

OCCURRENCE AND BEHAVIOR OF HARBOR PORPOISES

(Phocoena phocoena)

AT PAJARO DUNES, MONTEREY BAY, CALIFORNIA

A Thesis

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Keiko Sekiguchi

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ABSTRACT

From September 1984 to November 1985, I observed harbor porpoises (Phocoena phocoena) from a high vantage point at Pajaro Dunes, Monterey Bay, California, for 759.8 hours on 150 days. I sighted porpoises 4942 times, in 1594 groups, and on 116 days. More porpoises were sighted in summer and early fall (July, August and September) than at other times of year. Group sizes were also generally larger in summer and early fall. Porpoises came into the study area, to within 300 m of the shore, mainly in the morning, and spent most of their time apparently feeding nearshore. Tide was also correlated with the occurrence of harbor porpoises, with significantly more porpoises present nearshore during flood tide than ebb tide. Active feeding was associated with a variety of other behavioral patterns: spyhopping, staying at the surface, jumping, and diving with flukes out. Play behavior, consisting of surfing and "swimming in waves", occurred rarely. Apparently the study area was mainly used as a feeding habitat for harbor porpoises, and I hypothesize that abundance and group size variations were related to food availability. Stomach analyses of fifteen porpoises collected in the Monterey Bay area showed that northern anchovy had the highest Index of Relative Importance, spotted cusk eel was second, and Sebastes was

third. However, these prey items did not have the highest percentage of frequency of occurrence, and it may therefore be assumed that harbor porpoises change their diets seasonally in Monterey Bay.

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TABLE OF CONTENTS

| | page |
|--|------|
| ABSTRACT | iii |
| ACKNOWLEDGEMENTS | v |
| TABLE OF CONTENTS | vii |
| LIST OF FIGURES | ix |
| LIST OF TABLES | x |
| LIST OF APENDICES | xi |
| INTRODUCTION | 1 |
| METHODS | 5 |
| 1) Occurrence Patterns and Behavioral Observation | 5 |
| 2) Food Analyses | 8 |
| RESULTS | 9 |
| 1) Behavior Patterns | 9 |
| 2) Seasonal Changes | 13 |
| 3) Diurnal Changes | 14 |
| 4) Tidal Effects | 15 |
| 5) Respiratory Patterns | 16 |
| 6) Stomach Analyses | 16 |
| DISCUSSION | 17 |
| CONCLUSIONS | 27 |
| REFERENCES | 29 |
| FIGURES | 34 |

| | page |
|------------------|------|
| TABLES | 42 |
| APPENDICES | 46 |

LIST OF FIGURES

| | page |
|---|------|
| 1. The study area at Pajaro Dunes in Monterey Bay California, showing the shore-based observation station | 34 |
| 2. Jumping patterns of harbor porpoises with observation date. | |
| a. All of these jumps cleared the water surface | 35 |
| b. With tail remaining in the water | 36 |
| 3. Sighting success rate in each month | 37 |
| 4. Group sizes of harbor porpoises in each month | 38 |
| 5. Mean number of individual harbor porpoises observed per hour | 39 |
| 6. Estimated distances of groups of harbor porpoises from the shore, averaged per two hour period | 40 |
| 7. Ratio of three major behavioral patterns per two hour period | 41 |

LIST OF TABLES

| | page |
|---|------|
| 1. Summary of shore-based observations of harbor porpoises at Pajaro Dunes in Monterey Bay, California. | |
| a. from September to November 1984 | 42 |
| b. from January to November 1985 | 43 |
| 2. Coincidence of tidal state with occurrence and behavior of harbor porpoises | 44 |
| 3. A list of prey items of harbor porpoises ranked according to their value on the Index of Relative Importance | 45 |

LIST OF APPENDICES

| | page |
|---|------|
| A. Records of harbor porpoises used for stomach analyses | 46 |
| B. Stomach contents of examined harbor porpoises | 47 |
| C. Results of stomach analyses of harbor porpoises | 48 |
| D. A list of prey items of harbor porpoises in different seasons | 49 |



INTRODUCTION

The harbor porpoise (Phocoena phocoena) is one of the smallest odontocetes. It is distributed in cold temperate and subarctic waters of the northern hemisphere (Leatherwood and Reeves 1983), and is commonly found in bays, estuaries, and tidal channels of the Atlantic coast of Europe, both coasts of North America, and the Pacific coast of Asia (Gaskin et al. 1974).

Although the harbor porpoise is a coastal species, it can travel relatively long distances seasonally and diurnally. In the Bay of Fundy, harbor porpoises are abundant from July to September, but they move out of the bay in winter (Neave and Wright 1968, Gaskin et al. 1974). Similar seasonal movement has been reported in the Baltic Sea (Tomilin 1967), Greenland (Kapel 1977), Alaska (Taylor and Dawson 1984), and along coasts of the St. Lawrence estuary (Laurin 1976). In the Bay of Fundy, the direction of movement of porpoises coincides with the direction of tidal flow (Read and Gaskin 1985), and porpoises move inshore with the flood tide (Gaskin et al. 1975, Watson 1976, Gaskin and Watson 1985).

Gaskin (1977) mentioned that seasonal and daily movements of harbor porpoises are probably related to the movement of their prey items. Because harbor porpoises have a metabolism which is three times as high as that of a

terrestrial animal with comparable body weight (Gaskin et al. 1974), a ready supply of food must be very important for their survival. Main food items of harbor porpoises are herring (Clupea harengus), cod (Gadus morhua), and mackerel (Scomber scombrus) in the Bay of Fundy (Smith and Gaskin 1974); benthic fishes in the Black Sea and Sea of Azov (Tomilin 1967); herring, whiting (Gadus merlangus) and squid in Scottish waters (Rae 1965); sardines (Sardinops caerulea) in the North Pacific (Gaskin et al. 1974); and juvenile rockfish, northern anchovy (Engraulis mordax), and squid in north-central California (Jones 1981). Morejohn et al. (1978) reported that the most frequently consumed prey species of harbor porpoises in Monterey Bay was the market squid (Loligo opalescens), the second was juvenile rockfish, and the third were nearly equal ranks of Pacific hake (Merluccius productus) and northern anchovy.

The average group size of harbor porpoises has been reported to be small, with usually only two or three porpoises observed together. However, there are several studies which showed seasonal changes in group size in some areas. Harbor porpoises tend to be in larger groups in June and July in the Bay of Fundy (Neave and Wright 1968, Gaskin et al. 1974). On the contrary, Taylor and Dawson (1984) reported smaller group sizes in summer than in winter in Alaska.

Harbor porpoises often appear less playful than other

toothed cetaceans, and their normal surface action is a smooth rolling (Amundin and Amundin 1974). They are wary of boats and rarely ride bow waves (Tomilin 1967, Amundin and Amundin 1974, Gaskin et al. 1974, Prescott and Fiorelli 1980, Dohl et al. 1983). Jumping is infrequently observed during feeding (Watson 1976, Gaskin 1977), during group interactions (Amundin and Amundin 1974), during aggression in a group (Andersen and Dziedzic 1964), during courtship (Watson 1976), and when a motor boat is approaching (Amundin and Amundin 1974). Splashes associated with rapid swimming are also sometimes observed (Amundin and Amundin 1974, Taylor and Dawson 1984). Motionless behavior at the surface with flat posture has been reported by many researchers. This behavior was called resting (Amundin and Amundin 1974, Andersen and Dziedzic 1964, Gaskin et al. 1974), or searching for food or group members by using echolocation (Watson and Gaskin 1983). The period at the surface is usually 4-10 seconds, and at times up to 90 seconds (Andersen and Dziedzic 1964, Amundin and Amundin 1974, Gaskin 1977).

The dive times of harbor porpoises have been recorded as up to 6 min. long (Gaskin et al. 1974). In captivity, the shortest respiratory interval was 6.5 seconds, the longest 31.7 seconds, and the average 13.1 seconds (Parker 1932). Watson and Gaskin (1983) reported two basic ventilation patterns which might represent distinct

behavioral patterns. While traveling, porpoises submerged for shorter times (24.4 sec.) than while feeding (1.44 min.).

Dohl et al. (1980) estimated that about 600 harbor porpoises resided off southern to central California, and some of these occur in Monterey Bay (summary by Barlow 1984). They have been sighted regularly nearshore off Pajaro Dunes (Fig. 1). Therefore, Pajaro Dunes was chosen as my shore-based observation station. This study area has a sandy bottom, and, at a depth of 15 m off the Pajaro River (~1.8 km offshore), night smelt (Spirinchus starksi), white croaker (Genyonemus lineatus), spotfin surfperch (Hyperprosopon anale), Pacific sanddab (Citharichthys sordidus) and speckled sanddab (Citharichthys stigmaeus) are very abundant (Kukowski 1972).

The present study began with the premise that harbor porpoises might be feeding in the study area during morning hours. This hypothesis had been mentioned informally by several local observers (Donald Croll, Physiological Research Laboratory in Scripps Institution of Oceanography, La Jolla, CA; Thomas Keating, Moss Landing Marine Laboratories, pers. comm. 1984). I investigated occurrence and behavioral patterns in order to obtain data relevant to this hypothesis.

