SOUTHWEST FISHERIES CENTER

NATIONAL MARINE FISHERIES SERVICE SOUTHWEST FISHERIES SCIENCE CENTER P.O. BOX 271 LA JOLLA, CA 92038

AUGUST 1990

BIOACOUSTICS OF ODONTOCETES IN THE ETP: PROJECT DESCRIPTION, PRELIMINARY RESULTS, AND RECOMMENDATIONS FOR FUTURE WORK

By

Aleta A. Hohn and Scott R. Benson

ADMINISTRATIVE REPORT LJ-90-23

This Administrative Report is issued as an informal document to ensure prompt dissemination of preliminary results, interim reports and special studies. We recommend that it not be abstracted or cited.

BIOACOUSTICS OF ODONTOCETES IN THE ETP: PROJECT DESCRIPTION, PRELIMINARY RESULTS, AND RECOMMENDATIONS FOR FUTURE WORK

by

ALETA A. HOHN and SCOTT R. BENSON

Southwest Fisheries Science Center
National Marine Fisheries Service
P.O. Box 271
La Jolla, CA 92038

August 1990

ADMINISTRATIVE REPORT LJ-90-23

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

BIOACOUSTICS OF ODONTOCETES IN THE ETP: PROJECT DESCRIPTION, PRELIMINARY RESULTS, AND RECOMMENDATIONS FOR FUTURE WORK

by

Aleta A. Hohn and Scott R. Benson

ABSTRACT

Bioacoustics may be a useful tool for differentiating stocks of dolphins in the eastern tropical Pacific Ocean (ETP). A sonobuoy-receiver-recorder system was set up aboard the *R/V David Starr Jordan* in 1988 for the purpose of recording dolphin whistles during the Monitoring of Porpoise Stocks (MOPS) surveys. During MOPS '89, whistles were successfully recorded from three species of pelagic dolphins: pantropical spotted dolphin (*Stenella attenuata*), striped dolphin (*Stenella coeruleoalba*) and common dolphin (*Delphinus delphis*). The whistles were stored on high-quality video cassette tapes. A preliminary analysis showed the quality of the recordings to be sufficient for describing various attributes of dolphin whistles. The protocol to optimize recordings requires that sonobuoys be deployed on single-species/stock schools (or splinter subgroups) with fewer than 100 animals, when the school is at least two miles (3.2 km) off the stern of the ship, and in calm sea states. In order to use bioacoustics of pantropical spotted dolphins to distinguish stocks, whistles still need to be collected from specific geographic regions. It is recommended that recordings also be made of other odontocetes in the ETP, especially common dolphins and killer whales.

INTRODUCTION

STOCKS OF SPINNER, COMMON, AND SPOTTED DOLPHINS IN THE ETP

The waters of the eastern tropical Pacific Ocean (ETP) cover a vast expanse, encompassing a surface area equivalent to that of the United States. In this region, the tuna/dolphin association is used by tuna fishermen to efficiently locate and catch yellowfin tuna (Perrin 1969). The association, and, hence, incidental mortality, primarily involves three species of dolphins: spotted (*Stenella attenuata*), spinner (*S. longirostris*), and common (*Delphinus delphis*). Since the late 1970's, spotted dolphins have been the principal target of the tuna industry because of the limitations (quotas) imposed on the incidental kill of spinner dolphins, a species previously heavily exploited (Smith 1983, Hall and Boyer 1990 and previous years). In the mid- to late 1980's, the incidental mortality of common dolphins increased (Hall and Boyer 1990).

Dolphin populations subjected to incidental mortality due to purse-seine fishing by the international fleet are managed unilaterally by the United States by a quota system for U.S. vessels which is set, where possible, at the stock rather than at the species level. Three forms of spinner dolphin are recognized: a long, slender coastal form (Central American spinners, *S. longirostris centroamericanus*), the eastern form (*S. l. orientalis*), and the whitebelly form, a hybrid between *S. l. longirostris*, the pantropical form, and *S. l. orientalis* (Perrin, Scott, Walker, and Cass 1985, Perrin 1990). These forms are morphologically distinct, at least modally, in a number of characters and are managed independently of one another as separate stocks. In addition, for management purposes, the whitebelly form is further divided into two stocks: the northern whitebelly and the southern whitebelly, although more recent morphological data have suggested that this division may no longer be justified (Perrin, Akin, and Kashiwada, in prep.).

Common dolphins in the ETP also occur in more than one stock (Perrin *et al.* 1985). Off the coast of Baja California, two stocks, the Baja Neritic and northern stocks, are sympatric or parapatric and can be differentiated easily from specimens in hand and by careful observation at sea. The geographic distribution of common dolphins south of Baja (excluding a possible Guerrero stock) is notable because the dolphins cluster in relatively discrete areas (Au and Perryman 1985, Perrin *et al.* 1985, Reilly 1990). These groupings form natural management units, the northern, central, and southern stocks.

Spotted dolphins are distributed throughout much of the ETP, although not uniformly (Perrin, Scott, Walker, Ralston, and Au 1983). They comprise more than one stock (see review by Perrin *et al.* 1985), not surprising given their wide geographic distribution. Perrin (1975) identified a coastal form of spotted dolphin (*S. attenuata graffmani*) that is distinct from the offshore form. This finding was corroborated by Douglas, Schnell, and Hough (1984). Perrin, Sloan, and Henderson (1979) showed that spotted dolphins south of the equator are modally different in a number of characters from offshore spotted dolphins north of the equator and suggested that the "southern offshore spotted dolphin" be recognized as a separate stock. Hohn and Hammond (1985) found differences in reproductive seasonality within the northern offshore stock of spotted dolphins, indicating that spotted dolphins in the far offshore (more or less west of 120°W longitude) and southern range of the northern offshore area (south of 5°N latitude) may form groups separate from those eastward and northward.

Three stocks of spotted dolphins are currently recognized: coastal, northern offshore, and southern offshore (Perrin *et al.* 1985). Each stock is assigned a quota for maximum allowable incidental mortality, with the northern offshore stock having the largest quota of any stock or species. The possibility of the existence of more than one stock within the currently defined northern offshore area (per Hohn and Hammond 1985) has implications for management of this species, currently taken in the greatest numbers by the tuna fleet.

The Use of Bioacoustics to Differentiate Stocks

The bioacoustics project was initiated to determine the feasibility of using differences in acoustic patterns as a means of discriminating possible stocks of spotted dolphins in the northern offshore range. Previous recordings of spotted and spinner dolphins in the ETP have shown these dolphins to be vocal and to exhibit whistle patterns that are species-specific or at least different from whistle patterns of other species recorded in the ETP (Thomas, Fisher, Ferm, and Holt 1986). Moore (1990) found differences in whistle patterns between the pantropical spotted dolphin, *S. attenuata*, in the ETP and the Atlantic spotted dolphin, *S. frontalis*.

In the North Atlantic, whistles from five species of delphinids, bottlenose dolphin (*Tursiops truncatus*), Atlantic whited-sided dolphin (*Lagenorhynchus acutus*), Atlantic spotted dolphin, spinner dolphin (*S. longirostris*), and short-finned pilot whale (*Globicephala melaena*) were found to have species-specific characteristics (Steiner 1981). In addition, the degree of difference between species correlated with the taxonomic and zoogeographic relations of the species. The whistle parameters of congeneric species were more similar than species of different genera and whistles from sympatric species showed greater differences than those from allopatric species.

In captivity, spotted, common, Pacific white-sided (*L. obliquidens*), and bottlenose dolphins produce individually characteristic and recognizable whistles known as "signatures" (Caldwell and Caldwell, 1965, 1968; Caldwell, Caldwell, and Miller, 1973), as do free-ranging bottlenose dolphins (Sayigh, Tyack, Wells, and Scott 1990) and possibly free-ranging Atlantic spotted dolphins (Moore 1990). Conversely, Moore and Ridgway (in prep.) found that two captive common dolphins shared a repertoire of whistle types rather than having individual signatures.

There is some evidence that whistles are learned (Caldwell and Caldwell 1972, Richards, Wolz, and Herman 1984, Tyack 1986, Sayigh *et al.* 1990) and that dolphins can recognize other individuals, even those of different species, by their whistles (Caldwell, Caldwell, and Hall 1973). It has been suggested that similarities in whistles within a school or pod serve to identify members of the pod and maintain the cohesion of the group (Ford and Fisher 1983, Thomas, Fisher, and Awbrey 1986). Tyack (1986) has also suggested that dolphins mimic the signature whistles of other dolphins, possibly as a preface to social interaction.

Geographic variation in pulsed calls has been shown in killer whales, *Orcinus orca* (Awbrey, Thomas, Evans, and Leatherwood 1982, Ford and Fisher 1982, 1983, Moore, Francine, Bowles, and Ford 1988). Call variation has also been documented for sympatric pods of killer whales, where each pod has its own "dialect" and the extent of vocal differences between pods is related to the degree of their association (Ford and Fisher 1982). Similar variation in calls between pods is suspected for short-finned pilot whales, *G. macrorhynchus* (Evans, Thomas, and Kent 1984). Geographic variation in calls likely reflects discrete breeding populations (Ford and Fisher 1982, Payne and Guinee 1983, Thomas, Fisher, and Awbrey 1986).

