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DOI: https://doi.org/10.31979/etd.avbn-sgz6
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PACIFIC COAST BOTTLENOSE DOLPHINS (*Tursiops truncatus gilli*)

IN MONTEREY BAY, CALIFORNIA.

A Thesis

Presented to

The Faculty of Moss Landing Marine Laboratories

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Daniela Maldini Feinholz

December, 1996

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ABSTRACT

PACIFIC COAST BOTTLENOSE DOLPHINS (*Tursiops truncatus gilli*) IN MONTEREY BAY, CALIFORNIA.

by Daniela Maldini Feinholz

Between 1983 and 1993, 351 sightings of Pacific coastal bottlenose dolphins (*Tursiops truncatus gilli*) were reported off central California. Eighty-four boat-based surveys in Monterey Bay (Oct 1990 - Nov 1993), resulted in the photoidentification of 68 uniquely marked individuals. Forty-three (62 %) of the dolphins identified were previously photographed in the Southern California Bight.

School size ranged between 2 and 35 animals (mean ± S.D. = 16.60 ± 7.72). Jolly-Seber population estimates indicated a doubling in the population from 1990 to 1993.

Dolphins occupied the northern portion of Monterey Bay preferentially. Sightings were abundant in front of the Pajaro River mouth. At least 13 of the photoidentified dolphins were present in Monterey Bay throughout the study period.

Mean level of association was 0.17 (S.D. = 0.19). Thirty-four percent of the associations were significant. No statistical differences were found in mean school size and mean rate of increase of photoidentified dolphins between normal and El Niño conditions.

"...The story of the dolphins begins with the creation of our people.
We were seeds from a magic plant, sown by the Earth Goddess Hutash.
She took care of us as her own children and watched us grow.
Her children grew numerous and the villages grew crowded and noisy.
The noise bothered Hutash, so she decided that some of the people
would go to the mainland to start new villages. Hutash made a bridge,
a beautiful rainbow bridge that stretched from the tallest mountain on this island
to the tallest mountain on the mainland. Hutash told the people to cross the rainbow
and fill the whole world with people. Many of the people made it safely across,
but a few became dizzy and fell toward the Earth. Hutash was watching
and she saw them tumble off the rainbow bridge and fall through the sky.
Faster and faster they dropped, falling with great speed toward the ocean.
Hutash did not want to see them drown. As they fell,
she carefully changed them into dolphins and they slipped into the water safely.
That is why the dolphins remain our friends and our brothers today...".

a Chumash Legend

ACKNOWLEDGMENTS

I am in debt to many people for their patience and advice while I was completing this thesis. This work would not have been possible without the help and support of my husband, Michael, who shared with great patience the ups and downs of my writing process. I am also grateful to my parents for their unconditional support.

My research received numerous grants. Each of them made a big difference toward its completion. There were also numerous people that contributed time and enthusiasm. They were instrumental during data collection and in the maintenance of equipment. The first thanks goes to Tom Norris for providing, and for collecting the initial data. Thanks to Gene Kent for sharing with me many months of boat time and many a laugh. The staff of Moss Landing Marine Labs always offered logistic support, especially Aldo De Rose, Sandy Yarborough, and Gail Johnston. I am particularly indebted to the people at Marine Operations: Neddra Shutts, Mike Prince, Tracy Thomas, and John Douglas for always facilitating my boat work and taking care of the many technical difficulties.

The faculty at Moss Landing Marine Labs was a tremendous source of inspiration and knowledge: Dr. Harvey was a valuable advisor and teacher throughout the years, and a useful critic when the work needed improvement or development. Being part of the Vertebrate Lab surrounded me with many friends and enriched my life with some unforgettable moments. Dr. Welschmeyer was a valuable reviewer. I am also extremely grateful to Dr. Broenkow for access to his computers.

I had the honor of working with Dr. Defran, at San Diego State University, who provided both moral and technical support. His useful comments, his gracefully presented insights, and his cooperation made a dramatic difference. His students, Jo Anne Scott in particular, helped me immensely wading through the wealth of information at the Cetacean Behavior Lab in San Diego.

Many people came out on the boat, both to enjoy the dolphins and to help collecting data. A special thanks goes to Earthwatch Expedition and The Center for Field Studies, who provided logistic and financial support. Many Earthcorps volunteers traveled from all over the world to Monterey Bay to lend a willing and helping hand to this project. Many student assistants joined me in the field: Cheryl Baduini, Laura Bonomi, Kristi Brockway, Matt Burd, Benedetta De Marsanich, Ken Ichi-Saitoh, Kathy Hugh, Tony Orr, Sue Lynn Konopka-Reif, Dida Kutz, Jennifer Maucher, Doreen Moser, Deb Nebenzahl, Elena Politi, Mark Punton, Diana Reischel, Lesley Skelton, David Silver, and Derrik Spice. Many other people occasionally gave their contribution of time and logistic support. My greatest affection and respect goes to Sheila and Alan Baldridge, who always supported my efforts with trust and enthusiasm, and provided me with precious reference material.

I have enjoyed many a ride in a State Parks vehicle exploring the coastline for dolphins in the company of Eric Sturm. It was a fun and rewarding experience and I sincerely thank Eric and Dave Dixon at Marina State Beach for making it possible.

I am also profoundly in debt with Dennis Kelly, at Orange Coast College for his dedication and fresh perspectives on the California dolphins. He has been a dear friend and a valuable contributor to this work through the years.

All of these people made my experience very special. I do not think there will ever be a proper way to show my appreciation to them, so I will let my work speak for me, and hope they will enjoy the results.

The following sponsors (in alphabetical order) provided support for this project: Cetacean Society International; Earthwatch Expeditions and The Center for Field Studies; Dr. Earl Myer and Ethel Myer Oceanographic and Marine Biology Trust Fund; Long Marine Lab and Dr. Ron Shusterman; Moss Landing Marine Laboratories; State Parks and Recreation, Marina State Beach; The American Cetacean Society, Monterey Bay Chapter; The American Cetacean Society, Orange County Chapter; The American Museum of Natural History, New York; The Packard Foundation.
All photo-identification work was conducted under the following permits : National Marine Fisheries Service (NMFS) Permit No. 319, issued to Dr. Defran at the Cetacean Behavior Laboratory (CBL) at San Diego State University (SDSU), NMFS Permit No. 748, issued to Dr. Barrett, South West Fisheries Center (SWFC), La Jolla, California, and NMFS Permit No. 872, issued to Daniela M. Feinholz, Moss Landing Marine Laboratories (MLML), and Dennis Kelly, Coastal Dolphin Research Project, Orange Coast College (OCC), Costa Mesa, California. Photographic matching between Monterey Bay and the Southern California Bight was accomplished in collaboration with SDSU-CBL and OCC.

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INTRODUCTION

The study of free-ranging cetacean populations constitutes one of the major challenges in the study of marine life. Proper management dictates that populations should be maintained at a high level of genetic diversity, and it is important to define how much variability exists within them. It also is important to determine basic information such as population size, rate of population increase and decrease, life history, distribution, movement patterns, and genetics. Unfortunately, this information is incomplete for the majority of cetacean species.

Bottlenose dolphins (*Tursiops truncatus*) are distributed widely throughout the world. Some longitudinal studies of bottlenose dolphins worldwide are in progress (Wells *et al.* 1987, Connor *et al.* 1992, Wilson *et al.* 1993), but basic information for many coastal populations, and virtually all offshore populations is not yet available.

In most areas where bottlenose dolphins have been studied, the presence of two eco-types has been recognized: a coastal and an offshore form (Caldwell and Caldwell 1972, Walker 1975, 1981, Leatherwood and Reeves 1983). These two forms are almost indistinguishable in the field, but have striking differences in blood composition: i.e. hemoglobin levels, packed cell volume, and red blood cell counts (Duffield *et al.* 1983). The levels of these three factors are significantly greater in the offshore form, possibly because of the physiological demands of deeper dives. In general, the coastal form seems to be confined to lagoons, embayments, and shallow waters less than 20 meters in depth (Leatherwood and Reeves 1983). Bottlenose dolphins near islands are considered to be the offshore form (Duffield *et al.* 1983). Along the Pacific coast of North America, the coastal form is identified as *Tursiops truncatus gilli*, and the offshore form as *Tursiops truncatus nuanu* (Walker 1981, Duffield *et al.* 1983).

During the present century, coastal bottlenose dolphins have not been reported off central California and northward (Wells *et al.* 1990). Based on strandings, and natural history studies, the "normal range" for coastal bottlenose dolphins in California was considered to be from Point Conception (33° 33.0' N) southward, and sightings between Point Conception and Point Dume were considered rare before 1982-83 (Hansen 1990). Historical records indicated bottlenose dolphins occurred north of their "normal" range: a bottlenose dolphin skull was collected in Monterey Bay in 1871 (Scammon 1874), another, estimated to be 50-100 years old, was recovered in San Francisco Bay in 1958 (Orr 1963), and a third skull was dredged in Richmond, Contra Costa County, in 1980 (Sczcepaniack pers. comm.) indicating the presence of this species in central California waters in the past. Records unfortunately do not indicate whether this presence was due to a temporary shift in range, or indicative of long-term residency.

The recent re-appearance of coastal bottlenose dolphins along the central California coast, as far north as Monterey Bay, was attributed to the 1982-83 El Niño Southern Oscillation (ENSO) event (Wells *et al.* 1990). An El Niño Southern Oscillation is an inter-annual perturbation of the climate system characterized by a periodic weakening of the trade winds and a warming of the surface layers in the equatorial Pacific Ocean occurring approximately every 4 to 7 years. The impacts of ENSO are felt worldwide through a disruption of the general atmospheric circulation and associated global weather patterns. An ENSO also affects the ecosystem dynamics in the Pacific Ocean, particularly the higher trophic levels of the food chain on which fisheries depend (McPhaden 1993).

This kind of oceanographic phenomena was considered relevant in determining shifts in abundance and distribution of bottlenose dolphins, as well as other marine organisms along the California coast (Hansen 1990, Wells *et al.* 1990). The 1982-83 ENSO event was the strongest recorded for this century, and its beginnings could be traced to May 1982 (Glantz 1984). It caused massive movements of traditionally warmer water prey to northern latitudes (NOAA, 1992), and may have affected the dolphins foraging efficiency, causing them to move further north, although only indirect evidence of a possible effect of ENSO on the coastal dolphin population is currently available (Wells *et al.* 1990).

Objectives

Since Monterey Bay was designated a National Marine Sanctuary in 1992, there has been an increasing interest in obtaining information on cetaceans that inhabit its waters. Because bottlenose dolphins only recently expanded their range to occupy Monterey Bay, no previous study existed on their general ecology in this area. Furthermore, information on abundance and distribution patterns along the central California coast was limited to data collected between 1983 and 1988 (Wells *et al.* 1990). The primary objectives of this study were, therefore, to determine presence/absence patterns of bottlenose dolphins along the central California coast from 1983 to present, and to provide preliminary information on abundance, distribution, and social ecology of these animals in Monterey Bay.

Part of this study was carried out during an ENSO event. Positive sea surface temperature (SST) anomalies began to appear in the central and eastern tropical Pacific in mid-1991 (NOAA 1992, 1993 McPhaden 1993). Such occurrences provided the opportunity to gather preliminary information on the possible effects of an ENSO event on abundance and distribution of bottlenose dolphins in Monterey Bay.

METHODS

STUDY AREA

Monterey Bay is located along the central California coast, about 180 km south of San Francisco (Fig. 1). It is California's second largest bay, and one of the few major bays along the entire Pacific coast of the United States. The bay is approximately 37 km long, north to south, and 16 km wide, east to west (Breaker and Broenkow 1989). Another distinguishing characteristic of Monterey Bay is the presence of the deepest and largest submarine canyon along the west coast of North America. The biological importance of Monterey Bay lies in its nutrient rich waters, which support a diversity of aquatic populations.

Numerous marine mammal species forage within the bay's coastal strip. Among them are the southern sea otter (*Enhydra lutris nereis*), the harbor seal (*Phoca vitulina*), the California sea lion (*Zalophus californianus*), the harbor porpoise (*Phocoena phocoena*), and the coastal bottlenose dolphin (*Tursiops truncatus gilli*; NOAA 1990).

Near-shore waters are generally highly productive, and constitute an important spawning ground for coastal fishes. Few ichthyological studies, however, include the surf zone in Monterey Bay, probably because it is not exploited by commercial fishing activities. Abundance and distribution of local fish species are, therefore, poorly understood. Kukowski (1972) found that the most abundant prey species present in the nearshore environment of Monterey Bay were night smelt (*Spirinchus starski*), northern anchovy (*Engraulis mordax*), white croacker (*Genyonemus lineatus*), spotfin surfperch (*Hyperprosopon anale*), Pacific and speckled sandab (*Citharichthys sordidus* and *C. stigmaeus*), and various species of sole.

The study area for this study stretched from Marina, on the south side of the bay, to New Brighton Beach, on the north (Fig. 1). The area covered approximately 18 km along the coast to 1 km offshore. The study area was confined to within 1 km of shore because: a) despite the high commercial, recreational (Black pers. comm., Ternullo pers. comm., Baldridge pers. comm), and research vessel traffic year-round in Monterey Bay (Harvey *et al.* 1995), only one sighting of bottlenose dolphins beyond 1.5 km was reported (Mason pers. comm.); and b) studies in the Southern California Bight (Hansen 1990, Hanson and Defran 1993) supported the assumption that coastal bottlenose dolphins spent approximately 99 % of their time within 1 km of shore.

The southernmost section of the bay, between Marina and Monterey, was excluded for logistical reasons: the Fort Ord military base was located between Marina and Seaside until 1994. Navigation in front of the base was forbidden to any non-military craft within 5.6 km from shore. Circumnavigation of this area would have been lengthy and impractical for a small boat.

The designated study area was divided into two legs : Moss Landing to Marina (southern leg, 22 km^2), and Moss Landing to New Brighton Beach (northern leg, 11 km^2). To determine differences in distribution patterns, each leg (north and south) was subdivided into quadrates of equal size (3 nautical miles x 1 km; Fig. 1):

Area 1 - 36° 42.3' to 36° 45.5' N: Marina to Monterey Dunes

Area 2 - 36° 45.5' to 36° 48.3' N: Monterey Dunes to Moss Landing

Area 3 - 36° 48.3' to 36° 51.2' N: Moss Landing to the Pajaro River,

Area 4 - 36° 51.2' to 36° 53.8' N: Pajaro River to Sunset Beach,

Area 5 - 36° 53.8' to 36° 56.7' N: Sunset Beach to La Selva Beach,

Area 6 - 36° 56.7' to 36° 58.4' N: La Selva Beach to New Brighton Beach.

The study area accounted for 60 % of the coastal strip, and approximately 80 % of sandy bottom coastline in Monterey Bay. These waters are characterized by high turbulence, low visibility, and strong background noise. The sea floor is mostly uninterrupted sandy bottoms, 0 to 15 m deep. The surf zone is an extremely variable environment, with winter storms affecting the near-shore circulation. During the rainy season (January to March), the study area receives fresh water from the Pajaro River, 5.2 km north of Moss Landing, Elkhorn Slough, located at the center of Monterey Bay, and the Salinas River, 6.7 km north of the city of Marina. These inputs induce salinity changes in the near-shore waters, and the formation of extensive sand bars. Kelp forests are located at both ends of Monterey Bay, in the Monterey-Pacific Grove area, and between New Brighton Beach and Santa Cruz. No kelp is found within the study area except for occasional kelp detached by storms.

SAMPLING EFFORT

Survey Effort

Eighty-four boat-based surveys were conducted aboard a 4.5m Boston Whaler equipped with a 70 hp engine. The boat was driven at a constant speed of 10 to 12 knots at approximately 200 m from shore. Both sides of the boat were constantly scanned to detect the presence of dolphins. All surveys were conducted between 0600h and 1500h. Surveys in the afternoon where often not possible because winds from the northwest began to blow, increasing sea state, and decreasing sightability. No surveys were conducted when sea state was greater than Beaufort 3 or when surf was higher than 2 meters.. An attempt was made to survey the entire study area during each survey day. Generally, only one leg per day was completed because of weather and/or time restrictions. When both legs were sampled, the survey was defined as <u>complete</u>, otherwise the survey was defined as <u>partial</u>.

If dolphins were encountered, location, time, number of individuals, and age-class composition (adult, calf) were recorded. Calves were identified by their relative size (< 1 m), coloration, presence of fetal folds, swimming patterns (such as frequently slapping the water with the rostrum or "chin slap"), position relative to an adult, and association to a particular individual (Weller 1991). Juveniles were difficult to identify at a distance, therefore, no distinction was made on a visual basis.

Photoidentification

To ensure all individuals in the school were observed, the boat was driven approximately 1 km past the school before returning for the photoidentification effort. Dolphins were approached at low speed, with the boat parallel to their direction of travel. Dorsal fins were photographed using a Minolta 7000I 35 mm SLR camera equipped with a 210 mm zoom lens. Black and white Ilford HP 5 or Kodak T-Max film (400 ASA) was used. During overcast conditions, film was exposed at a higher rating (1600 ASA) and "push-processed" to allow increased depth of field and increased camera shutter speed (Miles 1988, Mizroch and Bigg 1988).

