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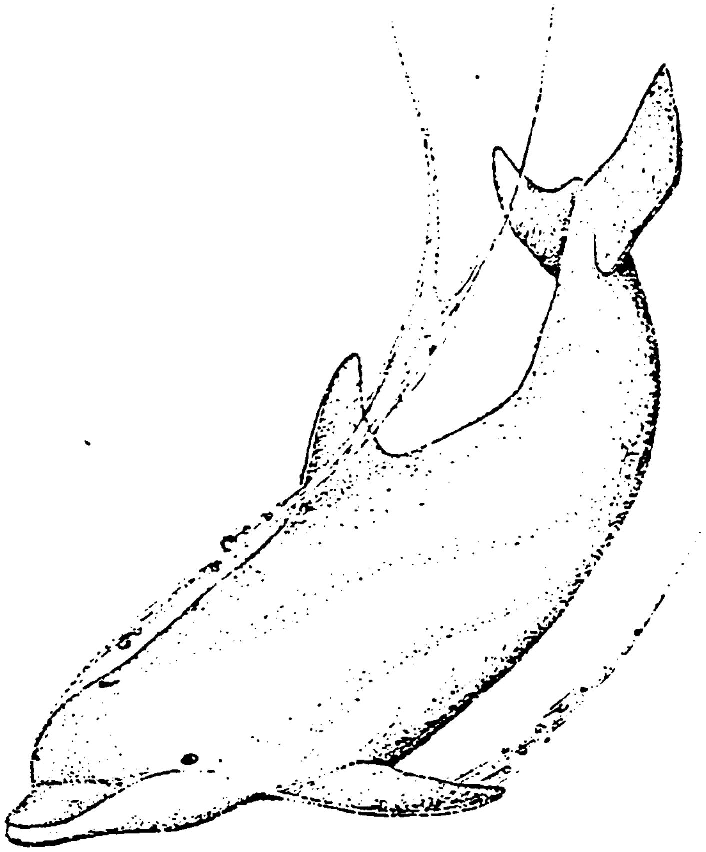
A REVIEW OF THE ECOLOGY, BEHAVIOR, AND LIFE HISTORY OF THE BOTTLENOSE DOLPHIN



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A REVIEW OF THE
ECOLOGY, BEHAVIOR LIFE HISTORY
OF THE BOTTLENOSE DOLPHIN

BY

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TABLE OF CONTENTS

INTRODUCTION

A conference on "Cetaceans and Sea Turtles in the Gulf of Mexico: Study Planning for Effects of OCS Development" was held at the University of Southern Mississippi (Gulf Park, Long Beach) on 6-8 April 1982. The bottlenose dolphin was the focus of much discussion at the conference, both because the species is better known than other cetaceans and because it is, perhaps, the species most likely to be affected by oil exploration and drilling in the Gulf of Mexico.

This report represents a summary of the current knowledge of bottlenose dolphin behavior and ecology. We have focused on information collected on free-ranging dolphins, and we have emphasized data available on _Tursiops truncatus_ in the Gulf of Mexico. We specifically note areas of potential impact of oil development activities on bottlenose dolphins.

It is clear that, despite the fact that bottlenose dolphins are relatively well known among the Cetacea, there are serious gaps in our understanding of these animals and in our ability to predict the effects of oil development on them. We hope that this report will be used to assess our current level of knowledge and will guide future avenues of research.

STOCK DISCRETENESS

The determination of the discreteness of stocks of bottlenose dolphins is critical to the assessment of potential effects of oil exploration and recovery on dolphins in the Gulf of Mexico. The impact of petroleum development would be much different on a small, local, discrete population than it would be on a large population that ranged over a wide area, or even a small, local population that mixed freely with similar adjacent populations. Little is known of the discreteness of Tursiops populations; it is only within the last 10-15 years that information contributing to the identification of population stocks has become available. The degree of mixing between populations can only be determined after individual population units have been identified through consideration of (ideally) behavior, morphology, and biochemical genetic factors. Though complete data on these three aspects are not available for any single population of bottlenose dolphins, a number of recent studies have emphasized one or more of these aspects for different populations.

Behavioral Data · The behavioral factors of primary importance in identifying populations of bottlenose dolphins include movement and association patterns of individuals. The movement patterns of Tursiops groups vary with location. As discussed elsewhere in this report, bottlenose dolphins maintain definable home ranges in many locations; the densities of dolphins within these ranges change seasonally in many cases. Seasonal migrations and seasonal changes in dolphin abundance are reported in a number of locations and are discussed in detail in the "Seasonal and Daily Movements" section. All of the studies of Tursiops movement patterns to date have dealt with coastal populations; no data are available on the movements of bottlenose dolphins more than a few miles from shore. In general, bottlenose dolphins in some areas inhabit ranges that are common to entire groups, and exclusive of other groups (these may be considered population ranges); in other areas there may be seasonal overlap in the ranges of individuals; and in still other areas dolphins may make extensive migrations. Each location of interest must be examined individually to determine the nature of the ranges of the individuals inhabiting the region.

In many cases, consideration of individual ranges may be insufficient to define populations behaviorally. In these cases, association patterns between individuals can be helpful in resolving population memberships. For example, adjacent but apparently separate populations off Aransas Pass and Port O'Connor, Texas and Sarasota, Florida were defined on the basis of a lack of association between inshore and offshore dolphins in the first two cases (Shane 1980, Gruber 1981) and by a lack of association between dolphins found strictly in the Gulf of Mexico or Tampa Bay and dolphins found in inshore waters near Sarasota, Florida in the latter case (Wells, Irvine and Scott 1980). Twelve years of observations of dolphins in the Sarasota area resulted in the creation of a "working" behavioral definition for *Tursiops* populations in that area as those dolphins that regularly move through the same waters and interact markedly more with each other than with similar units in adjacent areas (Wells et al. 1980; also see "Home Range" in this report). Within the 85 km^2 population range of the Sarasota dolphins, 94% of the adult females tagged during 1975-1976 were still present in 1982, while only one-third of the males were seen. The tagged and naturally-marked dolphins ranging through this area did not mix freely with other naturally-marked dolphins observed over as much as eight years in the adjacent Gulf of Mexico and

Tampa Bay. The regular, long-term sightings within a localized area, the social association patterns, and lack of interactions with dolphins in adjacent waters resulted in the consideration of the approximately 105 dolphins within the study area as a relatively discrete, resident population with a definable population home range.

The behavioral working definition should not, however, be considered absolute for the Sarasota population, nor should it be considered necessarily transferable to other areas. On very few occasions individuals or small groups from the Sarasota population were observed with adjacent groups. In addition, four dolphins that were not seen in the area for periods of several months or more were later resighted in the area. Similarly, Würsig (1978) described a 600 km roundtrip for six identifiable adult dolphins over a 15 month period off Argentina. Shane (1980) reported a sighting by Gruber of an identifiable dolphin 100 km from its presumed home range. Asper and Odell (1980) noted especially long movements by several of the dolphins they tagged on the east coast of Florida. Lockyer (1978) described the movements of an adult bottlenose dolphin off Great Britain as covering over 500 km in 18 months. These exceptional movements, considered in light of the variable dolphin densities in some areas, suggest that Tursiops stocks are not absolutely discrete; rather, the opportunity for mixing or genetic exchange between populations exists, barring as yet unknown social barriers between populations that would preclude interactions. Assuming that mixing does occur between identifiable populations, the factor that becomes of primary importance is the degree of mixing and exchange between populations. The existence of localized resident populations is well established. Is the degree of mixing sufficient to maintain the populations in the event of a natural or human-caused catastrophe? This question cannot be approached solely through consideration of behavioral studies; these studies need to be augmented with more precise measures of the reproductive contribution of various members or non-members to the population.

Morphological and Genetic Data Studies of morphology and biochemical genetics of members of dolphin populations, though more difficult to conduct because of the necessity of hands-on sampling, allow the determination of population differences through statistical comparison of a number of factors. Walker (1981) differentiated between populations of bottlenose dolphins in the Pacific Ocean on the basis of tooth size, skull length, size at sexual maturity, parasite loads, and stomach contents. Ross (1977) applied similar measures to *Tursiops* off South Africa, and identified two forms. Another promising technique is the examination of blood samples. Duffield (1980, 1981, 1982) has determined some degree of local population differentiation using electrophoresis of blood proteins from the east coast of Florida. She has also found a discernible pattern of interchange between populations.

Summary The large variety of bottlenose dolphin ranges and the lack of a clear definition of population for *Tursiops* strongly indicate that studies of the movements, associations, and genetics of potentially-impacted dolphins should be conducted. Such studies should cover at least a two-year period prior to initiation of petroleum development to define the population(s) inhabiting the waters, and to determine the discreteness of the stocks.

SOCIAL ORGANIZATION

The patterns of social organization of bottlenose dolphins appear to be quite complex, based on detailed observations of captive dolphins supplemented by information from a few studies of free-ranging animals. The general concensus is that bottlenose dolphin societies are structured as dominance hierarchies rather than some form of individual territoriality, at least under captive conditions.

Data from Captive Animals Since 1940, studies at a number of oceanaria have produced relatively consistent results from research on social behavior (e.g., Essapian 1953, 1963; McBride 1940; McBride and Hebb 1948; McBride and Kritzler 1951; Tavolga 1966; Tavolga and Essapian 1957). The first intensively studied bottlenose dolphin colony, at what is now Marineland of Florida, usually consisted of what was presumed to be the natural social unit of at least one mature male, five or six mature females and their offspring, and several subadults. Within this captive colony, the group was structured into a hierarchy, with the largest adult male dominant over all other tankmates. A somewhat less rigid dominance hierarchy existed between the females, with the largest females dominant over smaller animals (McBride and Hebb 1948; Tavolga 1966). Subsequent studies of colonies in Florida and elsewhere suggest that dominance hierarchies may be the "typical" social system for captive bottlenose dolphins, though the hierarchy may not always be rigidly maintained (Brown and Norris 1956; Caldwell, Caldwell and Siebenaler 1965; Caldwell and Caldwell 1967, 1972a, 1972b; Norris 1967; Tavolga 1966; Saayman, Tayler and Bower 1973).

Dominance has been displayed by captive dolphins in the forms of jaw claps, biting, ramming, or tailslaps against subordinates (Caldwell and

Caldwell 1972b; Caldwell, Caldwell and Townsend 1968; Essapian 1953; Lawrence and Schevill 1954; McBride and Hebb 1948; Norris 1967; Tavolga 1966). Dominance of males over females was usually expressed for mate selection. During most of the year adult males either swam alone or only for brief periods with females; however, longer associations, on the order of days or weeks, were maintained during a courtship period which was apparently terminated at the option of the male (Caldwell and Caldwell 1972b, 1977; Essapian 1953; Tavolga 1966; Tavolga and Essapian 1957). Adult males captured from the same groups and maintained together have been observed to maintain priority of access to food and females on the basis of size of the male, but with little aggression (McBride 1940). Much of the time, however, captive colonies have contained adult males from different capture localities, and in these cases the males have fought viciously during the breeding season, to the extent that most oceanaria now generally maintain a single adult male per tank (McBride and Kritzler 1951; Wood 1977). This suggests that dominance relationships may be long-established within dolphin groups, with little need for frequent contests.

