

STUDY TITLE: *Deepwater Program: Cooperative Research on Sperm Whales and Their Response to Seismic Exploration in the Gulf of Mexico – (Sperm Whale Seismic Study-SWSS)*

REPORT TITLE: Sperm Whale Seismic Study in the Gulf of Mexico: Summary Report, 2002-2004

CONTRACT NUMBER: 1435-01-02-CA-85186

SPONSORING OCS REGION: Gulf of Mexico

APPLICABLE PLANNING AREAS: Western, Central, and Eastern Gulf of Mexico

FISCAL YEARS OF PROJECT FUNDING: 2002, 2003, 2004, 2005, 2006, and 2007

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COSTS: FY 2002 \$2,069,017; FY 2003 \$1,792,477; FY 2004 \$2,280,205; FY 2005 \$2,516,537; FY 2006 \$643,149; FY 2007 \$0; CUMULATIVE PROJECT COST: \$9,301,385 (Note: \$260,972 of this total was contributed to MMS for SWSS by the Industry Research Funders Coalition)

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KEY WORDS: Sperm whale, *Physeter macrocephalus*, Gulf of Mexico

BACKGROUND: With oil and gas and related activities moving into the deepwater Gulf of Mexico, the Minerals Management Service (MMS), Gulf of Mexico Outer Continental Shelf Region, recognizes that such activities may occur in regions frequented by deepwater species of cetaceans, particularly the endangered sperm whale (*Physeter macrocephalus*). MMS seeks to expand the existing assessments of sperm whales and to improve the understanding of the effects of seismic exploration on sperm whales in the Gulf of Mexico (Gulf). At the MMS Information Transfer Meeting in January 2002, the geophysical industry through the International Association of Geophysical Contractors (IAGC) offered to provide a seismic source vessel as a sound source for several weeks of controlled exposure experiments (CEEs) of sperm whales to seismic exploration in the Gulf. With this contribution of the IAGC, MMS awarded the

Cooperative Agreement for research on sperm whales and their response to seismic exploration in the Gulf to a multi-institutional, interdisciplinary research team under the program management of Texas A&M University. In the second field year of the study, five major oil companies joined with IAGC to form the Industry Research Funders Coalition (IRFC) to allow a second summer of contribution of a seismic source vessel for CEEs. In field years 3 and 4, IRFC also provided contributions through MMS for additional sperm whale research under the Cooperative Agreement. This summary presents the main results of the Sperm Whale Seismic Study (SWSS) for 2002-2004 by program component.

OBJECTIVES: The objectives of this study were to (1) establish the normal behavior of sperm whales in the northern Gulf, (2) characterize sperm whale habitat use in the northern Gulf, and (3) determine possible changes in behavior of sperm whales when subjected to man-made noise, particularly from seismic airgun arrays used for offshore petroleum exploration and geological monitoring.

DESCRIPTION: Because sperm whales range widely, the study area essentially encompasses the entire Gulf. However, SWSS cruise activities in 2002-2004 were focused along the 1000-m isobath in the region off the Mississippi River Delta between 91°W and 86°W in the range of water depths of 800-1200 m. There were six project components. These were to: (1) study the long-term (months to seasonal) movements and distributions of sperm whales using satellite-tracked radio telemetry tags (S-tags); (2) study the short-term (hours) behavior of sperm whales using digital-recording acoustic tags (D-tags) and examine potential changes in behavior of the whales when subjected to seismic airgun sounds during controlled exposure experiments (CEEs); (3) examine the social behaviors of sperm whale groups using visual and passive acoustic observations over periods of days; (4) use biopsy samples to determine the sex of the S-tag and D-tag tagged animals and their relatedness to sperm whales from the North Atlantic Ocean and Mediterranean Sea; (5) examine diving depths and movements using 3-D passive acoustic tracking techniques; and (6) characterize the physical and biological oceanographic habitat in which the sperm whales in the Gulf are found.

