Mexico during 1989–90. The effort in transect km each season is in parentheses (h=number of herds sighted; a=number of animals sighted).

	Summer (6,436 km)		Fall (5,215 km)		Winter (2,095 km)		Spring (6,847 km)		Total (20,593 km)	
Species or species group	Herds (h)	Animals (a)	Herds (h)	Animals (a)	Herds (h)	Animals (a)	Herds (h)	Animals (a)	Herds (h)	Animals (a)
All cetaceans	1.46 (94)	16.80 (1,081)	2.01 (105)	52.25 (2,749)	0.91 (19)	32.12 (673)	1.49 (102)	42.87 (2,935)	1.55 (320)	36.12 (7,438)
Risso's dolphin (*Grampus griseus*)	0.26 (17)	2.63 (169)	0.06 (3)	1.00 (52)	0.10 (2)	1.53 (32)	0.57 (39)	7.73 (529)	0.29 (61)	3.80 (782)
Sperm whale (*Physeter macrocephalus*)	0.11 (7)	0.34 (22)	0.46 (24)	1.04 (54)	0.29 (6)	0.33 (7)	0.09 (6)	0.09 (6)	0.21 (43)	0.43 (89)
Bottlenose dolphin (*Tursiops truncatus*)	0.28 (18)	2.41 (155)	0.33 (17)	4.93 (257)	0.10 (2)	2.10 (44)	0.03 (2)	0.10 (7)	0.19 (39)	2.25 (463)
Atlantic spotted dolphin (*Stenella frontalis*)	0.12 (8)	2.41 (155)	0.31 (16)	11.03 (575)	0.10 (2)	2.10 (44)	0.13 (9)	2.31 (158)	0.17 (35)	4.53 (932)
Pygmy/dwarf sperm whales (*Kogia breviceps/simus*)	0.19 (12)	0.37 (24)	0.23 (12)	0.46 (24)	0	0	0.12 (8)	0.19 (13)	0.16 (32)	0.30 (61)
SSC dolphins (*S. coeruleoalba/ longirostris/clymene*)	0.12 (8)	2.42 (156)	0.12 (6)	11.43 (596)	0.14 (3)	25.78 (540)	0.10 (7)	11.89 (814)	0.12 (24)	10.23 (2,106)
Pantropical spotted dolphin (*S. attenuata*)	0.08 (5)	4.29 (276)	0.13 (7)	10.26 (535)	0	0	0.16 (11)	12.27 (840)	0.11 (23)	8.02 (1,651)
Pilot whale (*Globicephala* sp.)	0.02 (1)	0.08 (5)	0.08 (4)	1.65 (86)	0	0	0	0	0.02 (5)	0.44 (91)

Continued on next page

The ecological implications of Gulf stranding records are not clear since there are only a small number of strandings of most species. It is not known whether the stranded animals strayed into the Gulf from their primary ranges or whether they inhabited Gulf waters on a regular basis. The number and broad seasonality of sightings during this study of Risso's dolphins, sperm whales, pygmy and dwarf sperm whales, SSC dolphins, and pantropical spotted dolphins indicate that they are probably permanent residents of the Gulf.

How accurately our results reflected the abundance of each species relative to other species is uncertain. Factors that vary among species, such as surface behavior, herd size, and time spent at or near the surface, can affect sighting rates. In our study, water depth or area, or both (e.g. Mississippi Canyon), affected the distribution of some species. However, our survey effort was not equal seasonally over water depths or by area and this probably affected at least some of our relative abundance results (Tables 4–5). Forty-nine percent (19/39) of the bottlenose dolphin herds we sighted were encountered during summer and fall at the head of the Mississippi Canyon and on the Upper Mississippi Fan at depths less than 100 m. (Survey effort at <100 m made up <5% of the total effort, 8.5% of both the summer and fall effort, and 0% of the winter and spring effort.) Without these sightings, the seasonal sighting rates of bottlenose dolphins were less variable. Also, 28% (9/32) of the pygmy and dwarf sperm whale sightings and 26% (9/35) of the Atlantic spotted dolphin sightings occurred in the Mississippi Canyon (Block A2, surveyed during summer and fall) where only

Table 4 (Continued)