A variety of interactions between captive adult males and females with calves have been reported. It is generally agreed that females without calves are the preferred partners for adult males (Caldwell and Caldwell 1972a, 1972b; Tavolga and Essapian 1957). There have been a number of reports of aggression, often violent, by adult males toward calves, with the result being either reciprocated aggression by the mother, or prolonged avoidance of the adult males (Caldwell and Caldwell 1972a, 1972b; Essapian 1953, 1963; McBride and Hebb 1948; Tavolga and Essapian 1957).

The dominance of adult over subadult males has been frequently reported as being expressed by aggression, especially when subadults were attempting to copulate with females, or when the younger animals were recently added to an existing colony (Caldwell and Caldwell 1972a; McBride 1940; Norris 1967; Tavolga 1966). The usual response by the subadults to this aggression involved avoiding the adult males, often forming subadult male groups.

Data from Free-Ranging Animals While the details of social interactions are more easily obtained under captive conditions, the possible effects of this unnatural environment must be considered when attempting to generalize the patterns of captives to free-ranging animals. Recently, information from free-ranging bottlenose dolphin societies has become available for comparison, allowing the reliability of extrapolation to be assessed. Field studies have shown that bottlenose dolphin group composition is much more dynamic than previously believed (Irvine et al. 1981; Shane 1980; Würsig 1978; Würsig and Würsig 1977, 1979; Wells 1978; Wells et al. 1980). These researchers found that group composition changed frequently, though certain associations appeared to be more persistent or repeated more often than others. Wells et al. (1980) reported that the associations of bottlenose dolphins within a marked population on the west coast of Florida were based on the age and sex of the individuals. In general, adult males formed small bands that moved from female group to female group in one portion of the range of the population, while subadult males swam in somewhat larger bachelor groups in another portion of the range, occasionally moving with the female groups when they passed through the area inhabited by the younger males. Adult and subadult males were rarely seen together, though their ranges overlapped slightly. Continued observations of these marked animals 10-12 years after initiation of the marking studies have shown that these association patterns are recurrent and long-lasting (Wells, Scott and Irvine unpubl.). Females with calves moved regularly through apparent nursery areas (Irvine et al. 1981). Females show the greatest degree of site fidelity over long periods of time, moving relatively predictably through particular regions that change on a seasonal basis, while males tend to be lost from the population at a greater rate. Close associations between females and calves are maintained for 3-5 years. Associations between females tend to be based on the ages of their calves or on the absence of calves. Female groups often lack adult males. These observations suggest that male dominance is not the overall controlling factor in the ordering of free-ranging social systems that it is in captive situations.

While dominance may be expressed in a hierarchy in captivity, it may be expressed by positioning of individuals or subgroups and sexual segregation in the wild (Norris and Dohl 1980b). Leatherwood (1977) noted that bottlenose dolphin groups in the northern Gulf of Mexico contained mothers and small calves in the center of the groups, possibly as a protective mechanism against predation. This was not observed to any great degree in the marking-observation study described above (Wells et al. 1980).

The segregation of subadult males as reported from the west coast of Florida has also been reported from Cape Hatteras, North Carolina (Townsend 1914; True 1890). This segregation may be related to the dominance of adults over younger animals. Conspecific toothrakes have been observed in greater frequency on young males than other classes in several cases in the Gulf of Mexico (Gunter 1942; Wells et al. 1980). In the northern Gulf of Mexico, subgroups of young animals of unknown sex were often observed near the periphery of large groups of bottlenose dolphins (Leatherwood 1977).

Summary While the nature of the social organization of bottlenose dolphins remains incompletely known, several well-documented generalizations can be made that have bearing on the potential effects of petroleum exploration and development in the Gulf of Mexico. At least in some portions of the species' range, populations form relatively permanent social units that are closely tied to definable home ranges. Within these populations, social associations and individual movements are based on the age and sex of the individuals. The displacement of dolphins from particular portions of their ranges could have a serious impact on social structure; if particular age or sex classes are not afforded access to crucial portions of their range, for example, areas used as nursery areas, or regions where male and female ranges overlap, then recruitment to the population could suffer. In addition, the long-term associations between mothers and young, and between other individuals suggest that learning within the context of the social unit is of major importance.

GROUP SIZE

Group size is highly variable for bottlenose dolphins. Some of the reported variability is related to researchers' differing perceptions of the definition of a dolphin "group" (e.g., pod, herd, school, subgroup, sighting) and different criteria used to determine membership in such a unit. However, group size varies according to the physiography of an area and the activity of the group. Within at least some coastal populations of bottlenose dolphins in the Gulf of Mexico, group composition and hence, size, changes frequently during the course of a day (Wells et al. 1980). This kind of variability has led to the description of dolphin groups in the following way: at any given time the population consisted of a number of primary and secondary groups. Primary groups (= pods, Shane and Schmidly 1978, Gruber 1981) were considered the smallest unit of dolphins that was closely associating and engaged in similar activities; these units were often intact for days or weeks at a time. Secondary groups (= herds, Shane and Schmidly 1978, Gruber 1981) were temporary (minutes to hours) aggregations of primary groups (Irvine et al. 1981). Lear and Bryden (1980) described a similar pattern for bottlenose dolphins in Australia.

Wells, et al. (1980, Table 6.2, pp. 276-277) summarized information on group sizes of bottlenose dolphins. Sightings of bottlenose dolphins (primary or secondary groups) range from one individual to groups of over 100 dolphins. Most commonly, bottlenose dolphins are found in relatively small groups of 2-15 animals.

Seasonal Variation   No consistent pattern of seasonal variation in group size has been found. Odell and Reynolds (1980) reported an increase in group size during the winter off Florida's west coast, and Würsig (1978) observed the same trend in Argentina. Shane (1977) noted a slight decrease in group size for bottlenose dolphins off Texas during winter. Irvine et al. (1981) found no significant seasonal variation in group size in a coastal population of bottlenose dolphins south of Tampa Bay, Florida.

Variation According to Habitat In general, bottlenose dolphin group size tends to increase with increased water depth or openness of the habitat. Wells (1978) reported significantly larger groups in the deep water passes and offshore Gulf of Mexico than in the shallower inshore waters near Sarasota, Florida. Shane (1977) and Gruber (1981) noted that groups were, on the average, larger when in open waters than when in the constrained regions of channels or passes. Odell (1976) found a similar pattern when he compared group size in the open waters of Biscayne Bay to the complex aquatic habitat adjoining the Florida Everglades. Similarly, Leatherwood and Platter (1975) reported larger groups in the open sounds of the northern Gulf of Mexico than in the shallow marshlands. Within the marshlands, the largest groups were in the deep channels connecting shallower feeding areas (this relationship was not found in later work in the same region reported by Leatherwood, Gilbert and Chapman 1978). As discussed by Norris and Dohl (1980b) and Wells et al. (1980), the reasons for these variations in group size with physiography may be related to foraging techniques and protection from predation. Shallow, inshore waters often provide relatively predictable, evenly distributed food resources associated with reefs or seagrass flats. In more open waters, schooling fish become the predominate resource available to the dolphins. In this case, larger groups utilizing sensory integration capabilities increase the probability of locating these patchy but rich food sources, and provide the numbers of individuals necessary to cooperatively herd the prey as reported by a number of researchers. In the same way, larger groups in more open waters serve some of the same functions as the physical habitat in more inshore areas in terms of protection from predation (discussed in detail in "Predation" section of this report). Since petroleum exploration and development generally occur in open, offshore habitat, possible disruption of dolphin groups by these activities could have serious consequences.

Temporal Variation   Variation in group size with time of day has been reported by a number of researchers (Shane 1977; Wells 1978; Wells, Würsig and Norris 1981). These variations are probably related to the activity cycles of the animals; there are tendencies for groups of particular sizes to be engaged in particular activities, though these trends are not necessarily consistent from location to location. Shane (1977) reported that groups engaged in traveling, feeding, and resting were approximately the same size, and were smaller than socializing groups. Lear and Bryden (1980) found idling (i.e. resting) groups to be smaller than swimming (i.e. traveling) groups. Wells, Scott, and Irvine (unpubl.) noted that traveling and socializing groups were often smaller than feeding or resting groups.

BEHAVIOR AND ACTIVITY PATTERNS

In looking for patterns in the behavior of *Tursiops truncatus*, we are trying to establish a basis for predicting what dolphins might be expected to be doing at a given time. Ideally, if we can predict dolphin activity patterns, we can direct potentially disruptive human activities (oil exploration and drilling, for instance), so that they will not interfere with the dolphins' behavior. Possible impacts to be avoided include disturbance of feeding, reproduction, and other types of behavior, displacement of dolphins from critical habitat, disruption of food resources, and physical damage to the dolphins (e.g. auditory injury or effects from direct contact with spilled oil).

Captive Behavior Dolphin behavior patterns have been studied in depth in captivity and in the wild, and the literature is full of anecdotal accounts of behavior observed under both conditions. Classic work on captive *T. truncatus* behavior was done by McBride and Hebb (1948), McBride and Kritzler (1951), Tavolga and Essapian (1957) and Essapian (1963). Bottlenose dolphin behavior has been reviewed by Tavolga (1966) and Caldwell and Caldwell (1972a, 1972b). Epimeletic or care-giving behavior in cetaceans, with the bulk of information on *Tursiops*, was reviewed by Caldwell and Caldwell (1966). Anecdotes on play and aggression in captive *Tursiops* are provided by Brown and Norris (1956) and Norris (1967). Puente and Dewsbury (1976) analyzed nine elements of courtship behavior in a pair of captive *T. truncatus*. Saayman et al. (1973) quantified the occurrence of sexual, social and vocal behavior in captive *T. aduncus*. Reproductive and mother-young behavior were addressed in papers by Caldwell and Caldwell (1977), Leatherwood (1977), and Gurevich (1977). Powell (1966) investigated levels of vocal activity in captive bottlenose dolphins subjected to different feeding routines. Defran and Pryor (1980) reported on the frequency of occurrence of 55 "behavioral events" in several species of cetaceans, among them *T. truncatus* and *T. gilli*.

