ABUNDANCE OF CETACEANS IN THE OCEANIC NORTHERN GULF OF MEXICO FROM 2003 AND 2004 SHIP SURVEYS

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ABSTRACT

The Gulf of Mexico (GMx) is a subtropical marginal sea of the western North Atlantic Ocean with a diverse cetacean community. Ship-based, line-transect abundance surveys were conducted in oceanic waters ($\geq$200 m deep) of the northern GMx within U.S. waters (380,432 km^2) during summer 2003 and spring 2004. Data from these surveys were pooled and minimum abundance estimates were based on 10,933 km of effort and 433 sightings of at least 17 species. The most commonly sighted species (number of groups) were pantropical spotted dolphin, *Stenella attenuata* (115); sperm whale, *Physeter macrocephalus* (85); dwarf/pygmy sperm whale, *Kogia sima/breviceps* (27); Risso's dolphin, *Grampus griseus* (26); and bottlenose dolphin, *Tursiops truncatus* (26). The most abundant species (number of individuals; coefficient of variation) were *S. attenuata* (34,067; 0.18); Clymene dolphin, *S. clymene* (6,575; 0.36); *T. truncatus* (3,708; 0.42); and striped dolphin, *S. coeruleoalba* (3,325; 0.48). The only large whales sighted were *P. macrocephalus* (1,665; 0.20) and Bryde's whale, *Balaenoptera edeni* (15; 1.98). Abundances for other species or genera ranged from 57 to 2,283 animals. Cetaceans were sighted throughout the oceanic northern GMx, and whereas many species were widely distributed, some had more regional distributions. Compared to abundance estimates for this area based on 1996-2001 surveys, the estimate for *S. attenuata* was significantly smaller ($P < 0.05$) and that for the spinner dolphin, *S. longirostris*, appeared much smaller. Also, *P. macrocephalus* estimates were based on less negatively biased estimates of group-size using 90-minute counts during 2003 and 2004.

The Gulf of Mexico (GMx) is a subtropical marginal sea of the western North Atlantic Ocean with a diverse cetacean community. The northern GMx continental shelf waters (<200 m deep) are inhabited primarily by bottlenose dolphins (*Tursiops truncatus*) and Atlantic spotted dolphins (*Stenella frontalis*), and oceanic waters (>200 m deep) are routinely inhabited by at least 20 species, most of which have pantropical distributions (Mullin and Hansen 1999). The NMFS routinely conducts surveys of northern GMx waters in order to meet obligations specified by the U.S. Marine Mammal Protection Act. Cetacean abundance estimates for northern GMx continental shelf waters were reported by Fulling *et al.* (2003). Abundance estimates for the expanse of northern GMx oceanic waters based on ship surveys conducted from 1991-1995 and 1996-2001 were reported by Hansen *et al.* 1995 and Mullin and Fulling 2004, respectively. The purpose of this report is to update estimates of the abundance of cetacean species in the oceanic northern GMx based on ship surveys conducted during 2003 and 2004.

METHODS

Study Area

The GMx is physiographically diverse and oceanographically complex. Continental shelves (waters <200 m deep) make up 36% of the total area (Baumgartner 1997). The continental shelves are generally wide (up to 200 km) in the northern GMx and north of the Yucatan Peninsula, whereas they are much narrower near the Mississippi River Delta and in the southwestern GMx (Fig. 1). Continental slopes (waters 200-2,000 m) comprise 26% of total GMx area. Slope width is variable but is consistently broad off Louisiana and Texas and generally narrow in the southwestern GMx. The slope is broad off Florida in waters 200-1,000 m deep but narrows, becoming the West Florida Escarpment, in waters 1,000-2,000 m deep. Slope topography is most diverse off the Yucatan Peninsula in the eastern Bay of Campeche (Gore 1992).

The mean state of GMx oceanic waters is oligotrophic (< 0.1 mg chl • m^{-3}), but productivity is significantly enhanced in local areas by a variety of dynamic processes that are spatially and temporally variable (Biggs and Ressler 2001). The Loop Current (LC), the GMx's dominant oceanographic feature, enters the GMx between the Yucatan and Cuba, pushes variably north into the eastern GMx, sometimes as far as the Mississippi-Alabama Shelf, circulates anti-cyclonically and exits through the Straits of Florida where it joins the Antillean Current to form the Gulf Stream. The LC periodically sheds anti-cyclonic (warm-core) eddies 200-300 km in diameter which drift slowly (≈5 km•d^{-1}) to the west and spin down as they interact with the continental slope in the western GMx. Upwelling occurs along the LC front and in cyclonic (cold-core) eddies that routinely form in association with the LC front or eddies. Nutrient-rich shelf waters are periodically entrained in the confluence of these cyclone/anti-cyclone pairs and transported to oceanic water. Nutrient-rich Mississippi River water is also variably entrained, and the river plume periodically extends across the narrow shelf into the oceanic north-central GMx.

The study area (380,432 km^2) was the oceanic waters ($\geq$200 m deep) of the northern (U.S.) GMx west of 83°55' W, and generally north of a line between the U.S.-Mexico border and southern Florida (24.0°N).   The study area comprised 35% of the oceanic GMx.

Survey Design

Surveys were conducted during summer 2003 and spring 2004 from the 68-m NOAA Ship *Gordon Gunter*. Both surveys were ≈60 d in duration from 12 June to 18 August 2003 and from 13 April to 11 June 2004, and were divided into three legs of ≈20 d each. Standard visual line-transect survey methods for cetaceans similar to those used in other GMx surveys were used (Hansen *et al.* 1995, Mullin and Fulling 2004).

