Movement and Activity Patterns of Harbor Seals at the Point Reyes Peninsula, California

By

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Sarah Allen Miller

ABSTRACT

Seasonal and diel activity patterns of harbor seals were studied at Drakes Estero on the Point Reyes Peninsula, California, between 1985 and 1987. Activity patterns and movements were monitored with radio telemetry. Movements ranged south 210 km to Monterey Bay and north 480 km to the Klamath River. All movements >25 km occurred during the nonbreeding season and most seals returned to Drakes Estero by the following breeding season. More seals migrated in 1985 than 1986, and of the seals that migrated in 1985, more were females than males.

Seals hauled out for more hours per day and for more days per month during the breeding/molt season than during the winter. From November through March, the average percentage of radio-tagged seals hauled out per day varied between 52 and 81%, and from April through July, between 68% and 92%. Total hours per day that seals were hauled out during the breeding/molt season ranged from 9 to 11 hrs and for the nonbreeding season from 7 to 8 hrs. Foraging trips averaged 1.0 to 2.7 consecutive days per month, and seals took more trips per month during the nonbreeding season than during the breeding/molt season. The percentage of tagged seals hauled out over a 24-hr period was largest between 0500 and 1600 hr, regardless of season.

The amount of time that seals spent onshore varied seasonally. During the nonbreeding season seals spent about 30% of the time per day (7 hr) hauled out and 70% (17 hr) either traveling to feeding areas or engaged in foraging activities. During the breeding/molt season, however, they were hauled out 38 to 46% of the time per day (9 to 11 hr); the increase was due to additional haul-out bouts and during the molt to prolongation of individual bouts. The total hours per day, the length of a single haul-out bout, and the

proportion of days hauled out per month were similar for males and females. Preference for location of haul-out site was the only significant difference in haul-out behavior between males and females, and segregation occurred only during the breeding season.

Based on a mark-recapture model, an estimated 950 seals used Drakes Estero in March 1987 (95% confidence interval: LL 692 and UL 1206). Recommendations for further study are to 1) determine biases associated with age-related differences in movement and activity patterns, 2) devise methods for monitoring seals with radio telemetry through the molt, and 3) research biases associated with annual variation in movement patterns.

Approved: Dr. Reginald Barrett

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In memory of my father, Richard Donovan Allen, who loved the sea.

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INTRODUCTION

Conservation, management, and protection of harbor seals, Phoca vitulina richardsi, come under the purview of the Marine Mammal Protection Act (MMPA) of 1972 (Public Law 92-522). A primary directive of the MMPA is to protect marine mammal stocks from declining below the optimum sustainable population (OSP) which is defined as "the number of animals which will result in the maximum productivity of the population or the species, keeping in mind the carrying capacity of the habitat and the health of the ecosystem of which they form a constituent" (Sec. 3(9) of the MMPA). Eberhardt (1977) interpreted the meaning of OSP as a level ranging between the maximum sustainable yield and asymptotic levels. In fulfillment of the MMPA guidelines, research has been directed toward identifying the OSP for all marine mammal species.

In California, the California Department of Fish and Game (CDFG), in cooperation with the National Marine Fisheries Service (NMFS) of the U. S. Department of Commerce, has been conducting annual, statewide, aerial surveys of harbor seals to assess the status of the population (Miller 1983, Hanan 1986, and Hanan et al. 1987). Harbor seal colonies along the Point Reyes coastline, Marin County, represent about 20% of the California mainland population during the breeding season (Allen and Huber 1984a, Hanan 1986), and consequently, have received attention from CDFG and NMFS, the agencies responsible for enforcement of the MMPA. Estimates for the size of the Point Reyes population, though, are based on direct ground and aerial counts, without corrections for the number of seals hauled out on a given day relative to the total number of seals present in the area. As a result, estimates are likely low and one cannot relate numbers among seasons. In fact, establishing OSP for any marine mammal has been impeded by the difficulty of censusing species that spend a major portion of their lives in the water. A major endeavor in research, therefore, has been to devise accurate methods of population estimation (Eberhardt et al. 1979). For pinnipeds, all of these methods revolve around defining the amount of time seals, individually or as a group, spend on shore. Several researchers have addressed the problem using radio-tagged harbor seals and have derived correction factors with varying attendance patterns based on location, time of day,

and season of year (Brown and Mate 1983, Pitcher and McAllister 1981, Harvey 1987, Thompson 1987, and Yochem et al. 1987). Researchers have related differences between total number hauled out and estimates of abundance with variations in daily and seasonal haul-out patterns and with movements to other areas.