Behavior in the Wild Captive behavior has been analyzed in detail not yet possible under the less than optimum conditions typically found in *Tursiops*' natural habitat. Nonetheless, the activity patterns of free-ranging dolphins can be understood only through direct observations of the animals in the wild. Several approaches have been taken to the study of free-ranging *T. truncatus* activity patterns, but generally, investigators focus on temporal, seasonal, ecological, spatial, and environmental effects on behavior. No complete ethogram for *T. truncatus* has ever been established, and no set of behavioral terms has been used consistently, although the definitions provided by each author indicate that the same broad activities are usually being analyzed. Feeding, traveling, social interactions and idling are the major categories of behavior recorded by most authors observing free-ranging animals. Most types of feeding discussed by different authors are reviewed by Leatherwood (1975). Traveling (or swimming) generally refers to dolphins involved in persistent, directional movement. Social interactions are usually broken down into categories such as "mating," "play," "rubbing," etc., but most authors describe all of these categories as being intricately intertwined and probably serving social as well as sexual functions (Tayler and Saayman 1973; Norris 1974). "Idling," "resting," or "milling" usually refer to dolphins engaged in slow movements generally lacking components of the other types of behavior described here. True resting behavior has never been as clearly identified in *Tursiops* as it has in other cetaceans such as the Hawaiian spinner dolphin, *Stenella longirostris* (Norris and Dohl 1980a; Norris et al. 1982).

All reports of free-ranging bottlenose dolphin behavior indicate that the animals are active at night as well as during the day (Tayler and Saayman 1972; Hogan 1975; Shane and Schmidly 1978; Irvine et al. 1981; Gruber 1981). However, indications of nocturnal activity are usually based on auditory clues (breathing and splashing), anecdotes from fishermen, or the absence of diel variation in radio tag signals. Direct observations are needed to define the actual level of activity in bottlenose dolphins at night.

The earliest quantification of free-ranging bottlenose dolphin behavior was made by Saayman et al. (1973) on _T. aduncus_ in South Africa. These authors found evidence that dolphin behavior was influenced by "photoperiodic variables." "Feeding" peaked in the early morning and late afternoon (first reported by Tayler and Saayman 1972). "Mating" began after the morning feeding period and continued until the afternoon feeding period began. "Leaping" was associated with both mating and feeding, while "rubbing" began when mating began, but unlike mating, continued throughout the evening feeding period. These conclusions were derived from 80 hours of quantitative data collected between January 1970 and May 1971.

Shane (1977) and Shane and Schmidly (1978) reported on the occurrence of fourteen types of behavior in _T. truncatus_ in south Texas during 1064 hours of observation in 1976-77. Major categories of behavior were analyzed for possible effects due to season, time of day, tidal stage, weather conditions and location. Traveling, feeding, mating and resting were significantly more frequent in some months than in others. Traveling was more frequently observed in January-April and June (55-60% of all behaviors) than during the other months. Feeding occurred 15-21% of the time from August-December and only 4-14% of the time in other months. "Mating" was seen most frequently in April and May (∿ 20%). "Resting" (uniquely defined in this study as an animal maintaining position against a strong current) was generally more frequent from July-December (3-8%) than from January-June. Temporal relations (0700-2000 hours) with certain forms of behavior were also significant. Traveling increased during the day until 1700 h and was lowest after that. Feeding peaked between 0700 and 1000 h and again between 1700 and 2000 h. Mating peaked at midday (1000-1300 h) and resting peaked at 1700-2000 h. Tidal state significantly influenced resting (most resting occurred at ebb tide) and bow-riding on ships (bow-riding occurred almost exclusively during ebb and flood tides and rarely at slack tides, thus suggesting an energy conservation function for bow-riding). Weather exerted statistically significant effects on several behaviors, but the biological meaning of those results was unclear. Mating and feeding occurred in localized areas during the study. Mating took place in large, open bays off the path of boat traffic. Feeding was focused at a couple of 15m deep "fishing holes."

Würsig and Würsig (1979) discussed feeding, aerial and social behavior of _T. truncatus_ in Argentina, based on 260 hours of observation in 1974-76. Dolphins appeared to rest near shore during the morning. Aerial behavior was most frequent in the afternoon and included leaps, headslaps, noseouts, tailslaps and kelp tossing. This behavior was often accompanied by "nudging" between dolphins. Leaps were believed to be associated with feeding whereas noseouts, belly-ups and kelp tossing were considered a part of play and copulatory behavior. The Würsigs hypothesized that tailslaps, usually performed by one large adult, may have been warning signals from a dominant animal. Widely spread groups of dolphins moving rapidly in offshore waters were believed to be searching for food and "milling" upon the discovery of a food source.

Gruber (1981) reported on the behavior of dolphins in Texas during 1121 hours in 1978-79. She investigated the association between traveling, feeding, and mating and season, time of day, and tidal state. Only differing tidal stages failed to produce significant variations in the occurrence of these behaviors. Traveling and mating occurred more frequently in spring and summer than in fall and winter, but feeding occurred about 25% of the time in fall and winter and only 5-10% of the time in spring and summer. Traveling and mating increased gradually in frequency throughout the day, but feeding declined throughout the day.

Hussenot (1980) described the behavior of T. truncatus in Brittany. Leaping was associated with play and greeting behavior. Dolphins were believed to be resting when facing against a strong current and maintaining position there. Diving repeatedly in one location was believed to indicate feeding. Tyack (1976) associated different types and frequencies of vocalization in Tursiops in Argentina with different behaviors. Hogan (1975) reported on feeding, mating and play in T. truncatus living near the Georgia-South Carolina border.

Feeding Tursiops is reputed to be a "catholic feeder," generally eating the seasonally most abundant local fishes. Leatherwood (1975) summarized published reports on food types used by T. truncatus. Tursiops exhibits a variety of feeding behaviors. Leatherwood (1975) discussed 3 types of feeding in association with shrimpboats, two types of cooperative feeding, "crowding" of fish against shoals and shorelines, and individual shallow water feeding. The shrimper-dolphin association is discussed in the Human-Dolphin Interactions section of this report. Hogan (1975), Hoese (1971) and Bel'kovich et al. (1978) describe dolphins trapping fish against the shoreline. Irvine et al.

(1981) observed rapid, individual shallow water fishing and possible cooperative feeding as did Shane and Schmidly (1978). Bel'kovich et al. (1978) gave a detailed description of cooperative and individual feeding techniques used by _T. truncatus_ in the Black Sea. Like Würsig and Würsig (1979), they found certain types of leaps associated with feeding behavior. A number of authors mention fish tossing by _Tursiops_ and some ascribe it to play (Gunter 1942, Shane and Schmidly 1978), while others suggest that it may serve to soften or behead the fish (Norris and Prescott 1961; Würsig and Würsig 1979) or simply to turn the fish so it can be ingested headfirst (Bel'kovich et al. 1978). Leatherwood (1975), Bel'kovich et al. (1978), and Barham et al. (1980) described dolphins pursuing fish while belly-up, possibly to get the most direct line on the prey with their echolocation.

Aerial Surveys Very broad categories of behavior are frequently recorded for each sighting of _Tursiops_ made during the course of aerial surveys. Observer differences and the brief time spent on behavioral observations make these data of limited value. A summary of these data and behavioral data recorded at the initial sighting of marked and unmarked herds during boat surveys in the Indian and Banana Rivers in Florida are summarized in Table 1.

Summary The behavioral data available on free-ranging _Tursiops_ comes from widely disparate locations and habitats. Very few studies have quantified _Tursiops_ activity patterns in the Gulf of Mexico. However, several broad generalizations may be made: (1) dolphins appear to be active to some extent during both day and night; (2) based upon diurnal observations, several studies have noted feeding peaks in early morning and late afternoon; (3) the proportion of time devoted to feeding seems to increase in the fall and winter,

	Leatherwood 1979	Barham et al. 1980	Lear & Bryden 1980		Odell & Reynolds 1980	Odell & Asper 1982	
			Rocky Nearshore	Ocean Beach		Unmarked	Marked
Feeding (%)	36	49	8	8	18	15	21
Traveling (%)	--	37	23	39	--	48	34
Idling/Milling (%)	--	--	56	35	--	26	29
Mating/Playing (%)	--	--	14	19	--	4	10
Sample Size	64 groups	97 herds	2698 individuals		326 herds	489 herds	269 herds
Time of Survey	Aug. 1977	Mar. 1978	1 year		1975-1976	Dec.1980-Mar.1982	
Survey Location	E. Florida	S. Texas	E. Australia		W. Florida	E. Florida	

Table 1. Percentage of occurrence of different categories of behavior reported during four aerial survey studies and one boat study (Odell and Asper 1982) of bottlenose dolphins.

at least in Texas; (4) feeding strategies are flexible and adapted to the habitat and food resources available; (5) social behavior is a major component of the daily activity regime of *Tursiops*.

T. truncatus is a remarkably flexible animal in terms of its behavior. The fact that bottlenose dolphins adapt relatively easily to captivity is perhaps the most profound indication of their flexibility. Even so, habitat alteration (through increased boat activity, pollution, etc.) could potentially have serious disruptive effects on social behavior, food supply, and health of the animals.

SEASONAL AND DAILY MOVEMENTS

Animals may undergo short- and long-term movements for a variety of reasons, but major reasons appear to relate to food availability, protection from predators, reproduction, and thermoregulation. Bottlenose dolphins are no exception to this rule, and they change location in many varied (and often cyclical) ways in order to increase their chances for survival.

Seasonal Movements Bottlenose dolphins are found in temperate and subtropical waters worldwide. While they may at times migrate in the higher-latitude ends of their distribution (True 1890 and Townsend 1914 provide descriptions of movement past Cape Hatteras; see also Verwey 1975, Lockyer 1978, and Hussenot 1980, for seasonal movements in northern Europe), such movements are often obscured by the fact that some animals remain in the same areas year-round. This is particularly evident for populations of lower latitudes, where "migrations" as such cannot be discerned, but where there are definite differences in numbers in different seasons. Thus, although Gunter (1942) stated that there is no evidence for seasonal migration or seasonal change in abundance of bottlenose dolphins in Texas waters, more detailed analyses showed that there are twice as many dolphins present near Aransas Pass, Texas during the winter as during the summer (Shane 1980, Shane and Schmidly 1978). Gruber (1981) found a similar trend for the Pass Cavallo area of Matagorda Bay, Texas, and she elaborated on seasonal distribution of dolphins in different sections of her study area. Gruber found seasonal bottlenose dolphin concentrations in association with shrimp-fishing activities, but whether the movements of fish which were associated with shrimp or whether the shrimpers' operations were primarily responsible was not determined.