In both 2003 and 2004, transect lines covered waters from the 200-m isobath to the U.S. Exclusive Economic Zone (EEZ) (Fig. 1 & 2). Transects were laid out in a "zig-zag" pattern from a random start with more effort allocated to the slope waters (200-2,000 m) than the abyssal waters (>2,000 m).

Data were collected by three observers from the ship's flying bridge, located 14.5 m above the surface of the water, during daylight hours weather permitting (*i.e.*, no rain, Beaufort sea state <6). The left and right side observers searched out to the horizon in the arc from 10˚ right or left of the ship's bow to the left or right beam (90˚), respectively, using 25x binoculars. The third observer searched using unaided eye or 7x hand-held binoculars and recorded data. Six people served as observers on each cruise leg. Each observer rotated through each flying bridge position every 30 min. in the same sequence (left, recorder, right) and then rested or served other duties (*e.g.*, collected biopsies, edited data) for 90 min. throughout the day. The survey speed was usually 18 km•h^{-1}, but varied with sea conditions.

Data were recorded on a computer interfaced with a global positioning system (GPS) via a data acquisition program. Data collected for each cetacean sighting included time, position, bearing and reticle (a measure of radial distance) of the sighting, species, group-size, behavior, bottom depth, sea surface temperature, and associated animals (*e.g.*, seabirds, fish). The bearing and radial distance for sightings made close to the ship by the data recorder were estimated. Survey effort data were automatically recorded every 30 sec. and included position, heading, effort status, observer position, and environmental conditions which could affect the observers' ability to sight animals (*e.g.*, Beaufort sea state, sun position).

Typically, if a sighting was within a 5.5 km strip on either side of the ship, the ship was diverted from the transect line and the group approached so that observers could identify species and obtain group-size estimates. Each observer estimated group-size independently and recorded their estimate in a private notebook. Except for sperm whales, the final group-size for each sighting was an average of the independent estimates.

When sperm whales were encountered a group-size based on a "10-min count" was made similar to that for other cetacean species. After this count was made, observers notified the Chief

Scientist. Under specified conditions, a "90-min. count" was conducted to estimate group-size following protocols detailed in Barlow and Taylor (2005). Briefly, a 90-min. count was only started when in Beaufort sea state <5, good visibility, and usually between 0800 and 1600 hrs. The Chief Scientist independently consulted with the acoustic team monitoring a towed passive acoustic array and the visual team to determine whether there were more sperm whales in the area than were seen by the visual team. If the decision was made to conduct a 90-min. count all the observers were called to the flying bridge to participated in the count. Each observer recorded their estimate of group-size independently at the end of the count. Because of conditions or logistical considerations, a 90-min. count was conducted only on a subset of sperm whale groups where it might have been appropriate. Therefore the overall average sperm whale group-size was based on a combination of 10-min. counts and 90-min. counts.

Cetaceans were identified to the lowest taxonomic level possible based on descriptions in field guides and scientific literature (*e.g.*, Jefferson *et al.* 1993) (Table 1). Short-finned pilot whales (*Globicephala macrorhynchus*) cannot be reliably distinguished at sea from long-finned pilot whales (*G. melas*). Both species occur in the North Atlantic but only *G. macrorhynchus* are known to inhabit the GMx (Jefferson 1995). Overall abundances for the genus *Kogia* and the genus *Mesoplodon* were estimated. Dwarf sperm whales (*K. sima*) and pygmy sperm whales (*K. breviceps*) were difficult to distinguish during the survey and stranding records of both species are common from the GMx (Jefferson 1995). Stranding records of mesoplodont whales from the GMx indicate *Mesoplodon* sightings were probably Gervais' (*M. europaeus*) or Blainville's (*M. densirostris*) beaked whales (Mead 1989). An observer's ability to make identifications depended on weather and animal behavior, and in some cases cetaceans could only be identified as unidentified Ziphiidae (Cuvier's beaked whale, *Ziphius cavirostris* or *Mesoplodon* sp.), large whale (>7 m long), small whale (non-dolphin, <7 m), dolphin, or odontocete.

Analytical techniques

Because the distribution of survey effort was not uniformly or randomly distributed across depth strata (Fig. 1 & 2), for abundance estimates, the effort was delineated into three strata (Table 2): abyssal (AB), waters >2,000 m deep to the boundary of the U.S. Exclusive Economic Zone (EEZ) (186,412 km^2); northeast continental slope (NE), waters 200-2,000 m deep between 83°55.0' and 88°30.0' W (64,674 km^2); and northwest continental slope (NW), waters 200-2,000 m deep west of 88°30.0' W (129,346 km^2). Survey effort was excluded from the analysis that occurred in waters outside the study area or was in a Beaufort sea state >4.

For each species, genus, or unidentified category (*i*) and stratum (*j*), abundance ($N_{i,j}$) was estimated with line-transect methods using program DISTANCE (Laake *et al.* 1993, Buckland *et al.* 2001) and summed across strata for a total abundance by:

$$N_i = \sum_{j=1}^{3} \frac{A_j \cdot n_{i,j} \cdot S_{i,j} \cdot f_i(0)}{2 \cdot L_j \cdot g(0)}$$

where A_j = area of stratum j;

$n_{i,j}$ = number of group sightings of species i in stratum j;

$S_{i,j}$ = mean group size of species i in stratum j;

$f_i(0)$ = sighting probability density function at perpendicular distance zero for species i;

L_j = total length of transect line in stratum j; and

$g(0)$ = probability of seeing a group on the transect line.

