Aquatic Mammals 1995, **21.2**, 91–103

Occurrence, behavior and feeding habits of harbor porpoises (*Phocoena phocoena*) at Pajaro Dunes, Monterey Bay, California

Keiko Sekiguchi

*Moss Landing Marine Laboratories, Moss Landing, California 95039, USA**

Abstract

From September 1984 to November 1985, sightings of 1594 groups of harbor porpoises (*Phocoena phocoena*) were made from a high vantage point at Pajaro Dunes, Monterey Bay, California, in a total of 761 hours of observations. Porpoises were seen within 300 m of the shore, mostly between 0700 and 1000 hr., apparently feeding nearshore. The number and size of porpoise groups sighted were greater in July, August and September than in other months of the year. Significantly more porpoise groups were present nearshore during flood tide than ebb tide. Variations in both the number and size of groups seen may have been related to food availability.

Nine stomachs of harbor porpoises collected in the Monterey Bay area from 1985 to 1986 were used for feeding habit analysis. Two families of cephalopods and twelve families of fishes were found. Northern anchovy (*Engraulis mordax*) had the highest index of relative importance, spotted cusk eel (*Chilara taylori*) was second, and rockfish (*Sebastes* spp.) was third, but market squid (*Loligo opalescens*) had the highest percentage of frequency of occurrence. Harbor porpoises in Monterey Bay appear to change their diet seasonally.

Introduction

The harbor porpoise (*Phocoena phocoena*) is a small coastal odontocete which is distributed in cold temperate and subarctic waters of the Northern Hemisphere (Gaskin, 1984). Its diurnal and seasonal movements have been studied in the Bay of Fundy (Neave & Wright, 1968; Gaskin *et al*., 1974; Gaskin *et al*., 1985; Gaskin & Watson, 1985), the Baltic Sea (Tomilin, 1967), Alaska (Taylor & Dawson, 1984) and the western coast of the United States (Dohl *et al*., 1983; Szczepaniak & Webber, 1985; Barlow, 1988).

Several studies have also shown seasonal changes in group size of harbor porpoises in some areas. Porpoises tend to be in larger groups during summer to fall in the Bay of Fundy (Neave & Wright, 1968; Gaskin *et al*., 1974; Gaskin, 1982), although the opposite pattern was observed in Alaska (Taylor & Dawson, 1984).

Barlow (1988) estimated that about 1500 harbor porpoises resided between Half Moon Bay and Point Sur in central California, and many of these occur in Monterey Bay. During boat transects within Monterey Bay, 86% of sightings of harbor porpoises occurred in the shallow northern portion, including off Pajaro Dunes (Anderson & Newcomer, 1985). Because of other incidental reports of harbor porpoises occurring regularly off Pajaro Dunes in the morning, this study was undertaken to investigate the occurrence and behavioral patterns of harbor porpoises in the Pajaro Dunes area.

Methods

Occurrence patterns and behavioral observations

In total, 761 hours of shore-based observations were made from Pajaro Dunes in Monterey Bay, California (36°52′N, 121°49′W) (Fig. 1), from September 1984 to November 1985 (Table 1). Observations were made from the highest point of the dunes, about 10 m above sea level and about 50 m from the shore line. Although the study area was approximately 2 km long and 0.5 km wide, sightings of porpoises beyond 300 m offshore were very rare and have been omitted from calculations. Observation times were between about 0700 hr and 1800 hr Pacific Standard Time. Tide heights were estimated from a local tide table.

Continuous searching of the study area was made without binoculars, interspersed with surveys using 8 × 30 binoculars at about 10 minute intervals. Harbor porpoises located by naked eye were immediately inspected with binoculars. A group was

*Present address: Mammal Research Institute, University of Pretoria, South Africa; Mailing address: Whale Unit, c/o South African Museum, P.O. Box 61, Cape Town, 8000, South Africa.

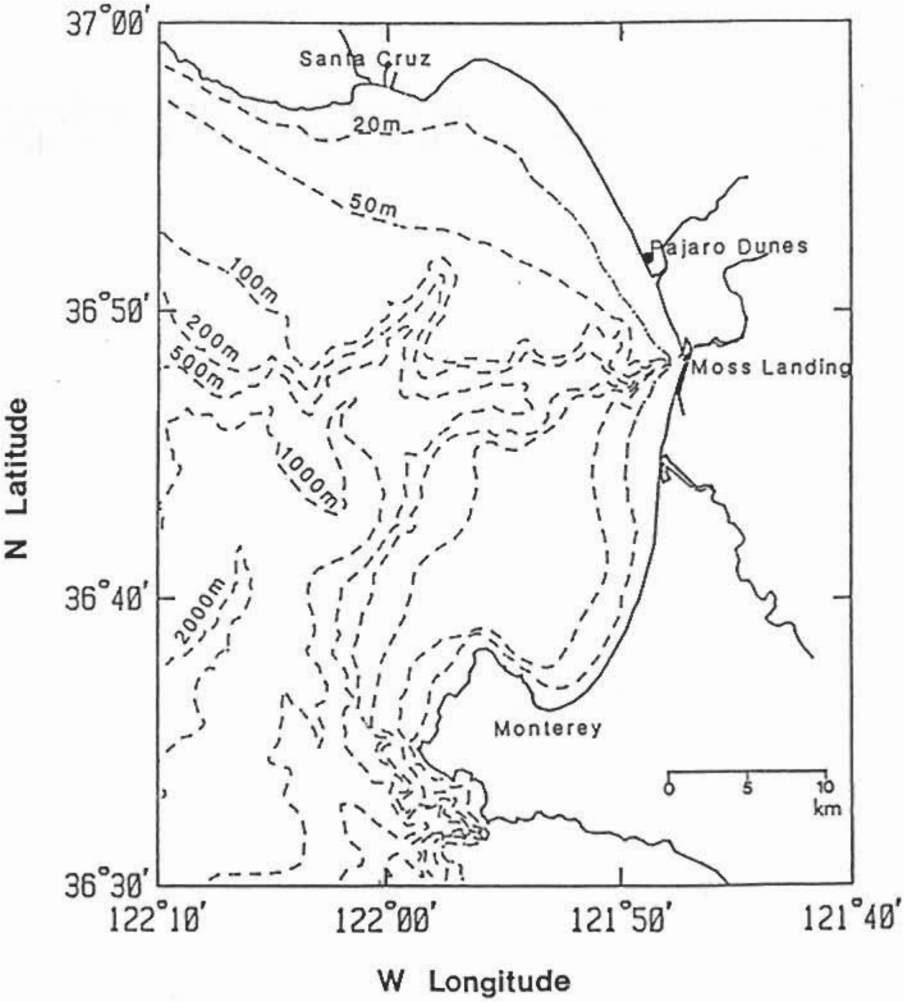

Figure 1. The study area for harbor porpoises at Pajaro Dunes in Monterey Bay, California from September 1984 to November 1985, showing the shore-based observation station.

followed with binoculars as long as possible, or until other groups were found in the area. Once contact was lost with a group, the regular survey method was resumed. When more than one group was sighted simultaneously, each group was observed just long enough to determine position and to get necessary data, and then the regular survey was resumed.