Caldwell and Caldwell (1972a) reported a limited seasonal movement along the Atlantic coast of Florida, with some dolphins moving southward in winter and northward in summer. However, these movements are probably no greater than about 150 km (D.K. Caldwell, pers. comm., 1973). Irvine and Wells (1972) reported no evidence for long-distance seasonal migrations of dolphins in the Sarasota area of West Florida, and a subsequent analysis revealed that in winter most dolphins are in passes and along the Gulf shore of the coastline while in summer they are found inshore of barrier islands (Irvine et al. 1981). Furthermore, females and calves tend to aggregate over shallow protected areas in summertime, and there is a tendency for dolphins to feed on mullet over shallow flats from spring to fall. As mullet move from shallow inshore waters to the passes and into the Gulf of Mexico, dolphins also move offshore and into the passes, presumably following this food supply (Wells et al. 1980, Irvine et al. 1981). Asper and Odell (1980) cited slight evidence that dolphins may move further south from mideast Florida during winter, and Odell (1975, 1976) stated that a possible increase of animals in south Florida, in the Everglades National Park, may take place. However, Moore (1953) noted a lack of seasonal migration in the Everglades. All of these reports deal with bottlenose dolphins which are found close to land; there are Tursiops populations which occur further than 10 km from shore, and it is generally believed that the offshore and inshore animals do not intermingle (Caldwell and Caldwell 1972a, Odell, Siniff and Waring 1975). Little is known about the movements of the offshore populations. Lear and Bryden (1980) report that numbers of dolphins appear greater in southern Queensland, Australia waters in winter than in summer. Würsig and Würsig (1979) found bottlenose dolphins in Argentina to be most abundant in winter, spring, and fall, with fewer present during the hottest months of the year.

In summary, some coastal bottlenose dolphins in higher latitudes show a clear tendency towards migration, while those in warmer waters like the coastal Gulf of Mexico show localized seasonal movements which probably have much to do with movements of food and need for safety in reproduction. At least in one case, off West Florida, movements of mullet are rather clearly implicated as one reason for bottlenose dolphin movement. The fact that bottlenose dolphins are "catholic" feeders may explain why their movement patterns are not as clear-cut and simple as those of some other cetaceans.

Short-Term Movements Diurnal and other short-term movement patterns in Tursiops have been described by a number of authors. Bottlenose dolphin movements have been described as highly variable and flexible off Europe (Verwey 1975, Duguy and Hussenot 1980). Lear and Bryden (1980) believed that bottlenose dolphins in eastern Australia seek shelter near shore to avoid rough water offshore during storms. They also report that there is evidence of tidally-related movement, but it is not a simple relationship with flood and ebb. A similar report comes from Würsig and Würsig (1979). In their study off Argentina, bottlenose dolphins moved into deeper water during midday and behaved and fed in different ways in different depths. They also moved differently depending on flood and ebb tides, but such movement was not of a simple nature, and tended to keep the animals in shallower water as the tide receded, until they were in water so shallow as to cause them to abruptly alter their movement into deeper water. Dolphins off Argentina also moved back and forth parallel to shore, using underwater obstructions as cues to turn by 180° and retrace their course. This tended to keep them in a confined area of about 0.5 km distance along shore for several hours before tidal changes or other factors caused them to abandon this zig-zag pattern.

Indian Ocean bottlenose dolphins off South Africa enter Plettenberg Bay only in the morning and afternoon, and spend much of this time feeding. It is likely that these animals are following the diurnal cycles of several species of food fish, but the authors do not detail the movements of prey (Saayman et al. 1973).

Relatively predictable movement patterns have been shown for Tursiops in U.S. coastal waters. Hoese (1971) reported dolphins entering salt marshes in order to feed on fish chased onto mudbanks at low tide. Caldwell and Caldwell (1972a) reported local movements of dolphins along the northeastern coast of Florida to be roughly southeasterly in the morning and northwesterly in the afternoon, paralleling the coastline. They hypothesized (as did Pilleri and Knuckey 1968, for common dolphins of the Mediterranean Sea) that this diurnal pattern may be sun-related. Caldwell and Caldwell (1972a) also reported movement with tidal flow in the inland waters near St. Augustine, Florida.

Bottlenose dolphins in the Sarasota area of west Florida move onto shallow seagrass flats with the incoming tide. They fragment into small groups during that time (Irvine and Wells 1972), and much of the feeding appears to be concentrated on mullet (Wells et al. 1980, Irvine et al. 1981). Shane (1980) describes tidally-related movements in Aransas Pass, Texas. Dolphins in her study stationed themselves against the tide especially during resting, and they showed a rough temporal pattern as well. In early morning, dolphins tended to move towards the north in a part of the study area, during midday they moved in all directions, and later on in the day they returned towards the south. Where the tide was strong, movement against the tide was evident, but where the tide was weak, the temporal pattern prevailed. Similarly, dolphins usually moved against the tidal flow in the Pass Cavallo area of Texas (Gruber 1981).

Bottlenose dolphins often frequent a particular area for a period of several days or weeks, and then abruptly change their pattern and move to another location (Hogan 1975; Shane 1977; Shane and Schmidly 1978; Würsig 1978; Irvine et al. 1981). Whether they are following a particular prey species or whether other factors account for these changes is not known.

Bottlenose dolphins often move with shrimp boats and other vessels which can supply food (Norris and Prescott 1961, Leatherwood 1975, Wells et al. 1980, Gruber 1981). This movement is temporarily adjusted to fit with the schedules of these boats.

In summary, coastal bottlenose dolphins move with concentrations of food, move into shallow safe areas, move with or against the tide, and show some regular (but usually not strong) diurnal movement patterns. The overriding theme is variability. These are large-brained social mammals which can learn much from their environment, and retain some knowledge certainly for life. It is likely that they know particular areas very well and that they remember when and where the best chances for finding prey are likely to be.

HOME RANGE

The literature clearly shows that at least some coastal bottlenose dolphins maintain home ranges. A home range, according to Burt (1943), is an area regularly used by an individual performing its normal daily activities. Jewell (1966) expanded the concept to refer to groups as well as individuals. Researchers have identified both individual and herd home ranges as well as apparently permanent and seasonal home ranges. The fact that T. truncatus does have home ranges indicates that disturbance within that range could potentially disrupt the animals' activities. Animals forced out of an area with which they are familiar and which supplies all of their needs might be severely impacted. In areas where the home range limits of a dolphin group are defined, it would be possible to monitor the effects of oil exploration and recovery on the dolphins by watching for alteration in their use of the home range.

The first indication that T. truncatus had a home range was provided by Caldwell (1955). Based on about seven sightings of a recognizable individual dolphin in Florida, a minimum home range was defined. Caldwell and Golley (1965) estimated a minimum home range of "95 shoreline miles" for an albino Tursiops in Georgia and South Carolina (previously described as a local animal by Essapian 1962). Caldwell and Caldwell (1972a) proposed that Tursiops may have seasonal home ranges linked by a traveling range.

The most detailed and informative study of T. truncatus home ranges has been conducted by Wells (1978) on the west coast of Florida (also see Irvine and Wells 1972, Irvine et al. 1981, Wells et al. 1980). They defined individual, herd, and age-sex class home ranges. The population of about 105 dolphins (47 of which were captured and tagged) appeared to maintain a home range of 85 km^2. Female-calf pairs and subadult males had home ranges averaging approximately 40 km^2, whereas adult females, subadult females and adult males had smaller ranges (15-20 km^2). The dolphins used certain parts of the study area more during certain seasons. For instance, they were seen more often in the passes and the Gulf during winter (Wells et al. 1980). In 1975-76 Irvine et al. (1981) recaptured 11 animals first taken in 1970-71 in the same area, indicating that their home range is permanent, and Wells (unpubl.) reported that 8 individuals have been seen in this area for over 10 years.

Shane (1980) (also see Shane 1977, Shane and Schmidly 1978) found that individual dolphins in her study area in Texas concentrated their activities in certain areas, and she defined three major home ranges shared by several individuals. These ranges were used seasonally by some dolphins and year-round by others. She believed the ranges of most dolphins extended outside of her study area. Würsig and Würsig (1979) identified an apparent northern limit for the Argentinian T. truncatus they studied, but were unable to determine how far the dolphins ranged beyond the 50 km^2 area they monitored. Gruber (1981) identified home ranges for individuals in her Texas study area as well as reporting on three nearly separate herd home ranges that coincided partially with her study area.

Some authors make brief references to home ranges for Tursiops. Hussenot (1980) reported that dolphins found in the Molène archipelago of Brittany had a larger range in winter than in summer. Saayman et al. (1973) found that T. aduncus in Plettenberg Bay, South Africa had a "semi-permanent" home range.

Home range size may be a function of dolphin densities and variable densities have been reported by different authors. Dolphin density within the Sarasota, Florida Tursiops home range was calculated by Irvine et al. (1981) to be 1.3 dolphins/km^2. Wells (1978) further reported that density was higher in the northern half of the herd home range (1.8 dolphins/km^2) than in the southern half (0.6 dolphins/km^2). Leatherwood (1979) summarized density estimates from four studies in the Gulf of Mexico; they varied from 0.23 to 0.65 dolphins/km^2. Leatherwood (1979) found a density of 0.68 dolphins/km^2 in the Indian River on Florida's east coast. Barham et al. (1980) reported a density of 0.75 *Tursiops*/km^2 on the Texas Gulf coast. Gruber (1981) found a density of 0.93 dolphins/km^2 in the Pass Cavallo area of Texas, and she noted that dolphin densities varied seasonally in different sections of her study area. Highest densities ever reported for *T. truncatus* were in the Aransas Pass area of Texas (Shane 1980): 1.4 (October) to 4.8 (January) dolphins/km^2.

Leatherwood (1975) hypothesized that the wide range of feeding behaviors exhibited by *T. truncatus* in different places represents a "plasticity" necessary for animals with limited ranges and faced with changing food resources. Although bottlenose dolphins clearly concentrate their activities within home ranges, how limiting these ranges are is questionable. Many studies show dolphins switching or enlarging their ranges seasonally, and Würsig and Würsig (1977) and Würsig (1978) found *Tursiops* capable of making a 600 km roundtrip away from what was thought to be their primary home range.

Wells et al. (1980) provided the best information on the apparent exclusivity of home ranges. While no defense of boundaries implying territoriality was observed, dolphins in Sarasota seemed to recognize range limits and consistently turn back at approximately the same location, thus defining the boundaries of their range. Hussenot (1980) pointed out that *T. truncatus* in Brittany usually followed the same routes repeatedly. Shane and Schmidly (1978), Shane (1980) and Gruber (1981) noted an apparent boundary between inshore waters and the Gulf of Mexico at passes in Texas; dolphins relatively rarely crossed that boundary. Irvine et al. (1981) did not find the same limitation at passes on the Gulf coast of Florida. The Sarasota dolphins were never seen over 1 km offshore in the Gulf, however. Dolphins presumably use underwater topography to recognize different locations within their ranges. The social mechanisms which must exist between dolphin populations to maintain these boundaries are as yet unknown.