Abundance estimates were negatively biased because observers without doubt missed groups on the transect line at the surface, and some groups were under the surface while in the observation area; therefore $g(0) < 1$ (see Discussion). However, the parameter $g(0)$ was not estimated and $g(0) = 1$ was used for each abundance estimate. The log-normal 95% confidence interval was computed for each abundance estimate because it was a product of estimates and tends to have a skewed distribution. The variance of $N_{i,j}$ was estimated as:

$$ \text{var}(N_{i,j}) = N_{i,j}^2 \left(\frac{\text{var}(n_{i,j})}{n^2} + \frac{\text{var}(S_{i,j})}{S^2} + \frac{\text{var}[f_i(0)]}{f_i(0)^2} \right) $$

The sampling unit was the length of the transect completed in a stratum on-effort each day with Beaufort sea state ≤ 4. The formula used to estimate each component of the variance followed Buckland *et al.* (2001). Var($n_{i,j}$) was length-weighted and based on the variation in the number of on-effort group sightings between sampling units that ranged up to 168 km•d^{-1}. Coefficient of variations were estimated as $CV(N_{i,j}) = [\text{var}(N_{i,j})]^{\frac{1}{2}}/N_{i,j}$ and $CV(N_i)$ as:

$$ CV(N_i) = \left[\sum_{j=1}^{3} CV^2(N_{i,j}) \cdot N_{i,j}^2 \right]^{1/2} \Big/ \sum_{j=1}^{3} N_{i,j} $$

For species sighted ≥ 30 times $f_i(0)$ was estimated separately. Since the number of groups sighted of most species was insufficient to estimate $f_i(0)$, data from species with similar sighting characteristics (*i.e.*, body size, group-size, surface behavior, blow visibility) were pooled to estimate $f_i(0)$ for four categories: Large Whales, Cryptic Whales, Small Whales/Large Dolphins, and Small Dolphins (Table 1). Data from species sighted ≥ 30 times were included in the pooled estimate of $f_i(0)$ for the appropriate category.

The perpendicular distance, y, for each sighting was estimated using bearing and reticle measurements. The reticle readings were converted to radial sighting distances (R) by the method of Lerczak and Hobbs (1998), using the formula $y = R \sin(b)$, where b = angle between the sighting and the transect line. Estimates of $f_i(0)$ were made using a hazard-rate, uniform, or half-normal model with exact perpendicular sighting distances. Model selection was determined using Akaike's Information Criterion (AIC; Buckland *et al.* 2001).

Where abundance was estimated with a pooled $f_i(0)$, if the individual detection functions of each species within a category were indeed very similar, by pooling, var[$f_i(0)$] was probably underestimated because var[$f_i(0)$] was based on an artificially high sample size. On the other hand, if the true detection functions of the species within a category are highly variable, var[$f_i(0)$] for an individual species may be overestimated.

The group-sizes for some species tended to be related to y, because in many cases larger groups are easier to see than small groups with increasing y. In general, the arithmetic mean of group-size may be an overestimate of the true mean group-size and could lead to positively-biased abundance estimates. Therefore, a regression of group-size by y was used to estimate an "expected mean group-size" (program DISTANCE). The expected mean group-size was used in the abundance estimate if it was significantly ($P < 0.15$) smaller than the arithmetic mean group-size. Var($S_{i,j}$) was the analytical variance for mean group-sizes based on arithmetic means or was estimated as in Buckland *et al.* (2001) for expected mean group-sizes.

One requirement for unbiased line-transect estimates of abundance is that the cetacean group should not move in response to the ship before it is sighted (Buckland *et al.* 2001). If cetaceans are not sighted before they respond to the ship, in cases of attraction to the ship, $f(0)$ and abundance will be overestimated. During previous GMx surveys, certain dolphin species (*e.g.*, *T. truncatus*; *Stenella* spp.; rough-toothed dolphin, *Steno bredanensis*) were consistently attracted to bowride as the ship approached (Würsig *et al.* 1998). Therefore, the abundance and variance of naked-eye sightings of these species were estimated separately using the formulas above for the entire study area (*i.e.*, without area j stratification) with the exception that $f_i(0)$ was treated as a constant. That is, they were estimated with strip-transect methods using a strip width equal to the line-transect effective strip half-width, $1/f_i(0)$, and var[$1/f_i(0)$] = 0.

RESULTS

Survey effort used for abundance estimates was 10,933 km. There was about twice as much effort per unit area in the NE Slope stratum (0.043 km•km^{-2}) than in the NW Slope or Abyssal strata (Table 2). Estimates of $f_i(0)$ ranged from 0.263 km^{-1} for Large Whales to 0.559 km^{-1} for Cryptic Whales (Table 1).

During 2003 and 2004, group-sizes were estimated for 106 sperm whale groups, and of these, 90-min. counts were conducted on 29 groups with an average group size of 8.9 whales (Table 3). The average group size for the 106 groups based on 10-min. counts was 2.6 whales and 4.1 whales based on a combination of 10-min. and 90-min. counts.

Minimum abundance estimates were based on 433 sightings of at least 17 cetacean species (Table 4). The most commonly sighted species (number of groups) were *S. attenuata* (115); sperm whale, *Physeter macrocephalus* (85); *Kogia sima/breviceps* (27); Risso's dolphin, *Grampus griseus* (26); and *T. truncatus* (26). The most abundant species (number of

individuals; coefficient of variation) were *S. attenuata* (34,067; 0.18); Clymene dolphin, *S. clymene* (6,575; 0.36); *T. truncatus* (3,708; 0.42); and striped dolphin, *S. coeruleoalba* (3,325; 0.48). The only large whales sighted were *P. macrocephalus* (1,665; 0.20) and Bryde's whale, *Balaenoptera edeni* (15; 1.98). Abundances for other species or genera ranged from 57 to 2,283 animals.