METHODS

1) Occurrence Patterns and Behavioral Observations:

Shore-based observations at Pajaro Dunes in Monterey Bay, California (Fig. 1) started in September, 1984, with most of the work done from February to November, 1985. A total of 38.5 hours of observations on 14 days were made from September to November, 1984 (Table 1-a); 721.3 hours of observations on 136 days were made from January to November, 1985 (Table 1-b). Observations were with Nikon 8 x 30 binoculars on a tripod, from the highest point of the dunes, about 10 m above the sea surface. The study area was approximately 2 km long and 0.5 km wide. Observation times were from about 0700 to about 1800 Pacific Standard Time, weather and logistics permitting. The morning hour observation (before 1200) was 64.8% of the entire observations.

I recorded time observed, weather (percentage of cloud cover, rain or fog), oceanic condition (visibility, Beaufort scale and wave height), group size, estimated distance from the shore line, direction of movement which was relative to the shore line, behavior, and dive time. Most observations were done under "good conditions" (i.e. no fog or rain, Beaufort scale less than 3, and smaller swell). Beaufort wind force was 4 or 5 in only 7.0% of total observation hours, and 1.1% of observations of

porpoises were made under those conditions (see discussion). However, as a general observation procedure, observations were stopped under the "poor condition" (fog or rain, Beaufort wind force over 5, and/or higher wave heights). The number of calves in a group was counted. The size of calf is approximately 1/2 to 2/3 of body length of an adult porpoise (Prescott and Fiorelli 1980), and easy to recognize. Potential human disturbances, which may have changed harbor porpoise occurrence and behavior, were also recorded. Dive times were recorded only when I could follow one animal.

Tide heights were estimated from a local tide table. The tidal conditions were categorized into flood tide, which is from high tide to low tide, and ebb tide, which is from low tide to high tide.

During observational times, I watched the study area without binoculars, interspersed with surveys using binoculars at about 10 minute intervals. When I first found harbor porpoises with naked eyes, I immediately used binoculars in order to ascertain group size, behavior, direction of movement, etc. A group was followed with binoculars as long as possible, or until I found other groups in the area. Once I lost that group, I went back to the regular survey method. When I found more than one group at once, or at one survey through the area, I observed each group just long enough to determine position, group size,

behavior, and direction of movement, and then I went back to the regular survey.

Harbor porpoises sighted together within 5 m and with the same general heading and the same behavior were initially labelled as a group. However, porpoises were in more flexible groups in summer. They sometimes formed large "loose" feeding groups; such groups did not really fit the initial definition of a group, and I had to make exceptions to this definition. A group sighted at the same spot by regular 10 min interval surveys was defined as the same group if porpoises showed the same behavioral pattern and contained the same number of individuals.

Most of the behaviors observed were categorized into three major patterns: (1)Traveling: straight line swimming with smooth rolling; (2)Probable Feeding: milling, including zigzag and circle swimming, especially with porpoises surfacing repeatedly at the same place (Gaskin et al. 1975, Watson and Gaskin 1983). Although a group of porpoises presented constant progressive movement in one direction during traveling, they came to the surface with random headings in or near the same spot during probable feeding. Dive times of probable feeding were also different from those of traveling and playing. Most porpoises in the category of probable feeding were also associated with traveling. Thus, such group behaviors were recorded as both traveling and probable feeding; (3)Playing: surfing,

chasing and "swimming in waves" were included in this behavior.

The sighting success rates were used to examine the seasonal changes of porpoise occurrence in the study area. It was calculated by the number of days porpoises were sighted per total number of observation days.

Standard statistical methods presented by Zar (1984) were used for data analyses. Each procedure is given in results.

2) Food Analyses:

The stomachs of fifteen harbor porpoises, collected in the Monterey Bay area during 1984 - 1986 (Appendix A), were used for diet analyses. Stomachs were kept in a laboratory freezer before analyses. For analysis, the thawed stomach was opened, and the entire volume of stomach content was measured. Next, undigested contents and entire vertebral columns of fishes were removed to count their number and to measure their lengths. Some "good condition" remains were kept in 10% formalin solution for later identification. Then, the rest of the contents were washed through a series of brass sieves (1.0 and 0.5 mm mesh) to get remaining otoliths and cephalopod beaks. All otoliths and beaks were collected, preserved in 70% ethanol, dried, and sent to Mr. Mark Lowry, Southwest Fisheries Center, La Jolla, California, for prey item identification.

The results of beak and otolith identification were evaluated using numerical percentage (%N), percent frequency of occurrence (%FO) and the Index of Relative Importance (IRI), modified from Pinkas, Oliphant and Iverson (1971), because I could not measure the volume of each prey item. Thus, the following equations were used for these calculations:

$$\%N = \frac{\sum nij}{\sum Ni}$$

nij : minimum number of each prey item (j) per stomach (i)

Ni : total of minimum number of prey items per stomach (i)

$$\%FO = \frac{\text{number of stomachs with each prey item}}{\text{total number of stomachs with prey item}}$$

$$IRI = \%N \times \%FO$$

RESULTS

1) Behavior Patterns:

Three main behavioral patterns (traveling, probable feeding and playing), and some occasional other behaviors were observed. The three major behaviors were accomplished by an entire group. On the other hand, occasional behaviors were performed by certain group members; those behaviors were spyhopping, staying at the surface, jumping, and a

fluke-up posture.

A total of 1719 occasions of major behavioral patterns were observed. Probable feeding was the main behavioral pattern, totalling 50.6% of all observed patterns, traveling was second, at 47.9%, and playing occurred least often, at 1.5%.

Most of the time, traveling was accompanied by probable feeding. Few groups swam into and out of the study area without probable feeding. Typically, observed groups traveled into the area, stopped at one spot apparently to feed for several minutes, and again started to travel to the next feeding spot. Probable feeding periods lasted from several seconds up to about 3.8 hours, which was observed on September 30, 1985.

Especially from summer to early fall (June - October), harbor porpoises in large "loose" feeding groups apparently tended to feed for longer times at a certain spot, and sometimes for over one hour. Many splashes were observed in such a feeding group. As compared with ordinary groups, the "loose" groups were widely spread, and porpoises moved around in the area so that it was sometimes hard to define group boundary and size.

Possible cooperative feeding behavior was observed on October 23, 1984 and on April 16, 1985. A large feeding group of about 10 porpoises formed a circle approximately 100 m in diameter, and all dove many times at the same

portion of the edge of the circle, always keeping the circle formation. The circle lasted for 20 minutes on October 23, 1984 and for 16 minutes on April 16, 1985.

Although other marine mammals (California sea lions, Zalophus californianus; harbor seals, Phoca vitulina; sea otters, Enhydra lutris) and marine birds were often sighted in the study area, only limited number of incidents of feeding association with other marine animals was observed. On June 4, 1985, one minke whale (Balaenoptera acutorostrata) came into the study area at 1100 and apparently fed for 15 minutes. Approximately 10 harbor porpoises exhibited probable feeding within 100 m of this whale during that time. On 12 occasions, I observed a group of terns following traveling harbor porpoises or diving with probably feeding harbor porpoises. No other species of marine mammals or birds were observed to be associated with porpoises.

Playing occurred on rare occasions in the study area, with only 26 incidents recorded. Some groups traveled into the surf zone, and surfed on the breaking waves (surfing), or swam through the breaking waves ("swimming in waves"), usually swimming parallel to each other, less than about 1 m apart from each other.

Only one or two harbor porpoises in a group were involved in spyhopping, in which an animal lifted half of its body from the water vertically and without a splash. A

total of 24 spyhops were observed (Table 1-a and 1-b), and most spyhops (79.2%) occurred during feeding.

Harbor porpoises at times stayed motionless at the surface with a flat posture for a period of 3 to 20 seconds. Usually only one animal per group showed this behavior, but on four occasions more than one porpoise was involved. On November 12, 1985, this behavior occurred three times in the same group between 1105 - 1112. It was unknown whether those three incidents involved the same animal. On July 19, 1985, two porpoises lay at the surface at the same time. Calves exhibited the behavior four times. It occurred mainly during probable feeding (84.2% in total occurrence, n = 38, Table 1-a and 1-b), but was observed several times (13.2%) during traveling as well.

Much variety in jumping patterns was observed (Fig. 2-a and 2-b). During most jumps, harbor porpoises kept their flukes in the water, but some complete leaps out of the water were also observed. Single jumps occurred during probable feeding (69.0% in total occurrence, n = 84). Sequential jumps (type (m), mostly) were observed in twelve groups, and 66.7% of these jumps occurred during traveling. On July 24, 1985, a large group with 20 porpoises traveled about 150 m toward the shore while jumping.

Harbor porpoises lifted their flukes vertically out of the water on eleven occasions in active groups during July, August and September (Table 1-a and 1-b). A total of 54.5%

of fluke-up behavior occurred in active groups, which were probably feeding. No splash was observed at fluke-up.

2) Seasonal Changes:

The sighting success rates showed seasonal differences in the study area (Fig. 3, and Kruskal-Wallis test on original data, for four seasons of January, February, March; April, May, June; July, August, September; October, November, December; $H = 9.510$, $P = 0.02$). July, August and September had the highest sighting success (100%), which means that harbor porpoises were observed every day on which observations were made, and the sighting success rates of those months were significantly different from the rest of months (multiple comparisons). Months with lower sighting success were January (0%), March (43.8%), April (61.5%) and May (42.9%), 1985. During the remaining months, sighting success rate was about 80%.