REPRODUCTION

Knowledge of bottlenose dolphin reproductive parameters is of the utmost importance in assessing the impact of petroleum-related activities on the animals. Unfortunately, it is difficult to determine "normal" reproduction and growth patterns. Among the problems is the confused state of Tursiops taxonomy. It is clear that two morphs (large and small) exist. The large form reaches a length of 3.2-3.5m (Gunter 1942; Ross 1977), and the small form reaches a length of about 2.5-2.7m (Ross 1977, Odell and Asper 1982). Mitchell (1975) recommended that all Tursiops be considered as T. truncatus until more material from various populations has been examined. The small form (often referred to as the inshore form) is the type that inhabits the coastal waters of the southeastern U.S. and the Gulf of Mexico. There is some evidence from strandings that the large form is also found in the Gulf of Mexico (Gunter 1942; Gruber 1981:115). Whatever the final specific designation(s), the inshore form is subject to the effects of human activities which may affect reproduction.

Among the approaches taken to elucidate the reproductive biology of Tursiops are analysis of material from stranded animals, observations in oceanaria, and long-term field studies.

Reproductive Anatomy: Males The male reproductive tract has been described by Green (1972, 1977). The gross structure is similar to the standard mammalian format. The size of the testes, epididymis tubule diameter, histological status of the testes with regard to sperm production, and the presence of sperm in the epididymis are factors used in assessing the reproductive status of a male. Testes weights and related data from bottlenose dolphins in Florida and

Mississippi (Harrison and Ridgway 1971), N.E. Florida (Sergeant, Caldwell and Caldwell 1973), and South Africa (Ross 1977) are presented in Table 2.

Both Harrison and Ridgway (1971) and Sergeant et al. (1973) demonstrated a rapid increase in testes weight in the small form of *Tursiops* at 10-12 years of age. However, the data base is quite limited, and one would expect to find differences in different populations. The fact that a given male is considered sexually mature on an anatomical basis does not necessarily mean that he is socially mature in terms of mating success.

Reproductive Anatomy: Females As with males, Green (1972, 1977) provided a general description of the female *Tursiops* reproductive tract. The major structures of the female tract follow the standard mammalian format. The uterus is of the bicornuate form. A somewhat unique structure is the psuedocervix formed by extensive folding of the vaginal wall just posterior to the true cervix (Green 1972). This structure may function to block the entrance of salt water during and after mating (P. J. Schroeder, pers. comm. 1981).

Upon examination, the flat diameter of the uterine horns can be used to determine whether or not the female has been or is pregnant. The presence or absence of an embryo or fetus and its size can be used to assess how long the animal has been pregnant. Gestation is 11-12 months and the length of the newborn can range from 98-126 cm (Gunter 1942; Harrison et al. 1972; Sergeant et al. 1973) in the small form.

The weight of the ovaries is a weak indicator of overall reproductive status. The presence of an active corpus luteum can increase ovarian weight several fold (Harrison et al. 1972). In general, ovarian weight increases from about 1 g (both ovaries) in a newborn to 10-20 grams in mature females

N	Combined Testes Weight (g)	Age (yrs.) or Stage of Maturity	Body Length (cm)	Morph and/or Species
8*	20-30	immature	--	small
7*	200-400	maturing	--	small
5*	600-1400	mature	--	small
11**	1200-1700	9-17+	224-254	small (*T. aduncus*)
2**	31 and ?	4 and 11	260 and 272	large (*T.truncatus*)
1***	1100 +	--	303	large (*T. gilli*)

*Sergeant et al. 1973

**Ross 1977

***Harrison and Ridgway 1971

Table 2. Reproductive data from male *Tursiops* in Florida and Mississippi (***), N.E. Florida (*) and South Africa (**).

depending on age and number of accumulated corpora albicantia. The placenta is of the epithelio-chorial type (Wislocki and Enders 1941).

Harrison et al. (1972) reviewed and discussed the histological structure of the ovary in *Tursiops*. Much effort has been devoted to the determination of the fate of the corpus luteum (CL) of pregnancy. Ohsumi (1964) reviewed the rate of corpus albicans (CA) accumulation between left and right ovaries for a number of cetacean species. In general, the left ovary is more active than the right. It is assumed that the CL persists in the ovary as the CA for the life of the animal (Harrison et al. 1972). If so, one can determine the reproductive history of a female by counting the number of CA's in the ovaries. This method can be complicated by the presence of CA's from accessory corpora lutea, CL's of incomplete pregnancies, and, possibly, CA's from ovulation that did not result in conception.

Reproductive Physiology: Males The brevity of Ridgway's (1972) review of reproductive physiology in male cetaceans (primarily *Tursiops*) is indicative of the general state of knowledge. As pointed out above, most conclusions about male reproductive status and seasonal changes come from direct examination of the gonads. The alternative approach is to follow changes in hormone levels (testosterone) on a daily, seasonal, and annual basis. This type of study usually requires captive animals, but one-time sampling for testosterone levels has been done in the Indian River, Florida (Asper and Odell 1980; Odell and Asper 1982) and Mississippi Sound (M. Solangi, pers. comm., 1982).

Harrison and Ridgway (1971) examined plasma testosterone levels in several *Tursiops* from Mississippi and Florida and found activity to be greatest in the spring and fall, correlating with spring and fall calving seasons.

Judd and Ridgway (1977) documented diurnal changes in the circulating testosterone levels in captive Tursiops.

Ridgway and Benirschke (1977) present the best review of reproduction in captive Tursiops. Population density and social structure can affect reproductive physiology, and these factors may be abnormal in captive situations.

Reproductive Physiology: Females As with males, most information about reproductive status has come from direct examination of the reproductive organs (Harrison et al. 1972). Using this information, Harrison and Ridgway (1971) concluded that ovulation is induced (reflex, as opposed to spontaneous) in Tursiops. However, Kirby and Ridgway (1981) demonstrated that non-fertilized spontaneous ovulations do occur in captive Tursiops using elevated (>3000 pg/ml) progesterone levels as the indicator. Ridgway (1972) stated the female is seasonally polyestrous (spring and/or fall). Kirby (1981) followed progesterone (P) and total immunoreactive estrogens (Et) over 1-2 year periods. She concluded from her small sample that females with P levels from 3-20 ng/ml had ovulated and that females with P levels of 30-50 ng/ml for longer than 6-8 weeks were pregnant. She estimated the estrous cycle to be 25-30 days. Variations in Et levels were inconclusive. Other investigators (Schroeder 1981; Richkind 1977; Sawyer-Steffan and Kirby 1980) have attempted to manipulate the female Tursiops reproductive cycle with injections of pregnant mare serum gonadotrophin and human chorionic gonadotrophin. New studies that document changes in pituitary gonadotrophin levels may be even more important for describing and manipulating the female reproductive cycle.

Asper and Odell (1980), Odell and Asper (1982) and Solangi (pers. comm., 1982) have examined progesterone and estradiol levels in wild females on a one-time basis. These values are of little use without knowledge of the details of the reproductive cycle.

McBride and Kritzler (1951) report an average calving interval of two years with lactation lasting as long as 18 months. However, Wells (unpubl.) has observed several females in the Sarasota, Florida area with calving intervals greater than three years, and mother-calf bonds have been maintained for the same amount of time.

Reproductive Behavior in Capitivity *Tursiops* has reproduced in captivity with varying degrees of success (Ridgway and Benirschke 1977). It is generally felt that the stress of performing in a captive situation has a negative effect on reproductive success. The literature on captive reproductive behavior patterns is briefly reviewed in the "Behavior and Activity Patterns" section of this report.

Seasonality In the northern Hemisphere, the *Tursiops* breeding season is in the spring and early summer as has been documented by the presence of calves in numerous studies (Shane 1977; Gruber 1981). In southern Florida (and possibly further south in the range) there is a fall breeding/calving season (Odell 1975). Similar seasonality patterns have been observed in captives (Caldwell and Caldwell 1972a). Ridgway (1972) feels that seasonal reproduction in *Tursiops* is under the control of photoperiod and possibly water temperature.

Summary Males mature at about 10 years of age and females at about 5 years. Gestation is 11-12 months and females bear a single calf every 2-3 years. Both sexes live to about 25 years of age. The number of years of reproductive activity is not known. Reproduction is seasonal (spring-early summer) in the northern hemisphere with a secondary peak in October-November in southern Florida. Research on captive dolphins, thorough use of stranded animals, and capture/recapture of free-ranging _Tursiops_ will all contribute to an improved understanding of reproduction.

PREDATION

Sharks and killer whales are the most commonly reported predators of bottlenose dolphins. Though killer whales are considered predators in Argentine waters (Würsig and Würsig 1979), the infrequent occurrence of Orcinus in waters inhabited by Tursiops in the Gulf of Mexico suggests that they are not of major concern in the Gulf. Sharks are probably the most important predator of bottlenose dolphins worldwide, and certainly in the Gulf of Mexico, though few data on shark attacks on dolphins are available. Wood, Caldwell and Caldwell (1970) stated ". . . the number of reports that sharks have dined on porpoises, as well as the fact that such reports encompass farflung geographical areas, lends credence to the assumption that porpoises do indeed constitute a not-infrequent article of diet for some of the larger sharks." They reported that of 22 bottlenose dolphins captured off the southeastern United States, four had definite shark attack scars, and seven others had scars that were probably from shark bites. Wells et al. (1980) reported that three of 47 dolphins tagged on the west coast of Florida had definite shark attack scars, and two others were missing large portions of their flukes, presumably as a result of shark attacks. Ross (1977) found evidence of shark attacks on two of 58 Tursiops he examined off South Africa. These reports of shark bite scars are of uncertain value as indicators of levels of predation, however, as they merely represent unsuccessful predation attempts at some unknown time during the animals' lives.

Dolphin remains have been found in the stomachs of a number of shark species, but most often in tiger (Galeocerdo cuvier), dusky (Carcharhinus obscurus), and bull sharks (Carcharhinus leucas). The responses of bottlenose dolphins to the presence of potential predators vary relative to the species and size of the predator, the activities and size of the dolphin group, and the physical habitat. These responses include tolerance, active avoidance, and active aggression. Observations of captive bottlenose dolphins have shown that they may recognize particular shark species as potential predators. Tiger sharks elicited a marked reaction by dolphins relative to other shark species placed in a community tank at other times (McBride and Hebb 1948). In another study, a bottlenose dolphin conditioned to repel various species of sharks could apparently distinguish between bull sharks and three other species. The dolphin responded appropriately to commands to repel sandbar (Carcharhinus milberti), lemon (Negaprion brevirostris), and nurse (Ginglyostoma cirratum) sharks, but when tests involved bull sharks the dolphin became agitated and refused to respond to commands in repeated tests (Irvine, Wells, and Gilbert 1973).