All data was recorded each time a regular survey was done or a 'new' group was sighted, including time of day, weather (percentage of cloud cover, rain or fog), sighting conditions (visibility, Beaufort sea state), group size, estimated distance from shore, direction of movement relative to the shore line, and all behaviors seen. The distance from shore was estimated by eye, always done by the author from the same spot for consistency. Most observations were carried out under good conditions (i.e. no fog or rain, Beaufort state less than 3). Beaufort wind force 4 or 5 occurred in only 7.0% of the total observation period, and 1.1% of observations of porpoises were made under those conditions. Observations were usually stopped when conditions were poor (fog or rain, Beaufort state over 5). The number of calves (approximately 1/2 to 2/3 of body length of an adult porpoise (Prescott & Fiorelli, 1980; Szczepaniak & Webber, 1985)) in each group was counted.

Harbor porpoises sighted within 5 m of one another and with the same general heading and behavior were initially labelled as a group. However, porpoises in summer sometimes formed large

Table 1. Summary of shore based observations of harbor porpoises at Pajaro Dunes in Monterey Bay, California from September 1984 to November 1985

	1984			1985											
	Sep	Oct	Nov	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total
Total observation hours (hr:min)	10:05	11:07	17:19	6:25	77:46	88:28	63:14	59:46	87:04	85:14	85:22	38:49	62:12	65:56	761:02
Total observation days	4	4	6	2	14	16	13	14	16	17	14	6	12	12	150
Number of days porpoises sighted	4	3	5	0	11	7	8	6	15	17	14	6	10	10	116
Total number of															
groups	52	38	29	0	74	28	29	26	227	320	302	236	125	108	1594
individuals	134	137	65	0	161	57	59	44	595	1154	1017	939	309	271	4942
calves	2	6	4	0	4	2	1	0	54	61	96	55	18	5	308
(% to all indiv.)	(1.5)	(4.4)	(6.2)	(0)	(2.5)	(3.5)	(1.7)	(0)	(9.1)	(5.3)	(9.4)	(5.9)	(5.8)	(1.8)	(6.2)
groups with calves	2	5	4	0	4	1	1	0	44	49	76	49	17	5	257

Table 2. Records of harbor porpoises used for feeding habit analysis. All specimens were collected in the Monterey Bay area, California

Sample no.	Collection			Body length (cm)	Sex	Specimen no.
	Date	Location	Status			
1	27 Feb 1985	Seaside Beach	gill-net catch	134.4	F	LML85-4A
2	4 Mar 1985	Moss Landing Harbor	stranded	127.3	M	MLML001
3	7 Mar 1985	Santa Cruz Boardwalk Beach	stranded	158.7	F	LML85-3
4	11 Apr 1985	Monterey Dune Colony	stranded (possible gill-net kill)	149.4	F	LML85-4B
5	25 Sep 1985	Sunset State Beach	stranded	136.0	M	MLML002
6	27 Sep 1985	La Selva Beach	stranded	141.0	F	MLML003
7	12 Mar 1986	La Selva Beach	stranded	123.4	M	LML86-3
8	10 Jul 1986	off Pajaro Dunes	gill-net catch	148.1	M	MLML004
9	5 Sep 1986	Sunset State Beach	gill-net catch	131.3	M	MLML005

'loose' feeding aggregations, which did not conform with the above definition., Such an aggregation sighted at the same spot at regular 10-min-interval surveys was therefore defined as the same group if porpoises showed the same behavioral pattern and consisted of the same number of individuals.

In total, 1594 groups consisting of an estimated 4942 porpoises (of which 306 were calves) were recorded during observation periods (Table 1), or about two sightings per hour of observations.

All behaviors observed were divided into group or individual behaviors. Group behaviors observed were categorized into three 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 & Gaskin, 1983); (3) 'Playing': surfing, chasing and 'swimming in waves' were included in this behavior. Most porpoises in the category of probable-feeding were also associated with traveling. Such groups were recorded as both traveling and probable-feeding.

Feeding habit analysis

The stomachs of nine harbor porpoises, collected in the Monterey Bay area between 1985 and 1986 (Table 2), were used for diet analysis. Stomachs which were stored frozen were opened following the methods given by Smith & Gaskin (1974). All recovered otoliths were kept dry and cephalopod beaks were preserved in 70% ethanol, and sent to Mark Lowry, Southwest Fisheries Science 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 *et al.* (1971), because the volume of each prey item could not be measured. Thus, the following equations were used for these calculations:

$$\%N = \frac{\Sigma n_{ij}}{\Sigma N_i} \times 100$$

where n_{ij} = minimum number of each prey item (j) per stomach (i) N_i = total of minimum number of prey items per stomach (i)

$$\%FO = \frac{\text{number of stomachs with each prey item}}{\text{total number of stomachs with prey remains}} \times 100$$

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

The minimum number of each prey species was taken from the larger number of either left or right otoliths (upper or lower beaks for cephalopods) present in a stomach.

Results

Behavior patterns

The three group behaviors observed (traveling, probable-feeding, and 'playing') were accomplished by all members in a group. Occasional behaviors (spyhopping, 'staying-at-the-surface', jumping, and fluke-up posture) were performed by individual group members.

Probable-feeding was the most frequent group behavior, totalling 50.3% of all 1740 group behaviors recorded; traveling was second, at 48.2% and 'playing' occurred least often, at 1.5%.

Traveling was often accompanied by probable-feeding (40.9% in total occurrence, n=839). Typically, observed groups traveled into the area, stopped at one spot apparently to feed for several minutes, before moving on (presumably to the next feeding spot). Probable-feeding periods lasted from several seconds up to about 3.8 h, which was observed on 30 September 1985.

'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 and less than about 1 m apart from each other.

Individual behaviors were occasionally observed, and were mostly associated with active feeding. One or two porpoises in a group sometimes lifted half of their body from the water vertically with no splash (spyhop), stayed motionless at the surface with a flat posture ('staying-at-the-surface'—Taylor & Dawson, 1984), jumped, or lifted their flukes vertically out of the water with no splash. The frequency of occurrence during probable-feeding was 79.2% for spyhops (total occurrence n=24), 84.2% for 'staying-at-the-surface' (n=24, of which the duration ranged from 3 to 20 s, mean=6.3 s, S.D.= ± 4.68 s), 69.0% for single jumps (n=84), and 54.4% for fluke-ups (n=11). However, 66.7% of sequential jumps were observed during traveling (n=12).

