Sperm Whale Research in the Gulf of Mexico

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ABSTRACT
Sperm whales occur throughout the oceanic Gulf of Mexico. Most research has been conducted in the northern Gulf where, until 2000, studies focused on abundance and distribution. Based on ship surveys conducted from 1996 to 2001, sperm whale density in the northern Gulf is 0.35 whales km\(^{-2}\) with an abundance of 1,349 whales (CV = 0.23). This estimate is negatively biased because it is not corrected for subsurface whales (i.e. \(g(0) < 1\)). Sperm whales occur throughout northern Gulf waters but there are concentrations near the Mississippi River delta and in the southeastern Gulf. Seasonal aerial surveys of slope waters in the northern Gulf indicated sperm whales are present throughout the year. In 2000, research was initiated that included habitat studies, genetics, satellite tagging, short-term acoustic tagging, acoustic monitoring, photo-identification, and prey studies. Through 2002, all aspects of this research have been extremely successful, however, in most cases only preliminary results are available. One satellite tagged whale traveled from the northern Gulf to the southern Gulf. Photo-identification studies indicate that some sperm whales either display site fidelity to small regions of the Gulf or return to those regions on a routine basis. Preliminary analyses of samples from free-ranging animals (floating fecal material) and stomach contents of stranded animals indicate that Gulf sperm whales feed on meso- and bathypelagic species of cephalopods. Genetic information from 89 individual sperm whales indicate that the majority of whales found in groups in the north-central Gulf fit the 'mixed' group scenario. However, some bachelor groups may also reside in the Gulf. Mitochondrial DNA (mtDNA) analyses showed that groups are comprised of both single and mixed matrilines. Two mtDNA haplotypes from the northern Gulf of Mexico appear to be unique on a global scale to this area. Significant differentiation between geographic areas was revealed for the maternally inherited mtDNA, but not for the bi-parentally inherited nuclear genome analysis.

INTRODUCTION
The sperm whale (Physeter macrocephalus) is the only great whale known to be widely distributed and abundant in the Gulf of Mexico (Mullin and Hansen, 1999). Sperm whales were commercially hunted in the Gulf by American whalers from sailing vessels until the early 1900s. Schmidly (1981) listed 51 Gulf sperm whale capture sites from Townsend (1935), but the number of whales taken is not known. Sperm whales were thought to be rare in the Gulf throughout most of the 1900s (Lowery, 1974). However, cetacean assessment surveys of the oceanic northern Gulf (waters >200m deep), which began to be routinely conducted in the 1980s, indicated sperm whales are relatively common (Collum and Fritts, 1985; Mullin et al., 1994; Hansen et al., 1995).

The oceanic Gulf (waters >200m deep) is about 1,100,000km\(^2\), and the northern oceanic Gulf (waters within U.S. Exclusive Economic Zone) covers about 36% of oceanic waters (Baumgartner, 1997). The U.S. National Marine Fisheries Service (NMFS) is ultimately responsible for protecting cetaceans in U.S. waters. However, the U.S. Marine Mammal Protection Act and U.S. Endangered Species Act mandate that the U.S. Minerals Management Service (MMS) take appropriate actions to ensure that activities related to minerals extraction (e.g. seismic exploration, vessel traffic) in U.S. waters do not contribute to the demise or depletion of marine mammal populations. About 95% of the oil and natural gas deposits extracted from North American waters come from the Gulf. Nearly 4,000 oil and gas related structures (e.g. drilling and production platforms) are in the U.S. Gulf with about 500 located in waters deeper than 200m (MMS, unpublished data). The NMFS Southeast Fisheries Science Center (SEFSC), the MMS, and Texas A&M University (TAMU) collaborated on two research programs, GulfCet I and II, to study cetacean abundance and distribution in the northern oceanic Gulf from 1991 to 1998 (Davis and Fargion, 1996; Davis et al., 2000).

In 2000 and 2001, the SEFSC and the MMS collaborated to sponsor a multifaceted sperm whale pilot study in the Gulf with scientists from the SEFSC, Oregon State University (OSU), and Woods Hole Oceanographic Institution (WHOI), among others. The research included genetics, photo-identification, satellite tagging, acoustics, and digital acoustic tagging (D-tag). The MMS along with TAMU, WHOI and OSU, initiated a new multi-year study, Sperm Whale Seismic Study (SWSS), in 2002 that continued much of the earlier work. SWSS is scheduled to continue through at least 2004 and includes controlled experiments to study the effects of seismic exploration on sperm whales.
SUMMARY OF RESEARCH

Distribution
Sperm whales have been sighted throughout northern Gulf waters but are concentrated in or near the continental slope, particularly in the region of the Mississippi River delta and west of southern Florida (Fig. 1). Seasonal aerial surveys of slope waters in the northern Gulf indicated sperm whales are present throughout the year (Hansen et al., 1996; Mullin and Hoggard, 2000). There is limited information on sperm whales from southern Gulf waters, but there are sightings and strandings from each season with sightings widely distributed in slope waters of the western Gulf of Campeche (Ortega-Ortiz, 2002). Except for a sighting of one whale, surveys of continental shelf waters indicated sperm whales do not occur in Gulf shelf waters (Collum and Fritts, 1985; Fulling et al., 2003).