Mean group size overall was 3.1 porpoises per group (S.D. = ± 2.25 , mode = 2, $n = 1594$ observed groups); however, mean group size changed seasonally (Fig. 4, and One Way ANOVA, $F = 14.171$, $P < 0.001$). It was significantly higher in October (3.6 porpoises per group), 1984; and in July (3.6), August (3.4) and September (4.0), 1985 (SNK multiple comparisons). The observed maximum group size was also larger in those months (25 in July, 15 in August, 22 in September; Table 1). The lowest mean group size occurred

in May (1.7), 1985; and March and April, 1985, also showed low mean group sizes (2.0).

Harbor porpoises sometimes occurred in large "loose" probable feeding groups. Such group formations were observed especially in summer and early fall. For example, the maximum group size observed on July 28, 1985, consisted of 25 porpoises which were in one probable feeding group. This group appeared to be made up of several smaller groups, small groups joined the main group on several occasions, and finally the large group divided into smaller groups, and then all disappeared. Such large assemblages were defined as "a group" as long as porpoises were in a certain spot with the same behavioral pattern (probable feeding). In most of these cases, large groups continued probable feeding behavior in the same spot for more than 15 minutes.

The numbers of calves sighted differed seasonally (Table 1-a and 1-b). None or a few calves were observed from January to May, 1985; however, sighting number increased to 54 in June, 1985. Numbers stayed high July through September (61, 96, 55), and decreased in October (18) and November (5).

3) Diurnal Changes:

More harbor porpoises were observed during morning than at other times (Fig. 5, and One Way ANOVA, $F = 9.263$, $P <$

0.001). The number was significantly higher at 0700 - 1000 (SNK multiple comparisons, and more than 10 porpoises sighted per hour), decreased toward afternoon, and the lowest sighting was at 1500 - 1600 (0.3 porpoises per hour).

The estimated distance of harbor porpoises from the shore line did not show a strong diurnal change (Fig. 6), but the slight differences were nevertheless significant (Chi-square, $X^2 = 30.005$, $0.01 < P < 0.025$). Porpoises were distributed evenly in the study area in early morning (0700 - 0900), moved farther from shore in the middle of the day (1100 - 1300), and moved closer to shore more often, within 150 m distance, during the late afternoon. No porpoises were observed at greater distances during this late period, although I had good visibility over the area even under afternoon sun glare.

The occurrences of the three major behavioral patterns also changed with time of day (Chi-square, $X^2 = 62.551$, $P < 0.001$). More instances of probable feeding were observed during morning than during afternoon (Fig. 7). Traveling increased to more than 50% in the afternoon, while playing occupied small amounts of time throughout the day.

4) Tidal Effects:

Tidal state also affected abundance of harbor porpoises (Table 2). Porpoises were more frequently observed during

flood tide than ebb tide (Chi-square, $X^2 = 334.071$, $P < 0.001$). In both morning and afternoon, significantly more porpoises were observed during flood tide than ebb tide (Chi-square; for morning, $X^2 = 212.355$, $P < 0.001$; for afternoon $X^2 = 32.898$, $P < 0.001$). However, throughout both tidal periods, occurrence of probable feeding behavior was significantly higher in the morning than in the afternoon (Chi-square; during ebb tide, $X^2 = 25.294$, $P < 0.001$; during flood tide, $X^2 = 393.192$, $P < 0.001$).

5) Respiratory Patterns:

Dive times were recorded for a total of 115 min 25 sec and for a total of 438 submergences. Average dive time was 21.8 sec (SE = ± 2.22 sec, number of submergences, $n = 119$) during traveling, and 16.5 sec (SE = ± 1.43 sec, $n = 80$) during playing. Dive time was the shortest during probable feeding, and was 12.6 sec (SE = ± 0.75 sec, $n = 239$). Dive times were significantly different among all these three major behavioral categories (Kruskal-Wallis test, $H = 14.982$, $P < 0.001$). However, there was no significant difference in length of dives between traveling and playing (Multiple comparison).

6) Stomach Analyses:

A total of nine out of fifteen stomachs contained identifiable prey items (Appendix B). I found 19

whole-length fishes (mean = 12.87 cm, S.D. = \pm 5.14 cm, range = 9.5 - 33.0 cm), and 10 whole length squid (mean = 12.50 cm, S.D. = \pm 2.98 cm, range = 7.5 - 17.0 cm). Some sand was found in five stomachs. A total of 44 cephalopod beaks and 1693 otoliths were collected.

Two families of cephalopods and ten families of fishes were found in the 9 harbor porpoise stomachs (Table 3). The total minimum number of cephalopods was 24, and of fishes was 876. Spotted cusk eels had the highest %N (41.33%), and market squid had the highest %FO (66.67%). However, northern anchovy had the highest IRI (920.07) of all prey items.

Unfortunately, sample size was too small to show a statistically significant seasonal trend. However, some possible seasonal tendencies were evident in prey items (Appendices C and D). Northern anchovy were rare or non-existent in stomachs collected in winter and spring, but were found in large numbers in summer and early fall. On the other hand, spotted cusk eels and Sebastes spp. were more abundant prey taken in winter and spring, but not in summer and early fall.

DISCUSSION

There were several conditions which could have affected

the results of the present shore-based observations. The most likely problems would be sea state, sun glare and observer fatigue.

Beaufort wind force was 4 and 5 for 12.6 hr. in winter (January, February, March), for 29.5 hr. in spring (April, May, June), for 6.2 hr. in summer (July, August, September), and for 4.3 hr. in fall (October, November). Beaufort wind force was 4 and 5 for 5.8 hr. in the morning, and 46.8 hr. in the afternoon. However, those higher Beaufort scale conditions were only 7.0% during all observations, and some porpoises were nevertheless observed during those conditions (38 individuals in 15 groups). Therefore, I am assuming that influence of sea state was relatively small, and seasonal and diurnal differences were large enough to be significant.

It is possible that some porpoises were not seen in the afternoon due to sun glare out of the west. However, sun glare was not too strong to hide porpoises until very late in the afternoon, and most of the study area had good visibility throughout the afternoon. Furthermore, during late fall and winter, most observations were terminated before 1600, and on only three days (February 18, November 1 and 12, 1985), were observations continued until 1700. Thus, I do not believe that this potential source of observer error due to sun glare resulted in the great difference in sightings between morning and afternoon. I

also believe that observer fatigue did not have an appreciable effect on the results, but I did not measure this factor in any way.

Distance from the shore line was estimated by eye. However, all observations were made by a single observer (myself) from the same spot, and I believe that errors in estimates were constant.

It is likely that this study area was used primarily as a feeding habitat for harbor porpoises in Monterey Bay. Probable feeding was the most frequently observed behavioral pattern (50.6% of total observed behavioral patterns). The shorter dive time of probable feeding represented a difference from that of Watson and Gaskin (1983), who noted a longer submergence time for feeding. However, the depth of my study area was shallower (less than about 10 m) than theirs (20-60 m), and this might have caused different dive times. Because porpoises came up at the same spot repeatedly during probable feeding, shorter dive times reinforced my suspicion that porpoises were indeed doing something different, such as successful feeding in that spot. Tidal influence also suggests the feeding habitat. Watson (1976) mentioned that harbor porpoises moved to shallow water with flood tide, following the movements of their prey species. The results of the present study also showed that more porpoises came into the area during flood tide. However, there is little evidence

to suggest that more prey organisms (i.e. squids and fishes) move inshore at flood tide in the study area.

A seasonal change of abundance of harbor porpoises in the study area was evident in the sighting success rate. Porpoises came to the area more often in July, August and September. This result is similar to that found for porpoises in the Bay of Fundy (Neave and Wright 1968, Gaskin 1977), where porpoises were mainly offshore during early fall to early spring. The Monterey Bay population may have a similar migration pattern, and most porpoises may be offshore from late fall to spring. This assumption does not entirely agree with results of aerial surveys in Monterey Bay by Dohl et al. (1983), who found a generally higher density nearshore in fall to winter, and offshore in spring and summer. However, recent studies at the Farallon Islands showed offshore movement in winter, with porpoises concentrated at depths between about 35 m to 80 m in winter, but during the rest of the year they are closer to shore, between shore to 45 m depth (Leatherwood and Reeves 1986).

Besides onshore and offshore migration, another possible seasonal migration pattern has been reported. Dohl et al. (1983) suggested a seasonal north-south migration along the coast in central and northern California. They observed porpoises primarily in the northern area (from Point St. George (41°47'N, 124°15'W) to Monterey Bay)

during winter; however, there was an almost equal distribution of porpoises along the coast in summer and fall. A similar north-south movement was reported on the British coast (Easton et al. 1982). Along the western coast of the Atlantic, north-south migration may be occurring as well as onshore and offshore seasonal migration (Gaskin et al. 1985).

However, in my study area, porpoises were never completely absent, even during the period with the lowest sighting success rate (March, April and May). Some porpoises were also observed approximately 5-10 km north of the study area from February through May (James Anderson and Michael Newcomer, Moss Landing Marine Laboratories, pers. comm. 1985). It is therefore likely that the entire population is not moving out of Monterey Bay at any time of year. Some residents may stay in the bay year round, as Gaskin (1984) reported, and may spread out in the bay from late fall to spring. Szczepaniak and Webber (1985) also reported the existence of porpoises year-round in the Gulf of the Farallones.