Through photo-identification, individual dolphins were recognized using photographs of a series of notches on the trailing edge (back side) of their dorsal fin. A detailed description of the tracing and matching procedure used in this study was described in Defran *et al.* (1988). This procedure was followed without modification.

RANGE LIMITS ALONG THE CALIFORNIA COAST

To determine northern and southern range limits of the Monterey Bay bottlenose dolphin population, historical and current data from other sources were integrated with data collected during this study. Investigation of range limits addressed the following hypotheses: a) bottlenose dolphins were present along the central California coast between 1983 and 1993, b) the northern range limit for Monterey Bay bottlenose dolphins was at least Monterey Bay, and c) the southern range limit was at least Ensenada, Mexico. Hypotheses were derived from existing information on the coastal bottlenose dolphin population in California (Wells *et al.* 1990, Defran *et al.* in prep., Defran and Weller in prep.).

Northern Range Limit

To determine presence of bottlenose dolphins along the central California coast and their northern range limit, historical data obtained from occasional sighting reports of bottlenose dolphins were collected from three sources: a) a sighting network for the central California coast, coordinated by Baldridge since 1966, including sightings from May 1983 to April 1988 (Wells *et al.* 1990), b) a sighting network for Monterey Bay coordinated by Feinholz since 1991, including sighting from January 1991 to November 1993 and c) a sighting network for the San Francisco bay area coordinated by Sczcepaniack since 1983, including sightings from December 1988 to May 1993 (Fig. 2). For each of these networks, sightings were collected mostly by local naturalists and biologists, and the quality of the information was carefully checked by the network coordinators. In the case of the Monterey Bay sighting network, some of the information was collected from the general public. Such information was screened by calling the observers and questioning them about the sighting to determine quality and accuracy. All three network coordinators discarded sightings of dubious quality.

Southern Range Limit

To determine the southern range limit for the Monterey Bay bottlenose dolphin population, all unique individuals photographed in Monterey Bay were compared with 426 dolphins photographed during 241 surveys (1981 to 1989) in the Southern California Bight (SCB). Data from the SCB are available at the Cetacean Behavior Laboratory (CBL) at San Diego State University (SDSU), and include dolphins sighted in Ensenada (Mexico), San Diego, Orange County, and Santa Barbara.

Matching among databases was possible because methods were consistent. To ensure each dolphin had an equal probability of being sighted and matching errors were low, strict standards of photographic quality were maintained. Only well marked dorsal fins with two or more notches were used. Only well lit and focused photographs were selected. Photographs at an extreme angle were not used. Matches were verified independently by three experienced reviewers.

POPULATION ESTIMATES

One method used to estimate the size of a population is to capture and mark individuals from that population, then release them, and resample to see what fraction of individuals carry marks. In this study, mark-recapture data were obtained through photoidentification to generate an estimate of population size. It was assumed that an animal was "captured" when photographed, "marked" when recognizable, and "recaptured" when photographed again. Because animals were not handled, or artificially marked, there were no tag losses, no mortalities due to marking, and all animals "captured" were "released".

Bottlenose dolphins in Monterey Bay were regarded as belonging to an open population, subject to the effects of birth, death, immigration, and emigration. A critical assumption of mark-recapture methods is that animals do not lose their marks during the sampling period. It has been demonstrated that patterns of notches on the trailing edge of the dorsal fin are a reliable characteristic for identifying individual cetaceans, especially odontocetes (Hammond 1986, Hammond *et al.* 1990). Although changes in these patterns are possible, this does not often prevent subsequent identification (Lockyer and Morris 1988). Mark-recapture models further assume that all marks are recorded correctly at each sampling occasion. By maintaining high standards when matching individuals, most errors of this type were avoided.

Mark-recapture studies also assume individuals have an equal probability of capture. Because this assumption is rarely obtained for animal populations, models were developed to allow for unequal catchability (Otis *et al.* 1978). Such models are now available in a variety of computer formats. In this study, the program JOLLY (Hines 1988) was used, which provided three Jolly-Seber models (Seber 1982) for open populations. All three models were evaluated to determine which one presented the most reliable results (Jolly 1965, Begon 1979, Hammond 1986). Model A assumed time-specific survival rates and capture probabilities. Model B assumed constant survival rates and time-specific capture probabilities. Model D assumed constant survival rates and constant capture probabilities. Population estimates were considered "reliable" if survival rates were less than or equal to 1, 95% confidence intervals were narrow and standard errors were low. Data were analyzed using each year as a single sample.

DISTRIBUTION PATTERNS

Bottlenose dolphins were found to adapt to local conditions and food resources in all locations where they have been studied, and were found to use certain areas within their range with some preference (Hogan 1975, Würsig and Würsig 1979, Shane 1980, Irvine *et al.* 1981, Shane *et al.* 1986, Ballance 1992, Wilson *et al.* 1993, Lynn 1995, Hanson and Defran 1993). Because no previous studies of bottlenose dolphins in Monterey Bay were available, trends in distribution patterns in this area were not known.

Bottlenose dolphin distribution in Monterey Bay was determined by recording sighting location during each survey. Observations were standardized as sightings per unit effort to avoid overemphasizing portions of the study area which were surveyed with higher frequency. Differences in distribution patterns between the northern and the southern portions of the study area (Leg a and b), and among six 3 nautical miles sections within the study area (Area 1 through 6) were analyzed (Fig. 1).

Movement Patterns

To determine general movement patterns within the study area, the direction of travel at the time the dolphins were first sighted was recorded. Dolphins were observed for up to five minutes before approaching to avoid possible effects of the boat on their movement patterns. Three movement patterns were defined: traveling north, traveling south, and milling (which indicated no directional movement). Three hypotheses were tested: a) there was no significant difference in sighting distribution between the northern and the southern portions of the study area, b) there was no significant difference among different sections of the coast within the study area, and c) there was no significant trend in movement patterns within the study area.

SOCIAL ORGANIZATION

Social organization of a dolphin population may be defined using several factors such as group size, association among individuals, associations based on age, gender, social and physiological status, and genetic relationships. This study addressed only a small fraction of such factors. Gender, age, physiological status and genetic relationships could not be determined without capturing the animals; therefore, efforts were concentrated on determining group size, and associations among recognizable individuals. In addition, preferential use of Monterey Bay by individual dolphins (site fidelity) was investigated.

School Size

A school was defined as an aggregation of animals swimming together as a unit (Norris and Dohl 1980). Differences in school size among years were analyzed using non-parametric statistics (Kruskal-Wallis). It was assumed that there was no difference in mean school size among years. Smaller groups of individuals swimming within 5 meters of one another within the school were defined as sub-groups and their presence was noted. Number of animals present in each sub-group was not quantified.

Site Fidelity

To define site fidelity, bottlenose dolphins were classified as either residents, or transients. Animals were classified as residents of the study area if: a) they had a sighting probability ≥ 0. 30, and b) they were present in 1991, 1992 and 1993. All animals which did not meet these criteria were classified as transients.

If a dolphin is a resident of an area one would expect to find this animal 100 % of the time. During photoidentification, some dolphins avoid the boat and are, therefore, more difficult to photograph. Environmental conditions such as glare, high surf, or wind also may affect photographic effort. As a result, some marked animals that are "present" in a school during a survey may not be identified, and the actual probability of detecting a resident is diminished. Partial surveys also diminish the probability of encountering an animal if it is not in one of the areas surveyed. Furthermore, the study area chosen may not encompass the entire range an animal resides in, which also decreases the sighting probability. A 70 % reduction in success of sighting residents was allocated to these effects and established the first criteria for residency (i.e. a sighting probability of 0.30 or more).

To reduce the influence of boat avoidance behaviors and weather related factors on sighting efficiency, only satisfactory surveys were used to calculate dolphin sighting probabilities. A survey was defined as satisfactory when at least 60 % of the animals present in a school were identified. Sighting probability (p) was then calculated as:

$$p = N_s / S_s$$

where N_s is the number of times an individual was identified during satisfactory surveys, and S_s is the number of satisfactory surveys (both partial and complete) conducted starting from the first sighting of an individual.

Animals were considered present in the study area if they were photographed at least once during 1991, 1992, and 1993. A dolphin was considered present during a particular month if it was seen at least once during that month. During 1990 only 2 months (Oct. and Dec.) were sampled. Such effort was not considered sufficient to adequately sample 1990, and therefore, 1990 sightings where not used. Four months (Aug., Sep., Oct., Nov.) were sampled in 1991, 9 months in 1992 (Jan., Feb., Apr., May, Jun., Jul., Aug., Sep., Oct.), and 5 months in 1993 (Jun., Jul., Aug., Sep., Nov).

Association Coefficients

Association coefficients described the frequency that two individuals were present in the same school at the same time (Weller 1991). Association coefficients for bottlenose dolphins in Monterey Bay were compared to those by Weller (1991) in the Southern California Bight, who studied association patterns of coastal bottlenose dolphins between 1981 and 1989.

Coefficients were examined in detail only for dolphins that were seen during more than one month. Association coefficients (K_a) between pairs of animals were calculated using the formula:

$$K_a = 2J / (A + B),$$

where J is the number of joint sightings for a pair, and A and B are the number of total sightings for each individual. Association coefficients can range from 0 for no association, to 1 for two individuals always observed together (Schaller 1972). Mean level of association for each individual was calculated by adding all association coefficients for that individual, then dividing by the number of associations.

Cluster analysis using the single linkage (nearest neighbor) method (Sneath 1966, Morgan *et al.* 1970, Legendre and Legendre 1983) was used to identify associated groups of individuals within the population. These associations were represented by a dendrogram.

Association of Significance

Associations of significance were used to depict stronger than average bonds between pairs of individuals. Two individuals had an "association of significance" if the coefficient of association for the pair was greater than one standard deviation above the mean level of association of one or both individuals to the rest of the population (Heimlich-Boran 1986). Furthermore, two types of association were used to analyze social structure : a) reciprocal association , where both individuals in the pair had an "association of significance" with each other, and b) unilateral association , where only one of the two individuals in the pair scored an "association of significance" with the other animal in the pair (Heimlich-Boran 1986). In this study, a reciprocal association was considered the strongest bond for a pair of individuals detectable through association coefficients. Reciprocal associations were used to determine potential social units, and the size of these social units was inferred by the number of reciprocal associations an individual was engaged in. For example, if an individual was reciprocally associated with 10 other animals, the size of that particular social unit was at least 10 animals.

EL NIÑO EFFECTS

For the purpose of this study, El Niño Southern Oscillation (ENSO) was considered to be affecting Monterey Bay when Sea Surface Temperature (SST) anomalies were positive along the central California coast. The evolution of El Niño in northern California was monitored through the NOAA Coastal Ocean Program, El Niño Watch Advisory, which was updated monthly, and reported SST deviations along the California coast. According to these reports, an El Niño began affecting Monterey Bay in January 1992, with water temperatures 1.6-3.2 °C above normal. By March 1992, SST anomalies reached a maximum of 7.2 °C above the long-term average, and fluctuated between 3.6 and 7.2 °C above normal throughout 1993 (NOAA 1992 - 1994). Therefore, the period 1990/91 was pooled and considered non-El Niño, and 1992 /93 was considered an ENSO.

To test the general hypothesis that ENSO conditions had an effect on bottlenose dolphin abundance in Monterey Bay, three separate hypotheses were tested: a) mean school size was grater during ENSO than during normal conditions, b) mean rate of discovery of new marked dolphins was greater during ENSO than during nomal conditions, and c) population size increased during the ENSO. The first two hypotheses were tested directly using non-parametric statistics (Mann-Whitney) and the third was inferred using the results of the Jolly-Seber population estimates and photoidentification data. To test the effects of ENSO on bottlenose dolphin distribution, it was hypothesized that influx of bottlenose dolphins into Monterey Bay was greater during ENSO. Influx of marked animals into the study area was assumed to reflect total influx of bottlenose dolphins in Monterey Bay.

RESULTS

SAMPLING EFFORT

Survey Effort

Eighty-four boat-based surveys were conducted in Monterey Bay between October 1990 and November 1993. Number of surveys varied greatly among years: 6 in 1990 (under the direction of Tom Norris), 17 in 1991, 43 in 1992, and 18 in 1993. Sixteen surveys were complete (surveyed both the northern and southern portion of the study area) and 68 were partial . Fifty-seven of the partial surveys went only north, 7 only south, and 4 went both north and south but did not survey the whole study area (Fig. 2).

Dolphins were encountered during 79 % of the surveys. Multiple schools were seen on only two occasions: during a complete survey on 19 May 1992, and during a complete survey on 25 May 1992, resulting in 68 schools encountered during 66 surveys (Table 1).

Photoidentification

Photographs were taken during 51 surveys: 4 in 1990, 10 in 1991, 26 in 1992, and 10 in 1993 (Table 1). One-thousand and forty-seven photographs were selected, among all rolls shot, because they met the established criteria for quality. Such photographs contained 1281 observations, an observation being a good quality image of a dolphin (marked or unmarked, adult or calf). Of these observations, 1143 were of marked animals (with one or more notches), and 138 observations were of unmarked animals (no notches).

Assuming the photographs were an unbiased sample of the population, the proportion of marked to unmarked animals calculated from all observations should reflect the proportion of marked to unmarked animals in the population. Such results indicated that 89 % of the population in Monterey Bay was marked.

Sixty-eight individual dolphins were identified (16 in 1990, 9 in 1991, 17 in 1992, and 26 in 1993). Fifty individuals (74 %) were sighted in multiple surveys. Fifteen animals (22 %) were observed only once: 2 in 1990, 1 in 1992, and 12 in 1993 (Table 2). It is unlikely that these dolphins were in the study area and were missed, because they had distinctive marks. Twenty-one new dolphins were identified during 6 surveys between August and September 1993. In particular, 10 animals were identified on August 1, and 6 on September 7, 1993 (Table 2).

RANGE LIMITS ALONG THE CALIFORNIA COAST

Northern Range Limits

Between 1983 and 1993, 351 sightings of bottlenose dolphins were reported in central California. Sightings (Fig. 3) were pooled by month, and subdivided by location along the central California coast: a) San Francisco to Santa Cruz: 28 sightings, b) Santa Cruz to Monterey: 297 sightings, and c) Monterey to Point Conception: 26 sightings (Appendix A, B, and C). These datasets contained some bias because locations of sightings were concentrated in areas where higher numbers of potential observers was present. As a consequence, locations of low accessibility were poorly represented. Absence of sightings may not have reflected absence of dolphins from the area, but rather absence of reports.

The available information reported the minimum number of times dolphins were seen along the central California coast between 1983 and 1993. Sightings occurred in all three central California regions (Fig. 3). When all reported sightings were, it became apparent that observations occurred at least once every year in one of the three regions along the central California coast, and were spread out across all months (Fig. 3). Such results supported the hypothesis that bottlenose dolphins were present year-round along the central California coast. The northernmost location reported (Appendix C) was Mussel Rocks (37° 40' N, 122° 30' W), south of San Francisco, where 15 animals were seen on June 14, 1990.

Four strandings of bottlenose dolphin also occurred north of Monterey Bay: one in May 1992 near Pigeon Point (37° 10.9' N, Sczcepaniack pers. comm.), one in June 1990 near Pacifica (37° 48.3' N), one in 1981 near Cape Mendocino (Szczepaniack pers. comm.), and one stranding, possibly an extraliminal event, occurred in Washington state in March 1988 (Ferrero and Tsunoda 1989).

Southern Range Limits

Forty-three (63 %) of the dolphins identified in Monterey Bay were previously photographed in the Southern California Bight (Table 2). Eighteen were observed only in San Diego, 9 both in San Diego and in Orange County, 6 both in San Diego and Santa Barbara, 2 only in Santa Barbara, and one in Santa Barbara and Orange County. Seven dolphins were observed in all three Southern California Bight study areas (Fig. 4). Two dolphins (# 024 and # 073) were observed in Ensenada, Mexico, 905 km south of Monterey Bay (Fig 4).

POPULATION ESTIMATES

Because of consistently lower standard errors and generally narrower confidence intervals, Model B, which assumed constant survival rates and time-specific capture probabilities, was chosen as the best estimate of population size in Monterey Bay (Table 3). The estimated population using Model B was between 25 and 35 dolphins in 1991, 45 to 70 in 1992, and 79 to 134 in 1993 (Table 3). In all three models, estimated number of marked animals (M) for each year was considerably lower than number of animals identified during the study. For example, Model B estimated between 38 and 58 marked individuals in the population (15 to 46 % underestimate) for 1993, whereas number of marked individuals (animals photoidentified) was 68. Such underestimation was consistent for all years, which may indicate an underestimation of population size. All three models predicted an increase. Model B predicted a 50 % increase in population size between 1991 and 1992, and a doubling of population size between 1992 and 1993 (Table 3).