Abundance and group-size
Based on five spring (April-early June) ship surveys conducted from 1996 to 2001 by the SEFSC, Mullin and Fulling (2003), using spatial stratification of effort, estimated a sperm whale density of 0.35 whales/100km² and an abundance of 1,349 whales (CV = 0.23; 95% CI = 869-2,093) for northern Gulf waters. This estimate is negatively biased because it is not corrected for subsurface whales (i.e. g(0) < 1). During these surveys, sperm whale group sizes averaged 2.6 whales (SE = 0.16, range 1-11, n = 164). However, this mean is based on very short (10-20min) assessments of the group-sizes at the surface during line-transect surveys. The water depth of sightings averaged 1,732m (SE = 74, range 198-3,462, n = 172). Based on the relative size of individual sperm whales, most groups appeared to be composed of females and juvenile males. Fifteen percent of these groups contained at least one animal that was classified as a ‘calf.’ Sightings of obviously large animals that could be socially mature males were rare.

The previous estimate of sperm whale abundance for the northern Gulf, 530 whales (CV = 0.31), was based on ship surveys conducted from 1991-1994 (Hansen et al., 1995; Waring et al., 2001). A reanalysis of these data using spatial stratification of effort resulted in an estimate of 805 whales (CV = 0.27) (SEFSC, unpublished).

Satellite tagging
A sperm whale satellite tagged in August 2001 just south of the Mississippi River delta was tracked for 137 days. The whale remained near the 1,000m isobath in the vicinity of the river delta for 95 days, after which it traveled to the western Gulf and then south into the western Gulf of Campeche, where the tag stopped transmitting (Mate, 2002). In 2002, eighteen sperm whales were satellite tagged in the northern Gulf as part of SWSS research (OSU/TAMU, unpublished).
D-tag
The WHOI D-tag is attached with suction cups for <12h and records whale vocalizations and ambient noise along with a suite of other data that include depth, pitch, roll, speed, and heading of the whale. The D-tag is the primary tool used in studies of the short-term effects of seismic exploration on sperm whales. Prior to 2002, the D-tag was successfully deployed on 15 sperm whales in the Gulf and Mediterranean Sea. The D-tag gives an incredibly detailed account of subsurface behavior in an acoustical context (e.g. foraging sequences). One tagged sperm whale in the Gulf foraged along the bottom at a depth of 900m, the deepest record in the Gulf to date (Johnson and Miller, 2003). During the 2002 SWSS research 19 D-tags were successfully attached to sperm whales in the Gulf. Three tags remained attached for 12 hours and each tag recorded 10 to 12 complete dives (WHOI/TAMU, unpublished).

Acoustics
In 2000, the SEFSC acquired a five-element passive acoustic array to use as an assessment tool and to integrate acoustic data with standard visual line-transect surveys. The array was also critical as a tracking tool for tagging, biopsy and photo-identification sampling. Thode et al. (2002) used data from the array to obtain dive-trajectories and contemporaneous vocalization characteristics of sperm whales in the Gulf. Sound propagation in the Gulf was also studied using the array. The detection distance of clicks of diving sperm whales with the array was estimated to be about 5km (Mellinger et al., 2003).

Genetics
Currently, sperm whales in the Gulf are treated as a separate stock from those in the western North Atlantic by the NMFS (Waring et al., 2001). To test hypotheses concerning genetic stock structure of Gulf sperm whales and to study gender composition and kinship patterns within and between clusters and groups, biopsy samples were collected during 2000, 2001 and 2002. Overall, eighty-nine individuals (including satellite-tagged, D-tag tagged, opportunistic, and stranded whales) were genotyped using both mtDNA and microsatellite techniques. Gender was determined for nearly all of these samples using molecular sexing techniques.

Due to the logistics involved, defined groups were rarely sampled in their entirety. However, on multiple occasions, greater than half of the individuals that comprised a group were sampled. Results indicate that the majority of whales sampled from groups throughout the north-central Gulf of Mexico fit the classic ‘mixed’ group scenario; comprised of females and subadults of both sexes (Best, 1979). While the majority of groups were predominately females, some groups appeared to contain only young males (suggesting that ‘bachelor’ groups may reside in the Gulf). Relatedness levels for groups in general suggest that the overall group is often unrelated, although groups did contain related whales. MtDNA analyses showed that groups are comprised of both single and mixed matrilines, which combined with the relatedness levels, may provide additional evidence for Whitehead et al.’s (1991) suggestion that sperm whale groups are comprised of “constant companions and casual acquaintances”.

