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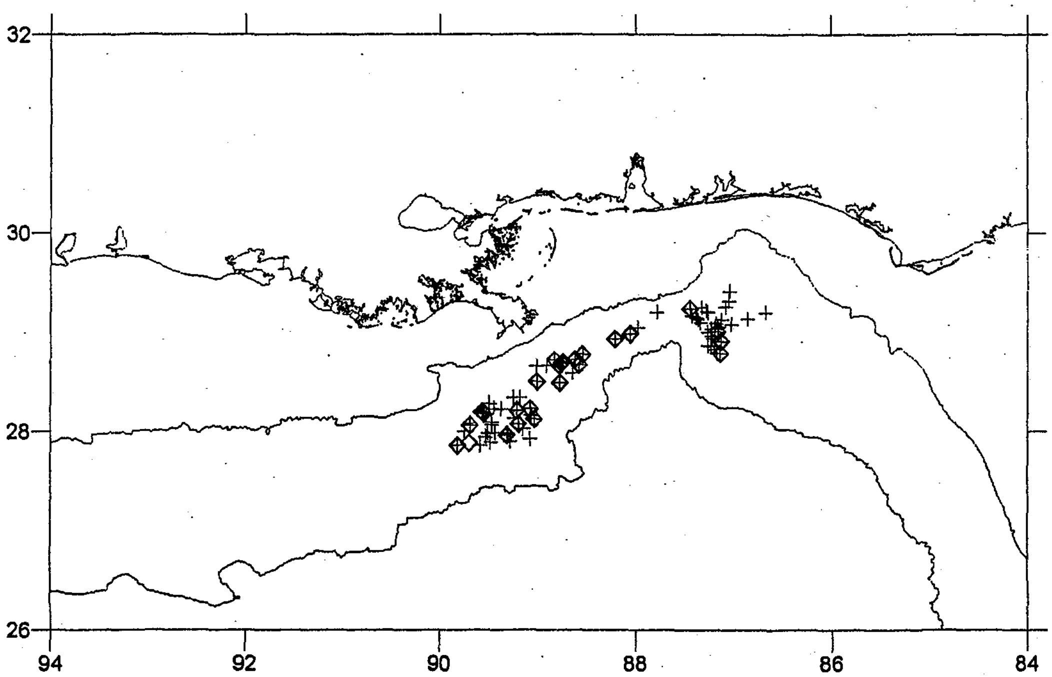
Cruise Results

Sperm Whale Pilot Study 2000
(SWY2K)

NOAA Ship *Gordon Gunter* Cruise GU-00-04 (009)
27 June - 27 July 2000



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INTRODUCTION

Numerous marine mammal surveys conducted by the National Marine Fisheries Service (NMFS) in the last decade have revealed a consistent population of sperm whales (*Physeter macrocephalus*), apparently present year round, in the Gulf of Mexico. Listed as an endangered species, the sperm whale is the only large whale observed throughout the oceanic waters of the Gulf of Mexico (the Bryde's whale is another large whale seen in the Gulf but appears to be limited in distribution to the waters in the eastern Gulf near DeSoto Canyon). Data on the biology of the sperm whale, including stock structure, distribution, abundance and habitat utilization are required by NMFS in order to adequately protect the species and produce stock assessment reports as mandated.

The Minerals Management Service (MMS) also has need of data on sperm whales in the Gulf of Mexico. Charged with managing the development of oil and natural gas resources while protecting the environment, MMS requires knowledge of the distribution, habitat utilization and acoustic traits of sperm whales in order to determine the potential impact of petroleum industry activities. Two factors, in particular, have elevated sperm whale issues for MMS. First, effects of anthropogenic noise in the marine environment, such as those associated with offshore petroleum operations, have become a concern in both scientific and public arenas. Secondly, the increase of petroleum activities in deepwater (defined by the industry as waters greater than 312 m) has been astronomic. In the past, petroleum activities were confined to more shallow water depths than sperm whales inhabited. However, recent technological developments have allowed the industry to move into much deeper water with the capability to drill in depths down to 3120 m (10,000'). Of the approximately 7600 currently active leases in the Gulf, 48 percent are in deepwater. This contrasts to 5600 active leases in 1992, of which only 27 percent were in deepwater. More than 50 percent of the oil production and 20 percent of the natural gas production in the Gulf now comes from deepwater. This represents a 2,800 percent increase in oil production and a 3,500 percent increase in natural gas production from deepwater just in the last decade.

Recognizing the need for similar data, NMFS and MMS developed the following set of research questions that would address the information needs of both agencies.

1. What are the effects of anthropogenic noise (e.g., seismic activity) on the distribution, behavior and vocalization patterns of sperm whales?

2. What is the stock status of sperm whales that inhabit the Gulf of Mexico compared to the adjacent Atlantic Ocean and Caribbean Sea? (The current NMFS stock status has not been tested but was thought to be conservative. It needs to be tested using genetics, contaminants, morphometrics, vocalizations and ranging and movement patterns.)

3. Will surveys using both acoustic array methods and visual surveys improve (change) NMFS's absolute abundance estimates of sperm whales in U.S. waters?

4. Is the group composition and social structure of sperm whales in the Gulf of Mexico similar or different compared to sperm whales in other parts of the world?

5. How do sperm whales spatially use the Gulf of Mexico? Are there specific feeding, breeding, socializing and resting areas?

OBJECTIVES

The objective of this pilot study was to test and/or refine a wide range of sperm whale research techniques in the Gulf of Mexico for use in future studies to address the above research questions. These research techniques included:

1. Visual line-transect surveys for abundance estimation.
2. Acoustic line-transect surveys for abundance estimation.
3. Collection of biopsied tissue samples using a variety of devices including rifles and crossbows.
4. Attachment and monitoring of acoustic tags to individual sperm whales.
5. Photographic identification of individual sperm whales.
6. Collection of sloughed skin and fecal samples.
7. Behavioral observations.

METHODS

The *Gordon Gunter* departed Pascagoula, Mississippi on 27 June 2000 for a 30-day pilot study. The study area was located in the northern Gulf of Mexico, south of the Mississippi River Delta, between 87.0^0 W and 91.0^0 W. Surveyed waters ranged in depth between approximately 750 m and 2500 m. This area was specifically targeted because sperm whales have been consistently sighted in this region throughout the year during previous research.

Several of the research techniques tested required the use of a small boat. A 7 m aluminum-hull work boat was designed and built for this purpose. Named the *Relentless II,* or R2, the boat was carried on a cradle aboard the *Gunter* and lowered to the surface when needed. The R2 was designed to carry a crew of four to five scientists and supported a variety of activities including acoustic tagging, biopsy sampling and photo ID work.

The cruise was divided into 2 legs. The first leg (12 days) was primarily devoted to attaching acoustic tags to sperm whales. The second leg targeted biopsy, photo ID and line transect techniques incorporating both visual and acoustic surveying. A full complement of 15 scientists participated in each leg of the cruise. The composition of the research team was recognized as crucial to the pilot study. An "expert" scientist that was well experienced in working with and around sperm whales, particularly from small boats, was included on each leg. Also, researchers with expertise in tagging, acoustics and genetics were enlisted to provide methodologies for research techniques new to Pascagoula/Miami NMFS marine mammal scientists.

Visual Surveys

Visual surveys were conducted in much the same manner as has been perfected during marine mammal cruises for the last 10 years. Teams of three observers stood two-hour watches and rotated between the positions of right and left observer and data recorder. Two sets of 25X "Big Eye" binoculars were mounted on the flying bridge and greatly increased the observers' ability to see marine mammals. Data on sightings and environmental conditions were entered into a laptop computer by the data recorder. Location and cruise track data were automatically entered into the data set every 60 seconds by a linked Global Positioning System (GPS) unit. As always, communication and cooperation between the observers and the ship's crew was crucial and this was accomplished with mounted and hand held VHF radios.