Seven field cruises were conducted during the summers of 2002, 2003, and 2004. One cruise each summer was in support of S-tag deployments and was aboard the R/V *Gyre*. A cruise in summer 2002 on *Gyre* and another in summer 2003 on R/V *Maurice Ewing* were in support of D-tag/CEE work. The offshore industry work boat M/V *Rylan T*, with the shallow-water airgun boat M/V *Speculator* attached to the rear work deck, provided an airgun array that was used as the sound source for the 2002 CEEs. The seismic survey vessel M/V *Kondor Explorer* provided the airgun sound source for the 2003 CEEs. A third cruise in 2003, Whale Survey and Habitat Characterization cruise, was conducted from *Gyre* concurrently with the D-tag/CEE cruise to collect the supporting suite of environmental, habitat data. In 2004, the acoustically quiet, 46' Hunter sailboat *Summer Breeze* was used to study the social behavior of sperm whale groups. Visual and passive acoustic observations of sperm whales were collected on all cruises, as were biopsy samples for genetic observations. Fluke photographs were taken for photo-identification, and data from hydrophone arrays were used to study 3-D

passive acoustic tracking of sperm whales. Habitat characterization data included currents from 153 kHz and 38 kHz acoustic Doppler current profilers; temperature and salinity profiles using both conductivity-temperature-depth and expendable bathythermograph profilers; continuous, near-surface temperature, salinity, and fluorescence/chlorophyll observations; and sea surface height fields and ocean color from remote sensing.

SIGNIFICANT CONCLUSIONS: Genetic analyses, coda vocalizations, and population structure support the conclusion that sperm whales in the Gulf of Mexico are different from other populations. Population size associated with the limited region between Mississippi Canyon and DeSoto Canyon about the 1000-m isobath is estimated at 398 individuals with a range of 253-607. Initial CEE observations seem to suggest that neither gross diving behavior nor direction of movement changed for any of the eight exposed whales at either the onset of gradual ramp-up at ranges of 7.3 – 12.5 km or during full power exposures at ranges of 1.5-12.8 km. This suggests that there is no horizontal avoidance of sperm whales in the Gulf to seismic survey activities. Results from observing foraging behavior suggest that there is some reduction in foraging during airgun exposure. However, additional studies are required to increase the sample size to numbers yielding the desired statistical power.

STUDY RESULTS: Comparisons of mitochondrial DNA and other molecular markers of tissue samples from sperm whales in the northern Gulf of Mexico, Mediterranean Sea, North Sea, and North Atlantic Ocean reveal a significant genetic differentiation between the Gulf population and populations of the other three regions. Preliminary analyses of coda vocalizations also suggest there are significant differences in repertoires between the Gulf population and the populations of the rest of the Atlantic. The available recorded coda vocalizations indicate that the mixed groups in the Gulf belong to an acoustic clan that is rarely encountered in other areas and, from this, it is inferred that groups from other clans rarely enter the northern Gulf. The population structure also is different. The mean group size in the study area is 9-11 individuals, which is about one-half the size of groups elsewhere. Individual whales are significantly smaller in length than what would be expected on the basis of whaling data from the Gulf or lengths in the Sea of Cortez. Mature males seem to have either a different behavior or a different seasonality to those in other regions as no large breeding males were observed in 2004 from the sailboat. Groups of females/immatures have a high site fidelity that has not been described elsewhere. There is no evidence of long-distance movements as no matches were found between the 185 individuals identified in the northern Gulf and the ~2500 individuals identified in the rest of the Atlantic (North Atlantic and Mediterranean Sperm Whale Catalogue). These results indicate a degree of segregation between sperm whales in the Gulf and the rest of the Atlantic, likely spanning temporal scales of years (absence of matches) to decades (differences in coda repertoire). These results suggest that, for management questions, sperm whales in the northern Gulf should be treated as a separate population.

Summer-to-summer variability in intensity and geographic location of Loop Current eddies, warm slope eddies, and areas of cyclonic eddy circulation forced striking year-

to-year differences in the locations along the 1000-m isobath where there was on-margin and off-margin flow and resulted in significant differences in the current structure and water properties on the northern slope. The integration of the physical and biological data show that, in summers 2002 and 2003, most sperm whales were encountered in regions of negative sea surface height anomaly and/or higher-than-average surface chlorophyll. This is consistent with the hypothesis that cyclonic eddies, which are features of negative sea surface height anomaly and new biological production, may support locally richer feeding grounds for sperm whales. In contrast, however, only a few of the whale encounters in summer 2004 were in regions of negative sea surface height anomaly and/or higher-than-average surface chlorophyll. These habitat associations in 2004 are anomalous when compared to the GulfCet II, SWAMP, and 2002-2003 SWSS results. In addition to considerable summer-to-summer variability, local oceanographic conditions also changed during the course of a single summer, with resultant changes in encounter rates with whales.