In a preliminary study of whistles in ETP spotted dolphins, Moore (1990) was unable to detect differences between the coastal and offshore forms. The recordings made from the coastal animals were of high quality, allowing the resolution of clearly distinguishable individual whistles. The recordings made from the offshore animals were affected by poor signal/noise ratios, too many individuals in the recordings, and the presence of spinner dolphins possibly contaminating the whistles of the spotted dolphins. These factors made it difficult to obtain a good sample of individual whistles from offshore spotted dolphins. Detecting differences in whistle patterns requires that the conditions for recording are optimal.

BIOACOUSTICS AS AN ANCILLARY PROJECT ON MOPS CRUISES

The 5-yr MOPS (Monitoring of Porpoise Stocks) cruises (1986-1991), designed to cover the geographic range of dolphins species taken incidentally during tuna purse-seine fishing (Holt, Gerrodette, and Cologne 1987), provided a platform for recording whistles from dolphins in the ETP. Recordings of most odontocete species that occur in the ETP are of biological interest. Such recordings can be made opportunistically, regardless of geographic location, if environmental conditions are good and there is little interference with other operations.

The focus of the study, however, has been the northern offshore spotted dolphin. Because of the geographic distribution of spotted dolphins in the ETP (Figs. 1-2) and the need to record from possibly isolated groups, specific areas for recordings have been defined, on the basis of the results of Hohn and Hammond (1985), and superimposed on the planned cruise tracks for the *R/V David Starr Jordan* (Fig. 3). These areas are west of 120°W longitude, south of 5°N latitude, and an inside area loosely defined as between 95-110°W longitude and north of 7°N latitude. In addition, it should be possible to take advantage of opportunities to record whistles from the southern offshore and coastal stocks.

During MOPS '88, the first year of the bioacoustics project, sonobuoys were deployed opportunistically, i.e., without dedicated ship or helicopter time, and with less-than-optimal equipment. Although the recordings obtained with this approach were inadequate for analyzing whistle patterns, the project was determined to be logistically feasible. During MOPS '89, helicopter and ship time were dedicated to deploying sonobuoys and recording whistles from dolphin schools. An improved sonobuoy-receiver-recorder system obtained high-quality recordings for three species.

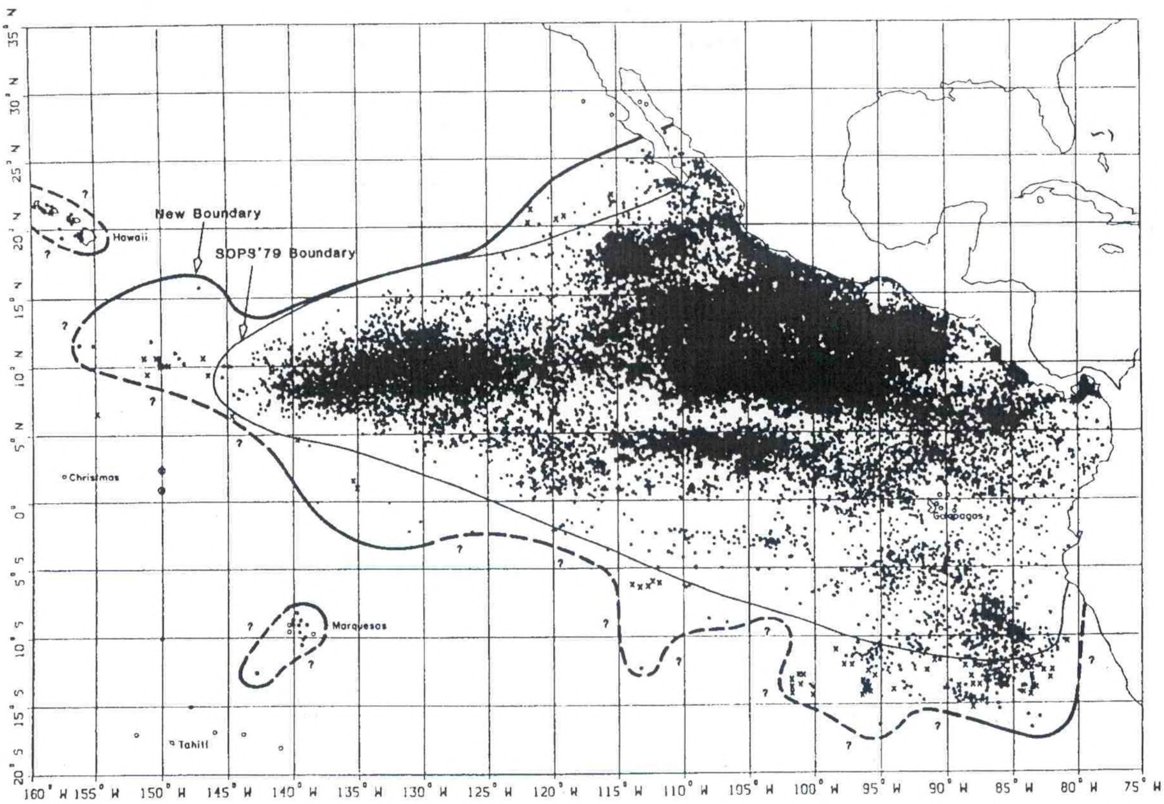
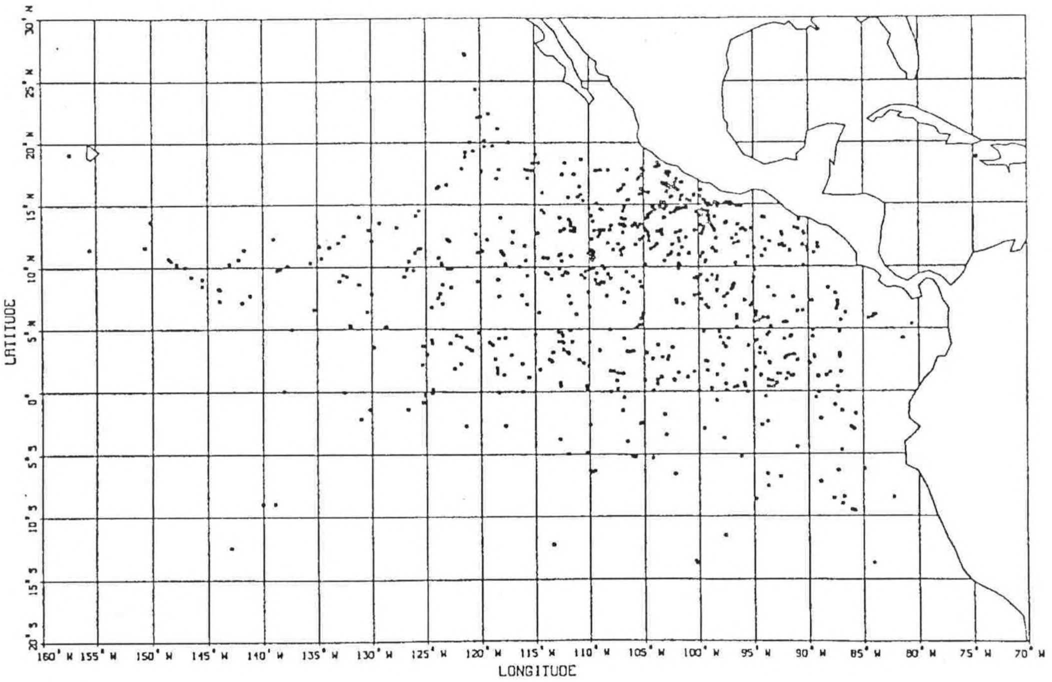


Figure 1. Distribution of spotted dolphins from approximately 30,000 sightings from tuna and research vessels, 1966 through part of 1983. The plot is Fig. 4 from Perrin *et al.* (1983) with the following caption: "Known distribution of *S. attenuata* in the eastern Pacific. Dashed portions of new boundaries are adjacent to areas of no recorded sighting effort. Dots are confirmed records, X's are 'probable' records, and circles X's are 'possible' records (see text)."