Photoidentification effort, represented by a cumulative frequency curve, was compared to the Jolly-Seber model predictions. Cumulative frequency curves are useful to detect population trends. A slope approaching zero indicates good effort or no population growth. A positive slope indicates either a poor photoidentification effort, or a growing population. Because animals at birth do not bear marks, and the cumulative frequency curve represents only marked animals, a positive slope (if the photoidentification effort is good) may be indicative of influx of animals by immigration.

In this study, the cumulative frequency curve represented four separate photoidentification periods: a) Oct - Dec 90, b) Jul - Dec 91, c) Jan - Dec 92, and d) Jun - Nov 93 (Fig 5). The slope of the curve agreed with the Jolly-Seber predictions of a population increase (Table 3, Fig. 5). Although the mean rate at which newly identified animals were added to the Monterey Bay catalog was approximately one animal per survey, the cumulative frequency curve indicated newly identified animals were added mostly at the beginning of each photoidentification period. Photoidentification periods were interrupted by a 6 month interval between 1990 and 1991, and a 5 month interval between 1992 and 1993. Here, the increased slope of the frequency curve may be explained by the fact that animals entered the study area during the interval between sampling, and were picked up as sampling resumed. Such explanation was weakened by results between 1991 and 1992 when sampling was continuous. The slope of the curve, in this case, increased between March and April, despite continuous sampling, indicating a possible influx of animals into the study area during this period.

DISTRIBUTION PATTERNS

Bottlenose dolphins were observed during 14 of the 16 complete surveys (88 %). During 11 of the complete surveys only a single school was encountered (69 %). Such observation indicated that a single school was more common than multiple schools within the study area. The northern leg was surveyed 77 times during which 60 sightings occurred (60 schools, encounters occurred 78 % of the time). The southern leg was surveyed 27 times during which 8 sightings occurred (8 schools, encounters occurred 30 % of the time). Although sightings were distributed throughout the study area (Fig. 6), the probability of finding a school in the northern leg (0.78) was more than double that of the southern leg (0.30). Sighing density was significantly greater in the northern leg (mean ± S.D. = 1.10 ± 0.87) than in the southern (mean ± S.D. = 0.65 ± 1.22; $U = 256$; $0.002 < p \leq 0.024$).

There was no significant difference in sighting distribution among six 3 nautical mile sections of the study area ($G = 1.184$, $0.75 < p < 0.90$; Fig. 7). Because sightings were standardized per unit effort, resulting values were less than one. The log-likelihood test is generally preferred to the chi-square test under such circumstances (Zar 1984), and both tests are poorly suited to deal with numbers less than one. The power of such tests may be low, therefore results should be treated with caution. When sighting distribution was analyzed for only the northern leg, sighting distribution was significantly higher in Area 3 and significantly lower in Area 4 ($X^2 = 9.949$, $0.025 < p \leq 0.1$). Within the southern leg, sightings were equally distributed between Area 1 and Area 2 ($X^2 = 0.5$, $0.002 < p \leq 0.024$).

Movement Patterns

When dolphin schools were encountered, they were traveling north (30 %) and traveling south (30 %) equally often, and were seen milling (no directional movement) 40 % of the times (Fig. 6). The frequencies with which these three patterns were observed were not significantly different ($X^2 = 1.395$, $0.50 < p \leq 0.25$). When the two patterns showing directional movement (traveling north and traveling south) were combined, differences in frequency of occurrence were still not significant ($X^2 = 2.522$, $0.25 < p \leq 0.10$).

SOCIAL ORGANIZATION

School size

School size ranged from 2 to 35 animals (mean ± S.D. = 16.6 ± 7.7), with schools of 1 to 5, and 31 to 35 individuals less common than expected if all categories of school size were equally common ($X^2 = 23.84$, $p < 0.001$; Fig. 8). Mean school size was similar to the value reported in the Southern California Bight (mean ± S.D. = 19.8 ± 18.4; Weller 1991, Weller and Defran in prep.). Seventy-four percent of the schools contained calves. Number of calves per school was 1 to 5 (mean ± S.D. = 1.5 ± 1.3; Table 1).

Visual observations indicated that large schools (>20 animals) were spread out along approximately 1 km of coastline. Schools were subdivided into sub-groups of approximately 3 - 10 individuals. Quantitative information about sub-group size and number of sub-groups within a school was not collected.

The median and relative inter-quartile range (IQR) were chosen to best represent the spread of school size data (Fig. 9). Although average school sizes were slightly greater in 1993 (mean ± S.D. = 20.3 ± 9.5) and less in 1991 (mean ± S.D. = 14.4 ± 6.1), there was no significant difference among years (Kruskal-Wallis, $H = 2.697$, $p = 0.441$). The fact that school size was not different among years, and that only single schools were found during the majority of complete surveys contradicted the population increase estimated by the Jolly-Seber models.

Site Fidelity

Of the 51 surveys where photoidentification data were obtained, 25 surveys were satisfactory (at least 60 % of the animals counted were also identified), and used to calculate the sighting probability of the Monterey Bay population (Table 4). Although 44 animals (65 %) met the first criteria for residency (had sighting probability ≥ 0.30; Table 5), only 13 (19 %) also met the second criteria for residency (were sighted at least once in 1991, 1992, and 1993; Table 5).

Association Coefficient

Association coefficients were calculated for 50 animals (13 residents and 37 transients), that were seen during multiple months throughout the study period (Table 5). Association coefficients were not equally distributed (X^2 = 1756.63, $p < 0.001$), no association ($K_a = 0$) being more common (Fig. 10). The 2450 association coefficients generated ranged from 0.00 to 1.00, (mean = 0.17, S.D. = ± 0.19). The range and mean for coefficients of association were similar to those found by Weller (1991) for bottlenose dolphins in the Southern California Bight (range = 0.00 to 1.000 and mean ± S.D.= 0.21 ± not reported). Weller (1991) also found that 95 % of the association coefficients were between 0.00 and 0.39, whereas in Monterey Bay, 95 % were between 0.00 and 0.50 (Fig. 10). Comparisons of the frequency of occurrence of association coefficient between Monterey Bay and the Southern California Bight (SCB) showed higher frequency of occurrence of associations > 0.40 in Monterey Bay than in the SCB (Fig. 10). Mean level of association (for $K_a > 0$) in Monterey Bay was 0.30 (S.D. = 0.17).

The single linkage (nearest neighbor) dendrogram generated by the association coefficient matrix (Fig. 11) indicated that the entire population used in the analysis was associated at some level. The lowest coefficient of association being 0.29, and the greatest being 1.00. Two somewhat distinct clusters were noticeable at $K_a > 0.50$. The first cluster contained 28 animals, 75 % of which were seen for the first time in 1990 and 1991, the rest in 1992. This cluster also included all the residents. The second cluster was composed of 12 individuals, 92 % of which were seen for the first time in 1993. The remaining animals formed smaller clusters with lower levels of association with the main two clusters. Dolphins # 008 and # 043 were highly associated with each other, and had a weak ($K_a = 0.29$) association with the rest of the clusters. These two animals were only seen in 1990 and were never re-photographed. Dolphins # 025 and # 064 had the strongest association ($K_a = 1.00$), but were only seen twice in 1993 and both times together. The high value in this case was partly an effect of the low number of resightings.

Associations of Significance

Of the 1418 association coefficients with values greater than zero (58 % of the total number of associations), 479 (34 %) were indicative of significant associations: 146 (30 %) unilateral and 333 (70 %) reciprocal associations. Bottlenose dolphins that had a greater number of associates tended to have a lesser number of significant associations

(Fig. 12). Mean number of associates was significantly higher for residents ($X = 39.30 \pm 6.48$) than for transients ($X = 25.15 \pm 8.01$; $T = 5.85$, $p(T \leq t_{(1,0.05)}) = 0.00$; Fig 13).

Reciprocal associations were indicative of the strongest bonds between two individuals. A dolphin was reciprocally associated with 1 to 12 other individuals, 7 to 9 individuals being the category observed with greater frequency. Residents were reciprocally associated with other residents with greater frequency than with transients ($X^2 = 11.8$, $p < 0.001$; Fig 14).

EL NIÑO EFFECTS

There was no significant difference in school size between non-El Niño (1990/91) and El Niño periods (1992/93; Mann Whitney, $U = 587.00$, $p = 0.686$), and no difference in mean rate of discovery of new dolphins between these two periods, (Mann-Whitney, $U = 222$, $p = 0.656$). The mean rate of discovery was 0.9 (SD = 1.73) in normal conditions, 1.1 (SD = 1.98) during El Niño. Nineteen percent of the dolphins were photoidentified during non-El Niño conditions, and 79 % during El Niño. Fifteen (22 %) new animals were identified between April and May 1992. This period coincided with a peak in positive Sea Surface Temperature (SST) anomalies along the central California coast (NOAA, Coast Watch Bulletin, SW Regional Node, NMFS, La Jolla, CA).

DISCUSSION

Previous information on range extension of coastal bottlenose dolphins in California covered the period 1983 to 1988 (Hansen 1983, Wells *et al.* 1990, Defran *et al.* in prep., Defran and Weller in prep.). This study reviewed historical data covering 1983 to 1993 (Fig. 3), which confirmed the presence of coastal bottlenose dolphins along the central California coast during the entire ten year period. This study also provided information on the occurrence of coastal bottlenose dolphins north of Monterey Bay, and determined that the northern range limit of the population included at least San Francisco, the northernmost location reported to date for live sightings (Appendix C).

Because photoidentification records for individuals found north of Monterey Bay were not available, it was not clear if bottlenose dolphins sighted in the San Francisco area were the same animals found in Monterey Bay and/or in the Southern California Bight. It was speculated that movements of bottlenose dolphins between Monterey Bay and San Francisco (approximately 200 km) were likely, because animals traveled between Monterey Bay and Ensenada, Mexico (approximately 905 km).

The southern range limit for coastal bottlenose dolphins in California is still unclear. We know that bottlenose dolphins occur off South America (Leatherwood and Reeves 1983), but subdivisions of genetic stocks have not been determined. In a preliminary study of stranded animals, Curry and Dizon (1993) found no genetic difference between coastal bottlenose dolphins from South America and California, indicating that interbreeding may occur, or that separation of genetic stocks may be relatively recent.

During the current study, dolphins were documented to have traveled at least the 905 km distance between Ensenada, Mexico and Monterey Bay, the longest documented distance traveled by bottlenose dolphins to date (Fig. 4). Defran *et al.* (in prep.) suggested that social exchange along the Pacific coast may cease between San Diego and San Quentin, Mexico. In-fact, only one of the animals photographed in San Quentin was photographed in the Southern California Bight, despite a photographic record of 105 bottlenose dolphins in San Quentin and 426 in the Southern California Bight. In comparison, 90 % of the dolphins photographed 200 km north, in Ensenada, Mexico were matched to the Southern California Bight catalog (Defran and Weller in prep.).

Because 63 % of the bottlenose dolphins identified in Monterey Bay also were photographed in the Southern California Bight (Table 2), it appeared that coastal bottlenose dolphins in California were the same population. The size of the Southern California Bight coastal bottlenose dolphin population was estimated to be at least 245 individuals by (Forney pers. comm., Forney and Carretta 1993), from longshore aerial transects (1991 - 1994) between the mexican border and Point Conception. Jolly-Seber models for Monterey Bay estimated a doubling of the population between 1992 and 1993 (from approx. 50 to 100 animals; Table 3), suggesting that about half of the entire

Southern California Bight population used Monterey Bay between 1992 and 1993. Comparison of photoidentification data between Monterey Bay and the Southern California Bight, on the other hand, indicated that only 5 % of the animals photoidentified in the Southern California Bight were identified in Monterey Bay. Such differences emphasize the need for further investigation to determine population size along the California coast.

Despite the estimated increase in population size (Table 3), school size in Monterey Bay was not significantly different among years (1990 -1993). Because data from complete surveys indicated only one school was present in Monterey Bay at any one time, school size during a survey was judged a good estimate of number of dolphins present in the bay during that survey, and the bias introduced by incomplete surveys was considered negligible. School size estimates determined by boat-based observers were believed to be accurate. However, greater difficulty in counting larger schools could have biased counts toward smaller school sizes, not allowing the detection of school size differences among years.

The apparent contradiction between the estimated increase in number of dolphins present in the bay and no increase in mean school size may be explained by a periodic influx and efflux of animals to and from Monterey Bay. Intermixing among bottlenose from adjacent geographical areas was documented by Würsig and Würsig (1979) during a

21 month study off Golfo San José, Argentina, another open coastal environment. The authors described groups of dolphins as dynamic units continually changing in size and membership, and concluded that even "core" animals within a group may not form a stable unit for periods exceeding 21 months. Ballance (1987, 1990), in her research on bottlenose dolphins in Bahia Kino, Mexico, also described group composition in as dynamic, with individuals frequently intermixing among groups.

Because of intermixing and continuous movements, distribution of bottlenose dolphins along the California coast may vary. For example, bottlenose dolphins may use some areas of the coast preferentially. In Monterey Bay, animals were found with higher frequency in the northern portion of the study area, which may be a more ideal environment for bottlenose dolphins. Because of a shallower coastal shelf, and prevailing circulation patterns, water temperatures in the northern portion of the bay are generally warmer (Broenkow and Smethie 1978, Breaker and Broenkow 1989). The northern area is also more protected from the prevailing northwesterly winds and seas.

Area 3, located between the entrance of Moss Landing harbor and the Pajaro River was used preferentially by bottlenose dolphins during this study (Fig 6 and Fig 7). A prominent feature area is the presence of the Pajaro River mouth. This river connects directly to the ocean only during rainy periods, typically between January and April. It is at this time that sediments carried by the river accumulate in the shallow waters off this area and build an extensive sand bar. Fresh waters percolate through the sandbar to the ocean and may release pockets of high nutrients. These nutrients may support greater primary and secondary production than adjacent areas. As a result, food availability in this area may be enhanced, although few data are available regarding prey in the surf zone in Monterey Bay. On many occasions, dolphins were observed moving back and forth in front of the Pajaro River mouth in approximately 1-2 meters of water. Such behavior also was observed when dolphins were encountered in front of the Salinas River mouth, a similar area located in the southern leg of the study area. In contrast, dolphins were never found milling in front of Moss Landing harbor, which is also the mouth of Elkhorn Slough. Elkhorn Slough provides the largest freshwater input to the ocean in Monterey Bay and a large plume of sediments can be seen from a plane in waters off this area. Here, large quantities of nutrients are available to the near-shore environment. In contrast to waters off the Pajaro and Salinas river mouths, waters offshore Elkhorn Slough are deep because of the presence of a submarine canyon. Such situation may not be ideal for coastal bottlenose dolphins because of increased exposure to deep water predators (such as the great white shark).

Bottlenose dolphins use any readily available food source, and adapt their feeding techniques to food type and local conditions (Shane *et al.* 1986, Hoese 1971, Hogan 1975, Bel'kovich *et al.* 1978). Hanson and Defran (1993) found coastal bottlenose dolphins off San Diego fed more frequently in rocky and estuarine areas than in open sand areas. Ballance (1992) found bottlenose dolphins in Bahia Kino, Mexico were concentrated and fed in areas within 5.5 km from estuary mouths. Feeding in estuarine areas has been widely documented (Gunter 1942, Barham *et al.* 1980, Gruber 1981, Schmidly 1981, Mead and Potter 1990, Hanson and Defran 1993).

Factors such as prey availability, and environmental conditions may play a role in the distribution of bottlenose dolphins along the coast. In particular, individual animals may use a geographical area for prolonged periods of time. Coastal bottlenose dolphins worldwide have varying site fidelity from temporary, seasonal, semi-permanent, to permanent (Caldwell 1955, Saayman and Tayler 1973, Würsig 1978, Shane 1980, Gruber 1981, Shane *et al.* 1986, Scott *et al.* 1988, Ballance 1990 and 1992, Würsig and Harris 1990, Kenney 1990, Shane 1990, Hansen 1990, Wells *et al.* 1990, Wilson *et al.* 1993, Fertl 1994, Lynn 1995, Defran *et al.*, in prep., Defran and Weller, in prep.). Longitudinal studies of bottlenose dolphins in Sarasota Bay, Florida (Wells 1978, Wells *et al.* 1980, Irvine *et al.* 1981, Wells 1986, Wells *et al.* 1987, Scott *et al.* 1990) provide evidence of long-term site fidelity (at least 25 years) to an approximately 100 km^2 area. A similar situation was reported for coastal bottlenose dolphins in Western Australia (Connor and Smolker 1985). In contrast, various reports exist of known individuals photographed a significant distance away from where they were originally identified (Würsig and Würsig 1979, Grüber 1981, Wells *et al.* 1990, Würsig and Harris 1990, Jones 1991, and Wilson *et al.* 1993).

Monterey Bay was an important core area for at least 13 individuals during this study. Such result was probably conservative, because it was limited to marked individuals and by the way residency was defined (animals with a weighted sighting probability greater than or equal to 0.30, and present in the study area throughout the study period). The size of the study area did not allow determination of whether other dolphin showed site fidelity to areas north and south of Monterey Bay. Animals determined to be transients in the bay may have resided in other adjacent areas that were not sampled. Overlapping ranges have been found in many other geographical areas for adjacent communities of bottlenose dolphins (Shane *et al.* 1986, Lynn 1995).