Species or species group	Summer (6,436 km) Herds (h)	Summer (6,436 km) Animals (a)	Fall (5,215 km) Herds (h)	Fall (5,215 km) Animals (a)	Winter (2,095 km) Herds (h)	Winter (2,095 km) Animals (a)	Spring (6,847 km) Herds (h)	Spring (6,847 km) Animals (a)	Total (20,593 km) Herds (h)	Total (20,593 km) Animals (a)
Cuvier's beaked whale (*Ziphius cavirostris*)	0	0	0.02 (1)	0.02 (1)	0.05 (1)	0.05 (1)	0.01 (1)	0.03 (2)	0.01 (3)	0.02 (4)
Mesoplodon sp.	0.02 (1)	0.02 (1)	0	0	0	0	0	0	<0.01 (1)	<0.01 (1)
Unidentified ziphiids (*Mesoplodon/Ziphius*)	0.02 (1)	0.03 (2)	0.02 (1)	0.02 (1)	0	0	0.01 (1)	0.01 (1)	0.01 (3)	0.02 (4)
Pygmy killer/melon-headed whales (*Feresa/Peponocephala*)	0.02 (1)	0.39 (25)	0	0	0	0	0	0	<0.01 (1)	0.12 (25)
False killer whale (*Pseudorca crassidens*)	0.02 (1)	0.05 (3)	0	0	0	0	0	0	<0.01 (1)	0.01 (3)
Killer whale (*Orcinus orca*)	0	0	0	0	0	0	0.01 (1)	0.12 (8)	<0.01 (1)	0.04 (8)
Rough-toothed dolphin (*Steno bredanensis*)	0	0	0	0	0	0	0.01 (1)	0.06 (4)	<0.01 (1)	0.02 (4)
Fin whale (*Balaenoptera physalus*)	0	0	0.02 (1)	0.02 (1)	0	0	0	0	<0.01 (1)	<0.01 (1)
Bryde's whale (*B. edeni*)	0.02 (1)	0.02 (1)	0	0	0	0	0	0	<0.01 (1)	<0.01 (1)
Unidentified large cetacean	0	0	0.02 (1)	0.06 (3)	0.05 (1)	0.05 (1)	0.04 (3)	0.07 (5)	0.02 (5)	0.04 (9)
Unidentified small cetacean	0.20 (13)	1.35 (87)	0.23 (12)	10.81 (564)	0.10 (2)	0.19 (4)	0.19 (13)	8.00 (548)	0.19 (40)	5.84 (1,203)

10% of the total survey effort occurred. The Mississippi Canyon region is probably an important cetacean habitat. Eight species or species groups were sighted there and when herd sighting rates were calculated for each survey block (Mullin et al.[5]), it had the highest sighting rate of any block.

The region near the 1,000-m isobath on the Upper Mississippi Fan appeared to be an important habitat for sperm whales. Most sperm whale herd sightings (72%, 31/43) occurred on the Upper Mississippi Fan (Blocks A1, B3, and B4) but only 40% of the total effort occurred there. Fall may have been a time of increased sperm whale abundance on the Upper Mississippi Fan. Of the total effort, 20% occurred in fall on the Upper Mississippi Fan and yielded 47% (20/43) of the total sperm whale herd sightings. Of course the same animals could have been seen repeatedly, but even if that were true, it indicates that a very small area (Fig. 2) could be important to some animals for a period of at least several months.

Our study was confined to the outer continental shelf and the upper continental slope and did not cover the entire range of water depths that each species inhabits. However, our results do not conflict with what is generally known about the water depth distribution of each species (Leatherwood and Reeves, 1983). While the supposition that only bottlenose dolphins and Atlantic spotted dolphins inhabit

[5] Mullin, K., W. Hoggard, C. Roden, R. Lohoefener, C. Rogers, and B. Taggart. 1991. Cetaceans on the upper continental slope in the north-central Gulf of Mexico. Outer Continental Shelf Study/ MMS 91-0027. U.S. Dep. Interior, Minerals Mgmt. Service, Gulf of Mexico OCS Regional Office, New Orleans, LA, 108 p.

Table 5

Sighting rates of cetacean herds (herds/100 km) and animals (animals/100 km) by zone (Fig. 2: Eastern=blocks A4, B1 and B2; Central=A1, A2, B3, B4 and B5; Western=A3, B6 and B7) in the Gulf of Mexico during 1989–90. Effort in kilometers in each zone is in parentheses (h=number of herds, a=number of animals).