THE SONOBUOY-RECEIVER-RECORDER SYSTEM

Dolphin whistles have been recorded with a system that uses sonobuoys to detect and transmit whistles to a receiver which, in turn, is connected to a recorder so that the transmissions can be stored on magnetic tape. Standard sonobuoys, containing a hydrophone, signal conditioning and amplification electronics, VHF transmitter, and battery, are deployed predominantly from the air at an altitude above 300 ft (91.4 m). Upon impact with the sea surface, the sonobuoy antenna and hydrophone are released and the salt-water battery is activated (Fig. 4). The hydrophone descends to a predetermined depth in the water column. Sonobuoys allow a choice of depth, with each sonobuoy type providing pre-set options, e.g., 60 ft (18.3 m) or 400 ft (122 m) on type 57A (60 or 300 ft on earlier versions). The setting must be made before the sonobuoy is deployed. Internal deactivation and scuttling



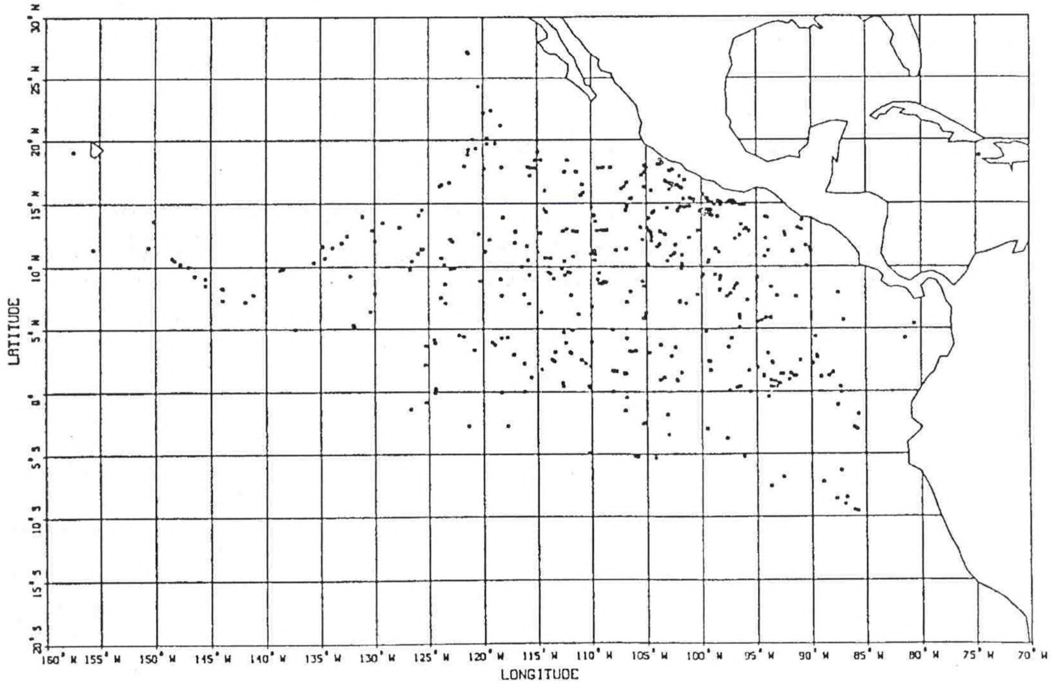


Figure 2. Distribution of spotted dolphins from sightings on research vessels, 1974-1988. The upper plot shows sightings made throughout the year. The lower plot shows sightings from July through December, the months during which the MOPS survey is being conducted.

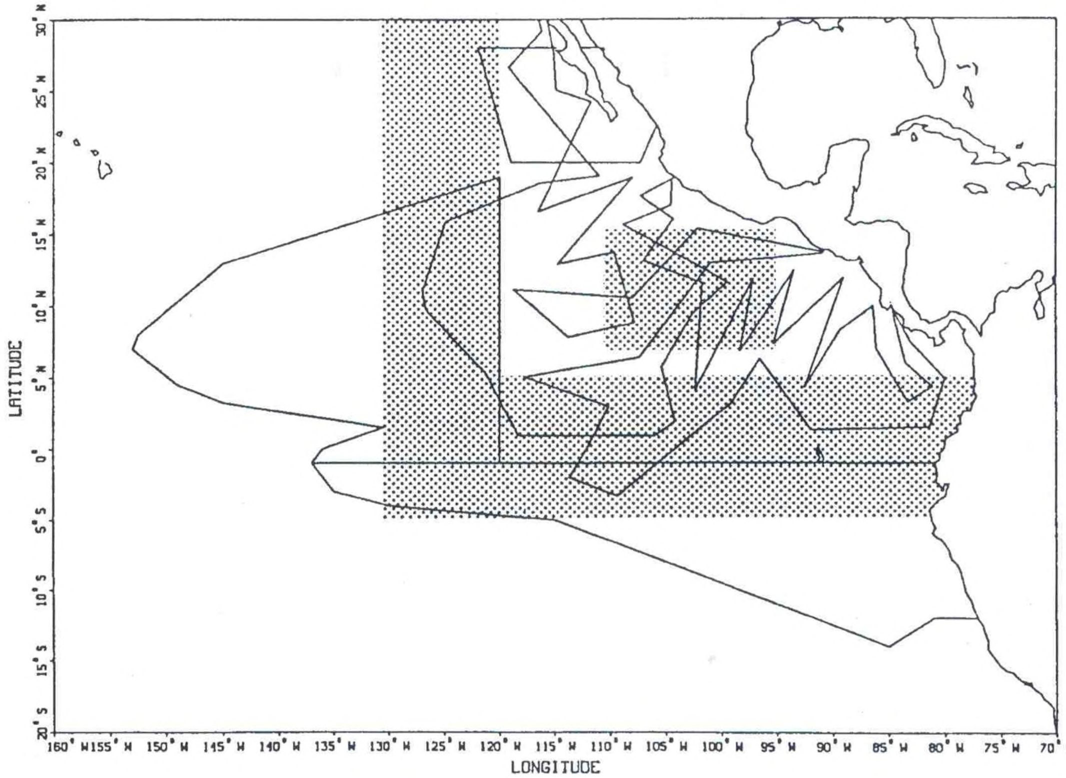


Figure 3. Preferred areas (stippled regions) for deployment of sonobuoys for recording whistles of spotted dolphins. These areas are superimposed on the cruise tracks for the *David Starr Jordan* during MOPS '90 (taken from cruise announcement for cruise DS-90-06 by S. Hill and T. Gerrodette).

mechanisms are also activated upon contact with seawater. A timer deactivates the transmitter. The time before deactivation must be set, e.g., 1 hr, 3 hr, or 8 hr, before deployment. The scuttling feature functions via a corrodible plug. This feature eliminates the need to retrieve the sonobuoy. Within about five minutes or less, a functioning sonobuoy will begin transmitting.

Sounds received at the sonobuoy hydrophone are converted to a VHF radio signal and, for the system set up on the *D. S. Jordan*, transmitted to an omni-directional antenna externally mounted on the mast of the ship and connected to a receiver. The receiver is set to correspond to the channel of the sonobuoy. Each sonobuoy channel corresponds to a specific frequency (Appendix 1). For some types of receivers, the frequency rather than the sonobuoy channel must be set. The sonobuoys have a response that increases linearly with frequency from 10Hz to about 2kHz, and a relatively flat response from a few kHz to about 15 kHz. The type 57A sonobuoys have a specified frequency response from about 10Hz to 15kHz $\pm$ 2dB (Fig. 5), so that distortion within this range can be minimized (Allman, Frisch, and Markland 1987). Most dolphin whistles occur within this range, although some occur at greater than 20kHz. These higher frequency whistles will not be accurately transmitted.

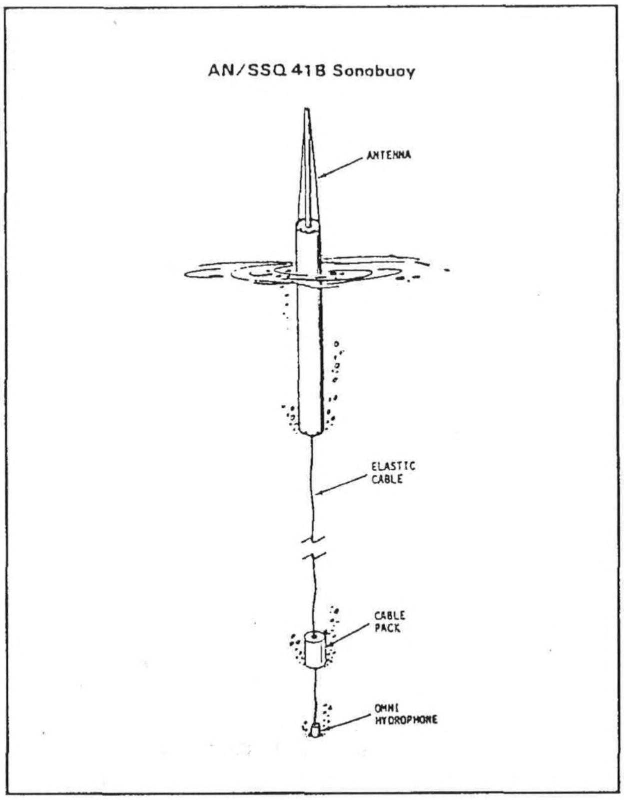


Figure 4. Schematic diagram of a deployed sonobuoy.

The step-by-step protocol for operating the equipment in the sonobuoy-receiver-recorder system is provided in Appendix 2.

SITUATIONS APPROPRIATE FOR THE DEPLOYMENT OF SONOBUOYS

Analysis of previous recordings of dolphins in the ETP (Moore 1990) and experience with sonobuoys (S. Moore, pers. comm.) indicated that certain situations are better than others for obtaining good-quality recordings. Sonobuoys deployed too close to the ship will transmit noise from the ship that may mask whistles from dolphins. High sea states will also introduce noise that may mask the desired signal. The depth of the thermocline must be greater than the depth to which the hydrophone will descend because the thermocline is an effective barrier to whistle transmission and reception. Sonobuoys deployed too close to a school will limit recording time because dolphin whistles are directed forward and, therefore, will not be detected by the sonobuoy once the school passes. Recordings from large schools may result in whistles from too many animals preventing discrimination of individual whistles. Recordings from pure schools of a stock or species are necessary as the whistle patterns of each species/stock have not yet been resolved.