Acoustic Array and Surveys

A new, custom-constructed five element acoustic array was installed on the *Gunter* for this cruise. The 100 m array, and its lead-in cable, were spooled on a large-drum-diameter winch specifically built for this purpose. The array was deployed through a custom-designed bend limiter mounted on the stern and, when deployed, trailed 200 to 300 m behind the ship. Lead strips were wrapped around the array to provide weight. Several software programs were incorporated with the array over the course of the cruise, including Ishmael, Rainbow Click and Whale Logger. Sperm whale clicks, vocalizations of other cetaceans and other sounds of interest were recorded. CTDs were deployed to 1000 m to supplement and calibrate the acoustic array data.

Biopsy

Biopsy samples provide a wealth of information about whales, including individual identification, sex, stock identification and social organization from sampled skin. Blubber samples can be analyzed for a wide variety of contaminants. Although this was the first cruise to specifically target sperm whales, the Pascagoula biopsy team had taken sperm whale biopsy samples opportunistically on other mammal cruises. Already aware of the toughness of the skin and relative difficulty in obtaining a tissue sample from a sperm whale, compared to other more frequently sampled species, the team gathered a variety of sampling head designs and sampling devices to test during the cruise. Animals were approached and biopsies were collected from the R2, which was launched from the *Gunter* when whales were sighted. Samples were immediately placed in a cooler and returned to the *Gunter* as soon as practical. On the ship, the samples were processed, documented, labeled and stored.

Photographic Identification

The flukes of sperm whales can be used to identify individuals and a worldwide catalog of fluke photographs exists. Photo identification can be used to study group size, composition and stability, and site fidelity. The animals rest at the surface for a short interval between deep dives and then lift the flukes in the air as they make the next dive from the surface. Sperm whale flukes were photographed with both a digital video camera and a 35 mm camera outfitted with a 100 - 300 mm zoom lens. The purpose of using both types of gear was to insure useable slides with the 35 mm set-up used by other researchers, but to experiment with the possibility of obtaining useable frames from a digital video. The video camera also recorded behavior of surfaced animals. Sperm whales were followed from a distance during a surface period and photos of flukes were obtained when the animals "fluked-up" for a dive. This work was conducted from the R2. Videography was also used from the *Gunter*. The camera was mounted to a set of Big Eyes at a known height above the surface. Animals were videotaped with the horizon in the frame. Length measurements can be derived from the snout-to-dorsal-hump distance in the video frame and age can then be estimated from growth charts. These data can be used to determine population structure.

Acoustic Tags

An acoustic tagging team from Woods Hole Oceanographic Institution (WHOI) joined the cruise for Leg 1. They attempted to place a suction cup-attached tag on a sperm whale that recorded a variety of information including a sound recording of both the whale and ambient noise, the depth and acceleration of a dive, and the pitch and roll of the animal while wearing the tag. The tag had a maximum recording time of about 4 ½ hours and then was released from the whale. The tag was located after release by homing in on radio signals sent out by the floating tag. The tag was designed by WHOI with funding from the Office of Naval Research. The tag was placed on the whale using a 10 m cantilever pole mounted in a custom fitting on the bow of the R2. Whales were approached by the R2 and, when close enough to a surfaced whale, the pole was swung downward, slapping the three suction cups on the tag down onto the back of the whale. These tags have been used successfully with right whales in the past but this was the first attempt to place a suction cup tag on a sperm whale. These tags can potentially measure the sounds that a whale is exposed to and record subsequent behavioral responses.

Sloughed Skin and Fecal Samples

Sperm whales are constantly shedding skin and, often following either breaches by an individual whale, or physical contact between two or more whales, the skin can be netted quickly as it drifts by. Small nets and skin diving gear were kept in the R2 to take advantage of the opportunity to collect skin. Sperm whales often defecate when diving and fecal samples can yield information about the whales' diet. Also, frequency of defecation can indicate feeding success. Nets were also kept on the R2 to scoop fecal samples in hopes of finding squid beaks.

Behavioral Observations

Behavioral observations are a crucial element in gaining an understanding of sperm whale biology and habitat utilization. Behavioral observations were recorded on appropriate forms from the R2 during biopsy and photo id sessions. A small voice recorder was also used. Behavior was also recorded from the *Gunter* using the software program Sperm Count. Mainly a tracking program for making herd size estimates, the program allowed the recording of a variety of behavioral data as well. Video cameras were also used to record the behavior of sperm whales on the surface.

RESULTS AND DISCUSSION

The Sperm Whale Pilot Study was very successful in both testing research techniques and in data collection. All of the techniques employed were refined to the point of being extremely useful research tools and the individual projects are briefly discussed below. Extensive data analysis is ongoing for each project and the results will be published at a later date.

Whales were located, in most cases, within a few hours of the start of daily effort. The area south of the Mississippi River delta continued to be an area of sperm whale concentration and finding animals to work with was generally not difficult or time consuming (Figure 1, Table 1). Well into Leg 2, the decision was made to move from the delta area east to the DeSoto Canyon. The shift in geographic location was in part due to interest in the presence of sperm whales in the Canyon area, but also because the successful sampling had given more than adequate coverage of the delta area. Whales were encountered along the 1000 m cruise track to, and in, the Canyon. Particularly notable was the size of one of the whales encountered and sampled in the Canyon area.. Observers with a great deal of experience in the Gulf of Mexico agreed that this was the largest sperm whale that they had seen in the Gulf. As male sperm whales are much larger than females, this animal was suspected to be a male. The biopsy sample collected will confirm the gender. This animal was accompanied by another whale only slightly smaller.

The new work boat, R2, proved to be a very important component of several of the tasks. The R2 was fast when speed was needed, highly maneuverable, very stable even in less-than-ideal conditions and accommodated needed personnel comfortably and, most important, safely. The reaction of sperm whales to the R2 varied with a number of factors, including weather and sea state. The R2 team experimented with various approach directions and speeds. The success of the biopsy sampling and photo ID work, as well as tagging, indicated that the R2 was able to get very close to whales without causing them to dive. On more than one occasion, whales aggregated around the R2 and got so close that the R2 had to back away to avoid contact with the animals. At no time did any whale exhibit aggressive or threatening behavior toward the R2.

The NOAA Ship *Gordon Gunter* was an ideal platform to use for this multi-faceted research. The capability of carrying 15 scientists was absolutely necessary for a cruise with this many tasks and the need for researchers from such a variety of disciplines. The flying bridge has been used for marine mammal operations for the last two years. Ongoing modifications and attention to design have resulted in a state of the art platform for visual observations. The spacious dry lab and computer areas were required to house the variety and quantity of electronics equipment used for the acoustic tagging operation, the acoustic array and environmental data collection. The quietness of the *Gunter's* diesel electric generators is a huge factor in the effectiveness of the acoustic array. The ship was designed to be an optimal platform for acoustic "listening" and it is the ship of choice for incorporating the acoustic array into a study design.

Central to the success of the cruise was the expertise onboard in all facets of the research and the exceptional communication and cooperation between the personnel. The presence of such a knowledgeable and experienced team of researchers, and their enthusiasm, willingness to share ideas and suggestions, and dedication during very long work hours, was the critical element in accomplishing all of the goals of this pilot study. Included in this is the crew of the *Gunter*, who became a very important part of the research team.

Visual Surveys

The visual component proved to be very valuable for all of the techniques tested. The visual team was responsible for initially sighting whales. The experience of several of the participating visual observers allowed sightings to be made at considerable distance from the ship and in occasionally poor conditions. The acoustic array was expected to assist in the initial location of whale groups. Generally, however, the visual observers were able to sight whales further away from the ship than the acoustic array could "hear" them. The array was valuable for detecting whales that were not surfaced, however, many groups of feeding whales seemed to alternate dive and surfacing periods, with at least a portion of the group on the surface most of the time. In these instances, the visual team often observed the surfaced animal(s) prior to the array picking up clicks from the diving animals in the same group.