Seasonal changes of group size (Fig. 4) showed similar patterns as the seasonal changes of sighting success. Group sizes were larger although highly variable when sighting success rate was higher, in July, August and September, and smaller when sighting success rate was lower, in March, April and May. I do not know from where porpoises came when

they occurred more frequently in the study area in summer to early fall.

The larger "loose" probable feeding groups were also observed in summer and early fall. Szczepaniak and Webber (1985) also mentioned large aggregations with 20 - 35 porpoises per group during late summer and fall in central California. Although Read (1983) observed two large feeding aggregations (12 and 18 porpoises per group) in August, and increasing group size from July to September in the Bay of Fundy, he concluded that this seasonal change in group size might be related to changes in social and reproductive behavior. However, in my study area, larger groups appeared to be feeding, and no obvious social or reproductive behavior was noticed.

Because probable feeding was the primary use made of this study area by harbor porpoises, seasonal changes of abundance and group size likely relate to their foraging strategies and perhaps to seasonal availability of prey items. Prey items may be abundant or occur in larger schools in the study area in summer to early fall. In the same area, Kukowski (1972) found the highest number of species and abundance of fishes in August and September. A study off the Salinas River mouth (Engineering-Science, Incorporated. 1980) also showed a greater abundance of fishes in summer and fall months, when porpoises were most frequently observed in larger groups in the study area. It

is therefore likely that the seasonal change in group size is related to food.

Wells et al. (1980) suggested that dolphins in smaller groups forage on an evenly-distributed food source nearshore, such as bottom fish or reef fish, and that dolphins in larger groups feed on schooling fishes or squid. Harbor porpoises probably feed on different prey items according to the seasonal abundance of their prey. Northern anchovies are reported to form larger schools in summer and fall (Frey 1971). Because such larger schooling fishes may be more abundant in summer to early fall in this region, porpoises may forage on those fishes in larger groups. More porpoises may come into the area because they are attracted by abundant prey in summer and early fall, and larger group sizes may also play a part in coordinated foraging activities of the porpoises. Porpoises may have occurred in smaller groups in winter to spring because "a smaller group size during individual foraging may allow each animal a better chance at catching at least one of a limited number of large rock-dwelling prey in a particular area" (Würsig 1986). If the primary prey items in winter and spring are non-schooling and bottom-dwelling fishes (spotted cusk eel and plainfin midshipman), it may not be necessary for porpoises to aggregate in larger groups since group coordinated hunting is not likely to occur on non-schooling prey.

The observed diurnal change of harbor porpoise sightings may also have been related to a diurnal change in abundance or distribution of prey items. Some prey may approach the shore mainly in the morning, and nocturnal prey, such as spotted cusk eel, plainfin midshipman, and shiner surfperch, may still be in the upper water column in early morning. As a result, porpoises may have spent more time feeding in that period (Fig. 7), and this may also explain why they were closer to shore in the early morning (Fig. 6). Fewer porpoises were observed in the afternoon, and these generally traveled through the area. It is still unknown where most harbor porpoises go in the afternoon. Porpoises may spread out in the bay or move to a more offshore area in afternoon.

The sudden increase in sightings of calves in June may indicate the calving season of harbor porpoises in Monterey Bay. Stuart-Simons (1984) assumed that the breeding season off California was in spring, especially during May and June. Because food is abundant during summer and early fall in the study area, cows may preferentially use this area to nurse. Smith and Gaskin (1983) indicated that cows preferred warm and stable waters with high secondary productivity for their nursing grounds.

Harbor porpoises have an 11 month gestation period (Gaskin et al. 1974). If their breeding season is in May and June, the mating season should be around June and July.

No copulating behavior was noticed in the study area. Gaskin and Blair (1977) mentioned that copulation was rarely observed in coastal waters, and suggested that much of the seasonal sexual activity might occur outside of the immediate coastal zone. However, play behavior was observed often in July on 36.5% of 26 observations, and play behavior may be related to social and reproductive behavior.

A variety of behavioral patterns was observed in harbor porpoises, not unlike many species of dolphins. This small porpoise, often labelled "shy" and without surface displays (Prescott and Fiorelli 1980), may not be as inactive as generally believed. Porpoises splash, jump, surf, swim in the surf, spyhop, and fluke-up. Read (1983) also reported that porpoises feeding near the surface often swam rapidly and lunged when surfacing, and these activities were different from the normal smooth rolling. In my study, surfing and "swimming in waves" were observed during playing; and spyhopping, staying at the surface, jumping and fluke-up were mainly recorded during probable feeding. Watson and Gaskin (1983) suggested that staying at the surface may be related to searching for food while echolocating. The higher rate of observation of this behavior during probable feeding (84.2%) may support their hypothesis.

The relative importance of prey items found in the

present study was somewhat different from that found in studies by Morejohn et al. (1978) and Jones (1981). In my study, northern anchovy, spotted cusk eel and Sebastes had much higher IRI's than other species. However, those prey items did not show higher %FO. Therefore, those items probably represent seasonally important prey or are based on lower numbers which are not representative. Harbor porpoises are likely to be opportunistic feeders (Rae 1965 and 1973). They may feed on cusk eels and rockfishes during winter and spring, because those fishes are abundant year round. However, they may consume anchovies (large schooling fish) during summer and fall.

Although some flatfishes are abundant in this area (Kukowski 1972, Environmental Research Consultants 1976, ECOMAR 1981), there were no flatfishes found in stomach contents. However, other bottom-dwelling fishes, such as cusk eels and plainfin midshipman, were found in large numbers. This may be related to the echolocation capability of harbor porpoises; because midshipman have large swim bladders, like those of anchovy, it may be easier for harbor porpoises to find even those fishes which are in the sediment during the day (Crane 1986, Greenfield 1968). The nighttime foraging of porpoises could also account for these nocturnal prey items. Another possibility for the large catch of midshipman is that harbor porpoises might be taking "trash fish" discarded by fishing boats (Brian Sak,

Moss Landing Marine Laboratories, pers. comm. 1986).

Further studies will be required in order to ascertain seasonal and diurnal movements of harbor porpoises over the entire range of Monterey Bay. Photographic identification of individuals and radio-tagging will be especially useful in determining how often and how many porpoises come into the present study area. More analyses of stomach contents are necessary to describe seasonal changes of prey items. Sampling of prey items in the area may also give us an idea about the diurnal changes in abundance of prey species in the area.

CONCLUSIONS

Evidence suggests that the Pajaro Dunes study area was primarily used as a feeding habitat for harbor porpoises, since probable feeding occurred more than other behaviors. A variety of behavioral patterns, which were jumping, spyhopping, staying at the surface, and fluke-up, were often associated with probable feeding.

The abundance of harbor porpoises shifted seasonally. They were most abundant in July, August and September, and least abundant in March, April and May. Mean group sizes were largest during the times of greatest nearshore abundance.

The average number of harbor porpoises sighted per hour was higher during morning than afternoon. In the morning, porpoises were closer to shore, and used more of their time for probable feeding than later in the afternoon.

Because of this general shift in behavior, it is likely that harbor porpoise abundance and group size variations are related to food availability patterns, both seasonally and diurnally. Although sample sizes of stomach analyses were too small to give an adequate description of prey items taken throughout the year, it is likely that there was some seasonal shift in prey taken.

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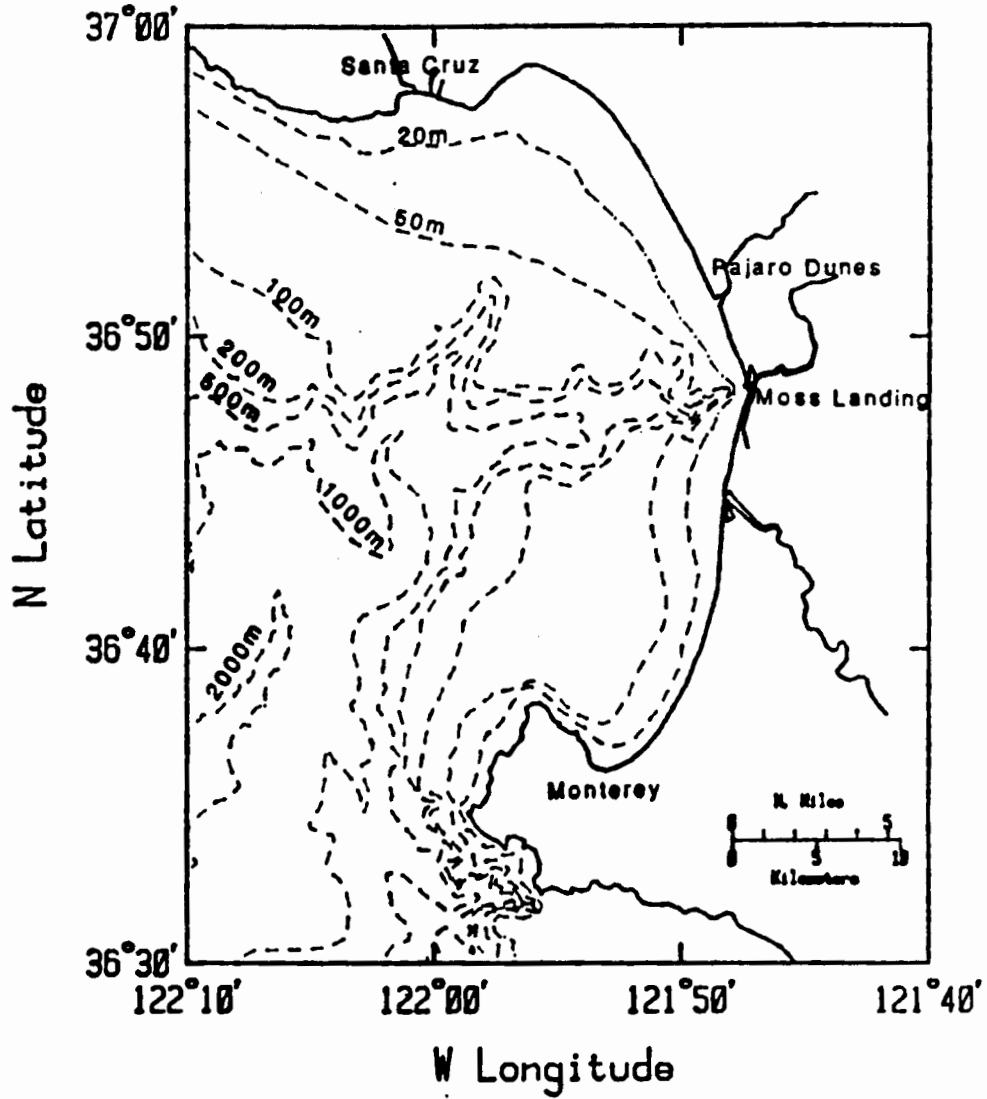