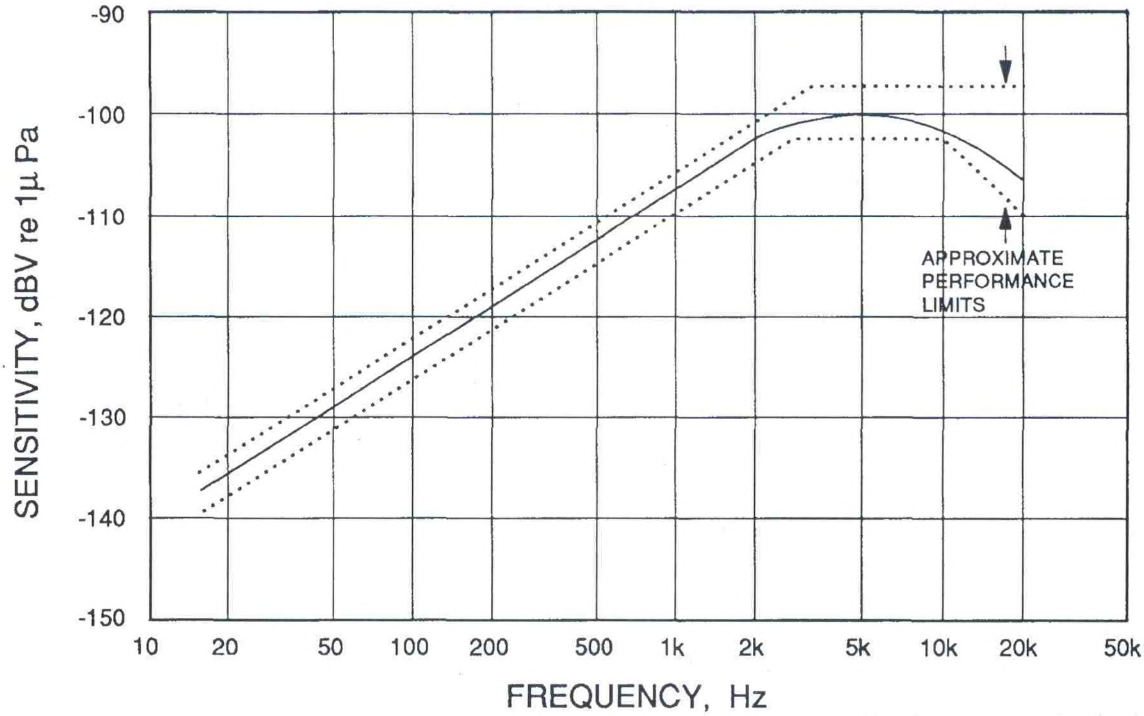


Figure 5. Typical system response: AN/SSQ-57A sonobuoy (with gain configuration) with AN/PRR-57 receiver (from Allman et al. 1987).

METHODS

Sonobuoys were deployed during MOPS '88 and '89. During MOPS '88, two sonobuoys were deployed: one from a skiff to test the equipment and the other from the helicopter in an attempt to obtain recordings from a school of common dolphins. A general-purpose dial receiver (Defense Electronics, Inc., model GPR-22) was used and the output from the receiver was recorded on an Uher[1] 4200 report monitor reel-to-reel recorder operated at a speed of 7.5 in/sec (19 cm/sec), giving a frequency response of 20 Hz - 25 kHz.

During MOPS '89, six sonobuoys (model AN/SSQ-57A) were deployed to evaluate the relative success of various methods of collecting dolphin whistles. Five sonobuoys were dropped from a helicopter by the photogrammetry team ("photogrammetrists") and one was deployed from the deck of the *D. S. Jordan*. Due to poor success experienced with the receiver used in 1988, in 1989 we switched to a four-channel (standard military) sonobuoy

---

[1]Use of brand names or models does not imply endorsement by the National Marine Fisheries Service.

receiver (model AN/ARR52A). The sonobuoys were monitored for as long as they remained within transmission range (ca. 5-7 km). The Uher recorder was used at the beginning of MOPS '89, but at-sea failure of the Uher during the first leg and the time required for repair led us to try recording on a RCA VR 625 HF[1] high-quality video recorder.

Data such as the type of sonobuoy, depth of hydrophone, date, time, and location of deployment and recording, environmental conditions, and characteristics of the school were recorded on a data form (Fig. 6). In addition, a microphone was connected to a separate channel of the recorder to add comments about the behavior and characteristics of the school or sub-group being recorded. Optimal deployment of the sonobuoys at a distance from the ship (see below), however, generally prevented visual observations from the ship. The photogrammetrists were usually depended upon to write comments concerning the school's (or subgroup's) behavior, size, and species composition.

A preliminary analysis of the whistles recorded during MOPS '89 was conducted at the Hubbs Marine Research Center (San Diego, CA). Whistles were analyzed in real time on a UNISCAN II digital sonograph set at 20-kHz bandwidth. Selected dolphin whistles were printed for documentation of sonogram quality and frequency range of the shipboard bioacoustics equipment.

RESULTS

Usable recordings were not obtained during MOPS '88 due to a poorly functioning receiver. In addition, few sonobuoys were deployed.

The change in receivers for MOPS '89 resulted in successful reception of transmissions. Recording equipment failure during the first leg of MOPS '89 prevented recording until the last leg, when the VCR was used to make recordings. The system response seemed to be limited by the sonobuoys (rather than the VCR) as whistle frequencies of over 20 kHz were recorded. The highest frequency whistles, at 24.96 kHz, were recorded from spotted dolphins.

Two schools each of spotted, common, and striped dolphins were recorded. For each of the sonobuoys deployed during MOPS '89, the situations in which the sonobuoys were deployed, the characteristics of the schools of dolphins, and the quality of the resulting recordings are described below (and summarized in Table 1):

1) The first sonobuoy was deployed from the helicopter in a sea state of Beaufort 2-3 approximately two miles (3.2 km) to the stern of the ship and about one mile (1.6 km) in front of a group of 50-60 **striped dolphins**. The group of dolphins was composed of

DOLPHIN BIOACOUSTICS STUDY
DATA FORM

Observer Name ______________________ Date ______________

SONOBUOY DATA

Sonobuoy Type ____________ Sonobuoy Depth ____________

Sonobuoy Channel ____________ Time Sonobuoy Deployed ____________

RECEIVER DATA

Receiver Channel ____________ Receiver Frequency ____________

RECORDER DATA

Gain Setting ____________ Time Recording Begins ____________

Tape No. ____________ Time Recording Ends ____________

SIGHTINGS/ENVIRONMENTAL DATA

Species/Stock ____________ Latitude ____________

Sighting No. ____________ Longitude ____________

Group Size* ____________ Sea State ____________

*Number of animals in group/subgroup recorded

OBSERVATIONS

(Document whether the whole school or a subgroup was recorded, behavior relative to the sonobuoys, or other interesting observations)

Figure 6. Data form used during MOPS '89.

Table 1. Summary of sonobuoy deployment on dolphin schools and results of recordings during MOPS '89. Sea state in on the Beaufort scale. 'Min.' refers to the number of minutes of recordings made without the interference of ship noise or too many animals in the group or sub-group being recorded, with '-' indicating that whistles of sufficient quality for stock comparisons were not recorded.

Species	Date	Position	Sea State	Group Size	Min.	Comments
Stenella coeruleoalba	11/04/89	13°21'N 107°54'W	2-3	40-50	35	Sub-group of 15-20 animals recorded, fair quality recordings but few whistles.
Stenella attenuata	11/04/89	12°53'N 108°17'W	2-3	60-70	58	Sub-group of 10-15 animals milling close to buoy. High quality for first 38 minutes before becoming intermittent. 23 sonograms printed.
Stenella attenuata	11/10/89	09°47'N 100°42'W	1-2	180	4	Sonobuoy dropped behind animals, recording brief - 9 whistles recorded. Five sonograms printed.
Stenella coeruleoalba	11/28/89	18°22'N 108°24'W	3	20-35	40	High-quality recordings from a very vocal group. Best recording during 1989. Dolphins were located 4.5 miles (7.2 km) off starboard beam and were not approached by the vessel.
Delphinus delphis	12/04/89	24°58'N 113°24'W	3	600	-	Sonobuoy deployed off the deck of the ship. Propeller noise and overlapping whistles from many animals provided continual interference.
Delphinus delphis	12/06/89	30°55'N 116°32'W	1	550	-	Large number of animals producing overlapping whistles.

several cohesive sub-groups and spread out over a 500 m² area (i.e., it was loosely aggregated). The photogrammetrists in the helicopter reported that a sub-group of 15-20 animals passed within a ½ mile (0.8 km) of the sonobuoy. A 62-minute recording resulted. The first 10-15 minutes of this recording are dominated by propeller noise and during the final 10 minutes the signal began to fade. During the remaining approximately 35 minutes, recordings of whistles of sufficient quality for evaluation were made. This group of striped dolphins was not particularly vocal, however, so there were few whistles. One sonogram was printed for documentation (Fig. 7).