Diurnal changes

More individual harbor porpoises were observed during morning than at other times of day (Fig. 2; one-way ANOVA, F=9.263, P<0.001). The number was significantly higher at 0700–1000 (SNK multiple comparisons, more than 10 porpoises sighted per hour), decreased toward afternoon, and was lowest at 1500–1600 (0.3 porpoises per hour). Despite possible observer fatigue, the difference in sightings between morning and afternoon is large enough to suggest diurnality.

The estimated distance of groups of harbor porpoises from the shore line did not show a strong dirunal change (Fig. 3), but the slight differences between two-hour periods were nevertheless significant (Chi-square on the number of groups seen, χ^2=30.005, 0.01<P<0.025). Porpoise groups 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 (within 150 m) more often during the late afternoon. No porpoise groups were observed at greater distances than 150 m during the latter period, although there was good visibility over the area even under afternoon sun glare.

The occurrence of the three group behaviors also changed with time of day (Chi-square on the number of groups seen, χ^2=62.551, P<0.001). More instances of probable-feeding were observed during morning than during afternoon (Fig. 4). Traveling increased to more than 50% in the afternoon, while 'playing' occupied small amounts of time throughout the day.

Seasonal changes

Seasonal differences were found in numbers of porpoise groups seen per hour (Fig. 5; Kruskal–Wallis test on original data, H=9.300, P=0.026), although there was no difference in effort by hour from 0800 to 1700 between the seasons; January to March, April to June, July to September, October to December (Fig. 6; Chi-square, χ^2=10.721, P=0.991). July, August and September had the highest rate of group sightings per hour (3.52, 3.55 and 5.43 groups per hour, respectively, in 1985), and harbor porpoises were observed every day in which observations were made (Table 1). Group sighting rates in these months were significantly different from the other months (multiple comparisons). Months with the lowest sighting rates were

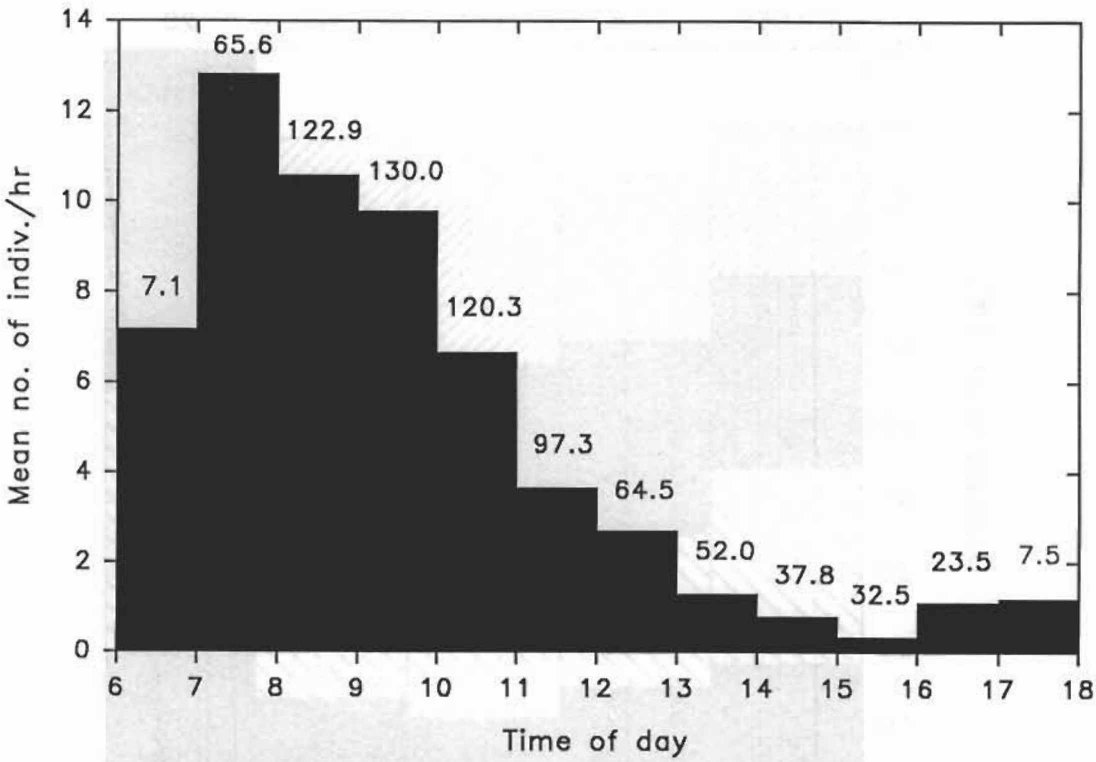

Figure 2. Mean number of individual harbor porpoise observed per hour at Pajaro Dunes from September 1984 to November 1985. Effort at top of bars in number of hours of observation.

January (0 groups per hour), March (0.32), April (0.31) and May (0.40), 1985.

Mean group size overall was 3.1 (S.D.= ± 2.25, range 1–25, mode=2, n=1594), but mean group size changed seasonally (Fig. 7; one-way ANOVA, F=14.171, P<0.001). Mean group size 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 lowest mean group size occurred in May (1.7), 1985. March and April, 1985, also showed low mean group sizes (2.0).

Maximum group size was also larger in the same periods that mean group size was larger. The maximum group size was 25 in July, 15 in August, and 22 in September, 1985. These large groups were 'loose', probable-feeding groups. Such group formations were often observed in summer and early fall (June–October).

The numbers of calves sighted differed seasonally (Table 1). The percentage of calves was lowest from January to May, 1985 (0–3.5%), but the percentage increased to 9.1% in June, 1985. The highest percentage occurred in August (9.4%) and then decreased to 1.8% in November. The percentages of calves in June to October were significantly different from these in the other months of 1985 (Mann–Whitney test, U=30, P<0.005).

Tidal effects

Tidal state affected the abundance of harbor porpoise groups (Table 3). Porpoise groups were more frequently observed during flood tide than ebb tide (Chi-square on the number of groups seen, χ^2=334.071, P<0.001). In both morning and afternoon, significantly more porpoise groups were observed during flood tide than ebb tide (Chi-square on the number of groups seen; for morning, χ^2=212.355, P<0.001; for afternoon χ^2=32.898, P<0.001). However, throughout both tidal periods, the occurrence of probable-feeding behavior was significantly higher in morning than in afternoon (Chi-square on the number of groups seen; during ebb tide, χ^2=25.294, P<0.001; during flood tide, χ^2=393.192, P<0.001).