During tagging, biopsy and photo ID operations, the visual team watched for surfacing whales from the *Gunter's* flying bridge. Whales were quickly sighted from this vantage point and directions to the animals were given to the R2 by VHF radio. This allowed the "away" team to very quickly respond to surfacing animals and maximize the surface interval for sampling approaches. Even a small swell made sighting surfaced whales difficult or impossible from the R2 due to the low vantage point of the surface. From the small boat, the only visible cue was usually the blow. A program called Sperm Count, developed to track surfaced whales, was very helpful in quickly establishing the range and bearing of the R2 to the surfaced whales. The program was run on a laptop computer on the *Gunter's* flying bridge and the information was passed to the R2 as soon as whales surfaced. This allowed the R2 to immediately begin movement toward the surfaced animals even before they could pick the whales up visually. As surface intervals were usually in the 10 minute range, getting the R2 in the vicinity of the target animals as quickly as possible was crucial. Observers on the *Gunter* also informed the R2 of the orientation of surfaced whales, which was very important information for setting up tagging or biopsy approaches. The only problem that was encountered during these sessions was that on the first leg of the cruise, the VHF radio being used between the flying bridge observers and the R2 had a limited distance in which it would transmit clearly. When the R2 moved out of range, communications had to be forwarded through the officer on the *Gunter's* bridge, where a stronger VHF radio was located. Although the officers were exceptional in quickly passing messages, even that delay affected how quickly the R2 was put on whales. A longer range VHF radio was installed on the flying bridge for the second leg of the cruise and the problem was alleviated.

One of the objectives of the cruise was to refine methodology for conducting simultaneous but independent visual and acoustic line-transect surveys. Two days were devoted to line-transects with both the visual team and the acoustic array team on "watch". Visual sightings were not broadcast until they were abeam of the ship and acoustic targets were not broadcast until they were abeam of the array. Analysis of the data is currently underway but the general impression was that the visual team could see targets (during these line-transects most sightings were dolphins) before the array "heard" them. However, on at least two occasions, the array was picking up very loud clicks and whistles characteristic of dolphins and none were sighted by the visual team. The ship even circled in the area to visually locate what sounded like many dolphins very close to the array, but none were sighted. It was not determined whether the dolphins remained submerged for an extremely long interval or whether some factor made the dolphins seem to be much closer to the array than they actually were. Generally, the dual line transects went smoothly and the questions aroused by the exercise are being addressed for future surveys.

The visual observers sighted several species other than sperm whales during the cruise. A total of 93 cetacean groups were recorded, of which 29 were sperm whale groups. (The data reported here is preliminary data recorded while the visual team was "on effort". Other sightings that were recorded into the Sperm Count program when visual observers were off effort are not included.) At least 10 species of cetaceans were recorded in the other 64 sightings including pantropical spotted dolphins (*Stenella attenuata* - 12 sightings), spinner dolphins (*Stenella longirostris* - 2 sightings), striped dolphins (*Stenella coeruleoalba* - 2 sightings), bottlenose dolphins (*Tursiops truncatus* - 1 sighting), rough-toothed dolphins (*Steno bredenensis* - 1 sighting), Risso's dolphin (*Grampus griseus* - 3 sightings), pilot whales (*Globicephala sp.* - 1 sighting), melon-headed whales (*Peponocephala electra* - 2 sightings), pygmy or dwarf sperm whales (*Kogia sp.* - 4 sightings) and beaked whales (unidentified *Ziphiid* - 4 sightings). There was one mixed species sighting of beaked whales and pygmy/dwarf sperm whales. These data were important not only as opportunistic sightings, but also to identify to species, when possible, the vocalizations that were recorded by the acoustic array. These data are currently being analyzed and cataloged. Many of the extraneous sightings were recorded only as unidentified dolphins. This was because sightings made with the Big Eyes were often miles away and, as this cruise was concentrating effort on sperm whales, the ship was not diverted to get species identifications or herd sizes of cetaceans other than sperm whales.

Acoustic Array and Survey

The acoustic array proved to be a very valuable whale tracking tool and analysis on acoustic line-transects is currently underway (for more on line-transects, please see Results on Visual Surveys above). The acoustic array team began the cruise with a completely new and untested system. Within a week, the array and associated software became the primary tool in keeping the ship in close proximity of a group of whales for over 50 hours. This allowed the tagging team to begin very early in the day and eliminated "search time" for the whales. The acoustic array was also used to get the ship into the vicinity of submerged, vocalizing whales. Sperm whales usually "click", or vocalize, when submerged and diving. The animals stop vocalizing a minute or two before surfacing. Sperm whales are generally believed to be silent when on the surface resting or socializing. Working closely together, the teams tracked the whales acoustically underwater and visually on the surface and consistently put the R2 on surfaced or surfacing sperm whales for tagging, biopsy sampling and photography. The acoustic array was particularly useful in focusing the attention of the visual team, and the R2, in the expected vicinity of surfacing whales. By the end of Leg 1, the acoustic team had become very adept at pinpointing where a vocalizing whale would surface.

The array was damaged on two occasions by starting the winch when the array was not properly secured. Tireless efforts by the array team and others led to workable repairs in both cases. Plans are for a micro switch to be installed on the winch to prevent such accidents in the future. Although the array performed well close to the whales, the range at which detections could be made was less than expected in these preliminary results. Similarly, the workable tow speed for the array appeared to be considerably less than the expected 10 kt. Hundreds of hours were spent varying a number of array parameters (i.e., the weight on the cable, the amount of cable out behind the ship, depth of tow, speed of tow) to determine the best set-up for the system. The array is currently being used by the NMFS lab in LaJolla, California, and further adjustments to the array are expected. The damage to the array will be permanently repaired prior to the next cruise.

The array was also used to record the vocalizations of sperm whales and other cetaceans. Sperm whale vocalizations are being compared to those of whales in other locations to identify similarities or differences. Recordings were made of many of the other species that were encountered and these will also be cataloged and compared to recordings from other areas.

CTD casts to 1000 m for array calibration and supplemental data were made at eight locations. A malfunctioning sensor corrupted the data on three of the casts, leaving five useable CTD profiles. The Scientific Computer System (SCS) on the *Gunter* was running 24 hours a day and recorded ship's location and navigation and environmental data from a suite of integrated sensors.

Genetic Sampling

Genetic sampling results were far more successful than expected with 45 tissue samples collected. Thirty-seven tissue samples were taken using either a modified .22 caliber rifle or a crossbow (Figure 2, Table 2). Both devices were effective, however the crossbow had a longer range than the rifle. A variety of sampling heads and shaft composition materials were tested and the results are being evaluated. Equipment ordered for future cruises will reflect the successful designs.

Equal in importance to the biopsy collection equipment was the ability to get close enough to the whales to take the tissue sample. The biopsy team spent many hours testing approach methods, including various speeds and directions of approach, and became very adept at moving close enough to animals to be successful. The team determined that slow but steady movement toward the animal, usually from the rear, worked best. The whales seemed to be aware of the presence of the R2 but were not startled by it. The biopsy caused a range of reactions from fairly strong tail slaps and accelerated diving to no reaction at all. On many occasions, even after an obvious reaction, the whale resurfaced within a few minutes not far from the location of the biopsy shot. Sea state or other conditions may have affected the approachability of the whales. Initial conjecture was that rougher seas might help mask the sound of the R2 and allow easier approaches to the whales. That seemed to be true on one group as several animals were biopsied with relative ease. The next day, in similar sea conditions, the R2 could not get close to another group of whales as the entire cluster seemed very skittish. No one particular trend was determined.

A hydrophone was used on the R2 during both biopsy and photo ID sessions and proved to be a very useful tool. When whales were not on the surface, the hydrophone was deployed over the side of the R2 and the direction to the submerged whales could be determined by turning the hydrophone to find the loudest clicks. As researchers gained experience with the hydrophone, a relative distance to the vocalizing whales could also be estimated. This definitely aided both teams in being near the whales when they surfaced.