2) The second sonobuoy was dropped about two miles (3.2 km) to the stern of the ship in a sea state of Beaufort 2-3, about ½ mile (0.8 km) in front of a loosely aggregated group of 70-80 **spotted dolphins**. The photogrammetrists reported that although the dolphins

initially turned away from the buoy for a brief period, a sub-group of 40-45 animals eventually stopped and milled within ¼ mile (0.4 km) of the device. A 62-minute recording was made. High-quality recordings of whistles were made from this group of spotted dolphins almost immediately after the sonobuoy was deployed. Strong whistle signals were received for 38 minutes before becoming somewhat intermittent and finally fading completely as the ship moved away from the sonobuoy. Overall, complete and well-defined whistles were recorded: 23 sonograms were printed for documentation (Fig. 7).

3) The third sonobuoy was deployed in a sea state of Beaufort 1-2 approximately 2-3 miles (3.2-4.8 km) from the ship at an angle of 145° relative to the bow on a loosely aggregated group of 180-200 **spotted dolphins**. Unfortunately, the buoy was dropped behind the targeted sub-group as they ran away from the ship. Although some bottlenose dolphins were originally seen in the vicinity, the photogrammetrists reported that they split off early and were not seen running with the spotted dolphins. A 26-minute recording was made. Despite the placement of the sonobuoy behind the spotted dolphins, nine clear, distinct whistles were received during a four minute period. Propeller noise and other outside interference were less prevalent in this recording relative to previous sessions, suggesting that increasing the distance between the sonobuoy and the ship to at least 2 miles (3.2 km) decreases propeller and machinery noise interference by the ship.

4) The fourth recording was made on a loosely aggregated group of 20-30 **striped dolphins** in a sea state of Beaufort 3. The sonobuoy was deployed ½ mile (0.8 km) in front of the animals, about 4½ miles (7.2 km) off the starboard beam of the ship. The group was not approached by the ship. The photogrammetrists reported seeing milling and occasional high leaping behavior. A 56-minute recording was made. This recording was the best of the six. Excellent whistles were received for 40 minutes from a very vocal group of animals. A considerable number of whistles was collected. Six sonograms were printed for documentation. Although the signal was occasionally interrupted by radio traffic between the ship and helicopter, no propeller noise interference occurred.

5) The fifth recording was unique in that it was the only instance in which the sonobuoy wasn't deployed via helicopter. The sonobuoy was dropped off the deck of the ship while moving through a moderately cohesive group of approximately 600 **common dolphins** in a sea state of Beaufort 3. Initially, the group appeared to be travelling. Upon our encounter, many approached the ship and rode the bow wave for an extended period. A 57-minute recording was made. Propellor noise and overlapping whistles were prominent features of this recording. Individual whistles (Fig. 7) could be detected 5 minutes into the recording, but intermittent propellor and other ship noise as the ship moved through the group of animals masked most of the whistles. The isolated whistles may have been produced by animals trailing the main group. Five sonograms were printed to illustrate the effects of masking and overlapping whistles (Fig. 8). Although the recording lasted for 57 minutes, the number of usable whistles is low.

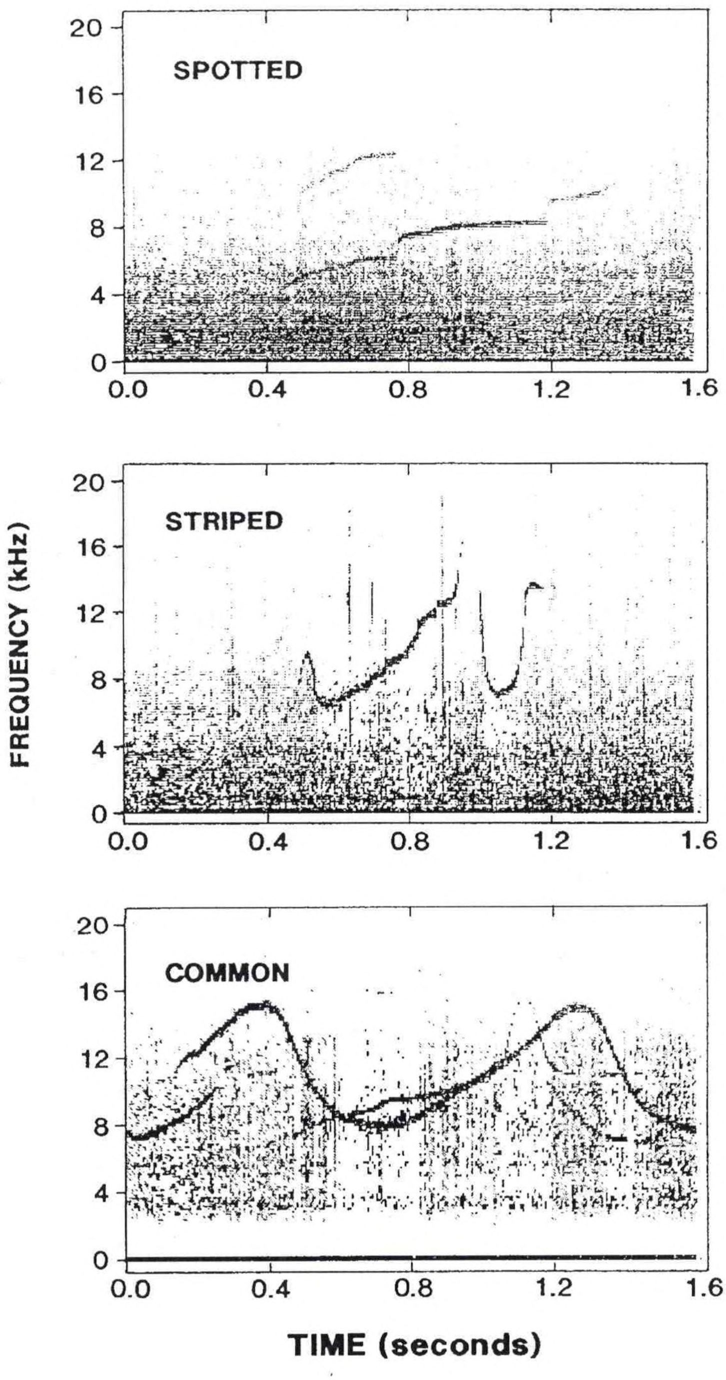


Figure 7. Examples of good-quality sonograms from recordings made during MOPS '89.