Feeding habit analysis

In total, 43 cephalopod beaks and 1696 otoliths were collected from nine porpoise stomachs. Eight

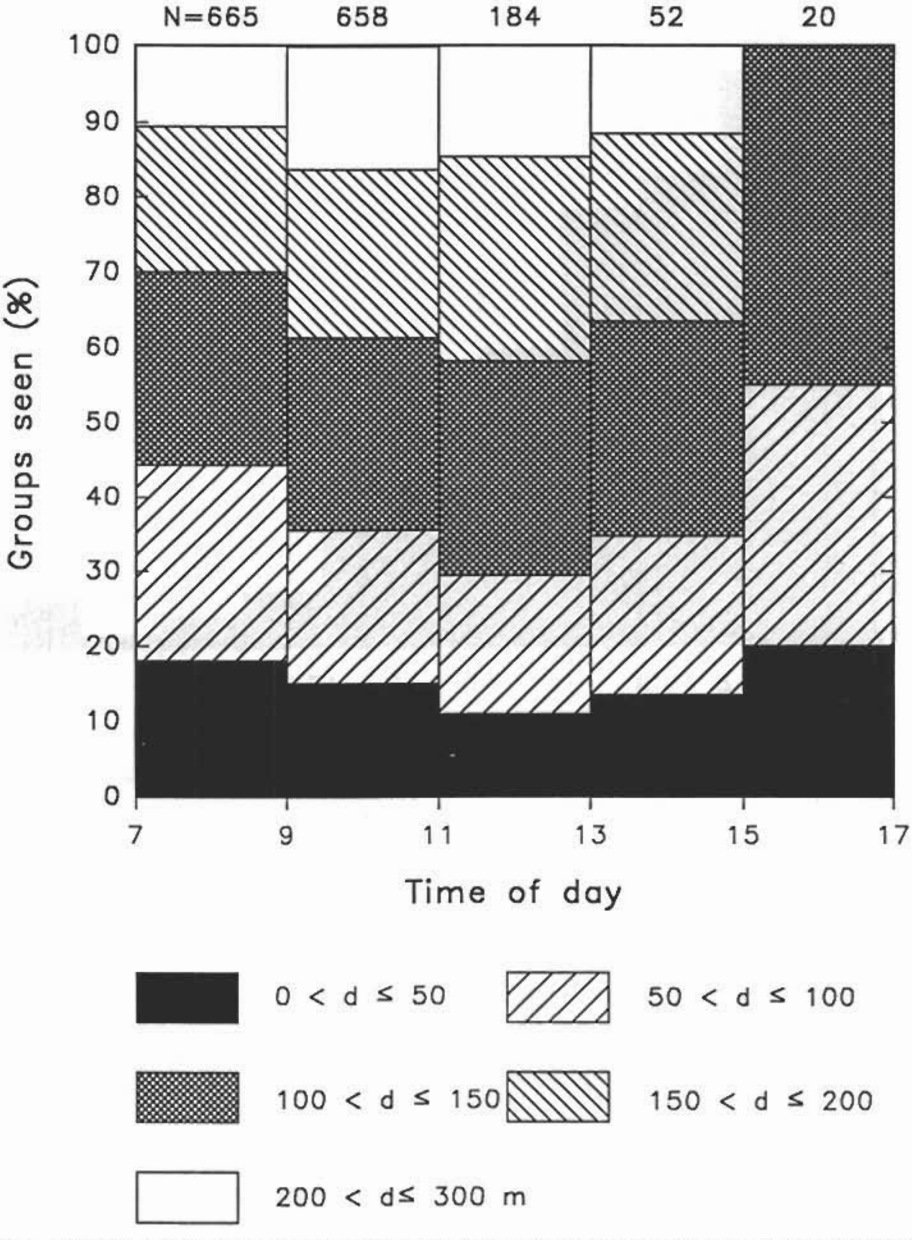

Figure 3. Estimated distances of groups of harbor porpoise from shore per two-hour period at Pajaro Dunes from September 1984 to November 1985. Total number of groups seen is indicated at top of each column.

stomachs also contained soft remains, and three stomachs contained measurable whole prey items. The lengths of 19 whole fishes (1 jack mackerel *Trachurus symmetricus* with 33.0 cm TL in sample no. 3, 18 anchovies with mean TL=11.75 cm, S.D.= ± 2.98 cm, range=9.5 – 14.5 cm, in sample no. 1), and 10 whole market squids (mean TL=12.50 cm, S.D.= ± 2.98 cm, range=7.5–17.0 cm, in sample nos 1, 3 and 5) could be measured. Some sand was found in three stomachs (sample nos 2, 7 and 8).

Two families of cephalopods and ten families of fishes were identified from stomach contents (Table 4). The total minimum number of cephalopods