Sloughed skin was collected on eight occasions. Three of the samples came from breaching individuals, one came from a whale whipping its tail stock on the surface, one came from an animal that reacted after an acoustic tag was applied, two were from socializing groups and the activity was not listed for one sample. The loose skin had to be netted quickly after the whale activity as it dispersed rapidly. Generally, the R2 had to be in the near vicinity of whale activity to get sloughed skin. With breaching or tail slapping whales, the "donor" of the skin was obvious. However, skin sloughed by a group of animals rubbing against each other was impossible to assign to an individual. Genetic analysis must be run on all pieces collected and several individuals may be represented in the sample. Each piece was put into a separate collection bag.

Fecal samples were difficult to collect and only one squid beak was recovered. The whales did defecate occasionally when "fluking-up" for a dive but, even more than sloughed skin, the R2 had to be in the area very quickly in order to get a sample. As photography of the fluke-up was a high priority, the R2 usually held its position well behind the whale for the duration of the fluke-up. The beaks were not present and the feces had often dispersed by the time the R2 was in the sampling area. However, little additional effort or equipment is required to check for sloughed skin or fecal samples so future cruises will undoubtedly yield more samples.

Photo ID

The photo ID work resulted in over 50 useable photographs of sperm whale flukes. Analysis and comparison will no doubt reveal some repeats in the group of photographs but these will certainly be a hefty addition to the Gulf of Mexico sperm whale fluke catalog. These photos will also be compared to worldwide catalogs to determine if any of these animals have been photographed elsewhere. Capturing fluke images proved to be a very time consuming task in the Gulf. Sperm whales generally make 40 to 50 minute dives, separated by surface intervals of about 10 minutes. The fluke-up occurs at the end of the surface interval, which means that it is a very short window of opportunity for obtaining fluke photos. To further complicate the task, the Gulf sperm whales observed did not fluke as often as expected. Social groups, which do not dive, were seen at all hours of the day, including mornings. Whales are generally believed to feed (dive) in the morning and socialize later in the day. Also, even when many of the observed whales appeared to be in a diving mode, they often did not fluke-up. Perhaps the food source was in the water column rather than on the bottom and deep dives were not always required, even when in the feeding mode.

Initially, the photo ID and biopsy sampling were planned to occur simultaneously. Researchers in other locations have used crossbows to obtain biopsy samples from the flukes as they were raised to dive. Photographs were taken at the same time. This method was not very successful in the Gulf. The distance that had to be kept between the R2 and the whale to keep from causing the whale to submerge without fluking was further than the crossbow could accurately shoot. Very few biopsy samples were obtained in this manner. In order to accommodate both tasks, on the second leg of the cruise, the morning was usually devoted to photo ID work with biopsies collected in the afternoon. Although it was expected that biopsy sampling would cause most whales to dive without fluking, several fluke photos were made after a biopsy sample was collected. In some instances, the animal fluked-up immediately after being sampled. In others, the animals submerged briefly and then resurfaced very close to the biopsy location and resumed the original activity, including fluking prior to a dive several minutes after the biopsy was taken. For this reason, a photographer should be included even during biopsy sampling.

Initial comparisons indicate that the digital video images of flukes are very clear and appear to be as useable for fluke comparison as the 35 mm slides. Using video would greatly enhance the chances of getting a good shot of the fluke edge, and also eliminate the delay and expense of purchasing film and then sending slides to be processed. Photography, both video and still, was also used to record the behavior of surfaced whales. Morphometric data gathered on whale length by a video camera mounted on the Big Eyes is being calculated and analyzed.

Acoustic Tagging

No project on this pilot study incorporated the efforts and talents of all the researchers, as well as the *Gunter* crew, as much as the acoustic tagging. And no project was more fascinating. Of six tags attached to whales, three came off within minutes. The other three remained attached for approximately 40 minutes, 90 minutes and 4 ½ hours, respectively. The goal was to attach one tag so this project, like others, far exceeded expectations.

The tagging and R2 crew began by practicing approaches and tagging on a floating buoy. The tag was constructed aboard the *Gunter* and the first suction cup tag to be attached to a sperm whale was placed on the fourth day of the cruise. The first tag stayed on for the entire data collection period and was then released from the whale. The tag was recovered in a fairly dramatic late night effort with a full data set intact. Subsequent tags stayed on for shorter lengths of time but all data collection by the tag was flawless. Minor structural changes to the suction cups appeared to be counterproductive as the tags did not remain on the whales. Reverting back to the original design, a tag placed on the final day of Leg 1 remained on the whale long enough to gather a third amazing data set. Analysis of the huge set of data gathered on each of the three whales will give researchers a replay of the animal's movements and vocalizations, and the noise coming in to the animal, during the tag's duration on the whale.

The rapid learning curve on how best to approach animals for tag attachment made the attempts toward the end of the cruise leg look almost easy. Obviously, the tag team got more familiar with the "feel" of the R2 and how best to place the tag on the animal as the cruise progressed. The function of the tags once attached was just as planned. The weak link in the operation was the suction cups and their ability to grip onto the whale. Researchers expected other whales to bump and rub against the tag and that was most definitely the case. The first animal tagged was not far from the *Gunter* and observers saw almost constant physical contact between the tagged whale and others, often with the tag somewhere in the middle. The tag moved all over the body of the whale, sometimes high on the back and at the next sighting, very low on the side, almost on the belly. When last seen before dark, the tag was being held on the whale by only one of the original three suction cups. But it stayed on for at least an hour in that condition. WHOI researchers suggested that an improvement for a future design would be to use "active" suction cups on the tag. These would not require the tagging pole handler to put the tag on with enough force to push down the cups, but rather the cup's suction would activate against the whale's skin upon contact.

As mentioned above, the tagging operation was an incredibly coordinated effort using the acoustic array team to track whales underwater, the visual team to locate surfaced animals and get the R2 to them quickly, the R2 team to make a rapid but steady approach and the tagging team to attach the tag. The *Gunter* crew then kept the ship in the vicinity of the animal, again with help from the acoustic array and visual teams. And when the tag detached, a radio signal was used to locate the floating tag and retrieve the data. Everyone aboard shared in the success of this exciting "first".

Behavioral Observations

Observations of whale behavior were recorded during every encounter and activity with sperm whales. A huge body of information was collected on sperm whale behavior in the Gulf of Mexico. Visual observations, biopsy sampling and photo ID operations used data sheets designed for the project (Figs 3, 4 and 5). A section on each is for recording associated sperm whale behavior. Many hours were spent observing whales and utilizing the Sperm Count program, which tracked movements of the whales as well as accepted behavior observations. An ethogram was prepared to assist the computer operator and the observers in correctly identifying and recording sperm whale behavior (Figure 6). Detailed analysis of this large body of data will undoubtedly yield a wealth of information on sperm whales in the Gulf of Mexico.

CRUISE GU-009 PARTICIPANTS

Leg 1 (27 June - 8 July 200)

Carol Roden	Chief Scientist	NMFS, Pascagoula, MS
Wayne Hoggard	Lead Biopsy	NMFS, Pascagoula, MS
Charlotte Cates	Photo ID/Behavior	JCWS, Pascagoula, MS
Tony Martinez	Visual Leader/Biopsy	NMFS, Miami, FL
Bill Lang	MMS Project Manager	Minerals Management Service New Orleans, LA
Dan Engelhaupt	Biopsy/Genetics	University of Durham, England
Sarah Stienessen	Acoustic Array	Contract
Carrie Hubard	Visual Leader	NMFS, Pascagoula, MS
Jonathan Gordon	Expert Advisor	University of Oxford, England
Peter Tyack	Lead Acoustic Tag	Woods Hole Oceanographic Inst. Woods Hole, MA
Mark Johnson	Acoustic Tag	Woods Hole Oceanographic Inst.
Alex Shorter	Acoustic Tag	Woods Hole Oceanographic Inst.
Aaron Thode	Lead Acoustic Array	Massachusetts Inst. of Technology
Dave Mellinger	Acoustic Array	Oregon State University
Sarah Tsoflias	Visual Observer	Minerals Management Service New Orleans, LA