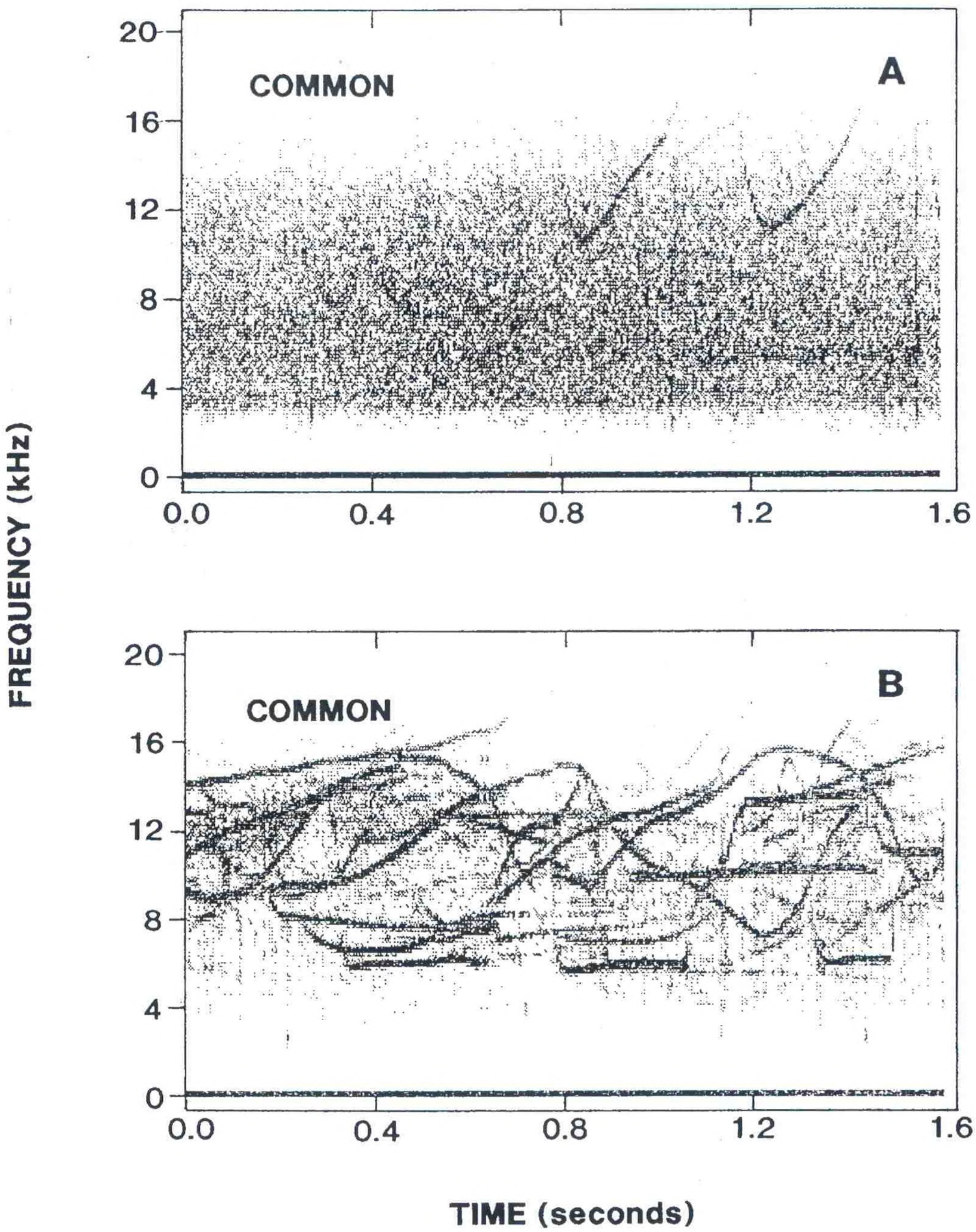


Figure 8. Examples of sonograms from recordings with interference. (A) Common dolphin whistle masked by noise from the ship. Although part of the whistle contour is easily visible, part is obscured. (B) Overlapping whistles from a large number of common dolphins. Individual whistle contours are difficult to discriminate.

6) The sixth sonobuoy was deployed in a sea state of Beaufort 1 approximately 1-1½ miles (1.6-2.4 km) astern of the ship ahead of a cohesive group of 500-600 **common dolphins**. Initially, the large group appeared to be travelling, but upon the approach of both the *D. S. Jordan* and *McArthur*, many animals approached the ships and rode the bow waves for extended periods. The sonobuoy was dropped after the ships had passed through the group to minimize prop noise in the recording. A 46-minute recording was made. Although this buoy was dropped far enough from the ship to prevent interference from ship noise, the large number of individuals in the school made it impossible to discriminate individual whistle contours. About 27 minutes into the recording, the whistles became somewhat isolated but the signal began to fade and the level of static noise increased as the ship moved out of the range of the sonobuoy. Three sonograms were produced to illustrate the effects of overlapping whistles and static noise on the data.

DISCUSSION

The sonobuoy-receiver-recorder system used on the last leg of MOPS '89 was superior to that used during MOPS '88. In 1989, we began using the sonobuoy receiver with good success and are continuing with it in 1990. During the last leg in 1989, we changed recording equipment from the Uher to the VCR and found the VCR to be easier to work while giving high-quality recordings. The primary recorder is now the VCR with the Uher available as a back-up. Given adequate conditions and the opportunity to deploy a sufficient number of sonobuoys, we think that this system is capable of making recordings of dolphin whistles that may be used to differentiate stocks.

Although the situation's and conditions varied greatly, successful recordings were obtained from each of the six sonobuoys deployed during the MOPS '89 survey. The quality of some of the recordings was good enough to evaluate whistle parameters, although too few groups were recorded to begin a comparison of whistle patterns to discriminate stocks. The best recordings were from the smaller aggregations of animals located at least two miles (3.2 km) from the ship. Recordings of large numbers of animals made it difficult to distinguish individual sounds, and noise from the propeller interfered with recordings made closer than two miles (3.2 km) from the ship.

From the results to date, the optimal protocol for recording distinct whistles from individual dolphins seems to be to deploy a sonobuoy 0.5-1.0 miles (0.8-1.6 km) in front of a school of 25-30 animals when the school is 2-5 miles (3.2-8 km) from the ship, preferably off the stern (Fig. 9). Sea state must be less than a low Beaufort 4 and the depth of the thermocline must be greater than the depth to which the hydrophone will descend. The minimum depth of the hydrophone in type 57A sonobuoys (the preferred type in this study) is 60 ft (18.3 m). That depth can be modified by manually shortening the cable and an attempt will be made to do so during MOPS '90. A summary of the situations appropriate for deployment is given in Appendix 3.

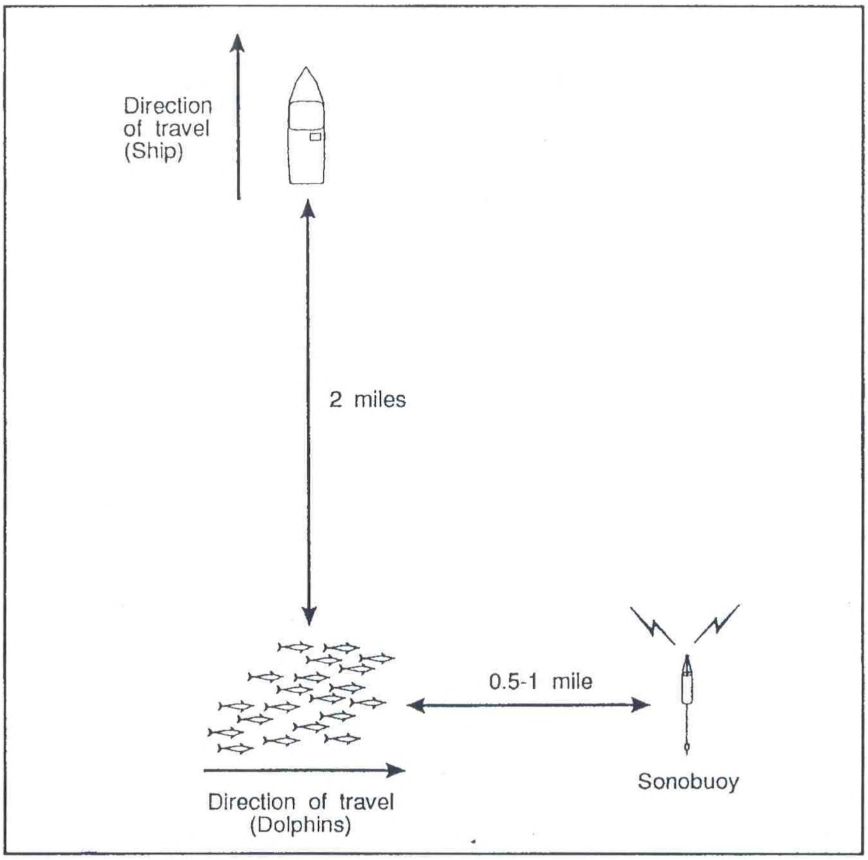


Figure 9. Schematic diagram of optimal deployment of sonobuoys showing the relative positions of the ship, dolphin school, and sonobuoy.

For each of the three species recorded during MOPS '89, the geographic distribution of the schools of each species were too close and the number of successful recordings from each too small to permit us to address the stock issue with the current sample. The plan is to continue making recordings during future MOPS cruises to obtain the necessary sample.

DATA NEEDS FOR SPOTTED DOLPHINS DURING MOPS '90 AND '91

In order to successfully meet the objective of using bioacoustics as a tool for differentiating relatively isolated groups of northern offshore spotted dolphins, 2 hours of high-quality recordings need to be collected from spotted dolphins in each of the three defined areas (see Fig. 3). The following whistles still need to be obtained:

1. Two hours of high-quality recordings west of 120°W longitude.

2. Two hours of high-quality recordings south of 5°N latitude.

3. One and one-half hours of high-quality recordings north of 7°N latitude and between 90-110°W longitude.

Although the proposed tracklines of the *D. S. Jordan* cover all three of these areas to some degree, the western and southern areas receive far less coverage than the "inside" areas. The western area particularly presents problems because the weather is often too rough to allow us to fly the helicopter let alone launch sonobuoys. Without a more pronounced effort in the western and southern regions, it may be impossible to get a large enough sample size to make comparisons with other areas. In contrast, the tracklines that transect the "inside" areas will allow plenty of opportunity for gathering whistles and provide a catalog of whistle repertoires in those areas.

RECOMMENDATIONS FOR FUTURE RECORDING

1. School size and distance from ship

   To lessen the effects of overlapping whistles and propellor and other ship noise, future recordings should be made only when school size, or size of a small splinter group, is less than 100 animals (25-30 animals is preferred). The school should be at least two miles (3.2 km) from the ship, a situation that might best be accomplished by waiting to deploy the buoy until after the school has been photographed and identified and its size estimated. The sonobuoy can be deployed ½-1 mile (0.8-1.6 km) in front of the group after the ship has moved at least two miles (3.2 km) away (illustrated in Figure 9). This may require the photogrammetry team to spend an additional 10-15 minutes with the group before resuming their search for additional animals. Deploying the sonobuoy on a group of animals in front of the ship should be avoided since it limits recording time before propellor noise begins to dominate the recording. Groups of animals that are located far off the beam (3 miles or 4.8 km) and are not approached by the ship provide excellent opportunities for recording calls, assuming that the photogrammetry team is able to accurately identify them as a pure school.