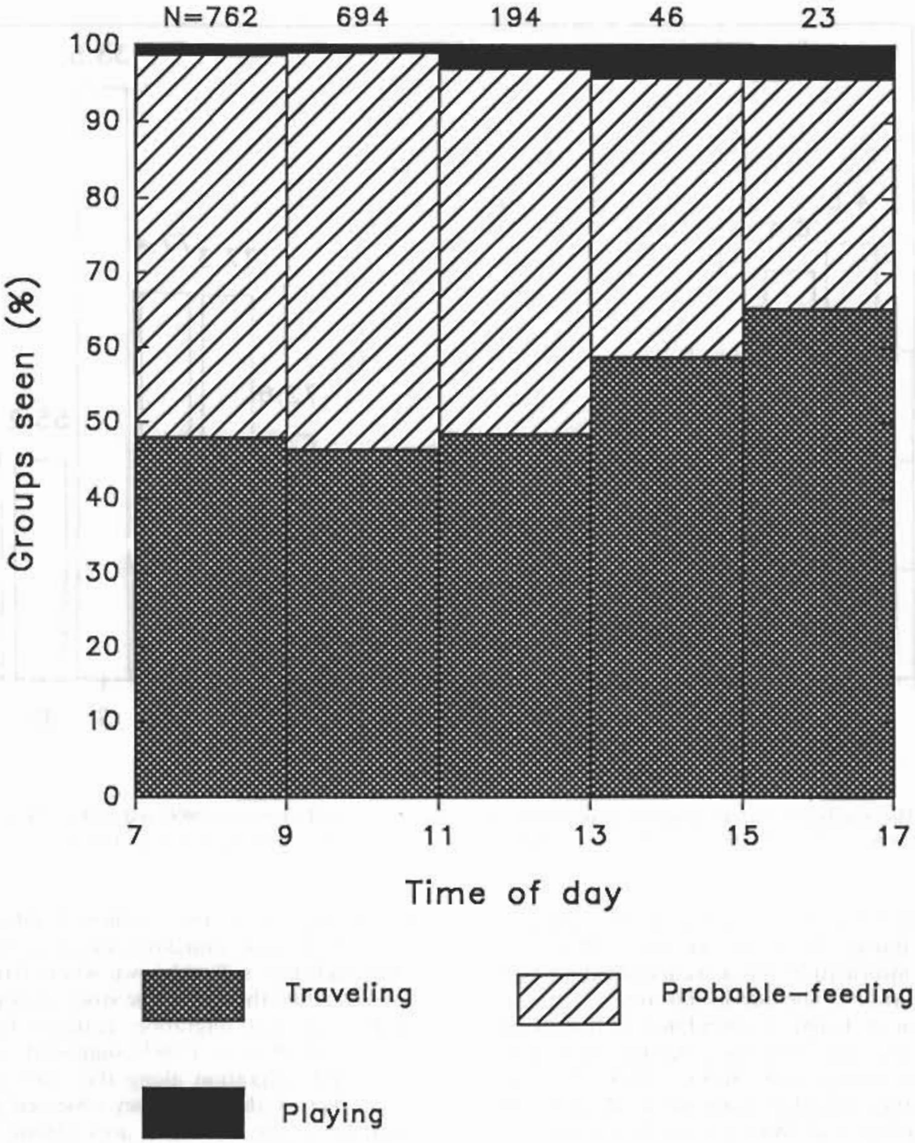

Figure 4. Proportions of three group behavior patterns per two-hour period. Total numbers of observed group behaviors are indicated at top of each column.

was 24, and of fishes was 876. Spotted cusk eel (*Chilara taylori*) had the highest %N (41.33%), and market squid (*Loligo opalescens*) had the highest %FO (66.67%). Northern anchovy (*Engraulis mordax*) had the highest modified IRI (920.07) of all prey items, but was rare or non-existent in stomachs collected in February, March and April. On the other hand, spotted cusk eel and rockfish (*Sebastes* spp.) were more often taken in these months.

Discussion

It is likely that this area was primarily a feeding habitat for harbor porpoises in Monterey Bay. Probable-feeding was the most frequently observed behavioral pattern. Tidal influence also suggests a feeding region. Gaskin & Watson (1985) mentioned that harbor porpoises seemed to move to shallow water with flood tide, following the movements of their prey species. The results of the present study

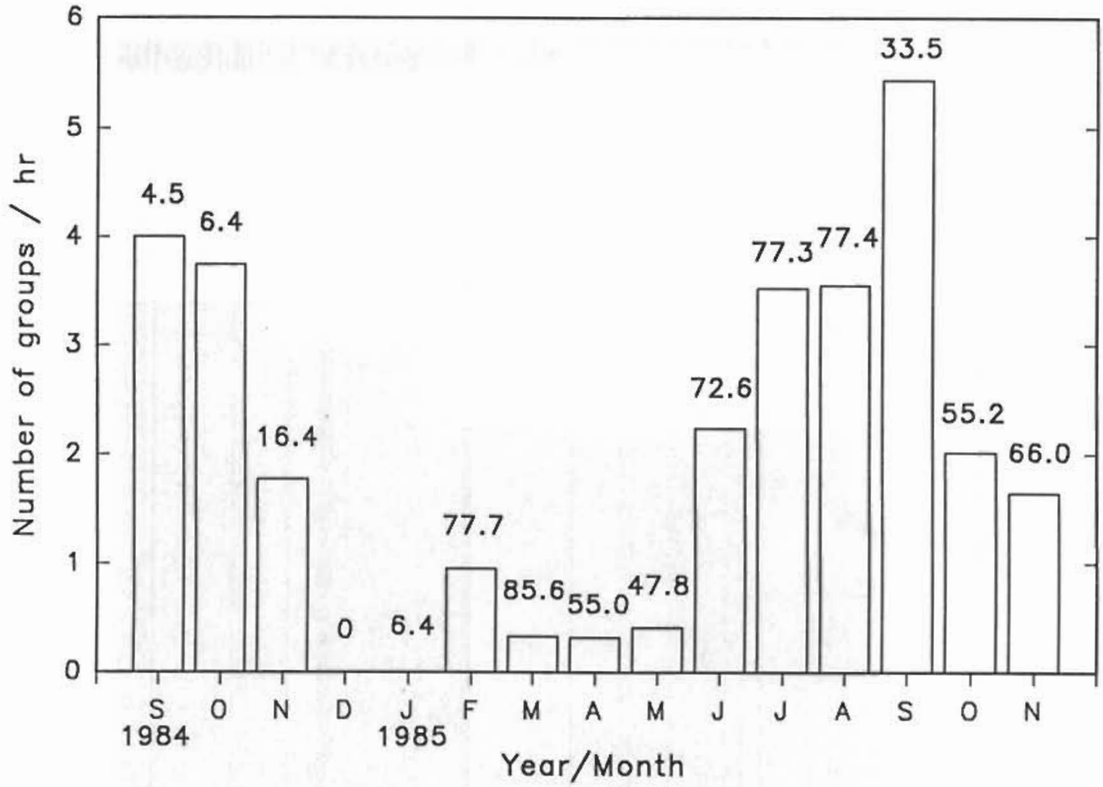

Figure 5. The number of harbor porpoise groups seen per hour each month (between 0800 and 1700) at Pajaro Dunes from September 1984 to November 1985; total number of observation hours indicated on top of bars.

also showed that more porpoise groups came into the area during flood tide. However, there is no available information about the movements of prey species relative to the tide in this area.

A seasonal change in abundance of harbor porpoises in the study area was evident in the number and size of groups seen. Barlow (1988) also found high densities of harbor porpoises in Monterey Bay on September and May cruises, but lower on a February cruise. This seasonality of abundance is similar to that found for porpoises in the Bay of Fundy, where the peak abundance was in summer to fall (Neave & Wright, 1968; Gaskin, 1977; Gaskin & Watson, 1985).

This seasonality, however, is opposite to the pattern described from aerial surveys in Monterey Bay by Dohl *et al.* (1983), where a generally higher density was found inshore in northern Monterey Bay in fall to winter, and in the northwest quadrant in spring and summer. However, the amount of searching effort expended in the Monterey Bay area must have been limited, as only 102 porpoises were seen in 3 years of aerial surveys, and the pattern of seasonal abundance described there is different to that for the central and northern California as a whole, where peak abundance occurred in fall.

Although it is still unknown where harbor porpoises go when they leave the study area in winter, possible seasonal migration patterns have 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. Recent studies at the Farallon Islands showed that porpoises moved offshore in winter, concentrating at depths between about 35 m and 80 m, but during the rest of the year they were between the shore and 45 m depth (Leatherwood & Reeves, 1986). Barlow (1988) suggested a possible seasonal change in the depth distribution of porpoises along the west coast of the United States.