Bottlenose dolphins along the California coast may not retain long-term fidelity to a particular area. Longitudinal studies in the Southern California Bight indicated temporal variation in distribution with some fidelity to the San Diego study area during a two-year study (Hansen 1983, 1990), and no long-term nor seasonal site fidelity during a nine-year study (Hansen and Defran 1990, Defran *et al.*, in prep, Defran and Weller, in prep.). The presence in the Southern California Bight of individuals classified as Monterey Bay residents indicated that residency in Monterey Bay was also dependent on the time frame of study.

Bottlenose dolphins classified as residents of Monterey Bay had stronger associations with other residents than with transients. Average values for association coefficients in Monterey Bay (0.17) were similar to those (0.13) found by Bräger *et al.* (1994), for 35 naturally marked bottlenose dolphins off Galveston, Texas. Smolker *et al.* (1992), found associations of 0.00-0.20 between pairs of bottlenose dolphins off Shark Bay, Australia, and interpreted this as indicative of inconsistent association. Wells (1991) reported values of 0.31-0.56 for "female band" members, values of 0.45-0.75 for strongly bonded adult males, and 0.08-0.10 for male-female affiliations for bottlenose dolphins off Sarasota Bay, Florida.. Weller (1991) found no long-term, high level associations for bottlenose dolphins off San Diego, California. Such an observation is particularly interesting considering that Weller's data set included some of the same dolphins studied in Monterey Bay. Such contrast in results may have been an effect of the different time scale of the photoidentification effort. Weller's study spanned 9 years, with monthly sampling intervals. This study included only 3 years with only a few days interval between surveys. Weller's data indicated schools in the Southern California Bight ranged from 2 to 90 individuals as oppoosed to 2 to 35 in Monterey Bay. When such large schools were encountered, known individuals that were "present" in the school could have been missed during the photoidentification effort resulting in lower average association coefficients.

Information gathered on the degree of association among individuals in Monterey Bay referred only to associations within the same school. Visual observations indicated schools were composed of several "sub-groups" ranging from 2 to 10 animals. These sub-groups were generally readily identifiable when the animals were traveling or milling, but they intermixed during feeding and socializing. Mother-calf pairs were encountered within the same sub-group. Sub-groups containing mother-calf pairs traveled either in the front or in the back of the school. These observations, suggested that "sub-groups" could be segregated by sex, or reproductive status. In Sarasota Bay, Florida, sex and age segregation appear to be the rule, and high cohesion among mother calf schools has been documented (Wells *et al.* 1980). Because little information on the gender of the animals identified was available, it was not possible to correlate association coefficients and sex of individuals.

The significance of Monterey Bay sub-groups as strongly bonded "social units" within the school is only speculative. Association coefficients indicated that an animal had a reciprocal association of significance with 3 to 9 other individuals, a range similar to the size range of sub-groups, as determined by visual observations. It is therefore possible that reciprocal associations of significance reflected associations among individuals traveling within the same "sub-group". Future long-term sampling of the Monterey population should test this hypoythesis, and include genetic sampling, to determine relationships between individuals within sub-groups.

The current study provided the first opportunity to monitor a bottlenose dolphin population during an ENSO event. If temperature is a regulating factor of bottlenose dolphin population dynamics, oceanographic phenomena such as an ENSO should enhance the effects of temperature changes on dolphin distribution and abundance patterns along the coast.

Wells *et al.*'s (1990) hypothesized that bottlenose dolphins moved north of their normal range during an ENSO. Based on this hypothesis, an increase in number of animals using Monterey Bay during the ENSO period was expected (i.e. increase should have been reflected by least one of the variables being monitored during this study such as school size, rate of discovery of new marked individuals, population size, and influx of animals into the study area). There was no significant difference in school size between normal and ENSO conditions. The rate of discovery was also not different (0.9 animals per survey were added to the catalog between normal conditions (1990/91), and 1.1 animals per survey were added during ENSO conditions (1992/93)). Nonetheless, 31 % of the new animals were identified in a short time period in 1993, indicating influx of animals into the study area. For example, 21 animals were photoidentified in the period between August and September 1993 (6 surveys), and 10 animals were photoidentified on August 1, 1993 alone (Table 2).

Both these results indicated no effect of ENSO. In contrast, population size estimates indicated a large increase in number of dolphins using the bay (Table 3), and it was proposed earlier in this discussion that this was best explained by an influx of animals into the study area. Furthermore, the influx of animals identified between April and May 1992 coincided with a peak in positive sea surface temperature anomalies along the central California coast. Such coincidence is likely an indication of an ENSO effect. The contrassting results from this study do not provide conclusive evidence but indicate that the hypothesis of an effect of ENSO on abundance and distribution of bottlenose dolphins along the California coast merith further investigation. Because ENSO is a recurring event along the California coast, more comparison data on bottlenose dolphin abundance and distribution between normal and ENSO conditions will become available.

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Table 1 - Summary of Monterey Bay boat-based surveys conducted between October 1990 and November 1993 indicating date, sighting number, time of sighting, location of sighting, leg surveyed (north: N, south: S, complete: C), number of adults and calves counted, and direction of travel at the time dolphins were encountered (traveling north: N, traveling south: S, milling: M). Photoidentification data were collected in 51 surveys (*). Two separate surveys were conducted on September 18, 1992.

Date	Sighting #	Time	Location	Leg	# Adults / Calves	Direction of Travel
1990						
* 9 Oct	A	0735	Pajaro Dunes	N	14/1	M
* 11 Oct	B	0915	New Brighton	N	15/0	M
14 Oct	-	-	-	N	-	-
20 Oct	-	-	-	N	-	-
* 1 Dec	C	1130	Zmudowski	N	30/0	M
* 8 Dec	D	0915	Rio del Mar	C	3/1	N
1991						
6 Jan	E	1040	Zmudowski	N	20/0	M
6 Jul	-	-	-	N	-	-
9 Jul	-	-	-	N	-	-
13 Jul	-	-	-	N	-	-
* 30 Aug	1	1035	Marina	S	13/1	M
* 6 Sep	2	0836	Salinas River	S	14/1	S
* 27 Sep	3	1149	Moss Landing	C	2/0	N
* 4 Oct	4	1100	Monterey Dunes	S	12/2	S
* 11 Oct	5	1122	La Selva	N/S	15/2	M
* 18 Oct	6	1015	New Brighton	N	13/2	N
* 25 Oct	7	1055	Rio del Mar	C	14/2	M
* 31 Oct	8	1415	Sand Plant	S	6/2	S
* 1 Nov	9	1022	New Brighton	C	22/2	N
* 15 Nov	10	1100	Pajaro River	N	9/0	M
4 Dec	-	-	-	C	-	-
14 Dec	-	-	-	N	-	-
20 Dec	-	-	-	S	-	-
1992						
6 Jan	-	-	-	N	-	-
* 10 Jan	11	0919	Manresa	N	8/0	M
7 Feb	-	-	-	C	-	-
* 25 Feb	12	0944	Rio del Mar	N/S	7/1	S
27 Feb	-	-	-	C	-	-
10 Mar	-	-	-	N	-	-
13 Mar	-	-	-	N	-	-

Table I - continued

Date	Sighting #	Time	Location	Leg	# Adults / Calves	Direction of Travel
* 3 Apr	13	0940	Pajaro Dunes	N	13/2	M
* 10 Apr	14	0940	Pajaro River	N	5/1	S
* 24 Apr	15	1230	Santa Cruz	N	20/0	N
* 28 Apr	16	0745	Pajaro River	N	13/3	S
* 6 May	17	0940	Manresa	N	23/2	S
* 7 May	18	0942	Rio del Mar	N	18/2	S
* 8 May	19	0907	Rio del Mar	N	33/2	N
* 19 May	20	0842	1. Potrero	C	1. 30/0	S
		1003	2. Pajaro River		2. 11/4	N
* 25 May	21	0836	1. Potrero	C	1. 10/0	M
		0912	2.Pajaro River		2. 21/3	N
* 12 Jun	22	0855	Salinas River	C	27/3	N
* 22 Jun	23	0850	Sunset Beach	C	19/5	S
* 23 Jun	24	0830	Sunset Beach	C	19/4	S
* 24 Jun	25	0803	Pajaro River	N	17/3	S
7 Jul	26	0830	Salinas River	S	6/0	M
9 Jul	27	0759	Rio del Mar	N	18/3	N
* 21 Jul	28	1017	New Brighton	C	23/3	S
* 22 Jul	29	0913	Rio del Mar	N	10/2	S
* 31 Jul	30	0730	Pajaro River	N	20/2	-
11 Aug	31	0944	Pajaro River	N	13/1	N
* 25 Aug	32	1026	New Brighton	N	18/2	S
28 Aug	33	1315	Myhouse	N	10/0	N
* 1 Sep	34	0957	Manresa	N	6/1	N
* 4 Sep	35	0930	Pajaro River	N	9/1	M
11 Sep	36	1021	Pajaro river	C	18/1	N
11 Sep	37	1454	Sunset Beach	N	7/0	N
15 Sep	38	0950	Pajaro River	N	6/2	M
18 Sep	-	-	-	N	-	-
18 Sep	39	0912	Pajaro River	N	15/1	M
* 22 Sep	40	1148	La Selva	N	9/1	M
* 29 Sep	41	0930	Sunset	N	22/0	S
30 Sep	42	0938	Moss Landing	N	5/0	N
* 6 Oct	43	1000	Manresa	N	5/2	N
* 9 Oct	44	0944	Sunset	C	12/3	N
* 16 Oct	45	1130	New Brighton	C	21/0	M

Table 1 - continued

Date	Sighting #	Time	Location	Leg	# Adults / Calves	Direction of Travel
13 Nov	46	1000	Moss Landing	N/S	10/0	S
23 Dec	-	-	-	N	-	-
1993						
* 25 Jun	47	0901	Manresa	N	12/2	S
1 Jul	-	-	-	S	-	-
* 12 Jul	48	0950	Pajaro River	N/S	9/1	M
* 16 Jul	49	0928	La Selva	N	25/2	M
* 1 Aug	50	0936	Myhouse	N	31/4	M
* 6 Aug	51	0935	Moss Landing	N	14/1	S
* 7 Aug	52	1051	Myhouse	N	9/1	M
14 Aug	53	1010	Pajaro River	N	8/0	M
* 31 Aug	54	1000	Rio del Mar	N	27/3	S
3 Sep	-	-	-	N	-	-
* 7 Sep	55	1040	La Selva	N	29/1	N
14 Sep	56		Myhouse	N	20/5	M
* 21 Sep	57		Manresa	N	20/2	N
3 Nov	-	-	-	N	-	-
4 Nov	58	0825	Sunset	N	14/0	M
* 21 Nov	59	0900	Myhouse	N	21/4	M
25 Nov	60	0935	Pajaro River	N	10/0	M
26 Nov	61	0935	Myhouse	N	18/2	M

Table 2 - Sighting history of distinctively marked bottlenose dolphins photoidentified in Monterey Bay. Each dolphin is identified by catalog number, date of first sighting in Monterey Bay (MB), and date of first and last sighting in the Southern California Bight (SCB).

Cat #	First in MB	First in SCB	Last in SCB	Cat #	First in MB	First in SCB	Last in SCB
001	9 Oct 90	18 Jun 88	18 Jun 88	049	6 May 92	13 Feb 84	16 Dec 89
002	9 Oct 90	18 Jul 83	20 Jun 87	037	7 May 92	-	-
003	9 Oct 90	23 May 87	20 Jun 87	028	8 May 92	8 May 87	27 Apr 91
005	9 Oct 90	2 Aug 82	20 Jun 87	018	25 May 92	7 Aug 83	29 Jul 89
006	9 Oct 90	15 Jun 84	6 Jun 89	047	25 May 92	29 Jun 82	23 May 87
011	9 Oct 90	15 Feb 85	8 May 88	048	21 Jul 92	-	-
020	9 Oct 90	20 Apr 86	29 Jul 89	053	22 Sep 92	-	-
021	9 Oct 90	8 May 85	4 Mar 89	032	25 Jun 93	29 Oct 82	25 Jun 89
027	9 Oct 90	21 May 88	25 Jun 89	035	25 Jun 93	20 Jul 84	27 Apr 91
034	9 Oct 90	1 Nov 81	30 Apr 82	062	25 Jun 93	-	-
038	9 Oct 90	19 Jul 87	8 Apr 89	024	12 Jul 93	6 Feb 85	18 Jun 88
043	9 Oct 90	13 Jul 84	13 Jul 84	004	1 Aug 93	-	-
008	11 Oct 90	23 Oct 81	27 Jul 84	033	1 Aug 93	31 Dec 88	31 Dec 88
017	11 Oct 90	31 Jul 83	20 Jun 87	036	1 Aug 93	7 Aug 83	20 Jun 89
015	1 Dec 90	-	-	056	1 Aug 93	-	-
054	1 Dec 90	31 Dec 88	29 Jul 89	067	1 Aug 93	-	-
007	30 Aug 91	20 Nov 81	10 Jun 89	068	1 Aug 93	-	-
019	30 Aug 91	-	-	071	1 Aug 93	30 Apr 82	30 Apr 82
010	6 Sep 91	-	-	072	1 Aug 93	23 Oct 81	28 Oct 89
012	6 Sep 91	-	-	073	1 Aug 93	6 Jul 85	27 Apr 91
013	6 Sep 91	13 Dec 83	10 Jun 89	095	1 Aug 93	-	-
014	6 Sep 91	20 Jun 87	20 Jun 87	070	6 Aug 93	-	-
016	6 Sep 91	-	-	052	7 Aug 93	-	-
022	6 Sep 91	-	-	096	31 Aug 93	19 Jul 87	17 Nov 89
009	4 Oct 91	-	-	025	7 Sep 93	-	-
023	3 Apr 92	22 Aug 87	27 Apr 91	060	7 Sep 93	-	-
041	10 Apr 92	20 Nov 81	28 Oct 89	064	7 Sep 93	20 Feb 88	27 Aug 89
051	10 Apr 92	4 Nov 82	26 Aug 89	065	7 Sep 93	6 Feb 88	27 Apr 91
042	24 Apr 92	-	-	069	7 Sep 93	-	-
057	24 Apr 92	30 Apr 82	28 Oct 89	078	7 Sep 93	-	-
030	28 Apr 92	4 Nov 82	24 Feb 91	026	21 Sep 93	2 Aug 82	28 Oct 89
039	28 Apr 92	-	-	031	21 Sep 93	20 Jun 87	24 Feb 91
040	6 May 92	-	-	097	21 Nov 93	30 Apr 82	27 Apr 91
044	6 May 92	26 Nov 84	6 Jun 89				
045	6 May 92	26 Nov 84	27 Apr 91				

Table 3 - Summary of results from Jolly-Seber opern population mark-recapture estimates for coastal bottlenose dolphins in Monterey Bay, using Model A, B, D, as calculated by Program JOLLY (Hines 1988). Model A assumed time-specific survival rates (phi) and capture probabilities (p), Model B assumed constant survival rates and time-specific capture probabilities, and Model D assumed constant survival rates and capture probabilities. M is the estimated number of animals marked. N is the estimated population size, and B is the number of animals joining the population. The standard error (S.E.) and the 95% conficence interval (95% C.I.) are reported for each estimated variable.

	Model A			Model B			Model D		
	PHI	S.E.	95% C.I.	PHI	S.E.	95% C.I.	PHI	S.E.	95% C.I.
1990	1	0.1	0.9-1.1	0.98	0.1	0.9-1.1	0.95	0.1	0.8-1.1
1991	0.9	0.1	0.7-1.2	0.98	0.1	0.9-1.1	0.95	0.1	0.8-1.1
1992	-	-	-	0.98	0.1	0.9-1.1	0.95	0.1	0.8-1.1
1993	-	-	-	0.98	0.1	0.9-1.1	0.95	0.1	0.8-1.1
	M	S.E.	95% C.I.	M	S.E.	95% C.I.	M	S.E.	95% C.I.
1990	-	-	-	-	-	-	-	-	-
1991	16.8	1.2	14.6-19.1	16.8	0.9	15.1-18.5	17.3	1.2	14.9-19.7
1992	25.1	2.8	19.7-30.6	25.7	2.4	21.0-30.4	26.1	2.7	20.8-31.4
1993	-	-	-	47.9	4.9	38.3-57.6	37.0	5.5	26.2-47.8
	N	S.E.	95% C.I.	N	S.E.	95% C.I.	N	S.E.	95% C.I.
1990	-	-	-	-	-	-	-	-	-
1991	30	3.5	22.9-36.7	30.7	2.6	25.6-35.8	33.4	4.3	25.0-41.8
1992	54.1	7.3	39.8-68.3	57.2	6.3	44.9-69.5	63.1	8.4	46.6-79.6
1993	-	-	-	106.3	14.1	78.7-133.8	82.1	11.4	59.7-104.4
	p	S.E.	95% C.I.	p	S.E.	95% C.I.	p	S.E.	95% C.I.
1990	-	-	-	-	-	-	0.62	0.1	0.5-0.8
1991	0.8	0.1	0.5-0.95	0.7	0.1	0.5-0.9	0.62	0.1	0.5-0.8
1992	0.8	0.1	0.5-1.0	0.7	0.1	0.5-0.9	0.62	0.1	0.5-0.8
1993	-	-	-	0.5	0.1	0.3-0.7	0.62	0.1	0.5-0.8
	B	S.E.	95% C.I.	B	S.E.	95% C.I.	B	S.E.	95% C.I.
1990	-	-	-	-	-	-	-	-	-
1991	26.2	5.9	14.7-37.7	27.7	6.3	15.4-40.0	31.3	6.2	19.1-43.4
1992	26.2	-	-	50.0	13.2	24.1-75.9	31.8	7.0	18.1-45.5
1993	-	-	-	-	-	-	-	-	-

Table 4 - Summary of photo-identification effort in Monterey Bay between 1990 and 1993. <u>Satisfactory</u> surveys, indicated by *, were used to calculate sighting probabilities. A = number of adult bottlenose dolphins counted (marked and unmarked individuals), P = number of animals photo-identified, and r = P / A.