2. Environmental conditions

   Two environmental considerations must be taken into account prior to deploying sonobuoys: thermocline depth and sea state. The thermocline must be below a depth of 60 ft (18.3 m) because the sonobuoy type most appropriate for this bioacoustics work (type 57A) deploys to a minimum depth of 60 ft and whistles above the thermocline will not be detected by a hydrophone below the thermocline. During MOPS '89, sonobuoys will be modified to decrease the minimum depth to one that will allow recording in the shallow thermoclines often encountered in the ETP. Sea state must not be higher than a

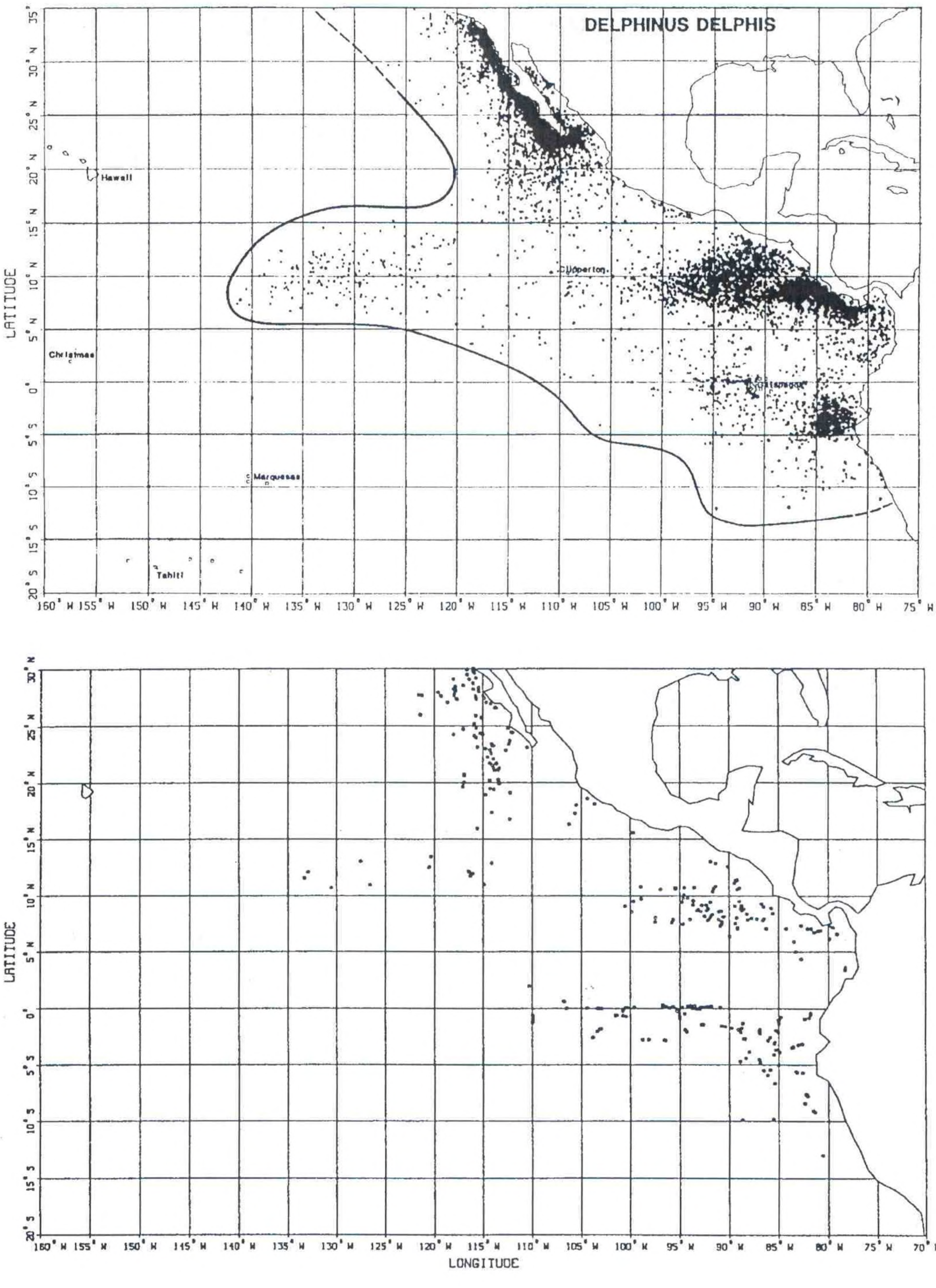


Figure 10. Distribution of common dolphins in the eastern Pacific. Upper plot is a slight modification of Fig. 23 from Perrin *et al.* (1985) and shows approximately 9,000 sightings from tuna and research vessels, 1966 through part of 1983. Lower plot shows the distribution of common dolphins in the eastern Pacific from sightings on research vessels, 1974-1988.

low Beaufort 4 because the ambient noise level becomes too great. Since cloudy or overcast days are generally not useful for photogrammetry work, they may provide excellent opportunities to deploy sonobuoys to minimize potential time conflicts between the two objectives.

3. Collection of whistles from common dolphins

The relatively localized distributions of common dolphins (compared to spotted dolphins) (Fig. 10) make this species valuable for testing whether whistle patterns can be used to distinguish stocks of dolphins. The tracklines of the *D. S. Jordan* adequately cover the distributions of both the northern and central tropical stocks and briefly dip into the southern tropical distribution, south of the equator. We recommend that recordings be made from pure schools from each stock of common dolphin.

4. Vocal repertoires of other odontocetes

There is little documentation of sounds from odontocetes in the ETP. Therefore, virtually all species of animals encountered during the MOPS survey could provide original data. In particular, it is recommended that calls of killer whales (*Orcinus orca*) be collected on an opportunistic basis. These calls could be compared to calls of killer whale from several regions of the world. Calls may provide clues to the abundance, movements, and relationships among populations and reproductively isolated sub-populations.

ACKNOWLEDGEMENTS

S. Moore has provided guidance since the inception of this project. D. DeMaster, SWFSC, helped initiate the study. R. Allman, Naval Ocean Systems Center, loaned us a receiver for MOPS '89 and '90 and has been invaluable in providing sonobuoys. P. Tyack, Woods Hole Oceanographic Institute, provided technical advise when our recorder failed and recommended use of the VCR. A. Jackson, SWFSC, contributed distribution plots of dolphins. Recordings were analyzed at the Acoustic Lab of the Hubbs Marine Research Center under the supervision of J. Francine. We also wish to thank the photogrammetry team of MOPS '88 and '89 for deploying the sonobuoys, and the officers and crew, especially Electronics Technician J. Anthony, of the NOAA ship *David Starr Jordan* for their cooperation. R. Allman, D. DeMaster, T. Gerrodette, S. Moore, W. Perrin, and M. Scott reviewed the report.

LITERATURE CITED

Allman, R.L., W. Frisch, and R. Markland. 1987. Portable bench calibration for sonobuoys. NOSC Tech. Doc. 1147. 18 pp.

Au, D.W.K. and W.L. Perryman. 1985. Dolphin habitats in the eastern tropical Pacific. Fish. Bull. US 83(4):623-643.

Awbrey, F.T., J.A. Thomas, W.E. Evans, and S. Leatherwood. 1982. Ross Sea killer whale vocalizations: preliminary description and comparison with those of some northern hemisphere killer whales. Rep. Int. Whal. Commn 32:667-670.

Caldwell, M.C. and D.K. Caldwell. 1965. Individualized whistle contours in bottlenosed dolphins (*Tursiops truncatus*). Nature 207:434-435.

Caldwell, M.C. and D.K. Caldwell. 1968. Vocalization of naive captive dolphins in small groups. Science 159:1121-1123.

Caldwell, M.C., D.K. Caldwell, and N.R. Hall. 1973. Ability of an Atlantic bottlenosed dolphin (*Tursiops truncatus*) to discriminate between, and potentially identify to individual, the whistles of another species, the common dolphin (*Delphinus delphis*). Cetology 14:1-7.

Caldwell, M.C., D.K. Caldwell, and J. F. Miller. 1973. Statistical evidence for individual signature whistles in the spotted dolphin, *Stenella plagiodon*. Cetology 16:1-21.

Douglas, M.E., G.D. Schnell, and D.J. Hough. 1984. Differentiation between inshore and offshore spotted dolphins in the eastern tropical Pacific Ocean. J. Mamm. 65(3):375-387.

Evans, W.E., J.A. Thomas, and D.K. Kent. 1984. A study of pilot whales (*Globicephala macrorhynchus*) in the southern California bight. NMFS Admin. Rep. LJ-84-38C. 47 pp.

Ford, J.K.B. and H.D. Fisher. 1982. Killer whale (*Orcinus orca*) dialects as an indicator of stocks in British Columbia. Rep. Int. Whal. Commn 32:671-679.

Ford, J.K.B. and H.D. Fisher. 1983. Group-specific dialects of killer whales (*Orcinus orca*) in British Columbia. pp 129-162 *In* R. Payne, ed. Communication and behavior of whales. AAAS Selected Symposium Series 76. Westview Press, Colorado. 543 pp.

Hall, M.A. and S.D. Boyer. 1990. Incidental mortality of dolphins in the tuna purse-seine fishery in the eastern Pacific Ocean during 1988. Rep. Int. whal. Commn 40:461-462.