The precision of the abundance estimates (expressed as *CV*) was quite variable among species and was primarily dependent on the number of sightings. For identified species or genera, the *CV* for overall estimates ranged from 0.18 to 0.48 for ten estimates and was >0.50 for the other seven estimates. Because the precision of most of the regional (stratum) estimates was generally poor (>0.30; Table 4), the power to detect statistically significant differences in estimates is low (Gerrodette 1987).

Cetaceans were sighted throughout the oceanic northern GMx (Fig. 3), and some commonly sighted species such as *P. macrocephalus*, *Kogia* spp., *G. griseus*, and *S. attenuata* were widely distributed. However, while based on a small number of group sightings, regional densities for some of these widely distributed species appear dissimilar (Table 4). The density of *P. macrocephalus* was lower in the NE Slope stratum than in the other two strata while that of *G. griseus* were higher in NE slope strata.

Other species were less broadly distributed. *T. truncatus* was encountered primarily in upper continental slope waters <1000 m deep (Fig.3) and had the highest densities in the NE Slope. Four of five *S. longirostris* sightings and both *B. edeni* sightings were in the NE Slope. Conversely, none of the 14 *S. clymene* groups was sighted in the NE Slope.

DISCUSSION

The surveys were designed to meet the assumptions of line-transect theory (Buckland *et al.* 2001). However, the abundance estimates are negatively biased because the central assumption, that all cetacean groups on the transect line are detected (*i.e.*, $g(0) = 1$), was certainly not met, and data were not collected to correct estimates for perception and availability bias (Marsh and Sinclair 1989). (See Mullin and Fulling (2004) for a discussion of these biases.)

Comparisons of the abundance estimate for each species from 2003-2004 to that from 1996-2001 (Mullin and Fulling 2004) show what appear to be differences in some cases (Table 5). However the only difference that is significant when tested using the methods described by Lo (1994) (see Forney and Barlow 1998) is that for *S. attenuata* ($P < 0.05$). The estimate of the abundance of *S. attenuata* (91,321; 0.16) for 1996-2001 was more than two times the current estimate of 34,067 (0.28). However, the current estimate is similar to that based on surveys conducted from 1991-1994 of 40,893 (0.19) (Hansen *et al.* 1995, Mullin and Fulling 2004). Typically, *S. attenuata* is the only species with a relatively large number of sightings during each survey year. For 1996-2001, Mullin and Fulling (2004) estimated abundance for *S. attenuata* based on each survey with the following results: 1996 - 132,360 (*CV* = 0.28); 1997 - 35,494 (0.28); 1999 - 83,087 (0.33);

2000 - 134,420 (0.29); and 2001 - 86,574 (0.48). While not significant, the current estimates for the other oceanic *Stenella* (*i.e.*, *S. coeruleoalba, S. clymene, and S. longirostris*) were smaller compared to those for 1996-2001 (Table 5). In the case of *S. longirostris*, the estimate is smaller by a factor of about six.

Although the abundances of some species may have changed compared to earlier studies, the distributions of sightings of species reported here (Fig. 3) appear similar to those from previous studies. The reasons for these large inter-survey differences is certainly due to both sampling and oceanographic variability. Productivity in the oceanic GMx, which ultimately affects the distribution of apex predators, is highly variable both spatially and temporally (Biggs and Ressler 2001).

Both *T. truncatus* and *S. frontalis* are abundant in northern GMx continental shelf waters (Fulling *et al.* 2003). In GMx oceanic waters, *S. frontalis* usually occur near the shelf-edge in waters <500 m deep (Davis *et al*. 1998). The current abundance for *S. frontalis*, 0, is certainly a sampling bias because one group was sighted "off-effort" during 2003-2004 in oceanic waters (Fig. 3). The smaller "offshore" form of *S. frontalis* that occurs far from the shelf-edge in parts of the oceanic North Atlantic (Perrin 2002, Mullin and Fulling 2003) has not been recorded from the northern GMx.

The current abundance of *L. hosei* is also "0." Sightings of *L. hosei* have been rare during past GMx surveys but have been made with some regularity since the early 1990s. *L. hosei* probably occurs in the GMx in very low numbers and it is possible that they were present but not encountered during 2003 and 2004.

All of these abundance estimates were based on surveys confined to the northern GMx and it is difficult to interpret the significance of changes in cetacean abundance without a GMx-wide perspective. Oceanic cetaceans are highly mobile and shifts in distribution on the small scale of the oceanic GMx (maximum distance ≈1,450 km) probably occur in response to changing oceanographic conditions. In the eastern tropical Pacific, groups of *S. attenuata* were found to travel an average net distance of 30-50 nmi (55-90 km) per day and may range over several hundred nautical miles (Perrin and Hohn 1994).

Sixty-five percent of GMx oceanic waters are south of the U.S. EEZ where cetacean abundance has not been assessed. Ortega-Ortiz (2002) summarized cetacean sightings in Mexican waters of the southern GMx. Species composition and distributions appear similar to that in the northern GMx; *T. truncatus* and *S. frontalis* occurred primarily in shelf waters and other species in oceanic waters. It is important to study cetacean abundance and distribution from a GMx-wide perspective for both cetacean management and basic understanding of the GMx ecosystem. Without a GMx-wide perspective, cetacean management decisions that potentially affect economic interests could be viewed with skepticism, because for oceanic waters it would be difficult to determine if changes in cetacean abundance and distribution in U.S. waters were the result of human activities or natural processes.