A comparative analysis of matrilinal mtDNA and biparentally inherited nuclear genetic markers (microsatellites) have begun to show population structure for female lineages, which is expected given previous findings on social and reproductive behavior in this species (Lyrlholm and Gyllensten, 1998; Lyrlholm et al., 1999). Only four mtDNA haplotypes were found in the northern Gulf, with two being unique (on a global scale) to this geographic area. Nuclear DNA variation across the North Atlantic Ocean appears non-significant, which supports Lyrlholm et al.’s (1999) suggestions that males disperse and spread their genes to the more philopatric females.

Photo-identification
Photo-identification of sperm whales from three years of SEFSC research (1999-2001) in a 53,000km² study area south of the Mississippi River delta resulted in the identification of 102 individual whales. The SEFSC catalog was matched against 30 individual whales identified in 1994 and 1996 (Weller et al., 2000), and combined, the two catalogs contain 122 individual whales. Six whales from the SEFSC catalog matched those from a catalog of 34 individuals identified in the same study area in 2002 (NAMSC - North Atlantic and Mediterranean Sperm Whale Catalog).

Fifty-eight of the whales from the SEFSC catalog were identified on only one occasion. Twenty-seven whales were identified in two separate years and three whales, in three separate years. Five whales were re-identified after a period of five or six years with distances between sightings ranging from 13.1 to 46.7km. Four whales identified in 1994 were resighted in 2001 at distances between resightings from 26.4 to 111.8km.

Abundance estimates were derived for this north-central Gulf study area using photo-identification samples from all three catalogs. Due to the time span of the capture occasions, open population models were selected from the Jolly-Seber (JS) family (Pollock et al., 1990) for abundance estimates and applied using the program JOLLY (Hines, 1988). Mean population size was estimated to be 190 whales (SE = 95).
Habitat
The mean state of Gulf oceanic waters is oligotrophic, 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) is the dominant oceanographic feature in the eastern Gulf. The LC periodically sheds warm-core eddies 200-300 km in diameter which drift slowly to the west. Upwelling occurs along the LC front and in cold-core eddies that routinely form in association with the LC front or eddies. Nutrient-rich shelf and Mississippi River waters are periodically entrained in the confluence of these warm-core/cold-core pairs and transported to oceanic waters.

Environmental data collected by the SEFSC and TAMU have been used in conjunction with remote sensing (e.g. sea surface altimetry), physiographical data, and biological data to study sperm whale habitats in the Gulf. Biggs et al. (2000) and Baumgartner et al. (2001) reported sperm whales were encountered less frequently near the interior of warm-core features in the northern Gulf. Biggs et al. (2000) also indicated that sperm whales occurred more commonly in waters with cold-core characteristics.

The aggregations of sperm whale sightings just off the Mississippi River delta and in the southeastern Gulf west of the Dry Tortugas (25°N 84°W) may result, respectively, from primary productivity associated with the Mississippi River plume, which is the highest recorded in the Gulf (Lohrenz et al., 1999), and productivity that is enhanced by nutrient upwelling associated with the LC front and the periodic formation of the cyclonic Tortugas Gyre in the southeastern Gulf (Wiseman and Sturges, 1999).

Predation
In 1994 and 2001, short-finned pilot whales (Globicephala macrorhynchus) and killer whales (Orcinus orca), respectively, were observed ‘harassing’ sperm whales in the northern Gulf (Weller et al., 1996; pers. obs.). No predation was observed in either case, but killer whales are known predators of sperm whales in other areas (Pitman et al., 2001).

Prey
There are no published reports on the diet of sperm whales in the Gulf. Preliminary analyses of samples obtained from free-ranging animals (floating fecal material) and stomach contents of stranded animals indicate that Gulf sperm whales feed on meso- and bathypelagic species of cephalopods, including the families Histioteuthidae, Cranchiidae, Chiroteuthidae, Pholidoteuthidae, Vampyroteuthidae, and Octopoteuthidae, among others.

Human-activities
In addition to activities related to the oil and gas industry, there are numerous human activities in the Gulf, including shipping, military training, and fishing. No fishing related mortalities of sperm whales have been recently reported from the Gulf, but one sperm whale stranded with cuts from the propeller of a large vessel (NMFS, unpublished).

Future research
In addition to the continuation of the MMS SWSS program, the SEFSC will conduct ship surveys in 2003 and 2004 with an emphasis on estimating sperm whale abundance and collecting biopsy, photo-identification and fecal samples in under-sampled areas of the northern Gulf. SEFSC survey methodologies will be modified to make a more precise and accurate estimate of sperm whale abundance for northern Gulf waters. Survey effort will be stratified based on previous distribution patterns, and group-size estimates will be made using 90 min counts similar to those used in Pacific (Barlow and Taylor, 2001). A five-element passive acoustic array will also be used during visual surveys to estimate the number of subsurface groups near the transect line. The SEFSC will also continue photo-identification sampling of sperm whales in the north-central Gulf on a quarterly basis.

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REFERENCES