In the present study area, porpoises were never completely absent from February through November, so it is unlikely that the entire population moves out of Monterey Bay at any time of

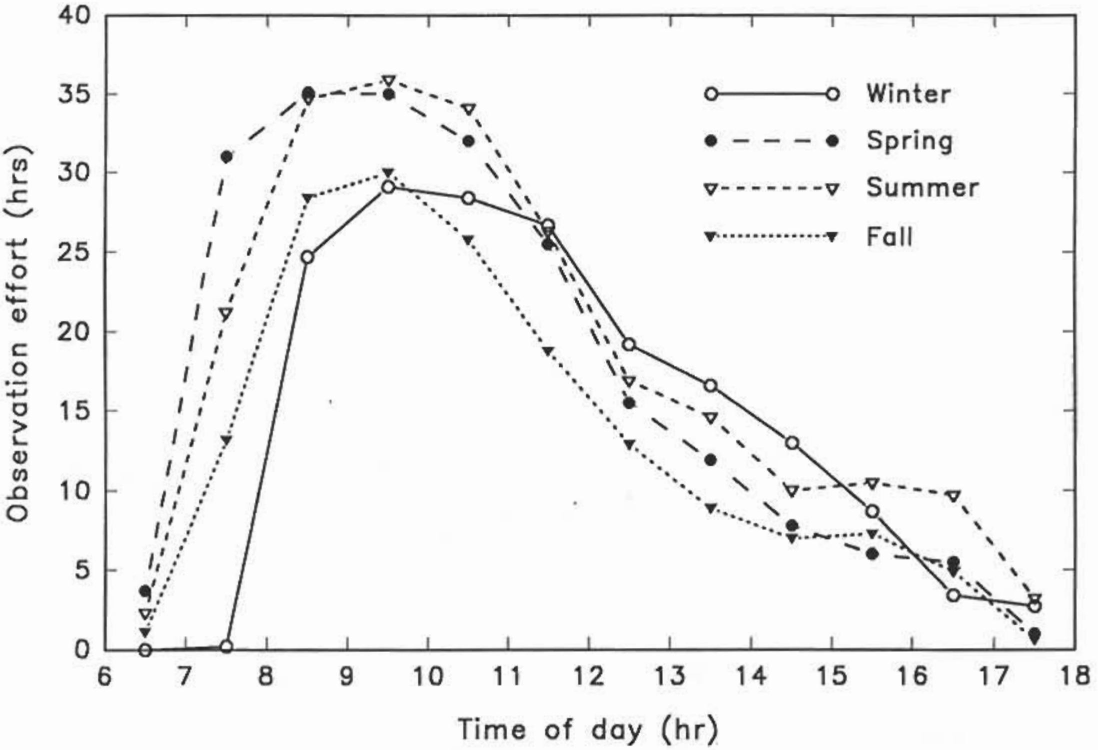

Figure 6. Hourly distribution of observation effort by season for the shore-based observation of harbor porpoises at Pajaro Dunes from September 1984 to November 1985; January to March for winter, April to June for spring, July to September for summer, October to December for fall.

year. Some residents may stay in Monterey Bay year round (Gaskin, 1984), and may disperse in the bay from late fall to spring. Szczepaniak & Webber (1985) also reported the existence of porpoises year-round in the Gulf of Farallones. In any event, the DDE/PCB concentration ratio in the blubber of harbor porpoises suggested only limited regional interchange between populations in central California (Calambokidis, 1986).

The larger, 'loose', probable-feeding groups were observed in summer and early fall. Szczepaniak & Webber (1985) 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. In the present study area, however, larger groups appeared to be feeding, and no obvious social or reproductive behavior was noticed.

If the study area is primarily a feeding habitat for harbor porpoises, seasonal changes in abundance and group size are likely to be related to their foraging strategies and perhaps to seasonal availability in prey items (Wells *et al.*, 1980; Taylor & Dawson, 1984). Prey items such as anchovy may be abundant in the study area in summer to early fall when they form larger shoals (Frey, 1971). In the same area, Kukowski (1972) found the greatest number of species and the highest abundance of benthic fishes (including some prey species of harbor porpoises) in August and September. A study off the Salinas River mouth (Engineering–Science, Incorporated, 1980) also showed a greater abundance of fishes (mainly benthic) in summer and fall months, when porpoises were most frequently observed in larger groups in the study area. The diurnal change seen in the number of individual porpoises may also have been related to a diurnal change in prey abundance or distribution in this possible feeding habitat.

The relative importance of prey items found in the present study was somewhat different from that found in studies in Monterey Bay by Morejohn, Harvey & Krasnow (1978) and in north-central California by Jones (1981). Both studies, based on stranded animals, indicated that market squid and

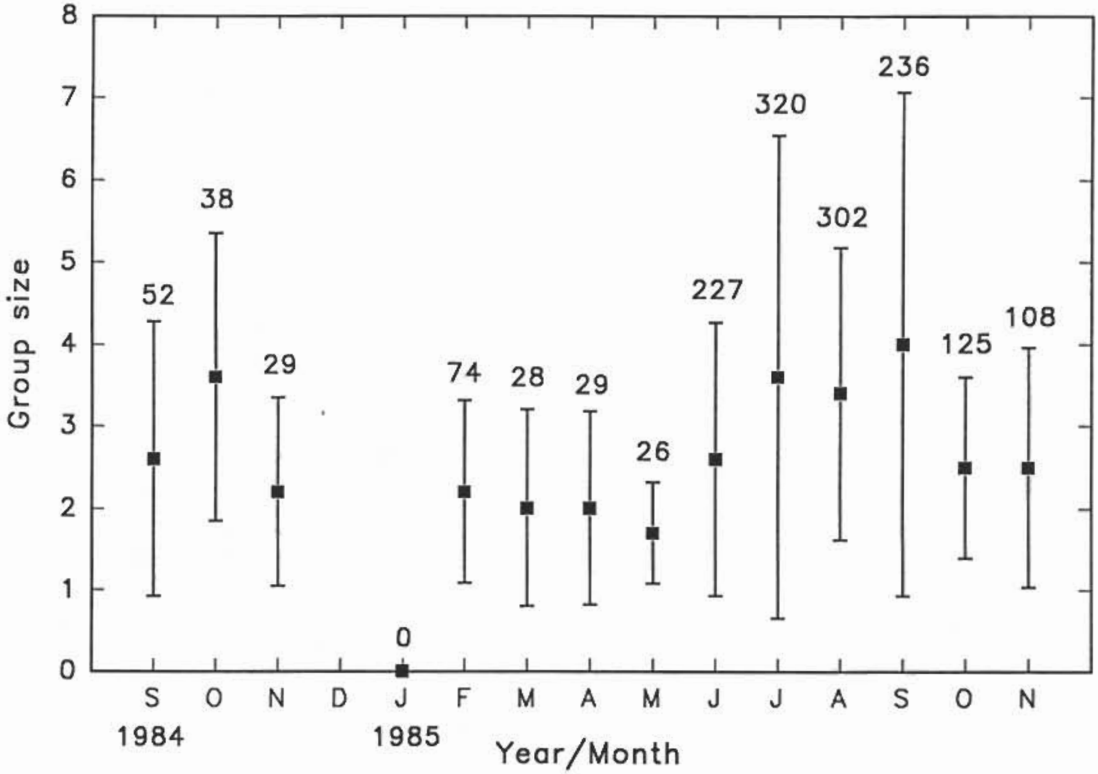

Figure 7. The mean group size of harbor porpoises in each month, with standard deviation (vertical bars). Total number of observed groups in each month indicated.

juvenile rockfish were important prey items. In this study, northern anchovy, spotted cusk eel and rockfish had much higher modified IRIs than other species in this study, but did not show higher %FO. These items probably represent seasonally important prey, since harbor porpoises are considered opportunistic feeders (Rae, 1965, 1973). Cusk eel and rockfish, on which propoises feed during winter and spring, are abundant year round. However, propoises may consume anchovy during summer and fall in Monterey Bay. It should also be noted that most of the stomachs came from stranded porpoises and contents might not be typical of healthy porpoises.