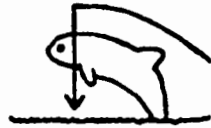




Figure 1. The study area at Pajaro Dunes in Monterey Bay, California, showing the shore-based observation station.

Figure 2-a. Jumping patterns of harbor porpoises with observation date. All of these jumps cleared the water surface.

| type | descriptions | observed date |
|------|--|--|
| (a) | 1/2 circle orbit head first entry | Feb 22, May 15 June 18, 22 July 22, 23, 24 Oct 29 |
| (b) | 1/4 circle orbit abdomen vertical entry | Feb 22, March 19 July 23, Sept 30 |
| (c) | vertical head-up out vertical head-down entry | Feb 22 |
| (d) | vertical head-up out vertical tail first entry | June 11 July 21 Aug 13 |
| (e) | vertical abdomen-up twist, abdomen-down entry | Aug 29 Sep 30 Nov 18 |
| (f) | 1/4 circle orbit abdomen-up jump out dorsal-down entry | Sept 20 |
| (g) | curved body like crescent head-up out tail-first entry | June 18 Aug 13 Nov 19 |

Figure 2-b. Jumping patterns of harbor porpoises with observation date, with tail remaining in the water.

| type | descriptions | observed date |
|------|---|--|
| (h) | 1/2 circle orbit body side-up out body side-down entry | July 23 |
| |  | |
| (i) | "pop-out" vertical dorsal-up vertical abdomen-down entry | Oct 28 Nov 12 |
| |  | |
| (j) | 1/4 circle orbit vertical head-up out body side-down entry | July 22 24 |
| |  | |
| (k) | 1/4 circle orbit head-up out vertical abdomen-down entry | June 20 Sept 20 Nov 9, 18 |
| |  | |
| (l) | vertical up & down body slightly forward | Sep 30 Oct 27, 29 Nov 8, 12, 19 |
| |  | |
| (m) | 1/2 circle orbit head first out & entry | Oct 23 ('84) May 15, June 20 July 22, 23, 24, 26, 28, 29 Aug 1, 6, 11, 13 Sept 16, 20, 30 Oct 7, 17, 22, 28, 29 Nov 4, 8, 16 |
| |  | |

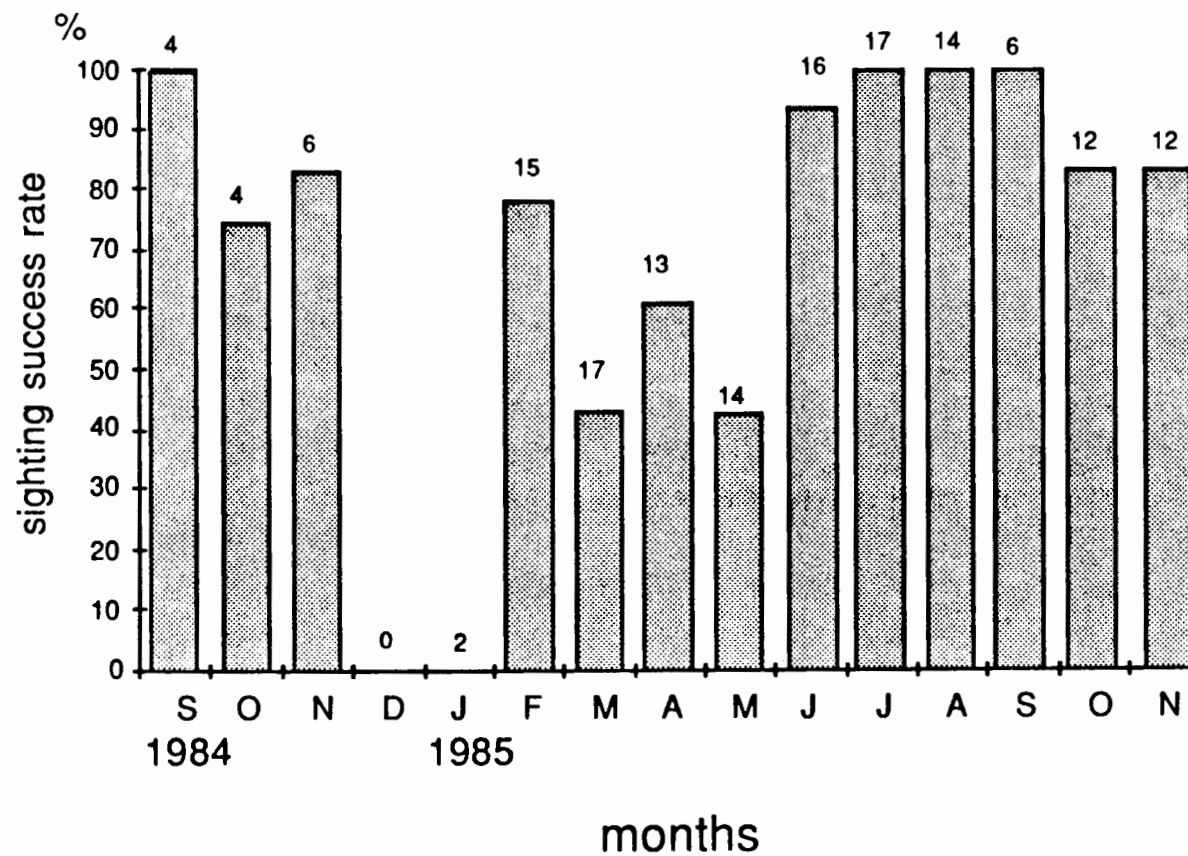


Figure 3. Sighting success rate in each month: number of days harbor porpoises were sighted per total number of observation days (shown on top of bars).