Mutual tolerance between bottlenose dolphins and sharks has been reported both from captivity and the wild. Studies of shark-dolphin interactions in the Bahamas (AIBS 1967) and Florida (Gilbert, Irvine and Martini 1971; Irvine et al. 1973) placed pairs of bottlenose dolphins in the presence of one, two, or three individuals of various sizes of sandbar, lemon, or bull sharks. No agonistic interactions were observed during the many hours of experimentation. A similar lack of agonistic behavior has been reported from several oceanaria that have maintained both sharks and dolphins in the same tanks (Essapian 1953; Wood et al. 1970). Non-aggressive interactions, including feeding on the same fish schools by sharks and dolphins in the wild have been reported by several authors (AIBS 1967; Leatherwood 1977; Wood et al. 1970).

Greater group cohesion and active avoidance have also been reported as responses to predators. Captive dolphins swam more rapidly and formed tighter groups when sandbar sharks were introduced into their tank (McBride and Hebb 1948; Wood et al. 1970). On another occasion all of the bottlenose dolphins in a tank were observed to gather around a female giving birth and herd approaching sharks away (McBride and Hebb 1948). Free-ranging bottlenose dolphins off South Africa have been observed to actively avoid hammerhead (Sphyrna zygaena) and great white (Carcharodon carcharias) sharks (Tayler and Saayman 1972). Wells (unpubl.) observed a group of bottlenose dolphins stop resting on a shallow sandbar and swim off into deeper water when approached by an unidentified 2m shark.

A number of authors have reported cases of aggression by dolphins towards sharks. Bottlenose dolphins have been observed to attack sharks in captivity (Brown and Norris 1956; Norris and Prescott 1961; McBride and Hebb 1948; Essapian 1953) and in the wild (Gunter 1954). Only one second-person account of a coordinated agonistic response of bottlenose dolphins towards a shark in the wild has been reported. Gunter (1942) received a report of dolphins killing a shark off Texas. Coordinated responses by other dolphin species have been reported, but this response does not seem to be as common for bottlenose dolphins as has been generally held in the past.

The relationship between group size and habitat characteristics may be an important factor in dealing with predation pressure on the west coast of Florida (Wells et al. 1980). Significantly smaller groups of dolphins were found in the complex, shallower inshore habitat than in the more open Gulf of Mexico and Tampa Bay waters. Bottlenose dolphins in the Sarasota, Florida area tend to rest over shallow bars or flats, or in shallow, dead-end bays. During the summer months, when bull sharks are the most common shark species in the Gulf waters off Sarasota (Clark and Von Schmidt 1965), the dolphins generally rest over inshore shallows, but during autumn and winter the dolphins are more typically found in the Gulf of Mexico. As discussed by Wells et al. (1980), larger groups of dolphins allow increased surveillance of the habitat for predators, provide cover for individuals, and are potentially suited for coordinated, active defense of the group. It appears that as the physical habitat provides less protection in terms of reducing the volume of water that must be monitored or providing physical barriers or paths for predators, the importance of the group as a means of protection of dolphins from predators increases. More observations are necessary, however, to test this hypothesis.

At this time one can only speculate as to the potential effects of petroleum exploration and recovery on predation on dolphins. If the dolphins are using particular regions within their ranges for protection from predators, then the loss of these areas could be detrimental. In deeper, more open waters where large group size may be a critical determinant of effectiveness of protection from predation, then activities resulting in the disruption of these larger groups or the normal functions of the larger groups could be detrimental. Additionally, disabilities introduced through water pollution or acoustic activities associated with petroleum development could make dolphins more susceptible to predation.

HUMAN-DOLPHIN INTERACTIONS

Interactions between humans and dolphins range from apparently beneficial to directly destructive to the animals.

Boats Perhaps the most common association is between *T. truncatus* and boats. Dolphins are frequently attracted to the pressure waves created at the bows of ships and bowride there (Norris and Prescott 1961; Walker 1974; Shane and Schmidly 1978; Gruber 1981). Bowriding may be a form of play or it may be an energy-saving means of locomotion. Ship bowriding is probably derived from whale bowriding. *Tursiops* has been seen taking advantage of the pressure waves at the heads of right whales (McBride and Kritzler 1951, Würsig and Würsig 1979), humpback whales (Darling, pers. comm.) and gray whales (Leatherwood 1974). Dolphins also ride in the stern wake of vessels. A related behavior is surfing, first reported by Caldwell and Fields (1959) and also seen by Norris and Prescott (1961), Saayman et al. (1973), and by the authors in Texas, California, Hawaii and Argentina. Bottlenose dolphins frequently ride waves alongside human surfers. On rare occasions a dolphin is killed by a ship's propeller (Shane and Schmidly 1978). Norris and Prescott (1961) reported that *T. gilli* fed in San Diego Bay where the Navy dumped its garbage. Norris (1974) reported bottlenose dolphins following ferries in San Diego Bay, presumably to feed on organisms stirred up in the propeller wash. Hussenot (1980) discussed different groups of dolphins in Brittany: some were attracted to boats and accompanied them and others fled at the sound of motors. Würsig and Würsig (1977) observed tailslapping in response to the approach of their boat and interpreted it as an indication of disturbance. Shane and Schmidly (1978) and Wells (1978) reported that dolphins became attracted to their research boats and often approached and accompanied them.

Capture Bottlenose dolphins, being the most widely held cetaceans in captivity, have been captured by the hundreds in U.S. waters and other countries (Odell et al. 1975, Ridgway and Benirschke 1977). It is common knowledge that Tursiops frequently is able to recognize boats previously used for capture and avoid them (Norris and Prescott 1961; Irvine and Wells 1972; Leatherwood 1974; Norris 1974; Norris and Dohl 1980b). However, Irvine et al. (1981) reported that dolphins did not seem to avoid their "tagging-observation boat," perhaps because it was camouflaged and towed by another boat during tagging.

Fisheries Tursiops interacts with a number of fisheries but none so much as the shrimp fishery. Leatherwood (1975) delineated three major types of feeding in association with shrimpers: (1) feeding behind actively trawling shrimp boats; (2) feeding on "trash fish" discarded after a trawl; (3) feeding around non-working, anchored shrimpboats. Dolphin-shrimp fishery interactions are also addressed by Gunter (1942, 1954), Norris and Prescott (1961), Caldwell and Caldwell (1972a), Hogan (1975), Shane and Schmidly (1978), and Wells, Würsig and Norris (1981). Gruber (1981) conducted in-depth interviews with Texas shrimp fishermen and observed dolphin-shrimpboat interactions. Her observations concurred with those of Gunter (1954) and Norris and Prescott (1961) who noted Tursiops response to changes in engine and winch sounds indicative of various stages of the shrimping operation. Gruber (1981) noted that dolphins moved toward shrimpboats at least 1.5 km away, while Norris and Prescott (1961) saw dolphins approach shrimpers from 2 miles away. She found an increase in dolphin abundance in one area at the time that shrimping began there, but she was unable to determine whether shrimping attracted more dolphins to the area or whether a seasonal increase in the abundance of food there drew additional dolphins to the area. Gruber's interviews with shrimpers indicated that dolphins were infrequently drowned in trawls (77% of the respondents had never captured a dolphin) and that shrimpers usually had a benevolent attitude towards dolphins (although 23% had shot at dolphins and 18% had killed them). Some shrimpers contended that dolphins tore their nets while taking fish from them while others were certain that only sharks tore the nets and that dolphins removed fish daintily (also recorded by Shane and Schmidly 1978). Irvine (1975 in Odell et al. 1975) contended that fishermen on the west coast of Florida generally "feel protective of local dolphins" but evidence of net scarring and a few dolphins killed by shooting showed that some conflicts occurred.

Busnel (1973) described a "symbiotic" interaction between *Tursiops* and native fishermen on the coast of Mauritania simultaneously fishing for mullet. The fishermen set up nets and beat the water to "call" the dolphins; the dolphins herd fish against the nets, presumably catching some for themselves while others are entrapped in the nets. In Georgia (Dean 1979) and in Florida (Shane, unpubl.) crab fishermen feed *T. truncatus* by hand from their boats.

Tursiops has been reported to be a nuisance to at least three fisheries. In the Indian River in Florida, Orr (1976) and Leatherwood (1979) reported damage by dolphins to lines and nets used in the mackerel fishery. To our knowledge, these charges have never been investigated to the extent that dolphins can specifically be implicated. In Florida, Cato and Prochaska (1976) implicated *Tursiops* in damaging handlines and nets. Dolphins also steal bait from lines in Hawaii. Kuljis, Baker and Gilmartin (1981) reported on tests of lithium chloride as aversive to dolphins when inserted in bait; the substance failed to cause one-trial aversion but was considered to have potential for diverting dolphins from fishery predation. At Iki Island, Japan bottlenose dolphins are slaughtered annually by fishermen who consider the animals significant competitors for local fish stocks (Imanishi 1981). _T. truncatus_ are reportedly taken alive accidentally in a menhaden fishery in Mississippi Sound and in a purse seine fishery off the Florida panhandle (Shane, notes from Conf.). Incidental _Tursiops_ mortality occurs in mullet gill nets off west Florida (Wells et al. 1981).

Contact Direct association between humans and dolphins has ancient roots, and is described in tales told in ancient Greece (Devine and Clark 1967). In recent times, bonds have been established between humans and individual bottlenose dolphins in New Zealand (Alpers 1961), England (Dobbs 1977; Webb 1978), South Africa (Saayman and Tayler 1971; Tayler and Saayman 1972), and France (Hussenot 1980). In western Australia, an entire group of _Tursiops_ comes close to shore to be fed and petted (Gawain 1981).

Habitat Alteration The impact of habitat destruction on bottlenose dolphins has never been thoroughly investigated. Odell (1976) suggested that pollution and heavy boat traffic in Biscayne Bay may have contributed to an apparent decline in abundance of _Tursiops_ there. Changes in bottlenose dolphin presence and behavior in San Diego Bay have been linked to pollution (FAO-ACMRR 1978, p. 112). Dolphins were absent from the bay when siltation from dredging and sewage discharges were at their peak and returned to the bay after conditions improved. Gunter (1942) believed that the _Tursiops_ population in south Texas declined since the early 1900s. Although no accurate abundance estimates are available, popular opinion indicates that _Tursiops_ numbers have declined in Galveston Bay concurrently with its increased use as a shipping route and increased pollution (Shane, unpubl.). Bottlenose dolphins are extremely abundant in Aransas Pass despite its use by oil tankers and a large number of smaller boats (Shane and Schmidly 1978). Extremely high chlorinated hydrocarbon residues have been found in the tissues of marine mammals, including *T. truncatus* (O'Shea et al. 1980). In fact, the blubber of California *Tursiops* contained some of the highest PCB and DDE residues ever found in cetaceans. DDT in California cetaceans and pinnipeds was the "highest known for any populations of wild mammals."