Although some flatfishes are abundant in this area (Kukowski, 1972; Environmental Research Consultants, 1976; ECOMAR, 1981), none was found in stomach contents. On the other hand, other bottom-dwelling fishes, such as the cusk eel and plainfin midshipman (*Porichthys notatus*), were consumed in large numbers. Because the midshipman has a large swim bladder, like those of anchovy, harbor porpoises may be able to use echolocation to find even those fishes buried in the sediment during the day (Crane, 1986; Greenfield, 1968). Other possible reasons for the large numbers of midshipman are night-time foraging or the taking of 'trash fish' discarded from commercial fishing boats by harbor porpoises, or juvenile midshipman possibly staying in shallow waters (Brian Sak, Moss Landing Marine Laboratories, pers. comm.).

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 calving season off California was in spring, especially during May and June. Harbor porpoises have an 11-month gestation period (Gaskin *et al.*, 1984). If their calving season is in May and June, the mating season should be around June and July in California. No copulation behavior was observed in the study area. Gaskin & Blair (1977) mentioned that copulation was rarely observed in coastal waters, and suggested that much of the seasonal sexual activity might occur outside the immediate coastal zone. However, 36.5% of 26 observations of 'play' behavior occurred in July; such behavior could be related to reproductive behavior (see Shane *et al.*, 1986).

Table 3. Coincidence of tidal state with occurrence and behavior of harbor porpoises at Pajara Dunes from September 1984 to November 1985

Condition	Total observation time (hr:min)	Number of groups seen	Percentage occurrence of group behavior (%)		
			Travel	Feed	Play
Ebb tide					
Morning	194:05	377	48.4	50.6	1.0
(average/hr)		(1.9/hr)			
Afternoon	135:48	93	52.3	43.0	4.7
(average/hr)		(0.7/hr)			
Flood tide					
Morning	299:38	979	47.8	50.8	1.4
(average/hr)		(3.3/hr)			
Afternoon	131:31	145	54.4	42.2	3.4
(average/hr)		(1.1/hr)			

Table 4. Results of feeding habit analysis of nine harbor porpoises, collected in Monterey Bay area in 1985–1986. The minimum number of each identified prey species is shown for each stomach sample according to season. Prey items were ranged according to their value on the Index of Relative Importance (IRI)

Seasons	Feb	March			Apr	July	Sept					
Sample numbers	1	2	3	7	4	8	5	6	9	%N	%FO	modified IRI
Total volume of stomach content (ml)	500	2	700	50	40	140	150	250	440			
Cephalopods												
Loligo opalescens	3		12		3	2		1	2	2.56	66.67	170.68
Octopus spp.								1		0.11	11.11	1.22
Fishes												
Engraulis mordax			1			5	91	1	51	16.56	55.56	920.07
Chilara taylori	19			353						41.33	22.22	918.35
Sebastes spp.	8		150	1	12					19.00	44.44	844.36
Porichthys notatus	1		75	1					1	8.66	44.44	384.85
Trachurus symmetricus	22		1		4			1		3.11	44.44	138.21
Scianidae spp.				47						5.22	11.11	57.99
Merluccius productus		2				6				0.89	22.22	19.11
Clupea pallasi							2		2	0.44	22.22	9.78
Sprinchus starksi				5						0.56	11.11	6.22
Phanerodon furcaus				3						0.33	11.11	3.67
Cymatogaster aggregata			1							0.11	11.11	1.22
Scomber japonicus	1									0.11	11.11	1.22
Lepidogobius lepidus				1						0.11	11.11	1.22
Hyperprosopogon anale					1					0.11	11.11	1.22
Cf Osmeridae			2					1	0.33	22.22	7.33	
Cf Embiotocidae									2	0.22	11.11	2.44
Cf Ophidiidae			1							0.11	11.11	1.22
unI.D. otoliths	1									0.33	11.11	1.22
otolith fragments			6		13		3					
										$\Sigma N=900$[a]	$n=9$[b]	

[a]Total minimum number of prey items.
[b]Total number of porpoise stomachs examined.

Acknowledgements

The present work comprised part of a Master's thesis performed at Moss Landing Marine Laboratories (MLML). I would like to give my appreciation to my thesis advisor, Dr Bernd Würsig, for his frequent help and encouragement, and also to my thesis committee Drs Gregor Cailliet and Hal Markowitz. Aleta Hohn and Hannha Bernard, Southwest Fisheries Science Center, La Jolla, California, kindly collected porpoise stomachs for me; Janet Stein at MLML was a great help in analyzing these. Mark Lowry, Southwest Fisheries Science Center, identified the cephalopod beaks and otoliths. I thank my many friends at MLML for their friendship and help. Dr Peter B. Best kindly reviewed this manuscript.

References

Anderson, J. R. & Newcomer, M. (1985) Distribution and abundance of harbor porpoise (*Phocoena phocoena* L.) in Monterey Bay, California. In *Abstract. Sixth Biennial Conference on the Biology of Marine Mammals*. Vancouver, British Columbia.

Barlow, J. (1988) Harbor porpoise, *Phocoena phocoena*, abundance estimation for California, Oregon and Washington: I. ship surveys. *U.S. Fish. Bull.* **86(3),** 417–432.

Calambokidis, J. (1986) Chlorinated hydrocarbons in harbor porpoise from Washington, Oregon, and California: regional differences in pollutant ratios. *NMFS/SWFC Admin. Rep.*, No. LJ-86-35C. 29 pp.

Crane, J. (1986) *Porichthys*: the midshipman fish. *Tidelines* **6(2),** 4–5.

Dohl, T. P., Guess, R. C., Duman, M. L. & Helm, R. C. (1983) Cetaceans of Central and Northern California, 1980–1983: status, abundance, and distribution. Pacific OCS Region. Minerals Management Service. Contract No. 14-12-0001-29090.

ECOMAR, Inc. (1981) Final Oceanographic Studies Report (November 1979 to December 1980). Vol. 1.