Hohn, A.A. and P.S. Hammond. 1985. Early postnatal growth of the spotted dolphin, *Stenella attenuata* in the offshore eastern tropical Pacific. Fish. Bull. US 83(4):553-566.

Holt, R.S., R. Gerrodette, and J.B. Cologne. 1987. Research vessel survey design for monitoring dolphin abundance in the eastern tropical Pacific. Fish. Bull. US 85(3):435-446.

Moore, S.E. 1990. Spotted dolphin bioacoustics. NMFS SWFC Admin. Rep. LJ-90-24C. 61 pp.

Moore, S.E., J.K. Francine, A. E. Bowles, and J.K.B. Ford. 1988. Analysis of calls of killer whales, *Orcinus orca*, from Iceland and Norway. J. Mar. Res. Inst. Reykavik 11:225-250.

Moore, S.E. and S.H. Ridgway. in prep. Whistles produced by common dolphins, *Delphinus delphis.*

Payne, R. and L.N. Guinee. 1983. Humpback whales (*Megaptera novaeangliae*) songs as an indicator of "stocks". pp 333-358 *In* R. Payne, ed. Communication and behavior of whales. AAAS Selected Symposium Series 76. Westview Press, Colorado. 643 pp.

Perrin, W.F. 1969. Using porpoise to catch tuna. World Fishing 18(6):42-45.

Perrin, W.F. 1975. Distribution and differentiation of populations of dolphins of the genus *Stenella* in the eastern tropical Pacific. J. Fish. Res. Bd. Can. 32(7):1059-1067.

Perrin, W.F. 1990. Subspecies of *Stenella longirostris* (Mammalia: Cetacea: Delphinidae). Proc. Biol. Soc. Wash. 103(2):453-463.

Perrin, W.F., P.S. Akin, and J.V. Kashiwada. in prep. Geographic variation in external morphology of the spinner dolphin, *Stenella longirostris*, in the eastern Pacific and implications for management.

Perrin, W.F., M.D. Scott, J. Walker, and V. Cass. 1985. Review of geographical stocks of tropical dolphins (*Stenella* spp. and *Delphinus delphis*) in the eastern Pacific. NOAA Technical Rep. NMFS 28. 28 pp.

Perrin, W.F., M.D. Scott, J. Walker, F.M. Ralston, and D.W.K. Au. 1983. Distribution of four dolphins (*Stenella* spp. and *Delphinus delphis*) in the eastern tropical Pacific, with an annotated catalog of data sources. NOAA-TM-NMFS-SWFC-38. 66 pp.

Perrin, W.F., P.A. Sloan, and J.R. Henderson. 1979. Taxonomic status of the 'southwestern stocks' of spinner dolphin *Stenella longirostris* and spotted dolphin *S. attenuata*. Rep. Int. Whal. Commn 29:175-184.

Reilly, S.B. 1990. Seasonal changes in distribution and habitat differences among dolphins in the eastern tropical Pacific. Mar. Ecol. Prog. Series: in press.

Richards, D.G., J.P. Wolz, and L.M. Herman. 1984. Vocal mimicry of computer-generated sounds and vocal labelling of objects by a bottlenosed dolphin, *Tursiops truncatus*. J. Comp. Psychol. 87:10-28.

Sayigh, L.S., P.L. Tyack, R.S. Wells, and M.D. Scott. 1990. Signature whistles of free-ranging bottlenose dolphins *Tursiops truncatus*: stability and mother-offspring comparisons. Behav. Ecol. Sociobiol. 26:247-260.

Smith, T.D. 1983. Changes in size of three dolphin (*Stenella* spp.) populations in the eastern tropical Pacific. Fish. Bull. US 81(1):1-13.

Steiner, W.W. 1981. Species-specific differences in pure tonal whistle vocalizations of five western north Atlantic dolphin species. Behav. Ecol. Sociobiol. 9:241-246.

Thomas, J.A., S.R. Fisher, and F.A. Awbrey. 1986. Use of acoustic techniques in studying whale behavior. Rep. Int. Whal. Commn Spec. Issue 8:121-138.

Thomas, J.A., S.R. Fisher, L.M. Ferm, and R.S. Holt. 1986. Acoustic detection of cetaceans using a towed array of hydrophones. Rep. Int. Whal. Commn Spec. Issue 8:139-148.

Tyack, P.L. 1986. Whistle repertoires of two bottlenosed dolphins, *Tursiops truncatus*: mimicry of signature whistles? Behav. Ecol. Sociobiol. 18:251-257.

APPENDICES

APPENDIX 1

SONOBUOY CHANNEL FREQUENCY ALLOCATIONS

CHANNEL	FREQUENCY (MHz)	CHANNEL	FREQUENCY (MHz)
1	162.25	17	162.625
2	163.00	18	163.375
3	163.75	19	164.125
4	164.50	20	164.875
5	165.25	21	165.625
6	166.00	22	166.375
7	166.75	23	167.125
8	167.50	24	167.875
9	168.25	25	168.625
10	169.00	26	169.375
11	169.75	27	170.125
12	170.50	28	170.875
13	171.25	29	171.625
14	172.00	30	173.125
15	172.75	31	173.125
16	173.50		

APPENDIX 2

DOLPHIN BIOACOUSTICS STUDY
PROCEDURE FOR RECORDING ODONTOCETE WHISTLES[2]

SONOBUOY

1. Before choosing sonobuoy frequency, check frequency on receiver to see if it's clear in the area at the time
2. Note channel number and tune in corresponding frequency on receiver (see table)
3. Check distance from coast to prevent use of restricted frequencies
4. If using channels 3-7 and 18-22, clear with skipper and electronics technician because the frequencies are the same as the NOAA radio frequencies
5. Set depth to shallow setting (60' for type 57A)
6. Set time to "short" frame (1 hr)
7. Set DB to 0 rather than 20
8. Deploy from helicopter at 300' or higher
9. Wait up to five minutes for a transmission - it takes time for battery and system to be activated

4-CHANNEL SONOBUOY RECEIVER

1. Use Channel B standard (not high)
2. Turn channel selection knob ***clockwise*** only or the calibration may be incorrect
3. Set all channels (A-D) of receiver to correspond to the channel of the deployed sonobuoy
4. Hook output into recorder (note channel, if there is more than one)

VCR AS RECORDER

1. Turn VCR on
2. Forward tape from previous session if it hadn't been done previously
3. Document the recording, fill out data sheet, if possible use a microphone to put comments on the tape

UHER RECORDER

1. Set recorder to 19cm/sec (7.5 ips)
2. Load tape and feed through 10-inch "leader"
3. Look and listen for signal (headset with jack)
4. Adjust gain/attenuation until needle is centered
5. Document the recording, fill out data sheet, if possible use a microphone to put comments on second channel of the recorder
6. If recorder not used for a week or more, note on counter the setting at the end of the last recording and rewind tape (otherwise it will stick to the heads and have to be cut off)

---

[2]Modified from instructions provided by Sue Moore

APPENDIX 3

DOLPHIN BIOACOUSTICS STUDY
SITUATIONS APPROPRIATE FOR DEPLOYMENT OF SONOBUOYS

WHICH SCHOOLS

- **Species:** Spotted dolphins and other odontocetes, especially common dolphins and killer whales

- **School type and size:** Single-species schools of fewer than about 100 animals (the smaller the better), including splinter groups from large schools

WHERE

- **Geographic location:** For *spotted dolphins*, the recommended areas are marked on the cruise-track plot. The purpose is to determine if we can separate stocks of spotted dolphins on the basis of differences in their acoustic patterns. We need to be very specific about where the sounds are collected. For *other species*, deploy opportunistically in regions where the species occur.

  Note: Within 200 miles (320 km) of the coast sonobuoy channels 1, 5, 12, 17, 19, and 25 are prohibited.

- **Distance from ship:** Between 2-5 miles (3.2-8 km) from the ship - deployment too close to the ship will result in masking of dolphin whistles because of prop noise. Transmissions from the sonobuoy can probably be received up to 5 miles (8 km) from the ship.

- **Location of school relative to the ship:** When the school is off the stern seems to provide the best results. Deployment in front of the ship, as the ship closes in on the school, limits time for recordings.

- **Distance from school:** Deploying the sonobuoy about ½-1 miles (0.8-1.6 km) ahead of the school should give adequate time to obtain a good recording. Predict the direction the school is going so that the school runs past the sonobuoy. The hydrophone is sensitive enough to detect sounds as far as a mile (1.6 km), but the quality will not be as high and any sounds from nearby animals may interfere.

WHEN

- **Sea state:** Low Beaufort (0 to low 4). High sea states are noisy and will interfere with the collection of dolphin whistles.

- **Thermocline:** Deeper than the depth of the deployed hydrophone.

- **Coordination with primary and other ancillary projects:** Deploy when interference with other operations is negligible. The best times for recording may be when daylight conditions are poor for photogrammetry, for example, early morning, noon, and late afternoon, and overcast days. Coordinate with cruise leader and photogrammetry team.

  Note: Radio traffic is picked-up during a recording session. It is advisable to limit use of radios when recordings are being made.