Leg 2 (10 July - 27 July 2000)

Carol Roden	Chief Scientist	NMFS, Pascagoula, MS
Wayne Hoggard	Lead Biopsy	NMFS, Pascagoula, MS
Charlotte Cates	Photo ID/Behavior	JCWS, Pascagoula, MS
Tony Martinez	Visual Leader/Biopsy	NMFS, Miami, FL
Bill Lang	MMS Project Manager	Minerals Management Service New Orleans, LA
Dan Engelhaupt	Biopsy/Genetics	University of Durham, England
Sarah Stienessen	Acoustic Array	Contract
Carolyn Burks	Visual Leader	NMFS, Pascagoula, MS
Kevin Rademacher	Visual/Acoustic Array	NMFS, Pascagoula, MS
David Hanisko	Visual/Acoustic Array	NMFS, Pascagoula, MS
Andre DeBose	Visual Observer	NMFS, Pascagoula, MS
Eric Zolman	Biopsy	NOS, Charleston, SC
Simon Ingram	Expert Advisor	University College Cork, Ireland
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Table 1. Locations, surface temperature and depth of sperm whale sightings on the Sperm Whale Pilot Survey, Cruise GU-009.

Sperm Whale Group Sightings

Date	Time	Latitude	Longitude	Temperature	Depth (m)
00/06/29	1535	$28^0$04.21	$89^0$11.55	29.7	1186
00/07/02	1400	$27^0$52.89	$89^0$41.63	30.0	991
00/07/07	0612	$28^0$42.89	$88^0$49.43	30.2	971
00/07/12	0656	$28^0$43.11	$88^0$37.01	31.3	918
00/07/12	0754	$28^0$41.72	$88^0$44.32	30.0	1210
00/07/12	0756	$28^0$41.51	$88^0$44.63	30.1	1210
00/07/12	0804	$28^0$40.93	$88^0$45.26	30.0	1210
00/07/12	0826	$28^0$39.20	$88^0$46.13	30.6	1144
00/07/12	1900	$28^0$07.48	$89^0$01.76	30.7	1277
00/07/13	0706	$28^0$13.34	$89^0$04.53	30.2	1174
00/07/13	1316	$28^0$10.33	$89^0$32.71	30.9	982
00/07/14	1055	$27^0$51.31	$89^0$48.79	30.5	944
00/07/15	1949	$28^0$11.66	$89^0$34.02	30.4	950
00/07/16	0801	$28^0$11.18	$89^0$33.55	30.2	941
00/07/17	0722	$28^0$03.60	$89^0$41.18	30.3	632
00/07/18	0836	$28^0$12.29	$89^0$12.45	30.8	929
00/07/18	1349	$27^0$57.61	$89^0$18.87	30.8	1281
00/07/19	0821	$28^0$29.76	$89^0$00.03	30.4	830
00/07/20	0930	$28^0$39.91	$88^0$34.54	30.9	1419
00/07/21	1047	$28^0$29.03	$88^0$46.02	30.8	1257
00/07/22	0857	$28^0$46.02	$88^0$32.26	30.4	1139
00/07/22	1534	$28^0$55.37	$88^0$12.51	30.4	1197
00/07/22	1726	$28^0$58.21	$88^0$03.38	30.4	1335
00/07/22	1729	$28^0$58.42	$88^0$03.31	30.4	1335
00/07/22	1730	$28^0$58.45	$88^0$03.25	30.4	1335
00/07/24	1200	$29^0$00.03	$87^0$09.57	30.4	909
00/07/24	1350	$28^0$54.18	$87^0$07.49	30.5	832
00/07/25	0718	$28^0$46.91	$87^0$08.04	30.2	856
00/07/26	0919	$29^0$14.26	$87^0$26.97	30.1	1029

Table 2. Sperm whale genetic samples collected during Cruise GU-009, June 27 - July 27, 2000.

Sperm Whale Genetic Samples

Data	Time	Latitude	Longitude	Group Size	Biopsy or Skin?
7/ 2/00	1713	27°51.22	89°36.80	3	B
7/ 7/00	1113	28°41.00	88°51.61	2	B
7/ 7/00	1109	28°41.01	88°51.65	6	B
7/ 7/00	819	28°41.58	88°50.09	6	S
7/13/00	1740	28°08.58	89°31.78	6	B
7/13/00	1807	28°08.52	89°31.78	6	B
7/ 5/00	2000	27°42.48	90°10.77	10	S
7/16/00	1530	28°05.30	89°43.61	4	B
7/16/00	1545	28°05.30	89°43.61	4	B
7/16/00	1738	28°02.43	89°46.10	3	B
7/16/00	1844	28°02.44	89°46.46	4	B
7/16/00	1853	28°02.16	89°46.66	4	B
7/17/00	1315	28°02.76	89°43.62	2	B
7/17/00	1320	28°02.76	89°43.62	2	B
7/17/00	1540	27°59.42	89°44.28	1	B
7/17/00	1752	27°57.84	89°46.18	2	B
7/17/00	1816	27°58.48	89°46.46	2	B
7/19/00	1221	28°29.71	89°03.68	1	B
7/19/00	1625	28°33.20	89°59.10		S
7/19/00	1650	28°33.30	88°59.12		S
7/19/00	1708	28°33.20	88°59.50		S
7/19/00	1737	28°33.38	88°59.31	1	B
7/19/00	1751	28°33.19	88°59.42	1	B
7/19/00	1809	28°33.12	88°59.52	7	B
7/19/00	1820	28°33.23	88°59.59	7	B
7/19/00	1830	28°33.21	88°59.90	5	B
7/20/00	1300	28°39.79	88°39.55	1	S
7/20/00	1618	28°41.58	88°43.14	3	B
7/20/00	1738	28°43.30	88°43.35	3	B
7/20/00	1748	28°43.44	88°43.54	1	S
7/20/00	1802	28°43.85	88°43.71	1	B

Table 2. continued

Date	Time	Latitude	Longitude	Group Size	Biopsy or Skin?
7/20/00	1910	$28^{0}45.72$	$88^{0}43.59$	1	S
7/21/00	1232	$28^{0}30.02$	$88^{0}48.87$	1	B
7/21/00	1618	$28^{0}34.97$	$88^{0}48.15$	3	B
7/21/00	1618	$28^{0}34.97$	$88^{0}48.15$	3	B
7/21/00	1637	$28^{0}35.50$	$88^{0}48.05$	4	B
7/21/00	1650	$28^{0}35.52$	$88^{0}47.90$	2	B
7/21/00	1650	$28^{0}35.52$	$88^{0}47.90$	2	B
7/21/00	1730	$28^{0}36.80$	$88^{0}47.64$	3	B
7/24/00	1548	$28^{0}50.47$	$87^{0}10.11$	1	B
7/24/00	1642	$28^{0}49.34$	$87^{0}08.44$	1	B
7/26/00	1031	$29^{0}11.13$	$87^{0}26.39$	1	B
7/26/00	1125	$29^{0}09.49$	$87^{0}25.33$	1	B
7/26/00	1219	$29^{0}10.17$	$87^{0}21.71$	1	B
7/26/00	1505	$29^{0}11.09$	$87^{0}23.86$	1	B