Date	A	P	r	Date	A	P	r
<u>1990</u>				<u>1992</u>			
9-Oct	14	12	0.86*	22-Jun	19	15	0.79*
11-Oct	15	6	0.40	23-Jun	19	7	0.37
1-Dec	30	13	0.43	24-Jun	17	3	0.18
8-Dec	3	3	1.00*	9-Jul	18	6	0.33
<u>1991</u>				21-Jul	23	19	0.83*
30-Aug	13	8	0.62*	22-Jul	10	1	0.10
6-Sep	14	12	0.86*	31-Jul	20	3	0.15
27-Sep	2	2	1.00*	25-Aug	18	9	0.50
4-Oct	12	12	1.00*	1-Sep	6	6	1.00*
11-Oct	15	15	1.00*	4-Sep	9	3	0.33
18-Oct	13	12	0.92*	22-Sep	9	9	1.00*
25-Oct	14	14	1.00*	29-Sep	22	9	0.41
31-Oct	6	4	0.67*	6-Oct	5	2	0.40
1-Nov	22	16	0.73*	9-Oct	12	7	0.58
15-Nov	9	5	0.56	16-Oct	21	7	0.33
<u>1992</u>				<u>1993</u>			
10-Jan	8	4	0.50	25-Jun	12	10	0.83*
25-Feb	7	6	0.86*	12-Jul	9	2	0.22
3-Apr	13	3	0.23	16-Jul	25	10	0.40
10-Apr	5	3	0.60*	1-Aug	31	24	0.77*
24-Apr	20	3	0.15	6-Aug	14	6	0.43
28-Apr	13	6	0.46	7-Aug	9	2	0.22
6-May	23	15	0.65*	31-Aug	27	3	0.11
7-May	18	15	0.83*	7-Sep	29	13	0.45
8-May	33	18	0.55	21-Sep	20	12	0.60*
19-May	30	16	0.53	21-Nov	21	16	0.76
25-May	21	21	1.00*	25-Nov	10	6	0.60*
12-Jun	27	18	0.67*				

Table 5 - Summary of sighting probabilities and monthly presence patterns for bottlenose dolphins photo-identified in Monterey Bay between 1991 and 1993. Such information was used to characterize animals as residents (*) or transients.

		1991				1992									1993				
Cat. #	p	A	S	O	N	J	F	A	M	J	J	A	S	O	J	J	A	S	N
014	0.72*		●	●	●			●	●	●	●		●		●		●		●
002	0.71*	●		●	●	●			●	●	●	●	●	●	●	●	●	●	●
001	0.63*	●	●	●	●		●	●	●	●	●			●		●	●		●
005	0.54*	●		●	●	●	●		●	●	●	●	●		●		●		
017	0.52*		●	●	●				●	●	●		●		●				
015	0.52*		●	●	●		●		●	●		●	●			●	●	●	●
013	0.45*		●	●	●		●		●		●				●				
016	0.45*		●	●	●				●	●			●	●		●			
010	0.41*		●	●	●	●	●	●							●	●	●	●	●
009	0.40*			●	●				●	●						●			
006	0.37*	●	●	●	●			●	●								●		
027	0.37*			●	●				●	●	●		●			●	●	●	●
011	0.33*		●						●	●	●	●	●						●
020	0.29		●	●															
008	0.09	●	●																
012	0.27		●	●	●														
019	0.17	●						●	●	●	●								
021	0.50		●	●	●			●	●	●	●	●	●						
022	0.36		●	●	●				●		●		●						
007	0.35	●		●	●	●	●		●	●	●								
003	0.21	●	●	●													●		●
042	0.58							●	●	●	●	●	●						
040	0.58								●	●	●		●	●					
037	0.45								●	●	●		●	●					
047	0.40								●	●	●	●		●					
018	0.10								●										
049	0.08								●										
028	0.30								●	●	●								
044	0.25								●										
030	0.17							●		●	●	●	●						
048	0.14										●			●					
043	0.08								●										

Table 5 - continue

Cat. #	p	1991 A	1991 S	1991 O	1991 N	1992 J	1992 F	1992 A	1992 M	1992 J	1992 J	1992 A	1992 S	1992 O	1993 J	1993 J	1993 A	1993 S	1993 N
038	0.29							●	●	●	●	●	●	●			●		
053	0.40												●	●					●
023	0.38							●	●	●	●	●				●	●	●	
057	0.17							●			●						●		
041	0.15							●						●				●	
039	0.17							●								●	●	●	●
051	0.15							●										●	
045	0.33								●								●		
097	1.00																		●
024	0.67															●	●	●	●
033	0.67																●		●
032	0.50														●				●
035	0.50														●			●	●
062	0.50														●		●		●
078	0.50																	●	
004	0.33																●		
036	0.33																●		
056	0.67																●	●	
071	0.67																●		●
067	0.33																●		
068	0.33																●	●	
072	0.33																●	●	
073	0.33																●		
026	0.50																	●	
031	0.50																	●	
095	0.33																●		
064	0.33																	●	●
065	0.33																●	●	
069	-																	●	
070	-																●		●
052	-																●		
096	-																●		
025	-																	●	●
060	-																	●	

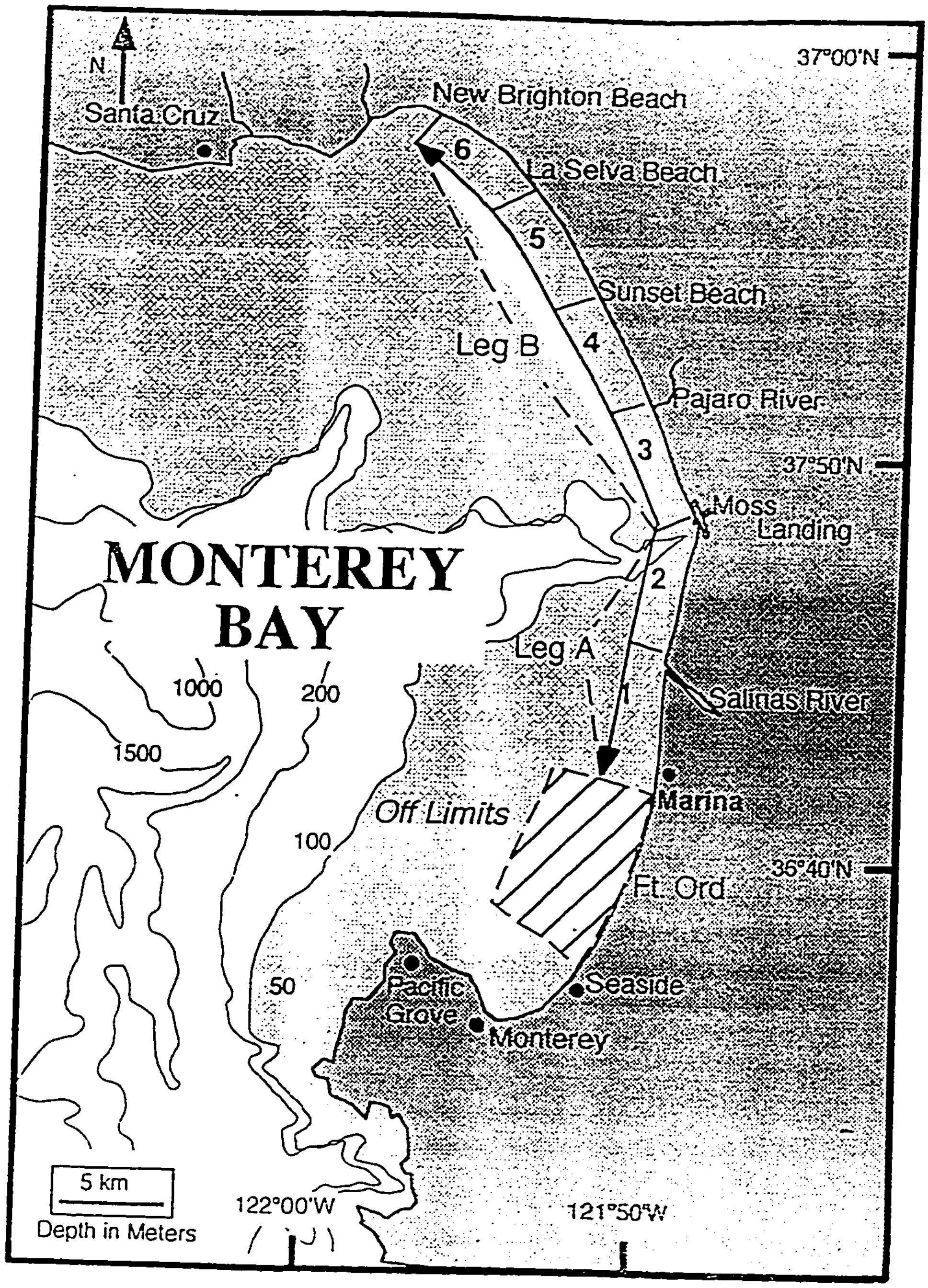

Fig. 1 - The study area, located within Monterey Bay, California, from Marina to New Brighton State Beach, covered approximately 33 km of coast and 1 km offshore. It was sub-divided into two legs: leg a from Moss Landing to New Brighton Beach (22 km^2), and leg b from Moss Landing harbor to Marina (11 km^2).

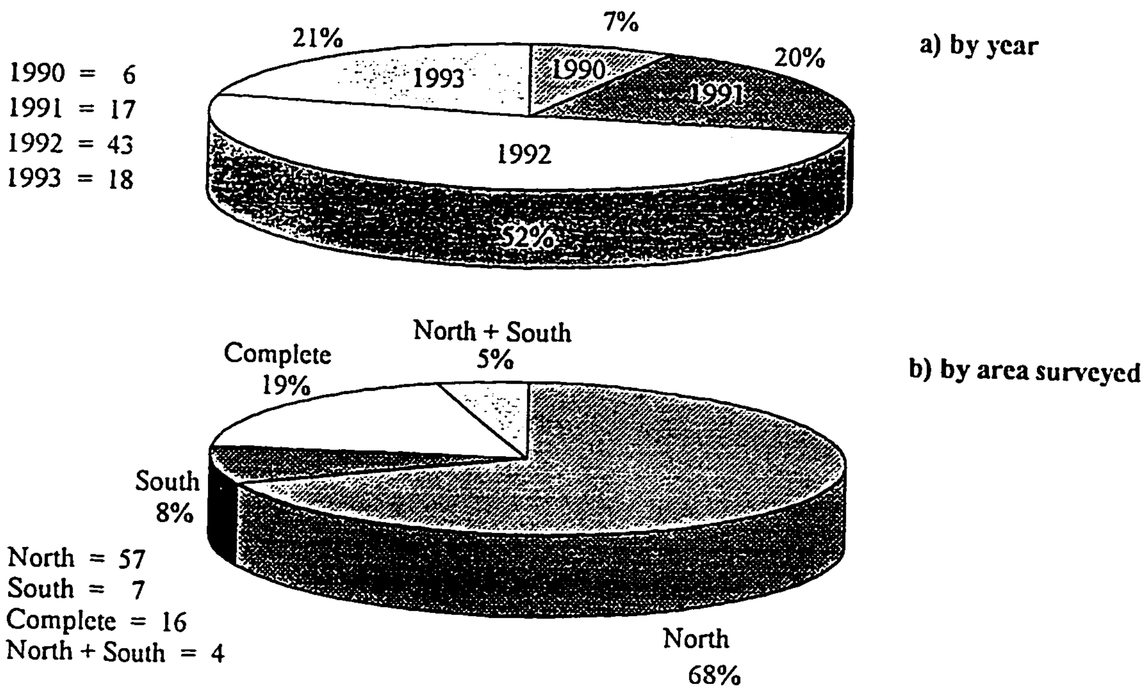

Fig. 2 - Summary of survey effort in Monterey Bay between October 1990 and November 1993. Effort is summarized by year (a), and by area covered during each survey (b). Complete surveys covered the entire study area.

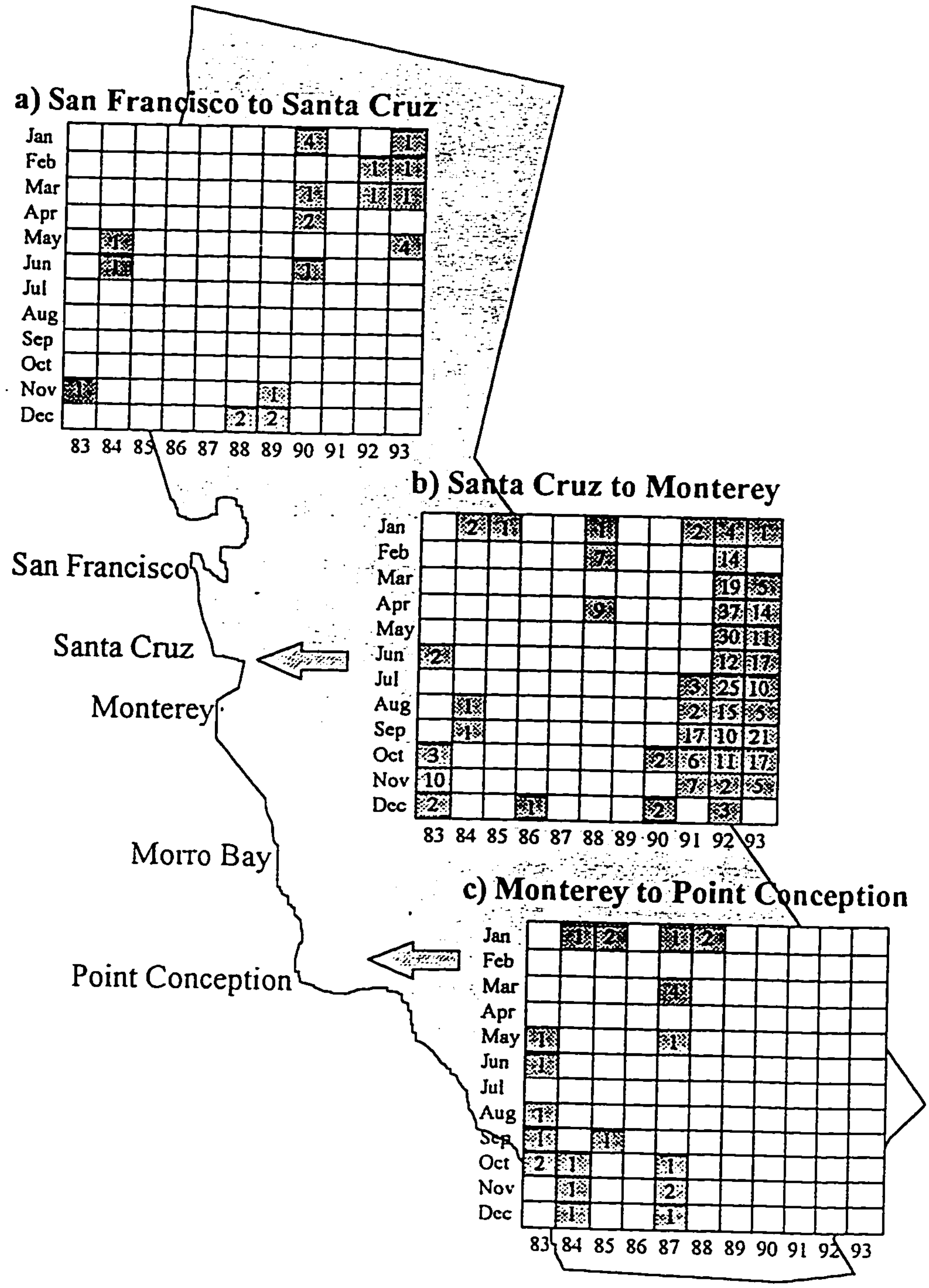

Fig. 3 - Summary of hustorical sightings off central California between 1983 and 1993. Shaded boxes represent months when dolphins were sighted, and numbers in shaded boxes represent number of sightings reported for that month.