Species or species group	Eastern (4,330 km)		Central (11,713 km)		Western (4,550 km)	
	Herds (h)	Animals (a)	Herds (h)	Animals (a)	Herds (h)	Animals (a)
All cetaceans	1.67 (72)	59.54 (2,578)	1.71 (200)	32.70 (3,830)	1.05 (48)	22.64 (1,030)
Risso's dolphin (*Grampus griseus*)	0.51 (22)	7.39 (320)	0.25 (29)	3.04 (356)	0.22 (10)	2.33 (106)
Sperm whale (*Physeter macrocephalus*)	0.14 (6)	0.18 (8)	0.30 (35)	0.67 (79)	0.04 (2)	0.04 (2)
Bottlenose dolphin (*Tursiops truncatus*)	0.07 (3)	1.39 (60)	0.29 (34)	2.95 (346)	0.04 (2)	1.25 (57)
Atlantic spotted dolphin (*Stenella frontalis*)	0.09 (4)	4.32 (187)	0.20 (23)	5.20 (609)	0.18 (8)	2.99 (136)
Pygmy/dwarf sperm whales (*Kogia breviceps/simus*)	0.14 (6)	0.30 (13)	0.19 (22)	0.34 (40)	0.09 (4)	0.18 (8)
SSC dolphins (*S. coeruleoalba/ longirostris/clymene*)	0.18 (8)	22.96 (994)	0.11 (13)	8.81 (1,032)	0.07 (3)	1.76 (80)
Pantropical spotted dolphin (*S. attenuata*)	0.18 (8)	9.63 (417)	0.08 (9)	5.43 (636)	0.13 (6)	13.14 (598)
Pilot whale (*Globicephala* sp.)	0	0	0.03 (4)	0.73 (86)	0.02 (1)	0.11 (5)
Cuvier's beaked whale (*Ziphius cavirostris*)	0.07 (3)	0.09 (4)	0	0	0	0

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most continental shelf waters of the U.S. Gulf (Lowery, 1974; Scott et al.[1]; Rademacher[2]) may be true, we did sight Risso's dolphins, pygmy and dwarf sperm whales, SSC dolphins, pantropical spotted dolphins, and a sperm whale at depths less than 200 m. Fritts et al. (1983) identified a sperm whale and SSC dolphins on the continental shelf off southern Florida.

In general, our results of mean herd size for most species were similar to those reported from the Atlantic and Pacific oceans (Yamada, 1954; Ross, 1978; Leatherwood et al., 1980; Fritts et al., 1983; Leatherwood and Reeves, 1983; Vidal et al., 1987; Scott and Cordaro, 1987; Kruse, 1989; Wade and Gerrodette, 1993; CeTAP[6]). Our mean herd size for sperm whales (2.1 animals) was slightly smaller than the mean of 3.5 animals reported by Collum and Fritts (1985) from Gulf sightings. However, in other areas of the world, mixed-sex herds and bachelor herds of sperm whales range from 20 to 40 whales (Rice, 1989).

The maximum herd sizes reported from the Atlantic and Pacific oceans were much greater than those observed in this study, where the largest herd was estimated at 325 animals. Maximum herd sizes of Risso's dolphins, bottlenose dolphins, striped dol-

[6] CeTAP. 1982. A characterization of marine mammals and turtles in the mid- and north-Atlantic areas of the U.S. outer continental shelf. Final Report of the Cetacean and Turtle Assessment Program, BLM Contract AA551-CT8-48, U.S. Dep. Interior, Washington D.C., 450 p.

Table 5 (Continued)

Species or species group	Eastern (4,330 km)		Central (11,713 km)		Western (4,550 km)	
	Herds (*h*)	Animals (*a*)	Herds (*h*)	Animals (*a*)	Herds (*h*)	Animals (*a*)
Mesoplodon sp.	0	0	0	0	0.02 (1)	0.02 (1)
Unidentified ziphiids (*Mesoplodon/Ziphius*)	0.02 (1)	0.02 (1)	0.02 (2)	0.03 (3)	0	0
Pygmy killer/melon-headed whales (*Feresa/Peponocephala*)	0	0	<0.01 (1)	0.21 (25)	0	0
False killer whale (*Pseudorca crassidens*)	0	0	<0.01 (1)	0.03 (3)	0	0
Killer whale (*Orcinus orca*)	0	0	<0.01 (1)	0.07 (8)	0	0
Rough-toothed dolphin (*Steno bredanensis*)	0	0	<0.01 (1)	0.03 (4)	0	0
Fin whale (*Balaenoptera physalus*)	0.02 (1)	0.02 (1)	0	0	0	0
Bryde's whale (*B. edeni*)	0.02 (1)	0.02 (1)	0	0	0	0
Unidentified large cetacean	0.05 (2)	0.09 (4)	0.02 (2)	0.02 (2)	0.02 (1)	0.07 (3)
Unidentified small cetacean	0.16 (7)	13.12 (568)	0.20 (23)	5.13 (601)	0.22 (10)	0.75 (34)

phins, and pilot whales in the Atlantic exceeded 350 animals (CeTAP[6]). Herds of striped dolphins, pantropical spotted dolphins, and spinner dolphins exceeding 1,000 animals in the Pacific are not uncommon (Leatherwood and Reeves, 1983). In Monterey Bay, California, Risso's dolphin herds as large as 500 animals have been reported (Kruse, 1989). These differences in maximum herd sizes may be related to how prey or predators, or both, are distributed in these areas (Norris and Dohl, 1980; Wells et al., 1980).