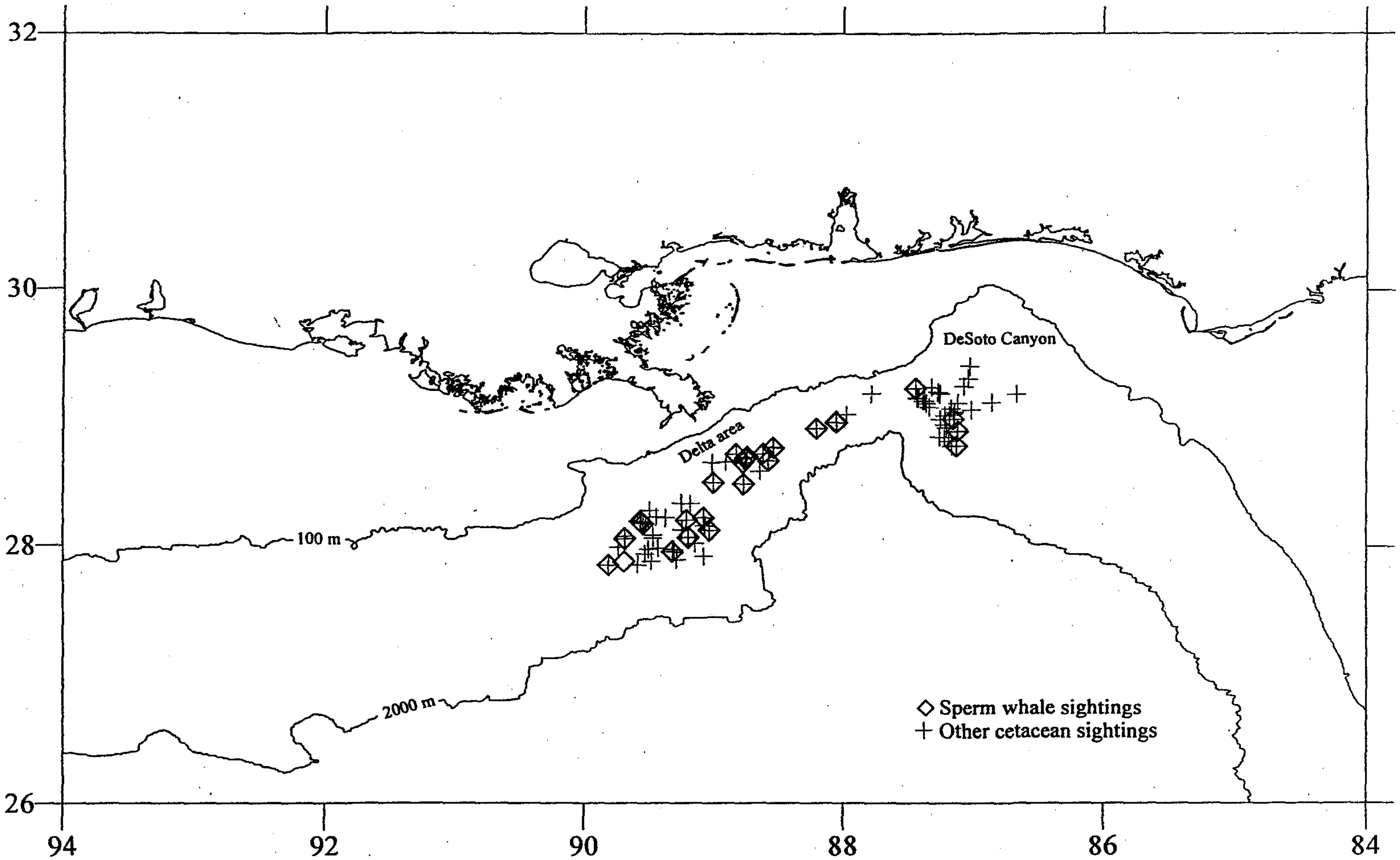


Figure 1. Locations of sperm whale sightings and other cetacean sightings on Cruise GU-009, June 27- July 27, 2000

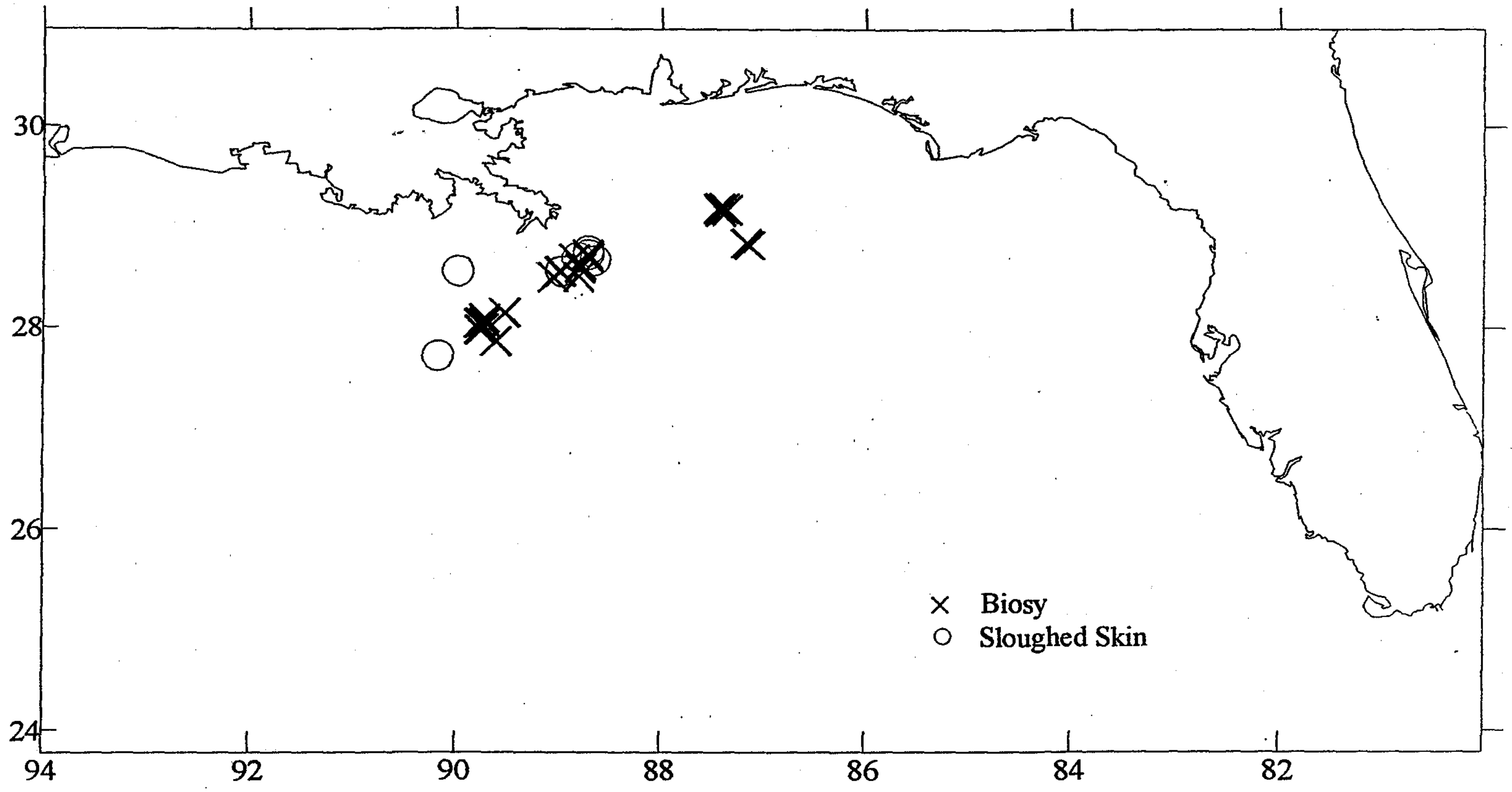


Figure 2. Locations where biopsy samples (n=37) and sloughed skin samples (n=8) were collected on Cruise GU-009, June 27 - July 27, 2000.

Figure 3. Biopsy data form.