Summary Considering past evidence from human-dolphin interactions, oil exploration and drilling in the Gulf of Mexico could have any number of effects ranging from positive to neutral to adverse. Baseline data on populations of *T. truncatus* to be affected by oil-related activities are necessary before any resulting impact can be measured.

IMPACT OF OIL-RELATED ACTIVITIES

Potential effects of oil-related activities on *Tursiops* in the Gulf of Mexico are wide-ranging and relate to the animals' behavior, ecology and physiology. However, there are almost no field data on the subject and experimental studies have been initiated only recently. Geraci and St. Aubin (1980) thoroughly reviewed potential and observed effects of petroleum-related activities on marine mammals. A report on experimental results of oil effects on *Tursiops* by Geraci and St. Aubin (1982) and anecdotal observations of the behavioral response of free-ranging *T. truncatus* to oil spills are the only concrete information available now.

Geraci and St. Aubin (1980) identified shock waves, noise, oil contamination (ingestion, inhalation and epidermal effects), and oil spill clean-up activities as the major potential problem areas for marine mammals. Explosive blasts were considered more threatening than the air guns regularly used in marine oil exploration. They proposed determining the "safe distance" from blasts for marine mammals and monitoring the behavioral response of animals to blasts. The authors felt that the low frequency noise associated with oil activities was potentially most harmful as stress-inducing. Stress, in turn, could make animals physiologically vulnerable to disease, parasitism, and environmental changes, as well as possibly influencing reproduction. Chronic noise could also displace marine mammals from their normal ranges. Geraci and St. Aubin (1980) felt that "prolonged inhalation" of volatile hydrocarbons could have severe effects. Geraci and St. Aubin (1982) reviewed the literature on inhalation of oil vapors by mammals and concluded that inspiration would be problematic only for animals stressed by existing pathologies, animals exposed to the freshest and most concentrated parts of a spill, and animals exposed for a long period of time. Geraci and St. Aubin (1980, 1982) felt that ingestion of small amounts of oil would probably not be toxic to dolphins, but that chronic ingestion of petroleum by-products in food items could result in tissue accumulation. In analyzing 258 tissue samples from marine mammals on the Atlantic coast of North America, Geraci and St. Aubin (1982) consistently found detectable amounts of naphthalene, a petroleum element. Geraci and St. Aubin (1980) noted a need to investigate the effects of "solvent-emulsifiers" used in oil spill clean-ups on marine mammals.

Geraci and St. Aubin (1982) conducted the first experimental studies of cetacean responses to oil. They reported on *Tursiops* ability to detect oil, *Tursiops* avoidance of oil in captivity, and the reaction of *Tursiops* skin to oil contamination. *T. truncatus* was able to visually detect varying concentrations of oil held directly above it in a bottomless cylinder suspended 1 m deep. From these results, the authors predicted that *Tursiops* could easily detect a 1 mm film of dark crude oil. Using only echolocation, dolphins should detect 12 mm or thicker patches of oil. In the experimental situation, dolphins exhibited a startle response when first contacting oiled sections of their sea pens, and thereafter, assiduously avoided the contaminated areas. Geraci and St. Aubin (1982) included findings by Caldwell and Caldwell on a study performed in 1968 on the effects of a film of hydraulic oil on four captive bottlenose dolphins (a total of 2.7 l of oil was introduced into the pool during the 3-month study, leaving a thin film on the water at all times). The Caldwells observed no apparent skin or lung pathology, but one dolphin exhibited signs of liver damage during the experiment. One dolphin died and 2 were euthanized within ten months of the conclusion of the study, but the postmortem pathologies could not be conclusively related to the oil exposure.

Geraci and St. Aubin (1982) found only a mild gross response by cetacean skin exposed to different types of oil and gas for up to 75 min. Decreased phospholipid synthesis was the only biochemical change of note in *Tursiops* epidermal cells.

Two accounts of the behavioral response of bottlenose dolphins encountering oil spills are available from the Gulf coast of Texas. Shane (1977) and Shane and Schmidly (1978) saw dolphins traveling through an oil slick resulting from a spill of 15,540 gallons of crude oil. They observed no unusual behavior and the dolphins surfaced in the oil, though apparently not in the thickest concentrations. Gruber (1981) observed *Tursiops* in a slick produced by a spill of No. 6 fuel oil (11,356 l of the oil washed ashore). She observed dolphins in the heaviest concentrations of oil and noted an unusually high level of aerial activity and fish tossing. Gruber (1981) felt that, as Geraci and St. Aubin (1980) suggested, fish debilitated by the oil spill might have attracted dolphins and thus, explain the frequent fish tossing. She had some evidence that individual dolphins remained in the slick for hours at a time.

Summary The impact of oil-related activities on *T. truncatus* cannot yet be predicted with assurance. Experimental data indicate that short-term exposure to oil may have minimal effects. However, the long-term effects of chronic oil ingestion (directly or through the food chain) and chronic exposure to noise may pose much greater threats. Field observations contradict the laboratory finding that dolphins will avoid an oil spill; indeed, fish debilitated by oil may attract dolphins to a spill. The need for additional field data is obvious, and baseline behavioral and ecological information is needed to ascertain any impacts that may result from petroleum-related activities.

TECHNIQUES OF RESEARCH

In the past fifteen years, the sophistication of field research techniques on animals has risen tremendously (Lehner 1979). We shall here confine ourselves to materials and methods proven of value in the study of the behavior, social organization, and ecology of small-toothed whales. We shall also suggest possible avenues for future research.

In order to study the behavior of a free-living mammal, we may sense it directly, either with our eyes (aided by binoculars, spotting telescopes, night-vision telescopes, cinematography, videorecording, still photography), or with our ears (aided by sound-enhancing and recording equipment). We may also sense it by converting physical phenomena which are not directly utilized by us into a human-intelligible form. Thus, we may place a radio transmitter on an animal and record its movement patterns by homing onto the source of transmission, or we may scan the environment with an infrared wavelength detector in order to pick up the exothermic products of mammal metabolism. While radio tracking has been of great utility for marine mammal movement studies, infrared sensors have so far proven to be of only limited use for pinnipeds and larger whales.

Because this paper focuses on behavior, social organization, movement patterns, and ecology of bottlenose dolphins, we will discuss techniques particularly amenable to obtaining such information. We will not detail, for example, the techniques required for assessing abundance of populations and overall distributions of animals. It will be readily apparent, however, that such methods as tag-resighting efforts and radio tracking can provide data not only on social organization and use of habitat, but on population counts and distribution as well.

Stationary or moving sites for data collection are required for gathering behavioral and ecological information on small toothed whales. For nearshore animals such as bottlenose dolphins, high coastal cliffs or vantage points (such as houses or other human-made structures) have been shown to be useful (Saayman and Tayler 1973, 1979; Saayman, Bower and Tayler 1972, Saayman et al. 1973 - humpback, common, striped, and bottlenose dolphins; Norris and Dohl 1980a, Norris et al. 1982 - spinner dolphins; Würsig and Würsig 1979, 1980 - bottlenose and dusky dolphins, respectively; Balcomb et al. 1980 - killer whales; Larry Hansen, pers. comm. - bottlenose dolphins; further review by Wells et al. 1980).

<u>Stationary Platforms</u> The advantages of a stationary platform are several. One can observe the animals with high-powered visual equipment; one can monitor radio-tagged animals with large antennas and, therefore, less portable receiving equipment; the researchers do not intrude on the animals and can be certain that they are not disturbing them. Visual tracking equipment, pioneered by Roger Payne (see Würsig 1978), can help to describe the nearshore movements, speeds, depth of water, and group-to-group associations in detail. Hydrophones can be staked to the bottom near the site, and dolphins can be monitored acoustically during day and night. A disadvantage is the immobility of the observation site. Animals can be studied only when they are within a few km of the site.

Stationary observation sites have not been used extensively in the Gulf of Mexico because of the low coastal terrain, but full advantage has not been taken of structures such as towers and condominiums. Also, offshore drilling and other oil and gas-related platforms might be used in the Gulf of Mexico.

When a suitable site is chosen where dolphins may pass by or aggregate on at least a casual basis, much long-term behavioral information on a group level (feeding, socializing, resting, traveling, response to vessels and other disturbances, etc.) as well as on a focal-animal level (details of inter-individual social behavior) may be gathered.

Small Boats Small boats (3 to 10 m) have an advantage over stationary observation sites because the investigators are able to approach dolphins, identify known individuals, study intra-group behavior in detail, and discover movement patterns by traveling with a group for several hours. The obvious disadvantage is the potential for disturbance by the presence of the vehicle.

Killer whales have been successfully monitored in this manner (Bigg, McAskie and Ellis 1976, Balcomb et al. 1980, Balcomb, Boran and Heimlich 1982), and Norris and Dohl (1980a) report good results in studying spinner dolphins from a small vessel. Würsig and Würsig relied heavily on small inflatable outboard motor vessels to follow dusky dolphins (1980) and bottlenose dolphins (1979) in southern Argentina. They had an independent check on whether such vessels were disturbing the movements and behaviors of the animals, because they monitored them from cliff sites at the same time. They found that disturbance depended on the behavior patterns of dolphins. In general, dolphins which were looking for food or resting were more easily disturbed than those which were socializing or playing. Spinner dolphins may be disturbed by vessels in a similar manner, and in Hawaii, they can even be "driven out" of a bay by boat noise in the morning as they descend into rest (Norris et al. 1982).

Most research on bottlenose dolphins in the Gulf of Mexico has relied heavily on small boat work (Wells et al. 1980 and Irvine et al. 1981 - Florida; and Shane 1977, 1980; Gruber 1981 - Texas, represent the most detailed work).

These researchers found that they could slowly move with groups for long periods of time, sometimes all day, without appearing to greatly affect the behavior of the dolphins.

Large Boats   Large vessels have been used mainly in pelagic waters to obtain distribution information and a limited amount of behavioral information on dolphins (Rice 1960, Norris 1974). Large vessels engaged in other work may be used as "platforms of opportunity," and observers have been stationed on these vessels to look for dolphin schools. (The tuna vessel observer program in the Eastern Tropical Pacific, coordinated by the National Marine Fisheries Service, Southwest Fisheries, La Jolla, California, is one such successful program). Large vessels in the form of shrimp boats and oil industry ships might be used as similar platforms of opportunity in the Gulf of Mexico.