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Table 1. Estimate of $f_i(0)$ for each species category. Species pooled to estimate $f_i(0)$ for species categories (*e.g.*, Large Whales) are listed (*n* - number of group sightings after truncation; ESW - effective half-strip width, $1/f(0)$).

Species/ Species Group	*n*	Truncation (m)	$f_i(0)$ (km⁻¹)	$CV[f_i(0)]$	ESW (m)
Large Whales	91	5,500	0.263	0.09	3,807
Physeter macrocephalus					
Balaenoptera edeni					
Unidentified large whale					
Cryptic Whales	68	4,000	0.559	0.14	1,788
Kogia spp.					
Ziphius cavirostris					
Mesoplodon spp.					
Unidentified small whale					
Unidentified ziphiid					
Unidentified odontocete					
Small Whales/Large Dolphins	76	4,000	0.418	0.08	2,392
Feresa attenuata					
Pseudorca crassidens					
Orcinus orca					
Globicephala macrorhynchus					
Tursiops truncatus					
Grampus griseus					
(Stenella frontalis)					
Steno bredanensis					
Small Dolphins	150	4,500	0.428	0.05	2,336
Peponocephala electra					
(Lagenodelphis hosei)					
Stenella longirostris					
Stenella attenuata					
Stenella clymene					
Stenella coeruleoalba					
Stenella spp.					

Table 2. Survey effort by stratum during summer 2003 and spring 2004 used to estimate the abundance of cetacean species in the oceanic northern Gulf of Mexico (Beaufort sea state ≤4; NE- Northeast Slope, 200-2,000 m, 88°30.0' to 83°55.0' W; NW- Northwest Slope, 200-2,000 m, west of 88°30.0' W; AB- Abyssal region >2,000 m to U.S. EEZ).

Year	Abyssal (km)	NE Slope (km)	NW Slope (km)	Total (km)
2003	2,327	1,620	2,030	5,977
2004	2,474	1,203	1,279	4,956
Total	4,801	2,823	3,309	10,933
Area (km²)	186,412	64,674	129,346	380,432

Table 3. Summary of sperm whale group-size statistics for "10-minute" and "90-minute" counts in the northern Gulf of Mexico during 2003 and 2004.

	"10 & 90"	"10/10"	"90/90"	"10 for 90"
n	106	106	26	26
Mean	4.1	2.6	8.9	3.0
SD	3.90	1.65	4.74	1.47
Range	1-23	1-7	2-23	1-6

"10 & 90" - mean group size based on 90-minute counts for those groups for which 90-minute ($n = 26$) counts were conducted and 10-minute counts for the other groups ($n = 80$).

"10/10" - mean group size based on 10-minute counts for all groups ($n = 106$)

"90/90" - mean group size based on 90-minute counts ($n = 26$).

"10 for 90" - mean group size based on the 10-minute count of the groups for which 90-minutes counts were made ($n = 26$).

Table 4. Group-size, density and abundance estimates of cetaceans in northern Gulf of Mexico oceanic waters (200 m - seaward boundary of the U.S. EEZ; NE - Northeast Slope, NW - Northwest Slope, AB - Abyssal, *n* - number of groups sighted, *S* - mean group size, *D* - animals•100 km^{-2}, *N* - number of animals, *CV* - coefficient of variation).

Species/Stratum	*n*	*S*	*CV(S)*	*D*	*N*	*CV(N)*	95% CI
Balaenoptera edeni							
NE	2	2.0	0.50	0.02	15	1.98	1-154
NW	0	-	-	0	0	-	-
AB	0	-	-	0	0	-	-
TOTAL	2			<0.01	15	1.98	1-154
Physeter macrocephalus (90 min)							
NE	18	2.6	0.19	0.22	140	0.36	70-281
NW	33	4.6	0.18	0.60	774	0.35	392-1,527
AB	34	4.3	0.15	0.40	751	0.25	456-1,239
TOTAL	85			0.44	1,665	0.20	1,129-2,456
Kogia spp.							
NE	5	1.2	0.17	0.06	38	0.59	13-114
NW	5	1.2	0.17	0.05	65	0.68	19-229
AB	17	1.6	0.13	0.16	305	0.43	135-687
TOTAL	27			0.12	453	0.35	233-882
Ziphius cavirostris							
NE	0	-	0	0.00	0	-	-
NW	2	3.0	0.00	0.05	65	0.67	19-226
AB	0	-	0	0.00	0	-	-
TOTAL	2			0.02	65	0.67	19-226
Mesoplodon spp.							
NE	1	2.0	-	0.02	13	4.03	0-385
NW	0	-	0.00	0.00	0	0.54	-
AB	1	4.0	-	0.02	44	1.36	6-338
TOTAL	2			0.01	57	1.40	7-437
Unidentified ziphiid							
NE	1	1.0	-	<0.01	6	0.90	1-30
NW	9	2.7	0.18	0.20	262	0.54	94-731
AB	5	2.0	0.15	0.06	109	0.51	41-286
TOTAL	15			0.10	337	0.40	176-807