PHYSETER BIOPSY SAMPLE DATA FORM

CRUISE: GU - 00 - 004 (09)

SEFSC

PAGE _____ OF _____ *THIS SIGHTING*

SIGHTING #: ____________________ DATE: ______ / ______ / ______ (MONTH / DAY / YEAR)

CLUSTER #: ____________________ TIME: ____________________

PLATFORM: ____________________ LATITUDE: ____________________

LEG: ____________________ LONGITUDE: ____________________

SAMPLE NUMBER: ____________________

TYPE OF SAMPLE: *BIOPSY* *SLOUGHED SKIN* (circle) (other) ____________________

RECORDER: ____________________ SAMPLER: ____________________

DEVICE: *DG* *CB* *PS* *CC* (circle) DART GUN CHARGE LEVEL: *B* *G* *Y* (circle)

SAMPLING HEAD: *F25* *F40* *F60* *G19* *G26* (circle) (other) ____________________

HIT MISS (circle) SAMPLE TAKEN: *YES* *NO* (circle) FULL SAMPLE TAKEN: *YES* *NO* (circle)

ESTIMATED AGE CLASS OF THIS WHALE: *ADULT* *IMMATURE* *CALF* *UNKNOWN* (circle)

OBSERVED SEX: *M* *F* *UNKNOWN* (circle) CONFIRMED SEX: *M* *F* (circle)

CLUSTER COMPOSITION: *NO. OF ADULTS* ________ *NO. OF IMMATURES* ________

NO. OF CALVES ________ *TOTAL NO. IN CLUSTER* ________

PHOTO: 35 MM *ROLL #* ______ *FRAME #* ______ VIDEO: *TAPE I.D.* ______

PHOTO COMMENTS: ____

WHALE I.D. # ________

ADDITIONAL COMMENTS: ____

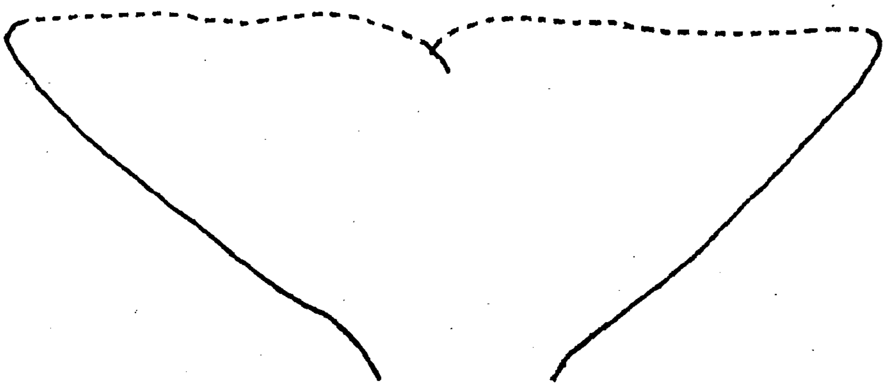
* *BIOPSY RESPONSE SECTION ON REVERSE SIDE*

BIOPSY RESPONSE SECTION

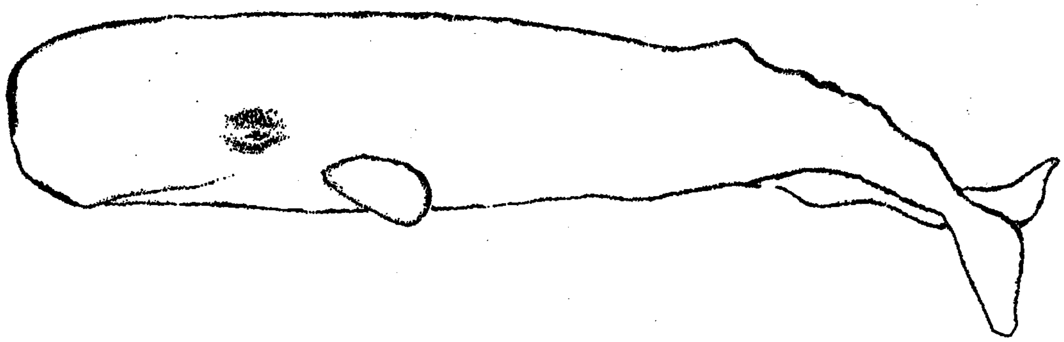
LEVEL OF RESPONSE TO BIOPSY: *LOW* *MEDIUM* *STRONG*
(CIRCLE)

BIOPSY BEHAVIOR RESPONSE CODES:

_____ 1. NO RESPONSE
_____ 2 BREACH
_____ 3 MULTIPLE BREACHES
_____ 4. QUIVER
_____ 5. STARTLE REACTION - *STILL APPROACHABLE*
_____ 6. STARTLE REACTION - *UNAPPROACHABLE*
_____ 7. TAIL SLAP
_____ 8. DEEP DIVE
_____ 9. ROLL - *TURNS ON EITHER SIDE*
_____ 10. DEFECATE
_____ 11. FORCEFUL BREATH - *LOUD EXHALATIONS*
_____ 12. SLIP-UNDER
_____ 13. TAIL SWEEP
_____ 14. CHANGE DIRECTIONS - *SIGNIFICANT CHANGE > 30 DEGREES*
_____ 15. TAIL WAVE
_____ 16. ACCELERATE QUICKLY
_____ 17. HIGH ARCHED BACK
_____ 18. MODERATE ARCHED BACK
_____ 19. HEAD OUT OF WATER
_____ 20. SIDE FLUKES
_____ 21. SINKING RAPIDLY
_____ 22. SNAPPING JAWS
_____ 23. SPY HOPPING
_____ 24. OTHER - *DESCRIBE IN COMMENTS*



MARK AREA HIT



MARK AREA HIT

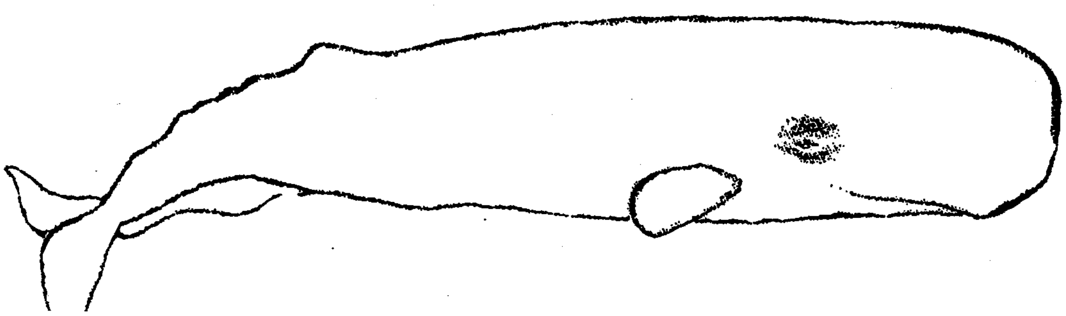


Figure 4. Photo ID data form.

PHYSETER PHOTO ID FORM

DATE: ________/________/________ PAGE: ________ OF ________

SIGHTING #: ________ CLUSTER # ________ PLATFORM: *GUNTER* *(CIRCLE)* *RELENTLESS II* *TIME IN* ________ *TIME OUT* ________

DRIVER: ________ PHOTOGRAPHER: ________ RECORDER: ________ BIOPSIER: ________

CLUSTER COMP: ________ ARRIVAL TIME AT GROUP: ________ DEPART TIME FROM GROUP: ________

DIRECTION OF MOVEMENT: *N E S W* *(CIRCLE)* DID BOAT CAUSE DISRUPTION OF BEHAVIOR: *Y N* *(CIRCLE)*

BEHAVIOR : *NUMBER BEHAVIORS AS THEY OCCURR.*

______ 1. NO CHANGE IN BEHAVIOR
______ 2 BREACH
______ 3 MULTIPLE BREACHES
______ 4. QUIVER
______ 5. STARTLE REACTION - *STILL APPROACHABLE*
______ 6. STARTLE REACTION - *UNAPPROACHABLE*
______ 7. TAIL SLAP
______ 8. DEEP DIVE
______ 9. ROLL - *TURNS ON EITHER SIDE*
______ 10. FORCEFUL BREATH - LOUD EXHALATIONS
______ 11. CHANGE DIRECTIONS - SIGNIFICANT CHANGE > 30 DEGREES
______ 12. SLIP UNDER
______ 13. TAIL SWEEP
______ 14. DEFECATE
______ 15. TAIL WAVE
______ 16. ACCELERATE QUICKLY
______ 17. HIGH ARCHED BACK
______ 18. MODERATE ARCHED BACK
______ 19. MODERATE ARCHED BACK
______ 20. HEAD OUT OF WATER
______ 21. SIDE FLUKES
______ 22. SNAPPING JAWS
______ 23. SPY HOPPING

TIME	ROLL #	FRAMES	INDIVIDUAL	ASPECT OF WHALE	NOTES

CODES: RT. HUMP (RH), LT. HUMP (LH), BLOWHOLE/DORSAL SHOT (BD), FLUKE (FK)

Figure 5. Sperm whale sighting sheet.