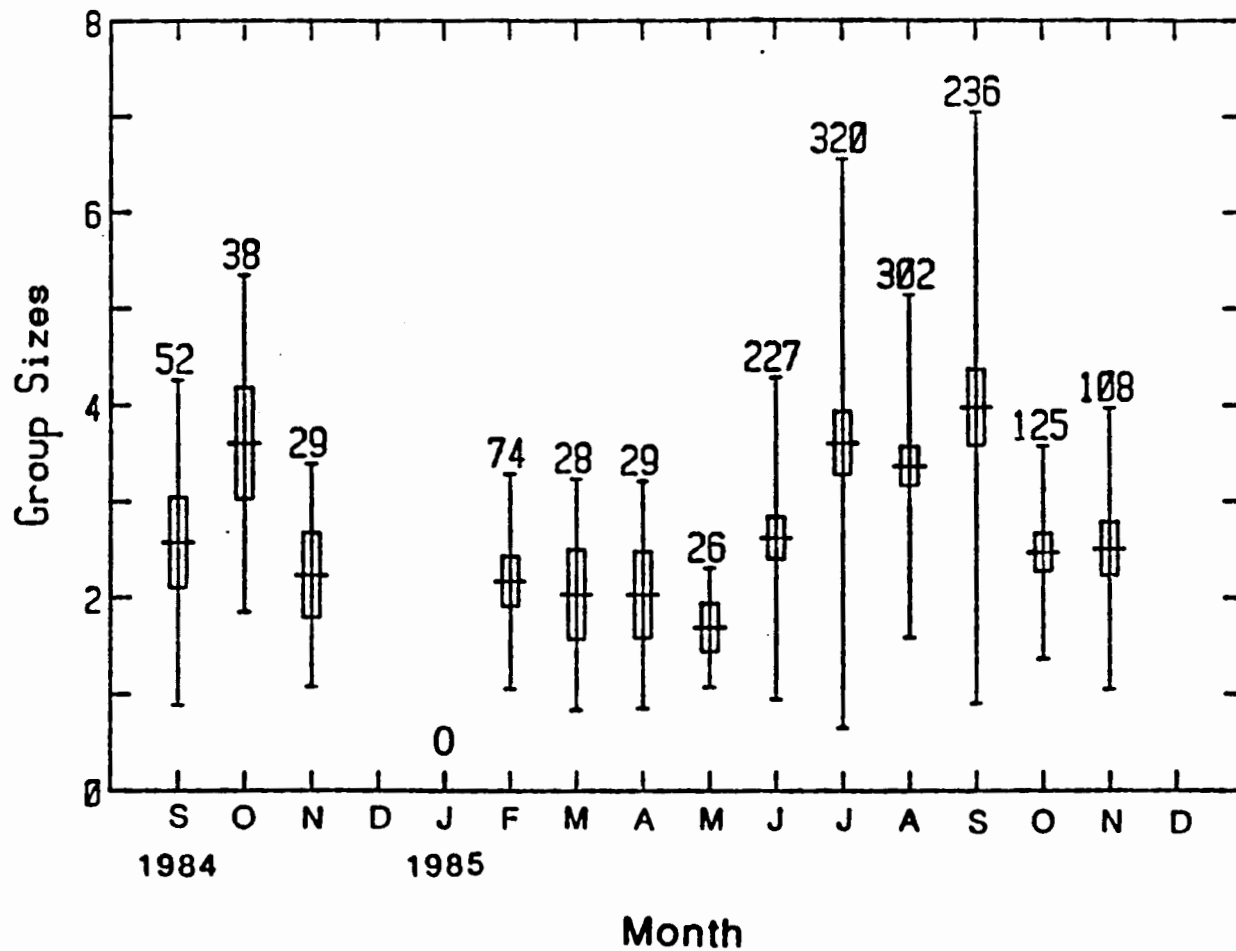


Figure 4. Group sizes of harbor porpoises in each month, with mean (horizontal line), standard deviation (vertical line), and 95% confidence interval (rectangle). Total number of observed groups in each month is indicated at the top of each line.

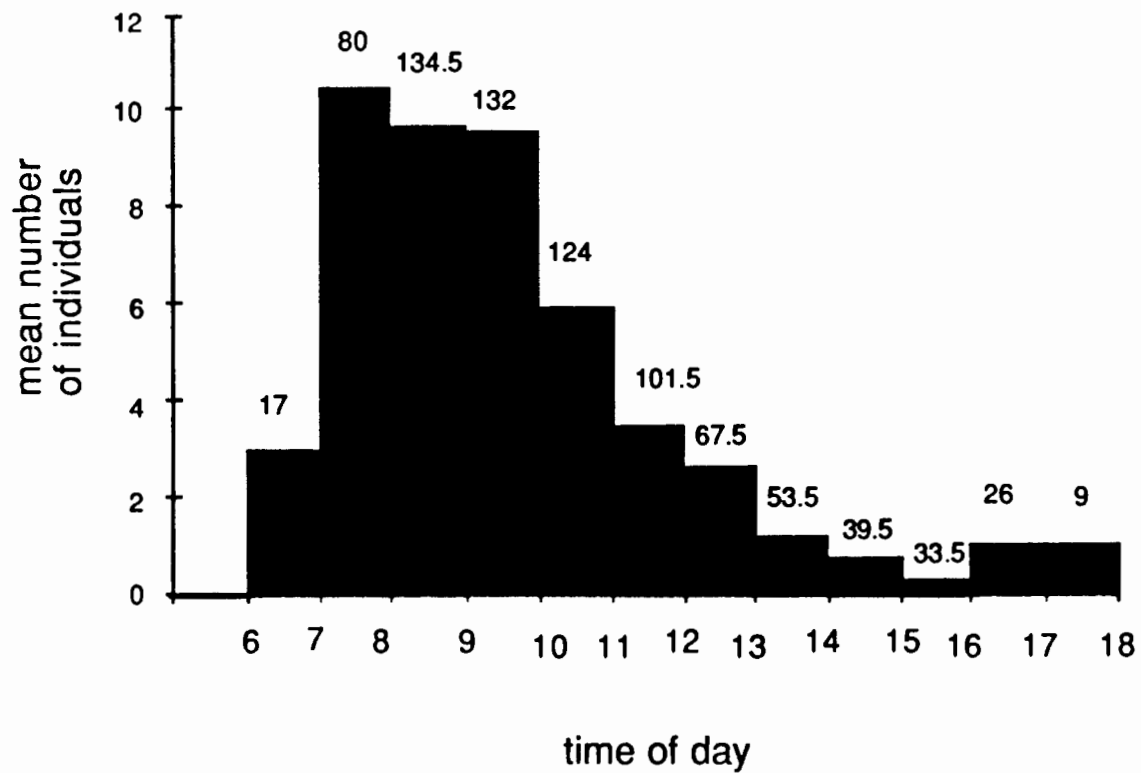


Figure 5. Mean number of individual harbor porpoises observed per hour. Effort at top of bars in number of hours of observation.

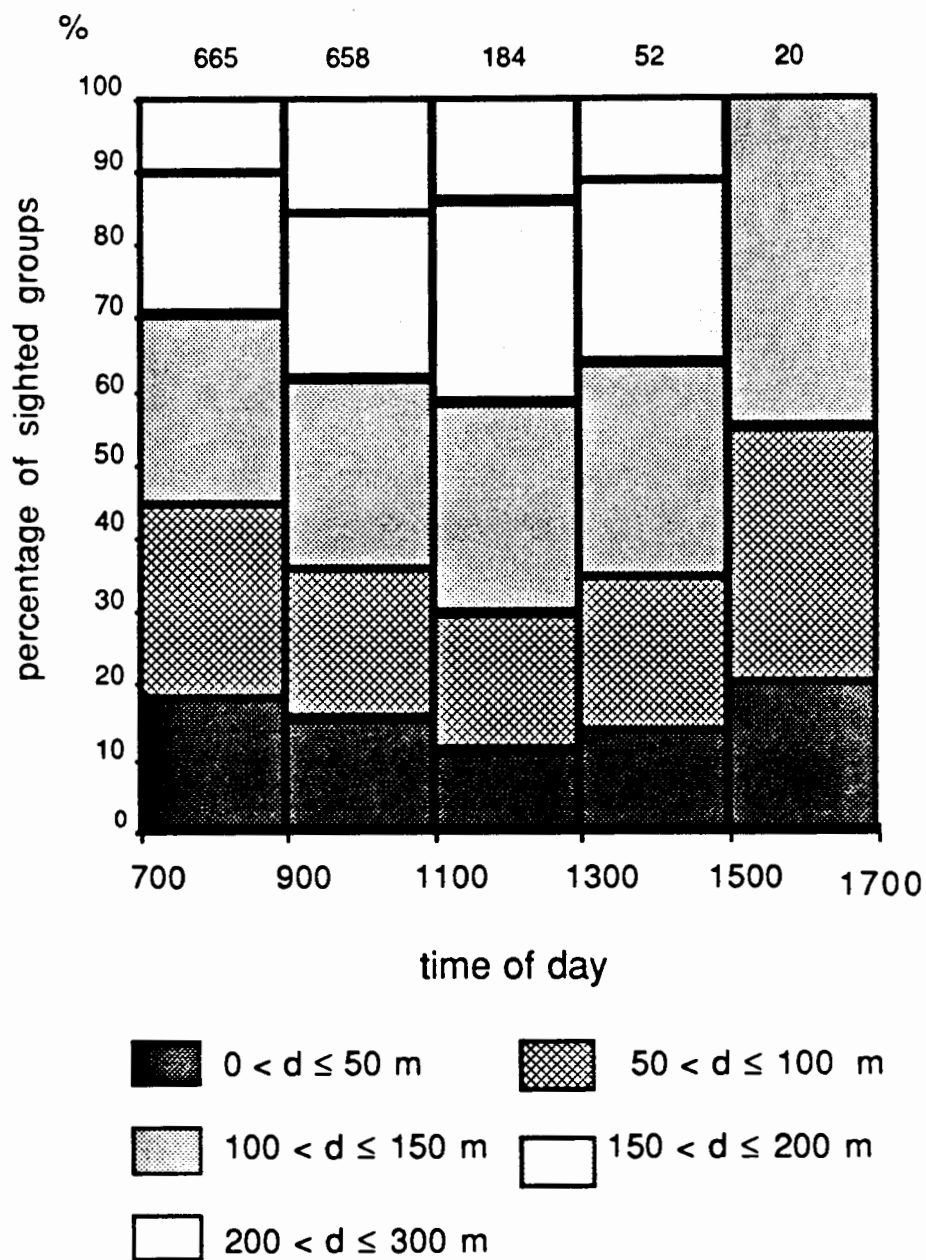


Figure 6. Estimated distances of groups of harbor porpoises from the shore, averaged per two hour period. Total number of groups are indicated at top of each column.