Table 4. continued

Species/Stratum	*n*	*S*	*CV(S)*	*D*	*N*	*CV(N)*	95% CI
Feresa attenuata							
NE	3	8.3	0.22	0.18	119	0.85	27-528
NW	1	13.0	-	0.08	106	0.69	30-374
AB	1	12.0	-	0.05	98	1.49	11-851
TOTAL	5			0.08	323	0.60	110-950
Pseudorca crassidens							
NE	1	25.0	-	0.18	119	0.78	29-481
NW	0	-	-	0	0	-	-
AB	3	27.0	0.35	0.35	658	0.65	190-2,284
TOTAL	4			0.20	777	0.56	278-2,174
Orcinus orca							
NE	0	-	-	0	0	-	-
NW	0	-	-	0	0	-	-
AB	1	6.0	-	0.03	49	0.77	12-191
TOTAL	1			0.01	49	0.77	12-191
Globicephala sp.							
NE	1	17.0	-	0.12	81	0.78	20-327
NW	4	12.8	0.13	0.32	416	0.47	169-1,026
AB	2	13.5	0.26	0.12	219	0.58	71-679
TOTAL	7			0.19	716	0.34	376-1,363
Peponocephala electra							
NE	1	250.0	-	1.88	1,216	1.30	163-9,081
NW	1	60.0	-	0.39	501	0.83	114-2,198
AB	1	68.0	-	0.30	566	1.03	103-3,106
TOTAL	3			0.40	2,283	0.76	608-8,577
Grampus griseus							
NE	16	10.9	0.16	1.29	832	0.41	380-1,822
NW	4	12.0	0.16	0.30	391	0.50	149-1,025
AB	6	7.5	0.15	0.20	366	0.44	158-848
TOTAL	26			0.42	1,589	0.27	949-2,660
Tursiops truncatus							
NE	21	32.6	0.38	5.03	3,253	0.47	1,327-7,975
NW	3	18.7	0.46	0.35	456	0.73	109-1,918
AB	0	-	-	0	0	-	-
Strip-transect	2	6.5	0.38	0.11	423	0.93	90-1,987
TOTAL	26			0.97	3,708	0.42	1,677-8,197

Table 4. continued

Species/Stratum	*n*	*S*	*CV(S)*	*D*	*N*	*CV(N)*	95% CI
Steno bredanensis							
NE	2	10.5	0.43	0.15	100	0.89	20-508
NW	3	21.0	0.27	0.40	514	0.71	139-1,894
AB	4	14.5	0.23	0.25	471	0.49	184-1,210
Strip-transect	1	56.0	-	0.11	423	0.93	90-1,987
TOTAL	10			0.40	1,508	0.39	719-3,163
Lagenodelphis hosei							
NE	0	-	-	0	0	-	-
NW	0	-	-	0	0	-	-
AB	0	-	-	0	0	-	-
TOTAL	0			0	0	-	-
Stenella frontalis							
NE	0	-	-	0	0	-	-
NW	0	-	-	0	0	-	-
AB	0	-	-	0	0	-	-
TOTAL	0			0	0	-	-
Stenella longirostris							
NE	4	56.5	0.38	1.70	1,099	0.66	315-3,837
NW	0	-	-	0	0	-	-
AB	1	107.0	-	0.48	890	0.67	263-3,011
TOTAL	5			0.52	1,989	0.48	826-4,791
Stenella attenuata							
NE	21	38.4	0.21	6.06	3,919	0.49	1,554-9,884
NW	27	43.1	0.26	7.51	9,707	0.26	5,789-16,278
AB	58	39.2	0.10	10.01	18,900	0.28	10,984-32,523
Strip-transect	9	22.7	0.31	0.40	1,541	0.67	457-5,190
TOTAL	115			8.95	34,067	0.18	23,841-48,679
Stenella coeruleoalba							
NE	7	43.1	0.20	2.27	1,469	0.38	704-3,064
NW	1	32.0	-	0.21	267	0.92	54-1,310
AB	5	38.2	0.20	0.85	1,589	0.92	331-7,630
TOTAL	13			0.87	3,325	0.48	1,370-8,068

Table 4. continued

Species/Stratum	*n*	*S*	*CV(S)*	*D*	*N*	*CV(N)*	95% CI
Stenella clymene							
NE	0	-	-	0	0	-	-
NW	9	56.7	0.29	3.29	4,255	0.43	1,826-9,916
AB	5	55.8	0.33	1.24	2,320	0.66	685-7,85
TOTAL	14			1.73	6,575	0.36	3,300-13,100
Stenella spp.							
NE	2	48.5	0.98	0.73	472	1.33	19-11,716
NW	6	20.2	0.26	0.78	1,009	0.69	283-3,595
AB	1	10.0	-	0.04	83	0.64	26-267
TOTAL	9			0.41	1,564	0.60	527-4,640
Unidentified dolphin							
NE	11	3.4	0.38	0.20	130	0.51	49-347
NW	5	7.7	0.82	0.20	260	0.99	37-1,846
AB	20	5.1	0.26	0.34	630	0.36	311-1,275
TOTAL	36			0.27	1,020	0.34	531-1,959
Unidentified small whale							
NE	1	1.0	-	<0.01	6	0.90	1-30
NW	3	1.3	0.25	0.03	44	0.98	8-231
AB	3	1.3	0.25	0.02	44	0.81	10-181
TOTAL	7			0.02	94	0.60	32-278
Unidentified large whale							
NE	1	2.0	-	<0.01	6	0.89	1-28
NW	2	2.5	0.60	0.02	26	0.97	3-189
AB	1	1.0	-	<0.01	5	0.67	2-17
TOTAL	4			0.01	37	0.70	11-128
Unidentified odontocete							
NE	6	2.5	0.29	0.15	95	0.54	34-267
NW	4	1.3	0.20	0.04	55	0.73	15-205
AB	5	1.4	0.29	0.04	76	0.46	31-187
TOTAL	15			0.06	226	0.33	121-422