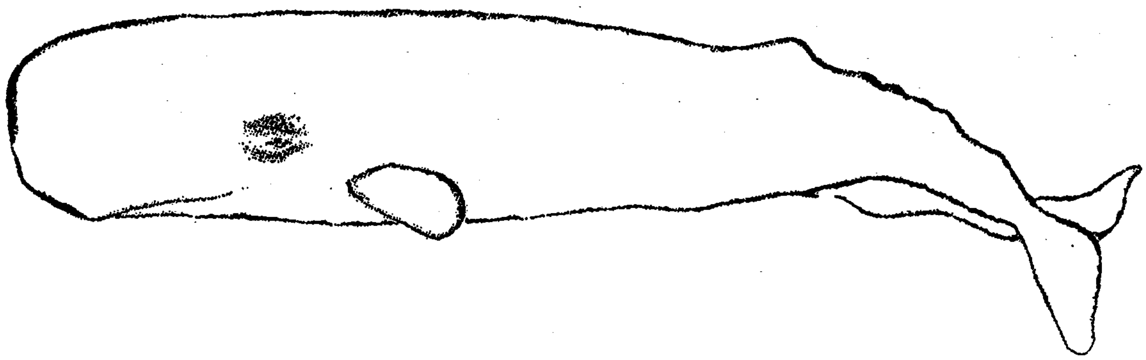
PHYSETER SIGHTING SHEET

CRUISE #: ____________ LEG #: ____________ OBSERVER CODE: ____________

DATE: ____/____/____ SIGHING #: ____________ BIOPSY YES NO

SIGHTING SUMMARY

List and sketch all diagnostic features observed including estimated body length



CALVES YES NO

BEHAVIOR

INITIAL BEHAVIOR ☐

BEHAVIOR CHANGE ☐ Y/N

WITHIN 1000 FEET ☐ Y/N

NEW BEHAVIOR ☐

CODES

00 = UNKNOWN
01 = SLOW TRAVEL
02 = FAST TRAVEL
03 = RAFTING ON THE SURFACE
04 = PHYSICAL CONTACT
05 = MILLING
07 = SPY HOPPING
08 = FEEDING
09 = FLUKE UP
10 = DIVING
11 = BREACH
12 = MULTIPLE BREACHES
13 = TAIL SLAP
14 = FLEEING SHIP
15 = APPROACHING SHIP
16 = TRAVELING SOUTH
17 = TRAVELING NORTH
18 = TRAVELING WEST
19 = TRAVELING EAST
20 = OTHER - SEE COMMENTS

COMMENTS: (*Describe aggregation, movement, blows, etc.*)

Figure 6. Sperm whale behavior ethogram.

SPERM WHALE ETHOGRAM

BEHAVIOR STATE:

LG Logging: whales(s) essentially motionless at the surface with no observable behavior other than breathing.

TR Travel: whales(s) moving in a decernible direction as indicated by forward movement.

ML Milling: more than one whale, whales moving in no discernible direction, whales may not be oriented the same direction, maybe physical contact between whales, if so please note in Sperm Count.

BEHAVIORAL EVENTS:

SR Surfacing: one or more animals surface in an existing cluster, may be very difficult to determine.

FL Fluking Up: raising of the flukes above the water surface at the commencement of a dive.

SL Slip-unders: a submergence without showing any portion of the flukes.

BR Breaching: whale leaps from water, much of the body clears the water.

TS Tail Slap/ Lobtailing: smashing the flukes down flat onto the water, count the number of tail slaps that occur.

RL Rolling: whale(s) rotates on the head to caudal axis.

SW Tail Sweep: while at the surface whale sweeps its flukes back and forth through the water.

TW Tail Wave: whale positions tail up in air and moves it back and forth without hitting the water.

AB Arched Back: whales pitches its body forward, lowering head, raising its back.

HO Head Out: whale raises its head out of the water but the eyes does not clear the water.

SH Spy Hopping: whale lifts its head out of water and eye clears the water's surface.

SF Side Flukes: when only a part of a fluke is seen above the water.

JS Jaw Snap whale opens mouth and snaps jaws shut.

PC Physical Contact: when two whales make physical contact.

UK Unkown observer can not see or can not tell what the whales were doing.

CLUSTER SEPARATES: whales in a cluster move apart forming two separate clusters, they would be given two separate letters and a comment (C) added that A becomes B & C.

CLUSTERS JOIN: if whales in two different clusters come together to form one cluster they would be given a new letter and a comment (C) added that A & B becomes C.

If you lose a cluster, please note in ***Sperm Count****. When the session ends please note why it ended, i.e. 90 minutes were up, cluster was lost, ship moving on etc.*

ENTERING DATA IN SPERM COUNT

Begin with Cluster Letter
Number of adult whales
Number of Calves (C)
Behavior State
Orientation
Therefore Cluster A: with 4 adults 2 calves, logging, heading North would look like:
A: 4, 2C, LG, N
If one more joined you would add 1 SR
A: 4, 2C, LG, N, 1 SR
The next time you update the sighting change the 4 to a 5
A: 5, 2C, LG, N
If two fluked up,
A:5, 2C, LG, N, 2 FL
Again the next time you update the sighting change the 5 to a 3
And if the rest fluke up,
A: 3, 2C, N, ALL FL

Record aerial behavior under C comments:
A: breach x 4
Record Behavior Condfidence rating under C comments at the beginnin of the session and adjust as needed:
A: 1, B: 2, C: 3

SPERM WHALE BEHAVIOR

Protocol for giving behavior information to the recorder

1. Cluster Letter
2. Number of Adults
3. Number of Calves
4. Behavior State
5. Orientation of Whales

Clusters for Sperm Count will be defined as whales that are within two body lengths of each other.

BEHAVIOR STATES

Logging (*LG*) whale(s) essentially motionless at the surface with no observable behavior other than breathing.

Travel (*TR*) whale(s) moving in a discernible direction as indicated by forward movement.

Milling (*ML*) more than one whale, moving in no discernible direction, whales may not be orientated in the same direction, maybe physical contact between whales.

Unknown (*UK*) can not see or can not tell what the whales are doing.

BEHAVIOR EVENTS

Each time the following events occur inform the recorder.

Fluke UP (*FL*) raising of the flukes above the water surface at the commencement of a dive.

Slip Under (*SL*) a submergence without showing any portion of the flukes.

Breaching (*BR*) whale leaps from water, much of the body clears the water. Count the number of times.

Tail Slap/ Lob Tailing (*TS*) smashing the flukes down flat onto the water, count the number of tail slaps that occur.

Tail Sweep (SW) while at the surface whale sweeps its flukes back and forth through the water.

Tail Wave (*TW*) whale positions tail up in the air and moves it back and forth without hitting the water.

Spy Hopping (*SH*) whale lifts its head out of the water and eye clears the water surface.

Physical Contact (*PC*) when two whales make physical contact.

Inform the recorder if:

1. A new whale surfaces in or joins a cluster.
2. Two clusters join (give the recorder the two letters).
3. A cluster separates (this may not always be obvious).
4. A cluster is lost and the time when it was last seen.

Please update your cluster every five minutes even if they do not appear to be moving.

Behavior Confidence Ratings:

Codes	Definition
1	Excellent behavioral data (confident you are missing none).
2	Maybe missing 10% of behavior, usually due to distance or enviromental conditions.
3	Maybe missing 25% of behavior, due to distance or environmental conditions.
4	Only very obvious behaviors.
5	No behavior data.