Engineering-Science, Inc. (1980) Final report predischarge oceanographic investigations in Central Monterey, 1977. 15 p.

Environmental Research Consultants, Inc. (1976) Watsonville wastewater treatment facility design project: predesign and pre-discharge ocean study. Vol. 2. Marine biology. 84 p. + appendices.

Frey, H. W. (ed.) (1971) *California's Living Marine Resources and Their Utilization*. California Department of Fish and Game. 147 p.

Gaskin, D. E. (1977) Harbour porpoise *Phocoena phocoena* (L.) in the western approaches to the Bay of Fundy 1969–75. *Rep. Int. Whal. Commn.* **27,** 487–492.

Gaskin, D. E. (1982) *The Ecology of Whales and Dolphins*. Heinemann Educational Books Ltd., London. 459 p.

Gaskin, D. E. (1984) The harbor porpoise *Phocoena phocoena* (L.): regional populations, status, and information on direct and indirect catches. *Rep. Int. Whal. Commn.* **34,** 569–586.

Gaskin, D. E., Arnold, P. W. & Blair, B. A. (1974) *Phocoena phocoena. Mammalian Species* **42,** 1–8.

Gaskin, D. E. & Blair, B. A. (1977) Age determination of harbour porpoise, *Phocoena phocoena* (L.), in the western North Atlantic. *Can. J. Zool.* **55(1),** 18–31.

Gaskin, D. E., Smith, G. J. D. & Watson, A. P. (1975) Preliminary study of movements of harbor porpoises (*Phocoena phocoena*) in the Bay of Fundy using radiotelemetry. *Can. J. Zool.* **53(10),** 1466–1471.

Gaskin, D. E., Smith, G. J. D., Watson, A. P., Yasui, W. Y. & Yurick, D. B. (1984) Reproduction in the Porpoises (Phocoenidae): implications for management. *Rep. Int. Whal. Commn.* (special issue 6), 135–148.

Gaskin, D. E., Read, A. J., Watts, P. F. & Smith, G. J. D. (1985) Population dispersal, size, and interactions of harbor porpoises in the Bay of Fundy and Gulf of Maine. *Can. Tech. Rep. Fish. Aquat. Sci.* No. 1291, 28 p.

Gaskin, D. E. & Watson, A. P. (1985) The harbor porpoise, *Phocoena phocoena*, in Fish Harbor, New Brunswick, Canada: occupancy, distribution, and movements. *U.S. Fish. Bull.* **83(3),** 427–442.

Greenfield, D. W. (1968) Observations on the behavior of the basketweave cusk-eel *Otophidium scrippsi* Hubbs. *Calif. Fish and Game* **54(2),** 108–114.

Jones, R. E. (1981) Food habits of smaller marine mammals from northern California. *Proc. Calif. Acad. Sci.* **42(16),** 409–433.

Kukowski, G. E. (1972) Benthic fishes associations from two depths in Monterey Bay, California. M.A. Thesis in San Jose State University. 42 p.

Leatherwood, S. & Reeves, R. R. (1986) Porpoises and dolphins. In *Marine Mammals* (second edition) (ed. D. Haley) pp.110–131. Pacific Search Press, Seattle, WA.

Morejohn, G. V., Harvey, J. T. & Krasnow, L. T. (1978) The importance of *Loligo opalescens* in the food web of marine vertebrates in Monterey Bay, California. In *Biological, Oceanographic, and Acoustic Aspects of the Market Squid,* Loligo opalescens *Berry*. (eds C. W. Recksiek and H. W. Frey) pp.67–98. *Calif. Dept. Fish and Game, Fish Bulletin* 169.

Neave, D. J. & Wright, B. S. (1968) Seasonal migrations of the harbor porpoise (*Phocoena phocoena*) and other Cetacea in the Bay of Fundy. *J. Mammal.* **49(2),** 259–264.

Pinkas, L., Oliphant, M. S. & Iverson, I. L. K. (1971) Food habits of albacore, bluefin tuna, and bonito in California waters. *Calif. Dept. Fish and Game, Fish Bulletin* 152. 105 p.

Prescott, J. H. & Fiorelli, P. M. (1980) Review of the harbor porpoise (*Phocoena phocoena*) in the U.S. Northwest Atlantic. Final Report to U.S. Marine Mammal Commission. Report No. MMC–78/08. 64 p.

Rae, B. B. (1965) The food of the common porpoise (*Phocoena phocoena*). *Proc. Zool. Soc. Lond.* **146,** 114–122.

Rae, B. B. (1973) Additional notes on the food of the common porpoise (*Phocoena phocoena*). *Proc. Zool. Soc. Lond.* **169,** 127–131.,

Read, A. J. (1983) Movements and distribution patterns of harbor porpoises, *Phocoena phocoena* (L.), in the western Bay of Fundy. M.Sc. Thesis, University of Guelph. 83 p.

Shane, S. H., Wells, R. S. & Würsig, B. (1986) Ecology, behavior and social organization of the bottlenose dolphins: a review. *Mar. Mamm. Sci.* **2(1),** 34–63.

Smith, G. J. D. & Gaskin, D. E. (1974) The diet of harbor porpoises (*Phocoena phocoena* (L.)) in coastal waters of Eastern Canada, with special reference to the Bay of Fundy. *Can. J. Zool.* **52(4),** 777–782.

Stuart-Simons, L. (1984) Seasonality of reproduction and dentinal structures in the harbor porpoise (*Phocoena phocoena*) of the North Pacific. *J. Mammal.* **65(3),** 491–495.

Szczepaniak, I. D. & Webber, H. A. (1985) Status of the harbor porpoise (*Phocoena phocoena*) in the eastern North Pacific, with an emphasis on California. Report to Center For Environmental Education. Washington, D.C. 52 p. (unpublished).

Taylor, B. L. & Dawson, P. K. (1984) Seasonal changes in density and behavior of harbor porpoise (*Phocoena phocoena*) affecting census methodology in Glacier Bay National Park, Alaska. *Rep. Int. Whal. Commn.* **34,** 479–483.

Tomilin, A. G. (1967) *Mammals of the U.S.S.R. and Adjacent Countries.* Vol. IX. Cetacea. Israel Prog. for Sci. Transl., Jerusalem. 717 p.

Watson, A. P. & Gaskin, D. E. (1983) Observations on the ventilation cycle of the harbor porpoise *Phocoena phocoena* (L.,) in coastal waters of the Bay of Fundy. *Can. J. Zool.* **61(1),** 126–132.

Wells, R. S., Irvine, A. B. & Scott, M. D. (1980) the social ecology of inshore odontocetes. In *Cetacean Behavior: Mechanisms and Functions.* (ed. L. M. Herman) pp. 263–317. John Wiley & Sons, Inc., N.Y.