The two D-tag/CEE cruises directly examined the behavior of sperm whales when exposed to airgun sounds. The movement and sound-recording D-tag was used to record acoustic exposure and foraging behaviors of 8 sperm whales before, during, and after 1-2 hr controlled sound exposures of industry-provided airgun arrays in the Gulf in 2002 and 2003. In 2002, two CEEs were conducted involving 4 subjects. In 2003, three CEEs were completed also with a total of 4 subjects. The 8 whales for which these CEEs were conducted were exposed to maximum sound levels between 130 and at least 162 dBp-p re 1 μ Pa at ranges of roughly 1.4-12 km from the sound source. Neither gross diving behavior nor direction of movement changed for any of the eight exposed whales at either the onset of gradual ramp-up at ranges of 7.3-12.5 km or during full power exposures at ranges of 1.5-12.8 km. The CEE results, together with results from two other independent approaches, do not indicate any horizontal avoidance of sperm whales in the Gulf to seismic survey activities. These data do not support the assumption that whales swim away from an airgun array as it ramps up or approaches the whale at full power. However, there was only limited exposure above 160 dBp-p re 1 mPa. Further research is required to test for avoidance at higher received levels. Gulf sperm whales, at least in the area studied, may have some level of acclimation to seismic airgun sounds. Moreover, whales were tagged in a region with substantial human activity, so they are not naïve to human-generated sounds. Follow-on studies in regions not as affected by human activities are needed to address the issue of habituation.