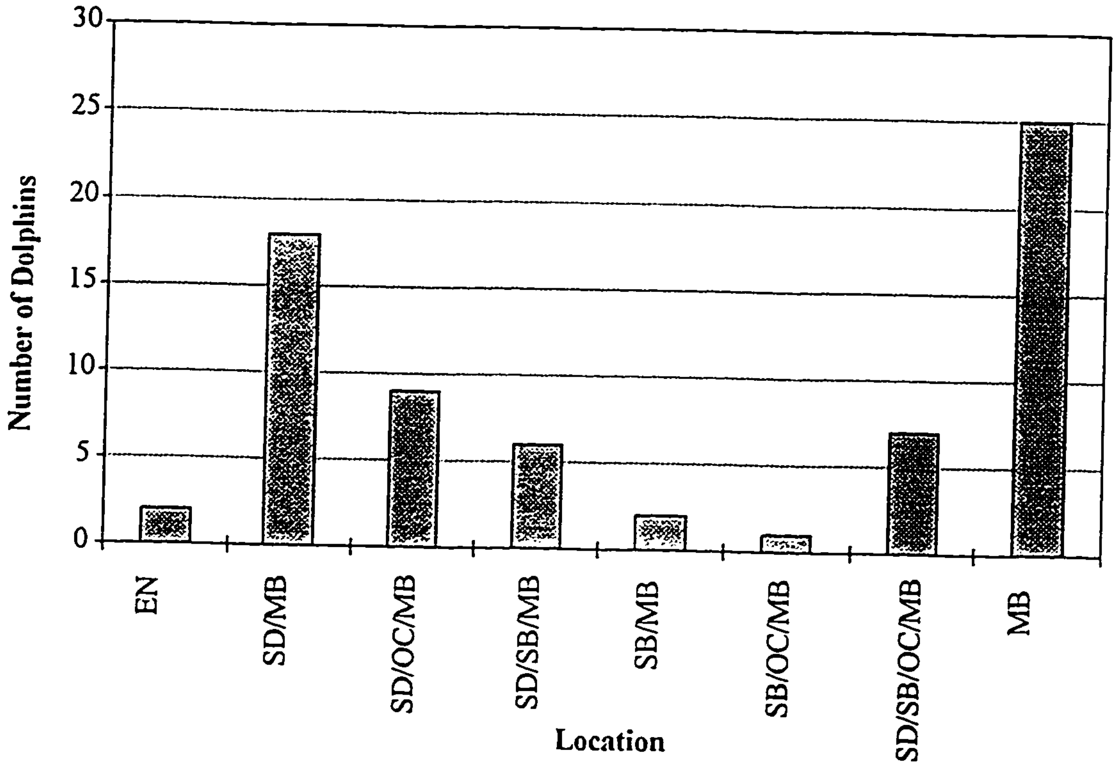

Fig. 4 - Summary of geographical areas where Monterey Bay bottlenose dolphins were photographed between 1981 and 1993. EN = Ensenada, Mexico, SD = San Diego, OC = Orange County, SB = Santa Barbara, MB = Monterey Bay.

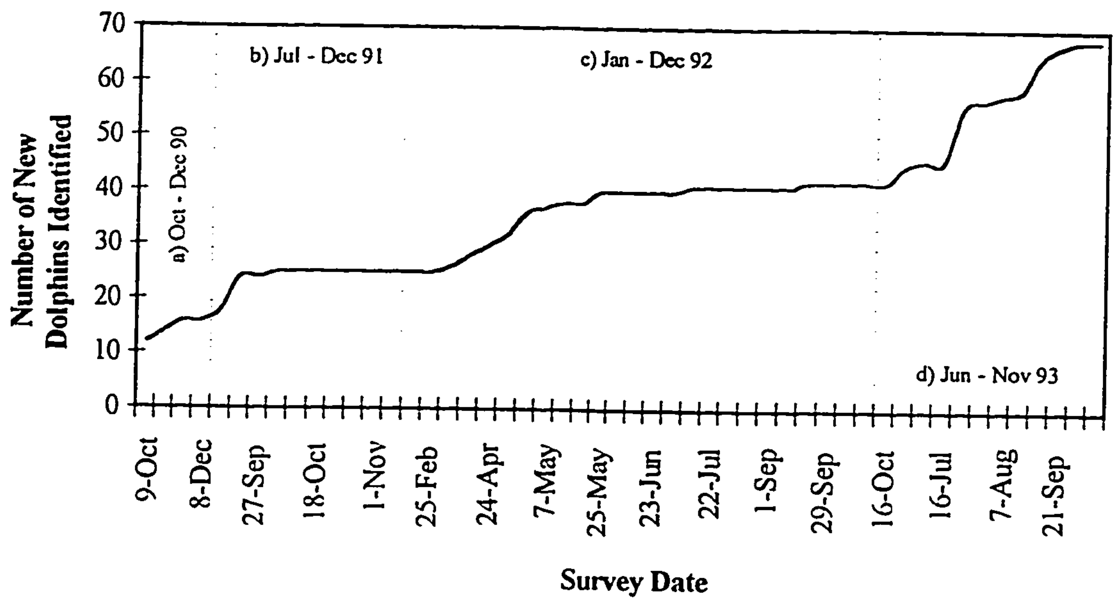

Fig. 5 - Cumulative frequency of marked individuals photoidentified in Monterey Bay between 1990 and 1993, during four photoidentification periods: a) Oct-Dec 90, b) Jul-Dec 91, c) Jan-Dec 92, and d) Jun-Nov 93. Number of photoidentified dolphins continued to increase throughout the study.

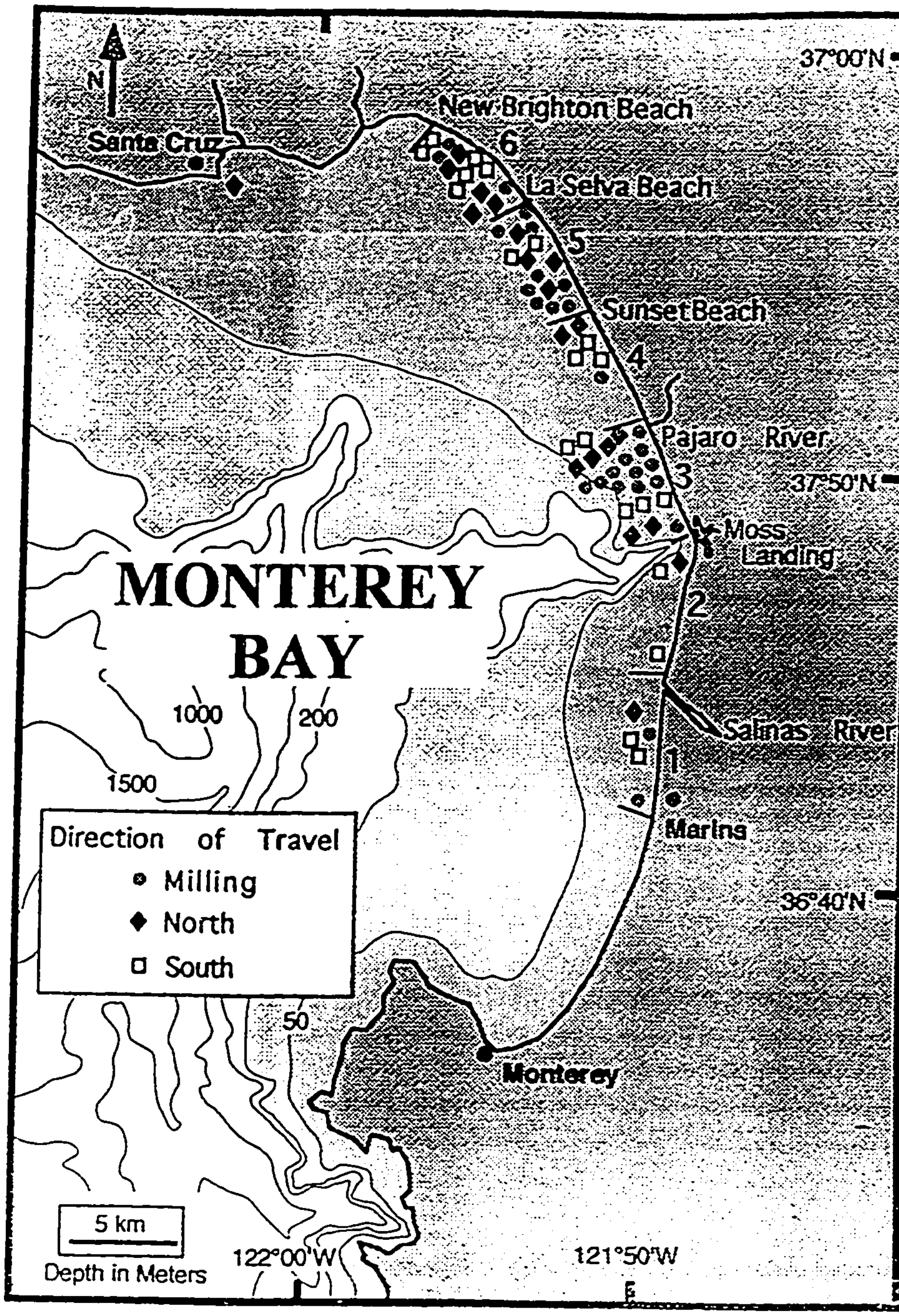

Fig. 6 - Sighting distribution patterns for Pacific coastal bottlenose dolphins in Monterey Bay between 1990 and 1993.

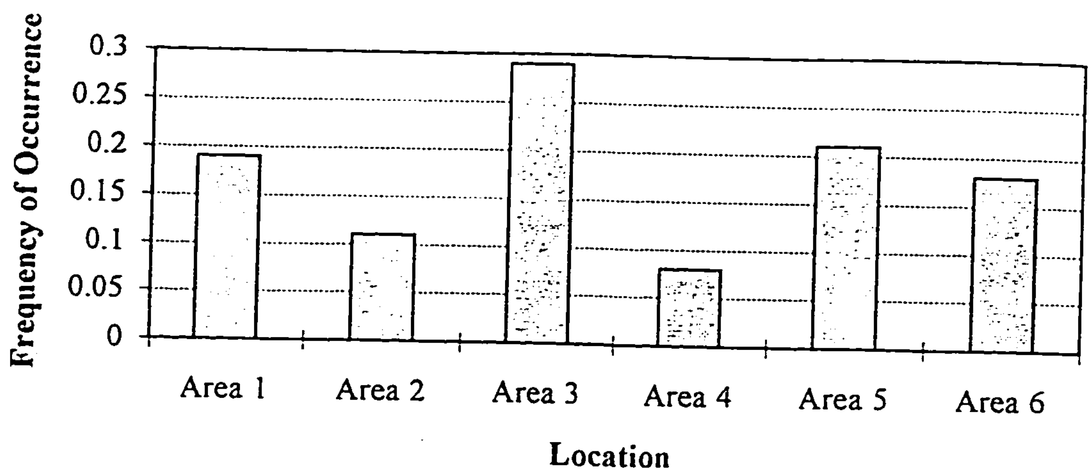

Fig. 7 - Frequency of occurrence of dolphin sightings in 3 nautical mile long stretches of coast in Monterey Bay. Area 1 = Marina to Monterey Dunes, Area 2 = Monterey Dunes to Moss Landing, Area 3 = Moss Landing to Pajaro River, Area 4 = Pajaro River to Sunset Beach, Area 5 = Sunset Beach to La Selva Beach, Area 6 = La Selva Beach to New Brighton Beach.

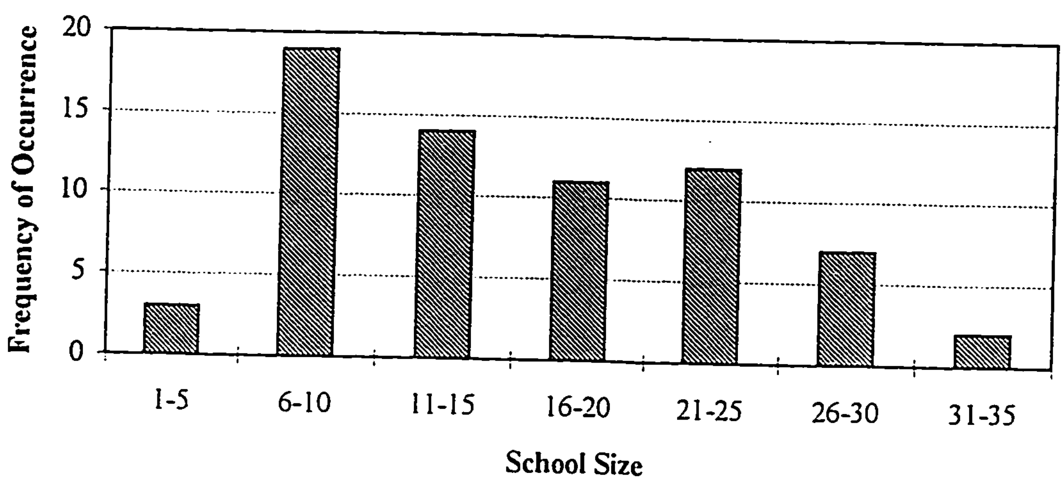

Fig. 8 - Frequency of occurrence of school size (n = 68) categories observed between October 1990 and November 1993 in Monterey Bay, California.

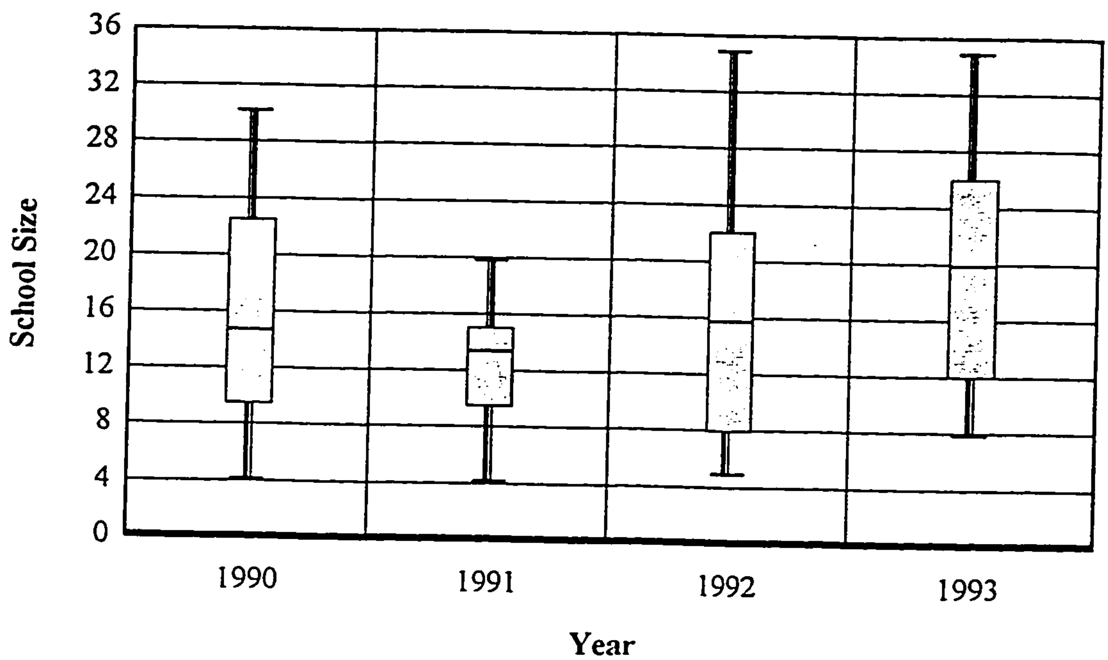

Fig. 9 - Yearly school size variability of Pacific coastal bottlenose dolphins in Monterey Bay between October 1990 and November 1993. The median and relative inter-quartile range (IQR) were chosen to best represent the spread of the school size data .

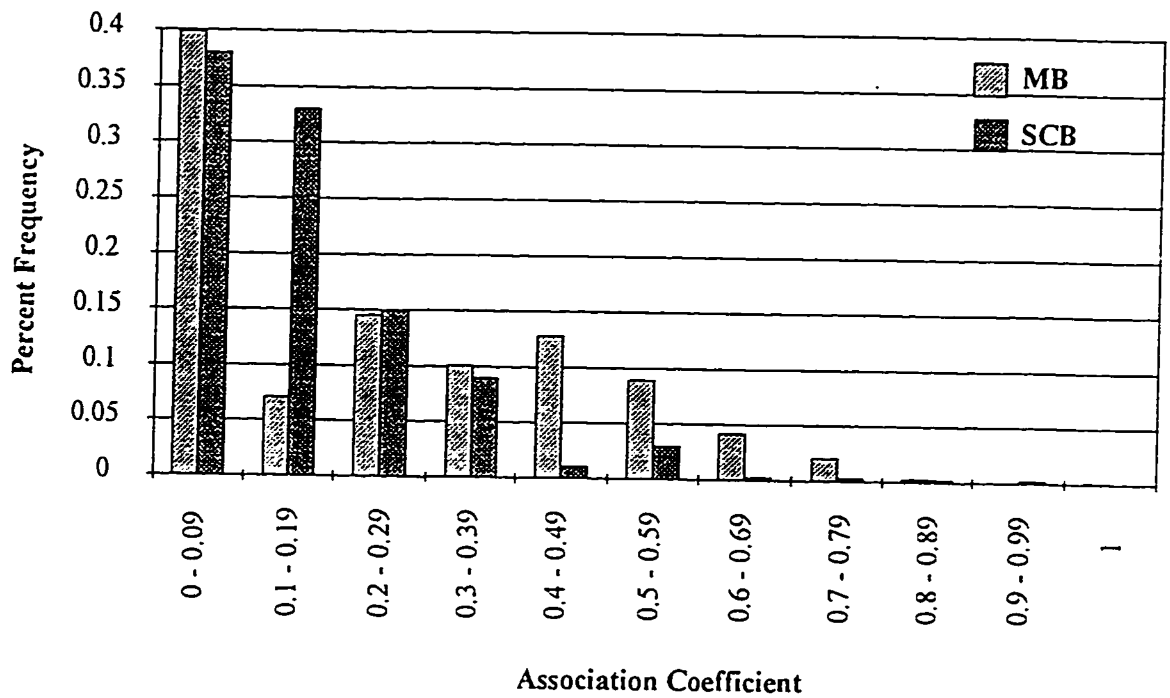

Fig. 10 - Comparison between distibutions of association coefficients for bottlenose dolphins photographed in Monterey Bay (MB; 1990-1993) and in the Southern California Bight (SCB; 1981-1989). Data from the SCB were collected by Weller (1991).