We sighted two mixed species herds (Risso's dolphins and pilot whales; Atlantic spotted and bottlenose dolphins). Fritts et al. (1983) reported only three mixed species herds in the Gulf: two herds of pilot whales and *Stenella* sp., and one herd of Risso's dolphins with an unidentified whale. Risso's dolphins are often associated with other oceanic cetaceans (Leatherwood and Reeves, 1983; Kruse, 1989). In the eastern tropical Pacific, spinner and pantropical spotted dolphins are commonly found together (Au and Perryman, 1985). Bottlenose dolphins were associated with other species (primarily pilot whales) in 20% of the sightings in the Pacific (Scott and Chivers, 1990). While we sighted only five herds of pilot whales, other species that are commonly in mixed species herds elsewhere (Risso's dolphins, bottlenose dolphins, and pantropical spotted dolphins), accounted for 44% of our identified herd sightings. The abundance and distribution of prey or predators, or both, may be factors involved in the formation of mixed species herds (see Scott and Chivers, 1990). There may be differences in these factors in the Gulf of Mexico compared with those in the northwestern Atlantic and Pacific oceans.

The abundance of prey species has been demonstrated to be positively correlated with the abundance of several species of cetaceans (e.g. Kenney and Winn, 1986; Payne et al., 1986; Selzer and Payne, 1988). Fish and squid are the primary prey of most odon-

tocetes (e.g. Clarke, 1986; Barros and Odell, 1990; Sekiguchi et al., 1992). However, very little is known about the distribution and abundance of potential prey species in Gulf oceanic waters beyond limited information on cephalopods (e.g. Voss, 1971; Voss and Brakoniecki, 1985) and records of the presence of species (e.g. Hoese et al., 1977).

Oceanographic features undoubtedly affect the distribution of prey species and, ultimately, cetacean diversity, abundance, and distribution. The Mississippi River and its distributary, the Atchafalaya River, enter the Gulf north of the area we surveyed and account for nearly one-half of the total freshwater flow into the entire 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 Upper Mississippi Fan or the 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 these features interact with the diverse bottom topography of the north-central Gulf, making it a very dynamic area.

In 1990, the Southeast Fisheries Science Center began conducting annual cetacean shipboard surveys of the entire oceanic U.S. Gulf of Mexico. Results to date (775 herd sightings) suggest that the comparatively small maximum herd sizes and single species herds found in this study in the Gulf are accurate (SEFSC[7]). Comparisons of the ecology of Gulf cetaceans with those from other areas should provide an excellent opportunity to understand the physical and biological factors that affect cetacean diversity, distribution, abundance, herd sizes, and associations.

Table 6

Comparison of relative abundances of cetaceans determined by aerial counts during 1989–90 and by historical strandings in the Gulf of Mexico.

Species or species group	Strandings[1]	This study
Balaenopterids	9.3% (48)	<0.1% (2)
Sperm whale (*Physeter macrocephalus*)	4.7% (24)	1.5% (89)
Pygmy/dwarf sperm whales (*Kogia breviceps/simus*)	15.3% (79)	1.1% (61)
Unidentified ziphiids (*Mesoplodon/Ziphius*)	10.6% (55)	0.2% (9)
Risso's dolphin (*Grampus griseus*)	2.7% (14)	13.6% (782)
Atlantic spotted dolphin (*Stenella frontalis*)	7.0% (36)	16.2% (932)
Pantropical spotted dolphin (*S. attenuata*)	1.4% (7)	28.6% (1,651)
SSC dolphins[1] (*S. coeruleoalba/ longirostris/clymene*)	22.3% (115)	36.5% (2,106)
Pilot whale (*Globicephala* sp.)	16.5% (85)	1.6% (91)
Pygmy killer/ melon-headed whales (*Feresa/Peponocephala*)	3.1% (16)	0.4% (25)
False killer whale (*Pseudorca crassidens*)	3.5% (18)	<0.1% (3)
Killer whale (*Orcinus orca*)	0.6% (3)	0.1% (8)
Rough-toothed dolphin (*Steno bredanensis*)	2.9% (15)	<0.1% (4)
Fraser's dolphin (*Lagenodelphis hosei*)	0.2% (1)	0%

[1] See Footnote 3.

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