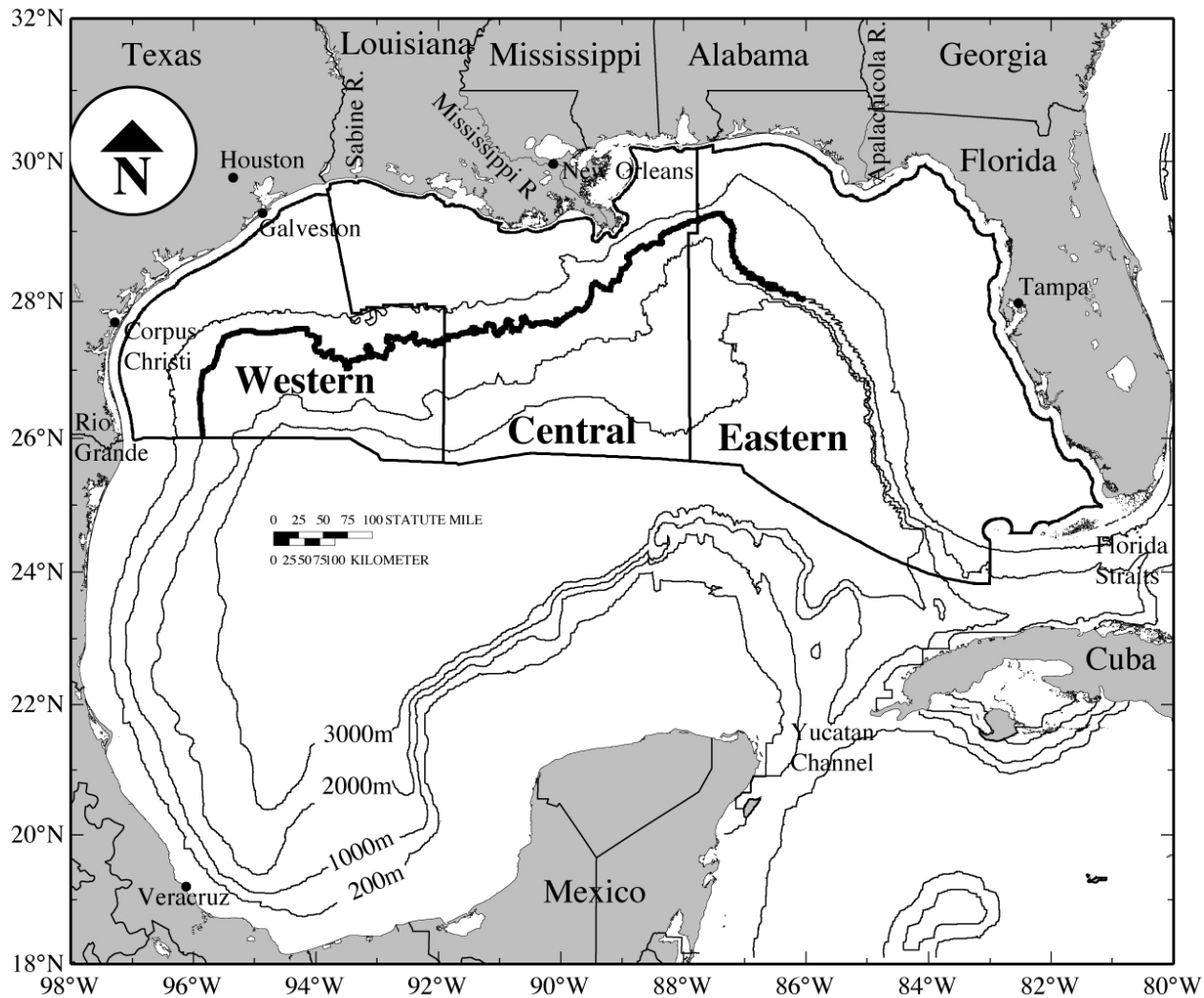
The effects of airguns on the foraging behavior of sperm whales were assessed. The whale that was approached most closely prolonged a surface resting bout hours longer than typical, but resumed foraging immediately after the airguns ceased. While this whale showed no horizontal avoidance, the alteration of diving behavior could be considered a vertical avoidance response. Differences of foraging response measures between exposure and post-exposure control periods in the remaining 7 exposed whales (which made foraging dives during both conditions) were compared to sham exposure and post-exposure control periods in 13 unexposed whales. Pitching movements generated by swimming motion were 6% lower during exposure ($P=0.014$).

Distinctive echolocation sounds, called buzzes, produced when whales attempt to capture prey were 19% lower during the exposure condition, but this effect was not statistically significant ($P=0.141$). Given the low sample size of exposure subjects, a Bayesian analysis was conducted to quantify the odds-ratio for whether the data support models of increase, decrease, or no change. The result indicates that a decrease in buzz rate is 3.6 times more likely than no change given our data; this is a Bayes factor considered to be "substantial" or "positive" evidence for an effect. The same analysis indicates that a decrease in pitching movement is 2.9 times more likely than no change. More research is needed to define the effects of seismic on foraging behavior on sperm whales, but this analysis suggests that a 20% decrease in foraging attempts at exposure levels ranging from <130 to 162 dBp-p re $1 \mu\text{Pa}$ at distances of roughly 1-12 km from the sound source is more likely than no effect.

STUDY PRODUCTS: Jochens, A., D. Biggs, D. Engelhaupt, J. Gordon, N. Jaquet, M. Johnson, R. Leben, B. Mate, P. Miller, J. Ortega-Ortiz, A. Thode, P. Tyack, J. Wormuth, and B. Würsig. 2006. Sperm whale seismic study in the Gulf of Mexico; Summary Report, 2002-2004. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2006-034. 352 pp.

Jochens, A.E. and D.C. Biggs, editors. 2004. Sperm whale seismic study in the Gulf of Mexico; Annual Report: Year 2. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2004-067. 167 pp.

Jochens, A.E. and D.C. Biggs, editors. 2003. Sperm whale seismic study in the Gulf of Mexico; Annual Report: Year 1. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2003-069. 139 pp.



Study area of the Sperm Whale Seismic Study (SWSS), which focused along the 1000-m isobath of the northern Gulf of Mexico. Bathymetry contours shown are 200, 1000, 2000, and 3000 m.