Airplanes   Airplanes have the advantage of quickly covering a large area, both near- and off-shore. This makes them valuable for assessing relative abundance of dolphins in different areas, but behavioral observations are usually limited. Nevertheless, airplanes have been used to describe behavior, and they have proven particularly helpful in gathering information on bottlenose dolphins in the Gulf of Mexico (Leatherwood 1975, 1977; Leatherwood et al. 1978; Odell 1976, Odell and Reynolds 1980; Barham et al. 1980). Recently, Wells used a small airplane to describe distribution, group structure, calf-adult ratios, and behavior in Hawaiian spinner dolphins (Norris et al. 1982), and Perryman, Scott and Hammond (1981) used airplanes equipped with large-format cameras to photogrammetrically measure sizes of spinner and spotted dolphins in large herds in the Eastern Tropical Pacific. This kind of work is expensive, but can teach us much about group organization, especially of animals not easily accessible from shore.

Underwater Observations   Underwater work has been done in clear water by several researchers. Evans and Bastian (1969), Norris (1974), Norris and Dohl (1980a), and Norris et al. (1982) reported on the use of semi-submersible vehicles with underwater portholes. Würsig and Würsig (1980) described behavior of feeding dusky dolphins by observing them with skindiving equipment, and researchers filmed Hawaiian spinner dolphins both from inside and outside of their underwater observation vehicle (Norris et al. 1982). However, such studies are limited to areas where dolphins congregate in relatively calm and clear waters. They may be used constructively offshore in the Gulf of Mexico, but it is unlikely that direct observation from underwater is possible nearshore, due to high turbidity.

Individual Identification   Bottlenose dolphins often show marks, scars, and pigment pattern variations on the body. These natural marks allow for individual recognition and a determination of group composition from day to day. Although some individuals have been recognized by gross deformities and pigment patterns for some time (Caldwell 1955, Irvine and Wells 1972), only some recent studies have taken advantage of subtle marks in order to study group composition in detail (Würsig and Würsig 1977; Wursig 1978; Shane 1977, 1980; Gruber 1981). An on-going study of bottlenose dolphins in the Sarasota area of Florida used photographic identification techniques to repeatedly identify resident members of several adjacent populations. Some of the naturally-marked dolphins have been reidentified over a twelve-year period (Wells et al. 1980, 1981, Irvine et al. 1981). Photographic identification of dolphins is possible from shore and from small vessels, and it avoids subjecting dolphins to the trauma of capture. Unfortunately, because bottlenose dolphins are relatively sexually monomorphic, such a study does not allow for an analysis of sex composition, except for presumed females accompanied by calves.

Capture and Tagging The capture of animals allows a determination of sex, size and approximate age. At the same time, tags or marks can be placed on the captured animals, and biotelemetric packages for remote sensing can be attached as well. Although bottlenose dolphins have been captured extensively for live-animal displays, this technique for gathering group composition data was pioneered by Evans (1971, 1974), Evans et al. (1972) for common dolphins, and by Irvine and Wells (1972), Irvine et al. (1981), and Irvine, Wells, and Scott (1982) for bottlenose dolphins in Florida. The history and techniques of capture for determining sex, size and age, and for tagging, have been reviewed by Leatherwood and Evans (1979) and by Irvine et al. (1982).

Dolphins can be captured either individually, by a hoop net or a tail grab device as they ride the bow wave of a traveling vessel, or as a group within an enclosing net (Asper 1975). This group capture technique has been extensively used in the shallow nearshore waters of the Gulf of Mexico, and will continue to serve well in gathering detailed information on bottlenose dolphins. Mass capture in shallow water (<2 m) has the advantage of rapidly and efficiently assessing the age and sex status of an entire group, but it must be carried out only by highly experienced animal handlers, because the risk of accidental drowning as dolphins become entangled in the capture net is great.

Capture of dolphins allows for the placement of different types of tags. Most attachment tags pose the possibility of injury to the dolphins and should be selected with care (Irvine et al. 1982). Radio tags can supply information on movement patterns, respiration rates, depths and lengths of dives. Many researchers have successfully employed radio tracking on close to one dozen species of toothed whales at this time (reviewed to about 1977 by Leatherwood and Evans 1979), and its utility has been best demonstrated by the work of Irvine et al. (1981) on bottlenose dolphins.

Jennings (1981) recently successfully satellite-tracked spotted dolphins off Hawaii. This long-range radio tracking technique holds great promise for future studies on large-scale movement patterns. A major problem with radio tags has been their size. The satellite tags, particularly, must be reduced in order to be comfortably fitted onto the dorsal fin of a bottlenose dolphin.

Cryogenic marks (freezebrands) are a highly effective means of providing unambiguous, long-term marks to animals without injury (Asper and Odell 1980; Irvine et al. 1982; Odell and Asper 1982).

While dolphins are briefly retained after capture, manipulations other than sizing, sexing, and tagging are possible. Thus, blood may be sampled for ascertaining reproductive state (Kirby 1981, Kirby and Ridgway 1981, Wells 1981) or for studies of population interactions (Duffield 1980, 1981, 1982). A tooth may be taken for ageing (Hohn 1980). A marker such as a tetracycline analogue may also be injected, so that tooth layer deposition for age determination can be calibrated upon future capture of the same animal. Hall (1977) reports on the use of a stomach pump to obtain information on what the dolphin has been eating, although this technique has not yet been tested extensively in the field.

Although there is a temptation to use all or most of these techniques on a captured animal at one time, we are of the opinion that the trauma of capture is great, and that as few as possible of such invasive techniques should be used at any one time. We also do not believe that animals should be killed in order to gather data on stomach contents, reproductive state, and other biological parameters. Instead, we should make full use of stranded animals, as is presently being done for bottlenose dolphins along the Atlantic and Gulf of Mexico shoreline (Odell and Asper 1982).

Captive Animal Research Captive dolphins can be used in non-harmful experimental studies such as those conducted on bottlenose dolphins by Geraci and St. Aubin (1982). These techniques are especially important in assessing the possible effects of oil and oil-related activities on dolphins. Blood samples from captive dolphins can be analyzed for hormone levels and genetic characteristics, thus providing further insight into reproduction and stock discreteness. Blood and tooth samples can be taken regularly from captive *Tursiops* and from dolphins handled and released by collectors to improve our knowledge of age-related reproductive parameters.

Acoustics A final technique for gathering information on live animals is that of acoustic behavior monitoring. Dolphins are vocal animals *par excellence*, and many of their social interactions and food-finding techniques involve sound. Because sound travels well in murky water and at night, animals which are out of sight can be monitored in this manner.. Tyack (1976) described sounds of bottlenose dolphins in Argentina, and discovered that he could assess the overall behavior patterns (such as resting, traveling, socializing, feeding, etc.), at least in part, by sounds emitted. Graycar (1976) hypothesized that populations may be differentiated by dialects of sound repertoire. Dialects have recently been demonstrated for killer whales (Ford and Fisher 1982).

Information on sound emission of bottlenose dolphins can be gathered by deploying hydrophones from shore, from vessels, or via sonobuoy relays from boats or airplanes. Snapping shrimp and other biological noises, as well as a high level of boat traffic, are ever-present problems in the shallow areas of the Gulf of Mexico, but if the dolphins can communicate among themselves, we can monitor at least some of this communication despite noise interference. On a more refined basis, a shallow-water, three-dimensional hydrophone array (Watkins and Schevill 1974) or a phase-shift detector (Clark 1980) may be used in order to localize sound, and in this manner be able to detect communication between approaching or departing groups, for example. Because sound is an integral part of dolphin behavior, it should also be a part of any comprehensive behavioral study of bottlenose dolphins.

New Techniques   Most of the methods of investigation discussed above have been used to gather information on dolphins in the wild, and they are readily available for further work if interest and financial support allow. We must consider new techniques for wresting information from these difficult to study animals as well.

Telemetry equipment may do more than merely provide a simple radio signal from an animal, but may also monitor heart rate, depth of water, and body temperature (Mackay 1964, 1970). The monitoring of heart rate may be particularly important in assessing the disturbance of dolphins by human-made stimuli such as can come from oil and gas exploration and development. Experimentation is now underway to record stomach temperature from great whales by the use of acoustic transmitters (Mackay and Dolphin 1982). The temperature sensors detect when food is being swallowed, and can thus provide valuable data on the feeding regime. Dolphins can hear acoustic transmitters even at ultrasonic (to human ears) frequencies, and a modification is possible to either send the information to a radio transmitter mounted on the back in conventional fashion, or to store the information in a mini-recorder also mounted to the dolphin.

Sonar has been used to detect dolphins underwater, and the recent sophisticated development of sidescan sonar makes it likely that dolphin depths of travel and underwater spacing, as well as feeding, may be studied with high-resolution capability in the near future. A sidescan sonar mounted on a pier in a nearshore channel or estuary may, for example, detect dolphins passing, group size, and spacing, although reflection problems associated with shallow water must be resolved.

Interest is increasing in experimentation with localizing dolphin sounds by the recording of vocalizations directly at the source, and by storing these vocalizations in micro-recorders or by sending them out from the animal in either acoustic or light form. Also, several videocamera prototypes are small enough to enable us to think about mounting them on the backs of dolphins in the near future, so that we can see what the dolphin sees, and gather detailed information on inter-individual relationships, spacing, and behavior patterns of moving dolphin schools. The combination of sound localizers and video camera techniques may greatly enhance our knowledge of social organization and behavior in the near future, although all visual techniques are hampered by poor visibility in nearshore waters of the Gulf of Mexico.

<u>Summary</u> A discussion of techniques of research leads us to recommendations for future research on bottlenose dolphins, with special emphasis on assessing the impact of oil and gas exploration and development in the Gulf of Mexico. Because it has been shown to be feasible to study this species, it may serve

well as an "indicator" species, allowing us to cautiously extrapolate information from bottlenose dolphins to other marine mammals less amenable to study. However, we must not forget that bottlenose dolphins are highly adaptable and flexible, and may therefore be less affected by potential disturbance than some other more specialized cetaceans.

In order to assess the impact of oil and gas exploration and development on the behavior of dolphins, we must design research projects to study behavior in areas where oil activities are established, in areas where oil exploration and development are planned, and in unaffected areas. At the simplest level, respiration rates, times at and below the surface, and time spent engaging in basic behaviors (such as traveling, feeding, resting, socializing) should be monitored and compared in these three areas. Just as important, however, is a determination of possible shifts in group size, group composition movement patterns and home range use due to development. It should be assumed that the undisturbed condition represents the most natural and most efficient system.

The techniques discussed here will be of use in the determination of both short-term and long-term effects. The most profitable of these, we feel, will be the long-term diligent monitoring of behavior and social patterns using photographic recognition, capture, tagging, and radio tracking.

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.