Table 5. Abundance estimates (*CV* in parentheses) for cetacean species of the oceanic Gulf of Mexico based on ship surveys conducted from 1996-2001 (Mullin and Fulling 2004) and ship surveys conducted from 2003-2004 (Table 3). Estimates in bold represent a significant difference ($P < 0.05$)

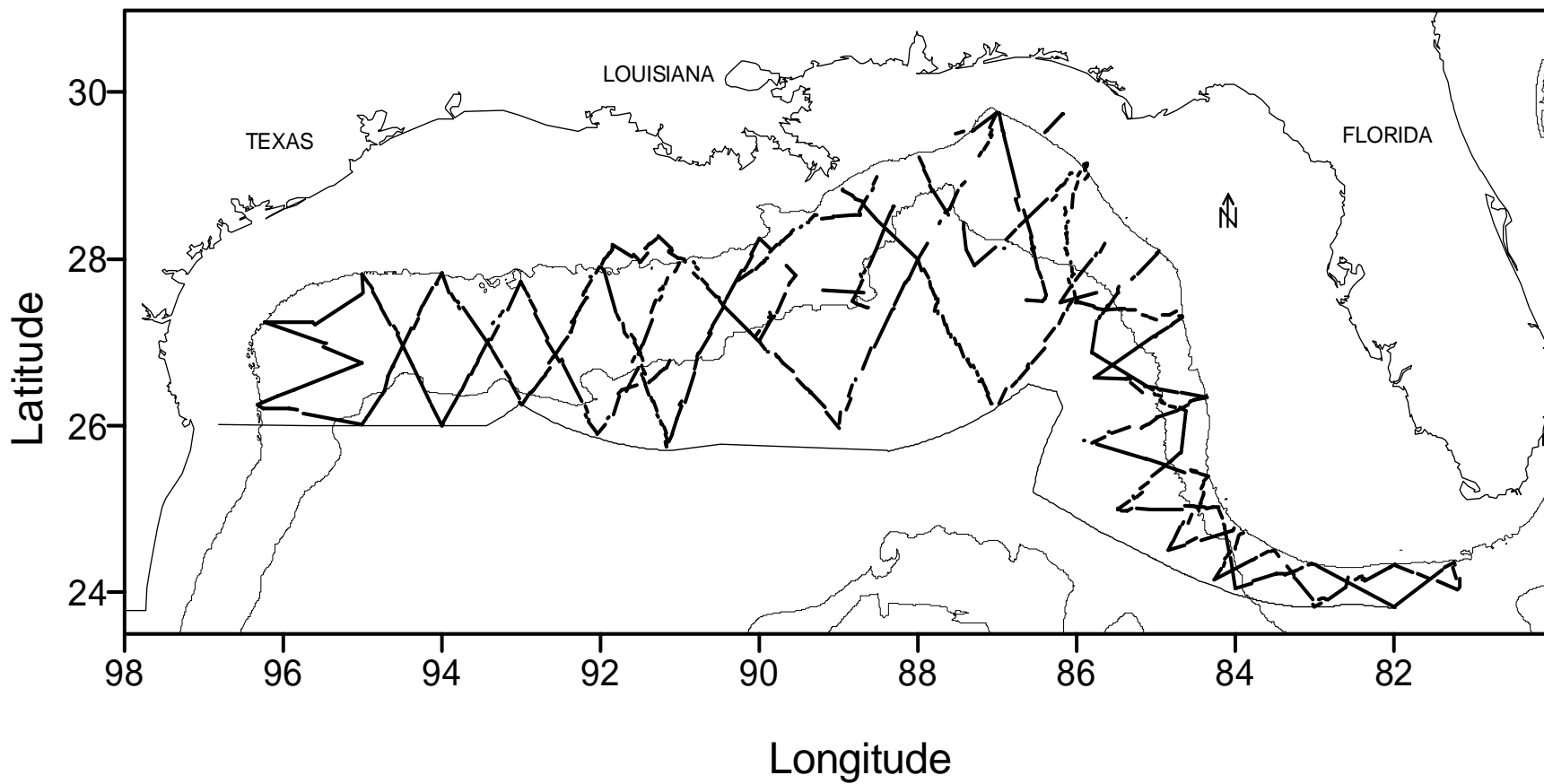| Species	1996-2001	2003-2004
Balaenoptera edeni	40 (0.61)	15 (1.98)
Physeter macrocephalus	1,349 (0.230	1,665 (0.20)
Kogia spp.	742 (0.29)	453 (0.35)
Ziphius cavirostris	95 (0.47)	65 (0.67)
Mesoplodon spp.	106 (0.41)	57 (1.40)
Globicephala macrorhychus	2,388 (0.48)	716 (0.34)
Orcinus orca	133 (0.49)	49 (0.77)
Feresa attenuata	408 (0.60)	323 (0.60)
Pseudorca crassidens	1,038 (0.71)	777 (0.56)
Peponocephala electra	3,451 (0.55)	2,283 (0.76)
Grampus griseus	2,169 (0.32)	1,589 (0.27)
Tursiops truncatus	2,239 (0.41)	3,708 (0.42)
Steno bredanensis	985 (0.44)	1,508 (0.39)
Lagneodelphis hosei	726 (0.70)	0
Stenella attenuata	**91,321 (0.16)**	**34,067 (0.18)**
Stenella coeruleoalba	6,505 (0.43)	3,325 (0.48)
Stenella clymene	17,355 (0.65)	6,575 (0.36)
Stenella frontalis	175 (0.84)	0
Stenella longirostris	11,971 (0.71)	1,989 (0.48)