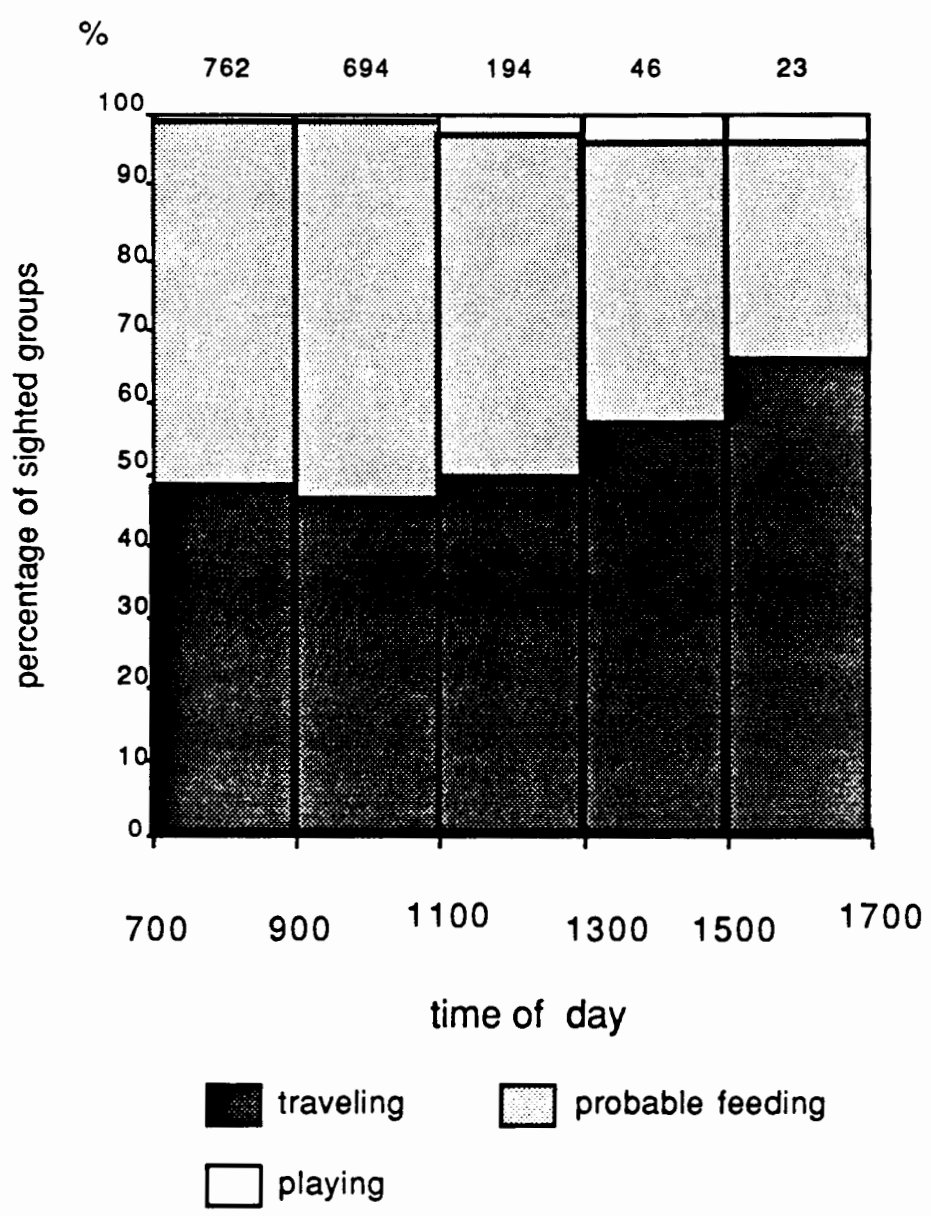


Figure 7. Ratio of three major behavioral patterns per two hour period. Total number of observed group behaviors are indicated at top of each column.

Table 1-a. Summary of shore-based observations of harbor porpoises at Pajaro Dunes in Monterey Bay, California, from September to November 1984.

| | Sep | Oct | Nov | Total |
|--|-------|-------|-------|-------|
| total observation hours (hr:min) | 10:05 | 11:07 | 17:19 | 38:31 |
| total observation days | 4 | 4 | 6 | 14 |
| number of days porpoises sighted | 4 | 3 | 5 | 12 |
| total number of groups | 52 | 38 | 29 | 119 |
| individuals | 134 | 137 | 65 | 336 |
| calves | 2 | 6 | 4 | 12 |
| groups with calves | 2 | 5 | 4 | 11 |
| group size | | | | |
| mean | 2.6 | 3.6 | 2.2 | 2.8 |
| range: max | 10 | 10 | 6 | 10 |
| min | 1 | 2 | 1 | 1 |
| ± S.D. | 1.68 | 1.75 | 1.15 | 1.68 |
| 95% Confidence Interval | 0.47 | 0.57 | 0.44 | 0.30 |
| observation frequency (the number of occurrence) | | | | |
| staying at the surface | 1 | 2 | 0 | 3 |
| spyhopping | 0 | 0 | 0 | 0 |
| fluke-up | 0 | 0 | 0 | 0 |

Table 1-b. Summary of shore based observations of harbor porpoises
at Pajaro Dunes in Monterey Bay, California, from January to November 1985.

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Total |
|-------------------------------------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|
| total observation hours (hr:min) | 6:25 | 77:46 | 88:28 | 63:14 | 59:46 | 87:04 | 85:14 | 85:22 | 38:49 | 62:12 | 65:56 | 721:16 |
| total observation days | 2 | 14 | 16 | 13 | 14 | 16 | 17 | 14 | 6 | 12 | 12 | 136 |
| number of days porpoises sighted | 0 | 11 | 7 | 8 | 6 | 15 | 17 | 14 | 6 | 10 | 10 | 104 |
| total number of groups | 0 | 74 | 28 | 29 | 26 | 227 | 320 | 302 | 236 | 125 | 108 | 1475 |
| individuals | 0 | 161 | 57 | 59 | 44 | 595 | 1154 | 1017 | 939 | 309 | 271 | 4606 |
| calves | 0 | 4 | 2 | 1 | 0 | 54 | 61 | 96 | 55 | 18 | 5 | 296 |
| groups with calves | 0 | 4 | 1 | 1 | 0 | 44 | 49 | 76 | 49 | 17 | 5 | 246 |
| group size | | | | | | | | | | | | |
| mean | | 2.2 | 2.0 | 2.0 | 1.7 | 2.6 | 3.6 | 3.4 | 3.0 | 2.5 | 2.5 | 3.1 |
| range: max | | 6 | 6 | 6 | 3 | 12 | 25 | 15 | 22 | 7 | 11 | 25 |
| min | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| ± S.D. | | 1.11 | 1.20 | 1.18 | 0.62 | 1.67 | 2.95 | 1.78 | 3.07 | 1.10 | 1.46 | 2.29 |
| 95% Confidence Interval | | 0.26 | 0.47 | 0.45 | 0.25 | 0.22 | 0.32 | 0.20 | 0.39 | 0.20 | 0.28 | 0.12 |
| observation frequency | | | | | | | | | | | | |
| staying at the surface | 0 | 1 | 0 | 0 | 0 | 5 | 5 | 3 | 9 | 2 | 10 | 35 |
| spyhopping | 0 | 2 | 0 | 0 | 0 | 0 | 5 | 3 | 3 | 0 | 11 | 24 |
| fluke-up | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 3 | 4 | 0 | 0 | 11 |

Table 2. Coincidence of tidal state with occurrence and behavior of harbor porpoises.

| condition | total observation time (hr:min) | number of observed groups | percentage of behavior patterns(%) | | |
|---------------------------|---------------------------------------|------------------------------|---------------------------------------|------|------|
| | | | travel | feed | play |
| ----- | | | | | |
| [ebb tide] | | | | | |
| morning (average/hr) | 192:50 | 377 (2.0/hr) | 48.4 | 50.6 | 0.1 |
| afternoon (average/hr) | 135:48 | 93 (0.7/hr) | 52.3 | 43.0 | 4.7 |
| [flood tide] | | | | | |
| morning (average/hr) | 299:38 | 939 (3.3/hr) | 47.8 | 50.8 | 1.4 |
| afternoon (average/hr) | 131:31 | 145 (1.1/hr) | 54.4 | 42.2 | 3.4 |
| ----- | | | | | |

Table 3. A list of prey items of harbor porpoises ranked according to their value on the Index of Relative Importance (IRI). (see pages 8 and 9 for method of calculation)

| common name | scientific name | %N | %FO | IRI |
|----------------------|-------------------------------|----------------|-------|--------|
| ----- | | | | |
| [cephalopods] | | | | |
| market squid | <u>Loligo opalescens</u> | 2.56 | 66.67 | 170.68 |
| octopus spp. | | 0.11 | 11.11 | 1.22 |
| [fishes] | | | | |
| northern anchovy | <u>Engraulis mordax</u> | 16.56 | 55.56 | 920.07 |
| spotted cusk eel | <u>Chilara taylori</u> | 41.33 | 22.22 | 918.35 |
| rockfish | <u>Sebastes spp.</u> | 19.00 | 44.44 | 844.36 |
| plainfin midshipman | <u>Porichthys notatus</u> | 8.66 | 44.44 | 384.85 |
| jack mackerel | <u>Trachurus symmetricus</u> | 3.11 | 44.44 | 138.21 |
| shiner surfperch | <u>Cymatogaster aggregata</u> | 5.44 | 22.22 | 120.88 |
| Pacific hake | <u>Merluccius productus</u> | 0.89 | 22.22 | 19.11 |
| Pacific herring | <u>Clupea pallasii</u> | 0.44 | 22.22 | 9.78 |
| night smelt | <u>Spirinchus starksi</u> | 0.56 | 11.11 | 6.22 |
| Pacific mackerel | <u>Scomber japonicus</u> | 0.11 | 11.11 | 1.22 |
| Embiotocidae spp. | | 0.11 | 11.11 | 1.22 |
| CF Embiotocidae | | 0.22 | 11.11 | 2.44 |
| CF Ophidiidae | | 0.11 | 11.11 | 1.22 |
| CF Osmeridae | | 0.11 | 11.11 | 1.22 |
| unidentified otolith | | 0.56 | 22.22 | 12.44 |
| ----- | | | | |
| | | | * ** | |
| | | $\Sigma N=900$ | $n=9$ | |

note * : total number of minimum number of prey items.
 ** : total number of porpoise stomachs which contained identifiable prey items.