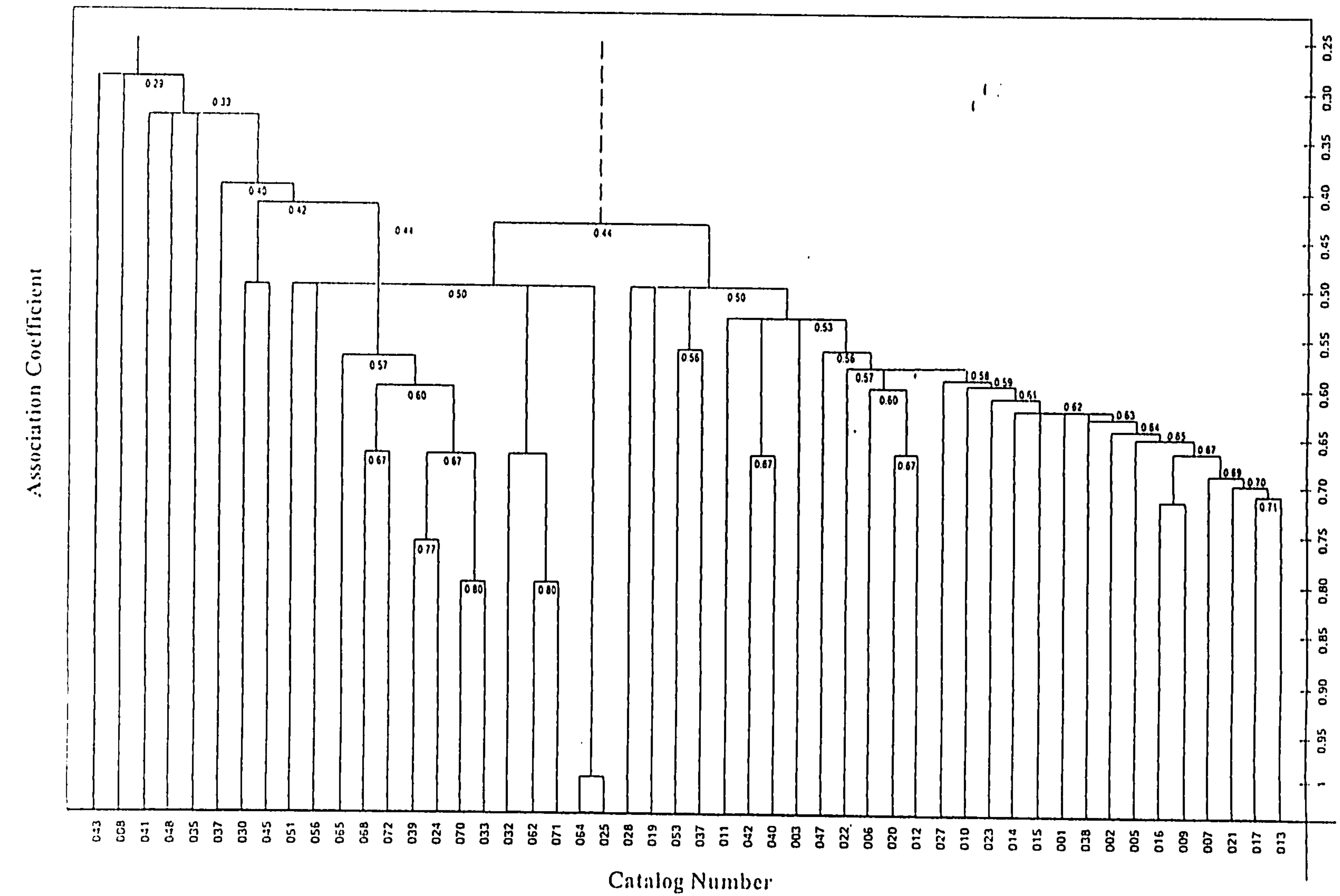

Fig. 11 - Single linkage (nearest neighbor) cluster analysis dendrogram for 50 bottlenose dolphins photo-identified in Monterey Bay between October 1990 and November 1993.

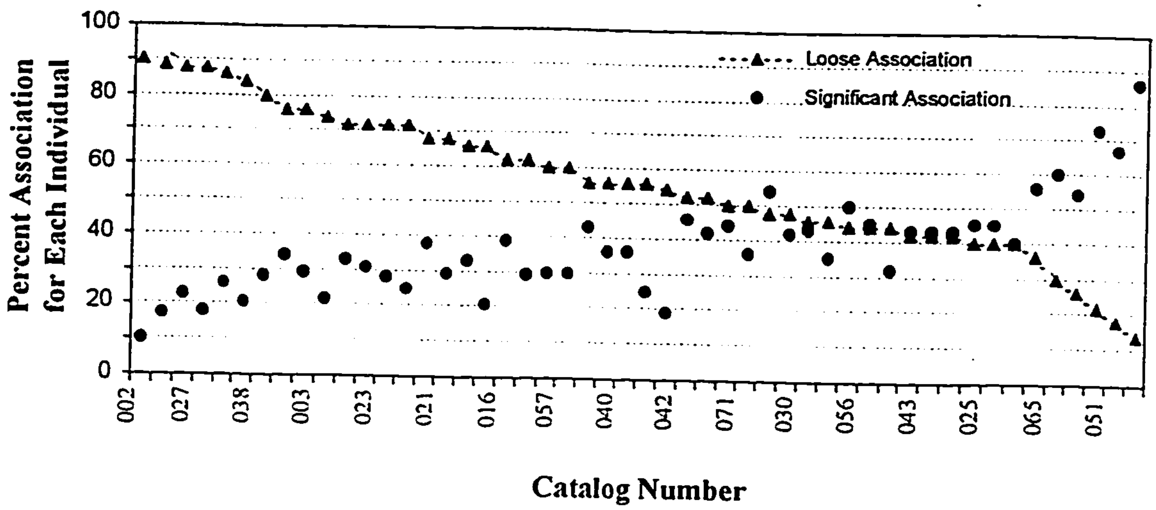

Fig. 12 - Loose associations and significant associations expressed as percent of total association for each bottlenose dolphin photoidentified in Monterey between 1990 and 1993.

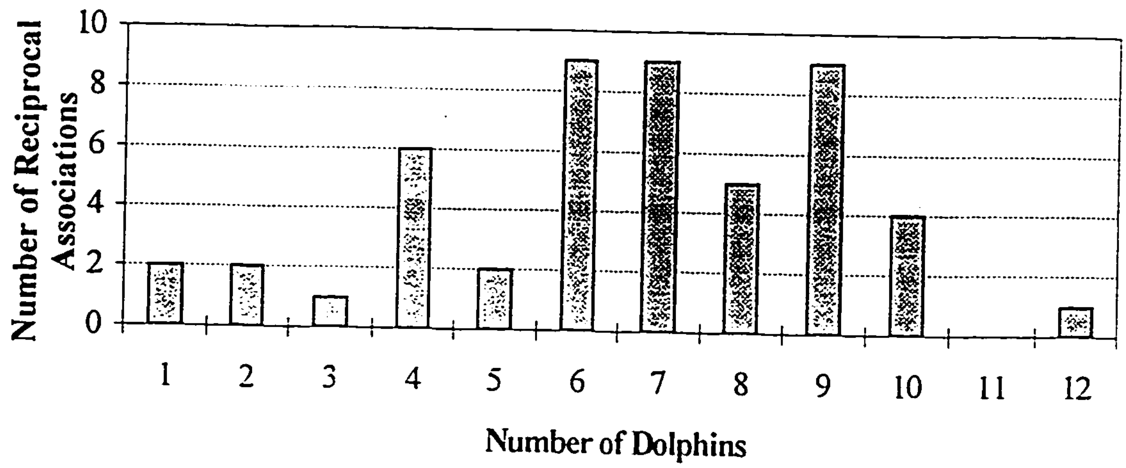

Fig. 13 - Frequency of occurrence of reciprocal associations among photoidentified bottlenose dolphins in Monterey Bay between 1990 and 1993.

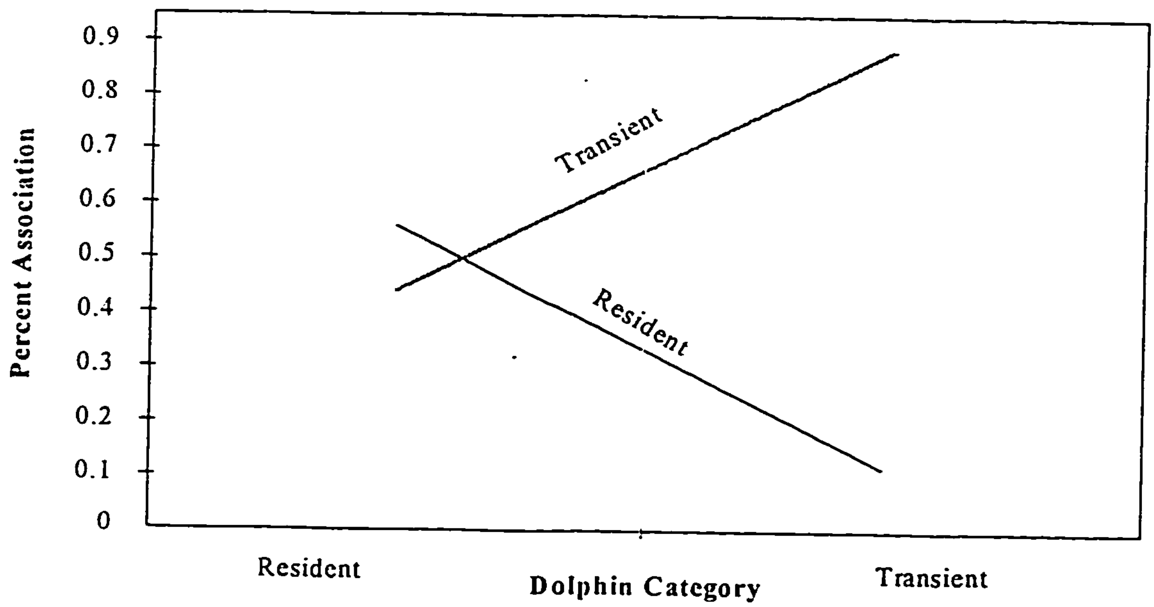

Fig 14 - Percent association between resident/resident and resident/transient bottlenose dolphins (thin line), compared to transient/resident and transient/transient bottlenose dolphins (thick line) in Monterey Bay between 1990 and 1993.

Appendix A - Sightings of bottlenose dolphins along the central California coast between 1983 and 1988 (from Wells et al. 1990).

#	Date	Time	Location	Lat/Long	Adults/Calves
1983					
1	May 18	0854	Shell Beach	35° 09' N 120° 40' W	3/0
2	Jun 8	0953	Cayucos Pier	35° 25' N 120° 52' W	6/0
3	Jun 18	1022	San Simeon Cove	35° 38' N 121° 12' W	5/0
4	Sep 18	-	27.8 km W of Cypress Pt.	36° 35' N 122° 14' W	30/0
5	Oct 25	0750	7.4 km N of Point Sur	36° 35' N 121° 55' W	8/0
6	Oct 27	1600	Moss Landing	36° 48' N 121° 48' W	6/0
7	Oct 29	1700	West Cliff, Santa Cruz	36° 47' N 122° 02' W	9/1
8	Oct 31	1030	Carmel Beach	36° 33' N 121° 56' W	3/1
9	Nov 3	1030	Terrace Pt., Santa Cruz	36° 57' N 122° 03' W	6/1
10	Nov 4	1125	West Cliff, Santa Cruz	36° 57' N 122° 02' W	8-9/1
11	Nov 7	1425	Cow Beach, Santa Cruz	36° 58' N 122° 07' W	3/0
12	Nov 9	0900	Pajaro Dunes	36° 52' N 121° 49' W	9-10/0
13	Nov 9	-	Monterey State Beach	36° 37' N 121° 52' W	5/0
14	Nov 11	-	Monterey State Beach	36° 37' N 121° 52' W	5/0
15	Nov 15	1635	Terrace Pt., Santa Cruz	36° 57' N 122° 03' W	2/0
16	Nov 16	1100	Monterey State Beach	36° 37' N 121° 52' W	2/0
17	Nov 18	0945	Moss Landing	36° 48' N 121° 48' W	3-5/0
18	Nov 20	1000	West Cliff, Santa Cruz	36° 47' N 122° 02' W	7-9/1
19	Nov 30	0955	Pescadero Pt.	37° 14' N 122° 24' W	5/0
20	Dec 23	-	Monterey State Beach	36° 37' N 121° 52' W	2/0
21	Dec 30	-	Monterey State Beach	36° 37' N 121° 52' W	2/0
1984					
22	Jan 5	1300	Moss Landing	36° 48' N 121° 48' W	7/0
23	Jan 7	0700	Cannery Row, Monterey	36° 37' N 121° 52' W	25-50/0
24	Jan 12	1330	Pacific Valley	35° 36' N 121° 29' W	25-40/0
25	May 24	1112	Waddell Creek	37° 05' N 122° 18' W	5/0
26	Jun 9	0715	Wilder Beach, Santa Cruz	36° 55' N 122° 05' W	8/0
27	Aug 22	0840	Pajaro Dunes	36° 52' N 121° 49' W	6/0
28	Sep 19	1020	Sand Hill, Santa Cruz	36° 59' N 122° 08' W	9/0
29	Nov 22	0745	Pt. Conception	34° 27' N 120° 28' W	3/0
30	Dec 24	1152	16.7 km of Piedras Blancas	-	10/2
1985					
31	Jan 1	-	Big Sur River mouth	-	10-15/0
32	Jan 2	0930	Pt. Piedras Blancas	35° 38' N 121° 12' W	8/0
33	Jan 3	1700	Terrace Pt., Santa Cruz	36° 57' N 122° 04' W	3-5/0
34	Sep 27	1300	Morro Bay	35° 24' N 120° 48' W	4
1986					
35	Dec 6	0630	Monterey State Beach	36° 37' N 121° 52' W	3-5/0
1987					
36	Jan 1	-	0.9 km S of Big Sur River	-	12-15/0
37	Mar 27	-	Pt. Sal	34° 58' N 120° 40' W	11
38	Mar 27	-	Pt. Sal	34° 58' N 120° 40' W	8
39	Mar 28	-	Pt. Sal	34° 58' N 120° 40' W	12
40	Mar 29	-	Pt. Sal	34° 58' N 120° 40' W	7

continue Appendix A

#	Date	Time	Location	Lat/Long	Adults/Calves
1987					
41	May 21	-	Pt. Sal	34° 58' N 120° 40' W	9/0
42	Oct 30	-	14.8 km W of Pt. Pinos	-	1/0
43	Nov 8	-	Pt. Piedras Blancas	35° 38' N 121° 12' W	10/0
44	Nov 17	-	W of Cayucos	35° 25' N 120° 52' W	15/0
45	Dec 29	-	Carmel River State Beach	36° 33' N 121° 56' W	12/3
1988					
46	Jan 2	1400	N of Carmel Point	36° 33' N 121° 56' W	12/3
47	Jan 29	1000	Pt. Lobos Reserve	36° 32' N 121° 57' W	11-12/0
48	Jan 29	-	Moss Landing	36° 48' N 121° 48' W	8/1
49	Feb 3	0900	Monterey State Beach	36° 37' N 121° 52' W	8/0
50	Feb 3	1345	Moss Landing	36° 48' N 121° 48' W	7-10/0
51	Feb 11	1600	Marina State Beach	36° 43' N 120° 42' W	5/0
52	Feb 17	1430	Moss Landing	36° 48' N 121° 48' W	4/0
53	Feb 20	1400	N of Pajaro River mouth	36° 48' N 121° 49' W	9/0
54	Feb 24	-	Monterey State Beach	36° 37' N 121° 52' W	13/3
55	Feb 24	1433	Ft. Ord	36° 42' N 121° 49' W	8/0
56	Apr 2	-	Seacliff Beach, Aptos	36° 57' N 121° 55' W	10/1
57	Apr 7	-	Seacliff Beach, Aptos	36° 57' N 121° 55' W	18/3
58	Apr 9	-	Seacliff Beach, Aptos	36° 57' N 121° 55' W	24-26/2
59	Apr 10	-	Seacliff Beach, Aptos	36° 57' N 121° 55' W	24-26/2
60	Apr 11	-	Seacliff Beach, Aptos	36° 57' N 121° 55' W	24/26/2
61	Apr 11	1600	Seacliff Beach, Aptos	36° 57' N 121° 55' W	15/2
62	Apr 15	0843	Seacliff Beach, Aptos	36° 57' N 121° 55' W	8-9/2
63	Apr 17	1830	Seacliff Beach, Aptos	36° 57' N 121° 55' W	10+
64	Apr 23	0900	Pajaro Dunes	36° 52' N 121° 49' W	8-10/1

Appendix B - Sightings of bottlenose dolphins in Monterey Bay between 1990 and 1993. See Fig. 1 for geographic location within the bay.