Figure 1. Location of visual survey effort during *Gordon Gunter* Cruise GU-03-02, June-August 2003. The 200 and 2000 m isobaths and the US EEZ are shown.
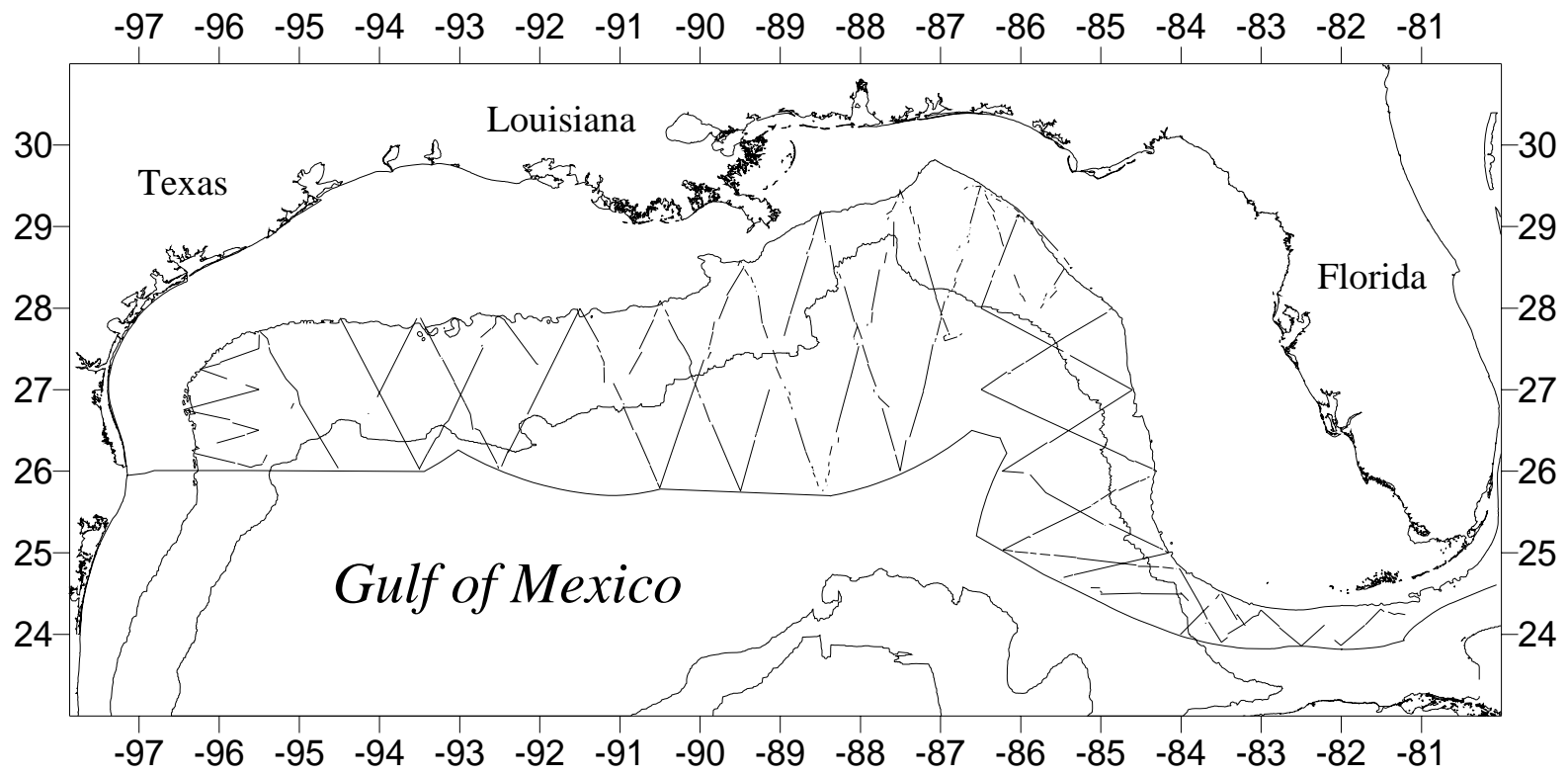
Figure 2. Location of visual survey effort during *Gordon Gunter* Cruise GU-04-02, April-June 2004. The 200 and 2000 m isobaths and the US EEZ are shown.

Figure 3. Locations of sightings of cetacean groups for selected species in the northern Gulf of Mexico during 1996-2001 and 2003-2004.

Short-finned Pilot Whale
● 2003-2004
+ 1996-2001

Killer Whale
● 2003-2004
+ 1996-2001

Pygmy Killer Whale
● 2003-2004
+ 1996-2001

False Killer Whale
● 2003-2004
+ 1996-2001

Melon-headed Whales
● 2003-2004
+ 1996-2001

Risso's Dolphin
● 2003-2004
+ 1996-2001

Bottlenose Dolphin
● 2003-2004
+ 1996-2001

Rough-toothed Dolphin
● 2003-2004
+ 1996-2001

Fraser's Dolphin
● 2003-2004
+ 1996-2001

Atlantic Spotted Dolphin
● 2003-2004
+ 1996-2001

Pantropical Spotted Dolphin
● 2003-2004
+ 1996-2001

Striped Dolphin
● 2003-2004
+ 1996-2001

Clymene Dolphin
● 2003-2004
+ 1996-2001

Spinner Dolphin
● 2003-2004
+ 1996-2001