Appendix A. Records of harbor porpoises used for stomach analyses.

| sample No. | collecting | | status | body length (cm) | sex |
|---------------|-------------|-------------------------------|--------------------------------------|---------------------|-----|
| | date | location | | | |
| 1) | 13 May 1984 | Natural Bridge Park | stranded | 79.5 | M |
| 2) | 27 Feb 1985 | Seaside Beach | gill net catch | 134.4 | F |
| 3) | 4 Mar 1985 | Moss Landing Harbor | stranded | 127.3 | M |
| 4) | 7 Mar 1985 | Santa Cruz Boardwalk Beach | stranded | 158.7 | F |
| 5) | 11 Apr 1985 | Monterey Dune Colony | stranded (possible gill net kill) | 149.4 | F |
| 6) | 27 Jul 1985 | Aptos | stranded | 103.1 | F |
| 7) | 23 Aug 1985 | Seacliff | stranded (alive at first) | 147.0 | F |
| 8) | 14 Sep 1985 | Manresa Beach | stranded | 117.0 | F |
| 9) | 25 Sep 1985 | Sunset State Beach | stranded | 136.0 | M |
| 10) | 27 Sep 1985 | La Selva Beach | stranded | 141.0 | F |
| 11) | 12 Mar 1986 | La Selva Beach | stranded | 123.4 | M |
| 12) | 10 Jul 1986 | off Pajaro Dunes | gill net catch | 148.1 | M |
| 13) | 28 Jul 1986 | Sunset State Beach | stranded | 96.2 | M |
| 14) | 27 Aug 1986 | Manresa Beach | stranded | 131.9 | M |
| 15) | 5 Sep 1986 | Sunset State Beach | gill net catch | 131.3 | M |

Appendix B. Stomach contents of examined harbor porpoises.

| sample number | total volume (ml) | the number of | | | | average length (cm) | | | squid | others |
|---------------|-------------------|---------------|------------------|----------|--------|---------------------|-----------------|--------------------------|---------------------------------------|--------|
| | | parasite | cephalopod beaks | otoliths | lenses | fishes | | | | |
| | | | | | | whole | half digested | vertebral column | | |
| 1) | 0 | 0 | 0 | 0 | 0 | | | | | |
| 2) | 500 | > 2 | 6 | 94 | yes | 11.75 (n=18) | | | 17.0 (n=1) | |
| 3) | 2 | 0 | 0 | 3 | yes | | | | some small stones (1-3mm diameter) | |
| 4) | 700 | ~200 | 22 | 442 | yes | 33.0 (n=1) | 23.0 (n=1) | | 11.38 (n=8) | |
| 5) | 40 | ~500 | 6 | 27 | yes | | | 8.0 (n=1) | fragmented otoliths (n=13) | |
| 6) | < 1 | 0 | 0 | 0 | 0 | | | | | |
| 7) | 30 | ~300 | 0 | 0 | 0 | | | | reddish inside | |
| 8) | 0 | 0 | 0 | 0 | 0 | | | | | |
| 9) | 150 | 2 | 0 | 183 | ~200 | | | 7.83 (n=25) | fragmented otoliths (n=3) | |
| 10) | 250 | 0 | 3 | 4 | ~60 | | 14.25 (n=2) | 3.80 (n=5) | a barnacle | |
| 11) | 50 | 0 | 0 | 811 | yes | | 8.50 (n=2) | 2.96 (n=7) | some black stones (3-5mm diameter) | |
| 12) | 140 | ~30 | 3 | 21 | yes | | 13.00 (n=2) | many broken vertebrae | 2ndry otoliths(n=5) | |
| 13) | < 1 | 0 | 0 | 0 | 0 | | | | some sand shell | |
| 14) | < 1 | 0 | 0 | 0 | ~60 | | | | some sand some black sand | |
| 15) | 440 | ~50 | 4 | 112 | yes | | 10.53 (n=20) | 4.32 (n=35) | 17.0 (n=1) | |
| total mean | | | 44 | 1693 | | 19 12.87 | 27 10.83 | 56 4.91 | 10 12.50 | |
| ± S.D. | | | | | | 5.142 | 1.861 | 2.018 | 2.980 | |

Appendix C. Results of stomach analyses of harbor porpoises:
 The identified cephalopod beaks and otoliths for each stomach sample. Inside of
 parentheses indicate lower beaks for cephalopods and right otoliths for fishes.

| seasons sample numbers | [Feb] 2 | [3 | March 4 |] 11 | [Apr] 5 | [July] 12 13 | [9 | Sept 10 |] 15 |
|---------------------------|------------|--------|------------|----------|------------|-------------------|--------|------------|---------|
| ----- | | | | | | | | | |
| [cephalopods] | | | | | | | | | |
| market squid | 3(3) | | 10(12) | | 3(3) | 1(2) | | 1 | 1(2) |
| octopus spp. | | | | | | | | 1(1) | |
| [fishes] | | | | | | | | | |
| northern anchovy | | | 1(1) | | | 5(4) | 91(89) | 1(1) | 51(50) |
| spotted cusk eel | 19(13) | | | 346(353) | | | | | |
| Sebastes spp. | 8(8) | | 150(143) | 1(1) | 6(12) | | | | |
| plainfin midshipman | (1) | | 67(75) | 1(1) | | | | | 1(1) |
| jack mackerel | 21(22) | | 1(1) | | 3(4) | | | 1(1) | |
| shiner surfperch | | | 1(1) | 48(44) | | | | | |
| Pacific hake | | 2(1) | | | | 6(6) | | | |
| Pacific herring | | | | | | | 1(2) | | 2(2) |
| night smelt | | | | 3(5) | | | | | |
| Pacific mackerel | (1) | | | | | | | | |
| Ebiotocidae spp. | | | | | 1(1) | | | | 2(2) |
| CF Ebiotocidae | | | | | | | | | |
| CF Ophidiidae | | | 1 | | | | | | |
| CF Osmoridae | | | | | | | | | 1 |
| unI.D. otoliths | 1 | | | 4 | | | | | |
| unI.D. 2ndry otoliths | | | | | | 5 | | | |
| otolith fragments | | | 6 | | 13 | | | 3 | |
| others | | | | | | | | | shells |
| ----- | | | | | | | | | |

Appendix D. A list of prey items of harbor porpoises in different seasons.

| seasons | [February] [%N | [%N | March %FO | IRI] | [April] [%N | [July] [%N | [%N | September %FO | IRI] |
|---------------------|-----------------|--------|-----------|---------|----------------|---------------|--------|---------------|---------|
| ----- | | | | | | | | | |
| [cephalopods] | | | | | | | | | |
| market squid | 5.45 | 1.03 | 33.33 | 60.99 | 15.00 | 15.30 | 1.92 | 66.67 | 120.01 |
| octopus spp. | | | | | | | 0.64 | 33.33 | 21.33 |
| [fishes] | | | | | | | | | |
| northern anchovy | | 0.15 | 33.33 | 5.00 | | 30.46 | 91.67 | 100.00 | 9167.00 |
| spotted cusk eel | 34.55 | 53.39 | 33.33 | 1779.49 | | | | | |
| Sebastes spp. | 14.55 | 23.05 | 66.67 | 1536.74 | 60.00 | | | | |
| plainfin midshipman | 1.82 | 11.60 | 66.67 | 773.37 | | | 0.64 | 33.33 | 21.33 |
| jack mackerel | 40.00 | 0.15 | 33.33 | 5.00 | 20.00 | | 0.64 | 33.33 | 21.33 |
| shiner surfperch | | 7.48 | 66.67 | 498.69 | | | | | |
| Pacific hake | | 0.31 | 33.33 | 10.33 | | 46.15 | | | |
| Pacific herring | | | | | | | 2.56 | 66.67 | 170.60 |
| night smelt | | 0.76 | 33.33 | 25.33 | | | | | |
| Pacific mackerel | 1.82 | | | | | | | | |
| Embiotocidae | | | | | 5.00 | | | | |
| CF Embiotocidae | | | | | | | 1.20 | 33.33 | 42.66 |
| CF Ophidiidae | | 0.15 | 33.33 | 5.00 | | | 0.64 | 33.33 | 21.33 |
| CF Osmoridae | | | | | | | | | |
| unI.D. otolith | 1.82 | 0.60 | 33.33 | 20.05 | | | | | |
| ----- | | | | | | | | | |
| | IN=55 n=1 | IN=655 | n=3 | | IN=20 n=1 | IN=13 n=1 | IN=156 | n=3 | |