#	Date	Time	Location	# Dolphins
1991				
1	21 Jan		Monterey Beach Hotel	9
2	6 Jul	1440	La Selva	6
3	6 Jul	1436	Seascape	3
4	9 Jul	1030	Marina	3
5	29 Aug	1028		9
6	1 Sep	1000	Marina	3
7	2 Sep	1035		4
8	5 Sep	1130	Manresa Beach	12
9	7 Sep	1500	Manresa Beach	8
10	7 Sep	1700	Manresa Beach	1
11	10 Sep	0905	Manresa Beach	6
12	15 Sep	1330	Salinas River	10
13	16 Sep	1030	Pajaro Dunes	5
14	18 Sep	0815	Manresa Beach	15
15	20 Sep	0945	Manresa Beach	5
16	20 Sep	1030	Sunset Beach	9
17	21 Sep	0812	Sunset Beach	11
18	22 Sep		Manresa Beach	6
19	24 Sep	1400	Manresa Beach	1
20	26 Sep	1214	Sunset Beach	4
21	30 Oct	0945	Marina	8
22	9 Nov	1015	Manresa	10
23	16 Nov	1030	La Selva	4
24	16 Nov	1445	Rio del Mar	25
25	21 Nov	0945	La Selva	7
26	22 Nov	1230	Moss Landing	5
1992				
27	8 Jan	1030	Moss Landing	8
28	9 Jan	0800	Rio del Mar	10
29	14 Jan	1100	Zmudowski	10
30	1 Feb	1747	Rio del Mar	2
31	4 Feb	0730	Rio del Mar	4
32	9 Feb	0730	Pacific Grove	20
33	9 Feb	0800	Stillwater Cove	4
34	9 Feb	0900	Pacific Grove	6
35	10 Feb	1100	Jetty	6
36	18 Feb	0730	Rio del Mar	15
37	18 Feb	1000	Pacific Grove	18
38	19 Feb	1130	Pacific Grove	
39	21 Feb	1400	Marina	15
40	25 Feb	0800	Rio del Mar	11
41	25 Feb	1000	Marina	20
42	7 Mar	0848	Rio del Mar	6
43	7 Mar	1600	Davenport	30

Appendix B - continued

#	Date	Time	Location	# Dolphins
1992				
44	7 Mar	1630	Santa Cruz	8
45	18 Mar	0800	Moss Landing	11
46	18 Mar	0900	Moss Landing	20
47	18 Mar	1043	Moss Landing	5
48	19 Mar	1100	Moss Landing	25
49	20 Mar	0800	Rio del Mar	4
50	21 Mar	1630	Santa Cruz	8
51	21 Mar	1655	Capitola	10
52	24 Mar	0659	Rio del Mar	20
53	25 Mar	1230	Santa Cruz	17
54	26 Mar	1030	Moss Landing	6
55	26 Mar	1345	Santa Cruz	12
56	27 Mar	1345	Seacliff	3
57	29 Mar	1600	Santa Cruz	10
58	30 Mar	1000	Monterey Beach Hotel	15
59	31 Mar	1100	Moss Landing	15
60	31 Mar	1600	Pleasure Point	10
61	2 Apr	1400	Rio del Mar	7
62	3 Apr	0810	Moss Landing	8
63	4 Apr	1150	Moss Landing	1
64	6 Apr	0700	Rio del Mar	12
65	7 Apr	1215	Pacific Grove	10
66	7 Apr	1430	Garrapata	11
67	8 Apr	1215	Sunset Beach	5
68	11 Apr	1100	Monterey	14
69	11 Apr	1812	Marina	4
70	12 Apr	1330	Moss Landing	100
71	14 Apr	1030	Santa Cruz - 38th Street	5
72	16 Apr	0800	New Brighton	9
73	16 Apr	0930	Moss Landing	25
74	22 Apr	1330	New Brighton	7
75	23 Apr	0900	New Brighton Beach	9
76	24 Apr	0730	New Brighton Beach	8
77	24 Apr	1120	Santa Cruz - 20th Street	
78	24 Apr	1230	Capitola	20
79	24 Apr	1345	New Brighton Beach	8
80	25 Apr	0700	Rio del Mar	12
81	27 Apr	1400	Marina	12
82	28 Apr	1427	New Brighton	2
83	28 Apr	1630	Santa Cruz - 16th-17th	12
84	28 Apr	1630	Santa Cruz - 17th	25
85	28 Apr	1700	Santa Cruz - 16th-17th	20
86	28 Apr	1845	New Brighton Beach	5

Appendix B - continued

#	Date	Time	Location	# Dolphins
1992				
87	29 Apr	0700	Rio del Mar	15
88	29 Apr	1145	Santa Cruz - 16th/17th	2
89	29 Apr	1200	Manresa	20
90	30 Apr	1600	Rio del Mar	15
91	30 Apr	1700	New Brighton Beach	6
92	6 May	0700	New Brighton Beach	12
93	7 May	0830	New Brighton Beach	6
94	8 May	0730	New Brighton Beach	12
95	13 May	1800	New Brighton Beach	6
96	15 May	1530	New Brighton Beach	2
97	16 May	0910	New Brighton Beach	8
98	17 May	0850	New Brighton Beach	3
99	17 May	1400	Manresa	10
100	18 May	0640	New Brighton Beach	17
101	18 May	0750	New Brighton Beach	17
102	18 May	1800	Rio del Mar	3
103	19 May	1300	Rio del Mar	25
104	20 May	2000	Rio del Mar	6
105	21 May	1600	Rio del Mar	4
106	22 May	1500	Rio del Mar	8
107	23 May	0745	Manresa	10
108	23 May	1105	Manresa	17
109	24 May	1300	Rio del Mar	3
110	25 May	1820	Rio del Mar	5
111	25 May	1830	New Brighton Beach	7
112	27 May	1720	New Brighton Beach	5
113	28 May	0830	Santa Cruz-Pleasure Pt.	5
114	29 May	0800	Santa Cruz-Pleasure Pt.	2
115	29 May	1400	Santa Cruz-Pleasure Pt.	8
116	3 Jun	0800	New Brighton Beach	10
117	4 Jun	1330	New Brighton Beach	11
118	11 Jun	1100	La Selva	12
119	13 Jun	0740	New Brighton Beach	8
120	20 Jun	1613	Rio del Mar	10
121	20 Jun	1630	New Brighton Beach	8
122	20 Jun	1930	New Brighton Beach	8
123	25 Jun	1200	Manresa	5
124	1 Jul	0630	New Brighton Beach	10
125	2 Jul	0730	Manresa	10
126	2 Jul	0900	Manresa	10
127	7 Jul	1200	Manresa	10
128	9 Jul	0700	Sunset Beach	-
129	9 Jul	0725	Rio del Mar	16

Appendix B - continued

#	Date	Time	Location	# Dolphins
1992				
130	9 Jul	0730	New Brighton Beach	10
131	11 Jul	1045	Zmudowski	6
132	12 Jul	1910	Moss Landing	45
133	14 Jul	0725	New Brighton Beach	8
134	19 Jul	1100	Capitola	30
135	19 Jul	1140	New Brighton Beach	3
136	19 Jul	1811	Seacliff Beach	10
137	20 Jul	0800	Manresa	10
138	22 Jul	0730	Rio del Mar	15
139	24 Jul	0630	New Brighton Beach	7
140	26 Jul	1045	Marina	10
141	29 Jul	1140	New Brighton Beach	9
142	30 Jul	2000	New Brighton Beach	7
143	31 Jul	1200	Manresa	3
144	2 Aug	1100	Manresa	8
145	7 Aug	0835	New Brighton Beach	8
146	8 Aug	0725	New Brighton Beach	7
147	8 Aug	0730	Seacliff Beach	15
148	8 Aug	1230	Manresa	3
149	10 Aug	0715	New Brighton Beach	7
150	10 Aug	1100	Hidden Beach	13
151	10 Aug	1800	Seacliff Beach	15
152	24 Aug	1850	New Brighton Beach	8
153	25 Aug	0800	New Brighton Beach	10
154	31 Aug	0700	New Brighton Beach	20
155	31 Aug	1230	New Brighton Beach	12
156	24 Sep	0930	New Brighton Beach	9
157	5 Oct	0700	New Brighton Beach	10
158	10 Oct	1300	Seascape	15
159	10 Oct	1630	New Brighton Beach	10
160	12 Oct	0945	Seaside	7
161	13 Oct	0915	New Brighton Beach	10
162	16 Oct	1100	New Brighton Beach	12
163	16 Oct	1700	New Brighton Beach	9
164	21 Oct	1100	Moss Landing	10
165	12 Nov	1715	Moss Landing	10
166	2 Dec	0656	New Brighton Beach	12
167	6 Dec	1030	New Brighton Beach	6
168	9 Dec	1630	New Brighton Beach	6
1993				
169	12 Jan	0830	Seacliff Beach	7
170	21 Mar	1250	New Brighton Beach	6
171	22 Mar	0830	New Brighton Beach	8
172	22 Mar	1250	New Brighton Beach	7

#	Date	Time	Location	# Dolphins
1993				
173	24 Mar	0702	New Brighton Beach	3
174	24 Mar	0712	New Brighton Beach	6
175	2 Apr	0710	New Brighton Beach	2
176	2 Apr	0800	New Brighton Beach	2
177	2 Apr	1040	New Brighton Beach	2
178	5 Apr	0730	New Brighton Beach	11
179	6 Apr	1200	New Brighton Beach	7
180	6 Apr	1430	Asilomar	6
181	8 Apr	1100	New Brighton Beach	10
182	15 Apr	0900	Monterey	4
183	16 Apr	1400	New Brighton Beach	12
185	17 Apr	0915	New Brighton Beach	2
186	18 Apr	1315	New Brighton Beach	10
187	26 Apr	1805	New Brighton Beach	2
188	28 Apr	1340	New Brighton Beach	2
189	29 Apr	1050	New Brighton Beach	4
190	5 May	0600	New Brighton Beach	6
191	7 May	1515	New Brighton Beach	6
192	9 May	1938	New Brighton Beach	3
193	11 May	1900	New Brighton Beach	8
194	14 May	1250	New Brighton Beach	9
195	22 May	1250	New Brighton Beach	8
196	23 May	0825	New Brighton Beach	10
197	29 May	0905	New Brighton Beach	12
198	29 May	1030	New Brighton Beach	6
199	30 May	1045	New Brighton Beach	7
200	30 May	1130	New Brighton Beach	8
201	1 Jun	1300	New Brighton Beach	4
202	2 Jun	1850	New Brighton Beach	9
203	3 Jun	1530	New Brighton Beach	8
204	5 Jun	1850	New Brighton Beach	4
205	10 Jun	1250	New Brighton Beach	15
206	10 Jun	1315	New Brighton Beach	10
207	11 Jun	1350	New Brighton Beach	12
208	11 Jun	1430	New Brighton Beach	15
209	11 Jun	1610	New Brighton Beach	10
210	11 Jun	1700	New Brighton Beach	7
211	16 Jun	0805	New Brighton Beach	8
212	16 Jun	1200	New Brighton Beach	13
213	17 Jun	1310	New Brighton Beach	8
214	23 Jun	1345	New Brighton Beach	10
215	27 Jun	0928	New Brighton Beach	14
216	28 Jun	1115	New Brighton Beach	5

#	Date	Time	Location	# Dolphins
1993				
217	13 Jul	1815	New Brighton Beach	9
218	14 Jul	0642	New Brighton Beach	6
219	15 Jul	0915	New Brighton Beach	6
220	15 Jul	1215	New Brighton Beach	8
221	16 Jul	0715	New Brighton Beach	12
222	17 Jul	0820	New Brighton Beach	9
223	17 Jul	1235	New Brighton Beach	7
224	24 Jul	1000	New Brighton Beach	7
225	6 Sep	1107	Rio del Mar	20
226	10 Sep	1220	Rio del Mar	5
227	13 Sep	0850	Rio del Mar	3
228	14 Sep	1545	Rio del Mar	7
229	19 Sep	1130	Rio del Mar	9
230	19 Sep	1300	Rio del Mar	-
231	20 Sep	1200	Rio del Mar	4
232	21 Sep	1130	Rio del Mar	5
233	22 Sep	0930	Rio del Mar	9
234	22 Sep	1212	Rio del Mar	8
235	23 Sep	1200	Rio del Mar	5
236	24 Sep	0640	Rio del Mar	20
237	24 Sep	1412	Rio del Mar	8
238	24 Sep	1416	Rio del Mar	-
239	25 Sep	0915	Rio del Mar	15
240	27 Sep	0645	Rio del Mar	8
241	27 Sep	1845	Rio del Mar	8
242	28 Sep	1830	Rio del Mar	8
243	1 Oct	0653	Rio del Mar	16
244	2 Oct	1235	Rio del Mar	9
245	5 Oct	0745	Rio del Mar	4
246	5 Oct	0900	Rio del Mar	4
247	5 Oct	1034	Rio del Mar	5
248	7 Oct	0805	Rio del Mar	7
249	7 Oct	1022	Rio del Mar	-
250	14 Oct	1738	Rio del Mar	9
251	14 Oct	1820	Rio del Mar	20
252	18 Oct	1840	Rio del Mar	9
253	20 Oct	1411	Rio del Mar	12
254	22 Oct	1423	Rio del Mar	4
255	27 Oct	1135	Rio del Mar	12
256	1 Nov	0650	Rio del Mar	10
257	2 Nov	0710	Rio del Mar	9
258	2 Nov	0722	Rio del Mar	7
259	2 Nov	0727	Rio del Mar	7
260	2 Nov	0650	Rio del Mar	6

Appendix C - Sightings of bottlenose dolphins in the San Francisco Bay area between 1988 and 1993 (Szczepaniack unpubl. data).

#	Date	Time	Location	Lat/Long	# Dolphins
1988					
1	Dec 2	-	Rockaway Beach	-	11
2	Dec 3	-	San Pedro Bay	37° 35' N 122° 30' W	11
1989					
3	Nov 10	-	San Pedro Bay	37° 35' N 122° 30' W	8
4	Dec 16	-	Pidgeon Point	37° 10' N 122° 25' W	20
5	Dec 18	-	Pomponio Beach	37° 25' N 122° 25' W	25
1990					
6	Jan 5	-	San Pedro Bay	37° 35' N 122° 30' W	7
7	Jan 20	-	San Gregorio Beach	-	20
8	Jan 20	-	San Pedro Bay	37° 35' N 122° 30' W	8
9	Jan 21	-	San Pedro Bay	37° 35' N 122° 30' W	6
10	Mar 29	-	San Pedro Bay	37° 35' N 122° 30' W	6
11	Apr 9	-	Sharp Park Beach	37° 40' N 122° 30' W	6
12	Apr	-	San Pedro Bay	37° 35' N 122° 30' W	-
13	Jun 14	-	Mussel Rock	37° 45' N 122° 32' W	15
1992					
14	Feb	-	San Pedro Bay	37° 35' N 122° 30' W	-
15	Mar 5	-	San Pedro Bay	37° 35' N 122° 30' W	6
1993					
16	Jan 12	-	San Pedro Bay	37° 35' N 122° 30' W	6
17	Jan 13	-	San Pedro Bay	37° 35' N 122° 30' W	6
18	Feb 2		Montara	37° 32' N 122° 30' W	4
19	Mar 15	-	San Pedro Bay	37° 35' N 122° 30' W	-
20	Mar 20	-	San Pedro Bay	37° 35' N 122° 30' W	5
21	Mar 21	-	San Pedro Bay	37° 35' N 122° 30' W	12
22	May 16	-	Half Moon Bay	37° 30' N 122° 30' W	18+
23	May 17	-	Sharp Park Beach	37° 40' N 122° 30' W	-
24	May 18	-	San Pedro Bay	37° 35' N 122° 30' W	30-50
25	May 19	-	Sharp Park Beach	37° 40' N 122° 30' W	18-20