Local factors influencing the number of harbor seals hauled out on shore have been ascribed to food availability, tide level, time of day, weather, and disturbance (Brown and Mate 1983, Slater and Markowitz 1983, Stewart 1984, Allen et al. 1985, Harvey 1987, and Thompson 1987). Seasonal factors affecting number of seals hauled out include breeding, molt, and food availability (Loughlin 1978, Brown and Mate 1983, Stewart and Yochem 1983, Allen et al. 1985, Harvey 1987). Brown and Mate (1983) suggested that movement accounted for seasonal changes in number of harbor seals hauled out in Oregon and that movements were associated with seasonal changes in reproductive status and in response to seasonal variability in the abundance of coastal fish populations. Harbor seals at the Klamath River, California, moved locally to alternate haul-out sites year round and dispersed long distances in winter months (Herder 1986).

In the Point Reyes area harbor seals display diurnal and seasonal variation in haul-out patterns (Allen and Huber 1984a, Allen et al. 1985). Seals were seasonally most abundant during the spring and summer, coincident with the breeding and molt periods, with a maximum of 2502 seals counted on June 28, 1984. Diurnal and tidal effects on seal haul-out behavior varied but most seals hauled out from mid-day to late afternoon at low to medium tides, depending on the physical attributes of each location. The diurnal pattern was similar to that of the southern Channel Islands (Stewart 1984), Mowry Slough in San Francisco Bay (Fancher 1979), Southeast Farallon Island (Ainley et al. 1977), and Bolinas Lagoon (Allen et al. 1985). During fall and winter months, the maximum number of seals was around 1000 animals. The winter decline in seal numbers may be the result of seals either moving to other haul-out sites outside of Point Reyes, or spending more time at sea.

Information on seasonal activity patterns and fall/winter movements would be valuable for any long-term management program for seals in the Point Reyes area, and in conjunction with results accumulated elsewhere (Harvey 1987, Herder 1986, Yochem et al. 1987), could provide more accurate estimates of abundance of the harbor seal population in California (Ribic et al. 1986). The objectives of this study were

to determine: 1) if the apparent decline in seal numbers during the winter months is a function of seasonal migration or a change in the haul-out pattern, 2) the destination of departing animals, 3) daily and seasonal variability in haul-out behavior, and 4) if gender or age accounted for variations in the above. Hypotheses associated with these objectives are that the winter decline in the number of seals hauled out is a function of movement out of the area and that daily and seasonal variability in haul-out behavior is related to sex and age class.

STUDY AREA AND METHODS

Study Area

The Point Reyes coastline extends from the mouth of Tomales Bay (38^{O} 30'N) south to and including Bolinas Bay (37^{O} 30'N) (Figure 1). Coastal embayments include Tomales Bay, Drakes Estero and Bolinas Lagoon. The Point Reyes National Seashore, the Golden Gate National Recreation Area, the Gulf of the Farallones National Marine Sanctuary, and the Marin County Department of Parks and Recreation share jurisdiction over segments of this coastline. In addition to the protection afforded by these agencies, Bird Rock, Point Reyes Headland, and Double Point were designated by the California Department of Fish and Game and the California State Water Resources Control Board as Areas of Special Biological Significance because of their unique biological attributes (Chan 1979). The safeguards provided by these agencies and the inaccessibility of much of the area have protected the seals from human disruption. Consequently, seal terrestrial habitat usage probably has not changed significantly over the past century.

The topographical diversity of this coastline provides a broad range of substrates upon which seals haul-out in large groups. These include tidal mud flats, offshore tidal ledges and sandy beaches. A haul-out site is a terrestrial location where seals aggregate for periods of rest, birthing, and suckling of young (Harvey 1987, Thompson 1987). At Point Reyes, these sites include sand bars in Tomales Bay, Tomales Point, Point Reyes Headland, Drakes Estero, Limantour Spit, Double Point, Duxbury Reef, and Bolinas Lagoon (Figure 1).

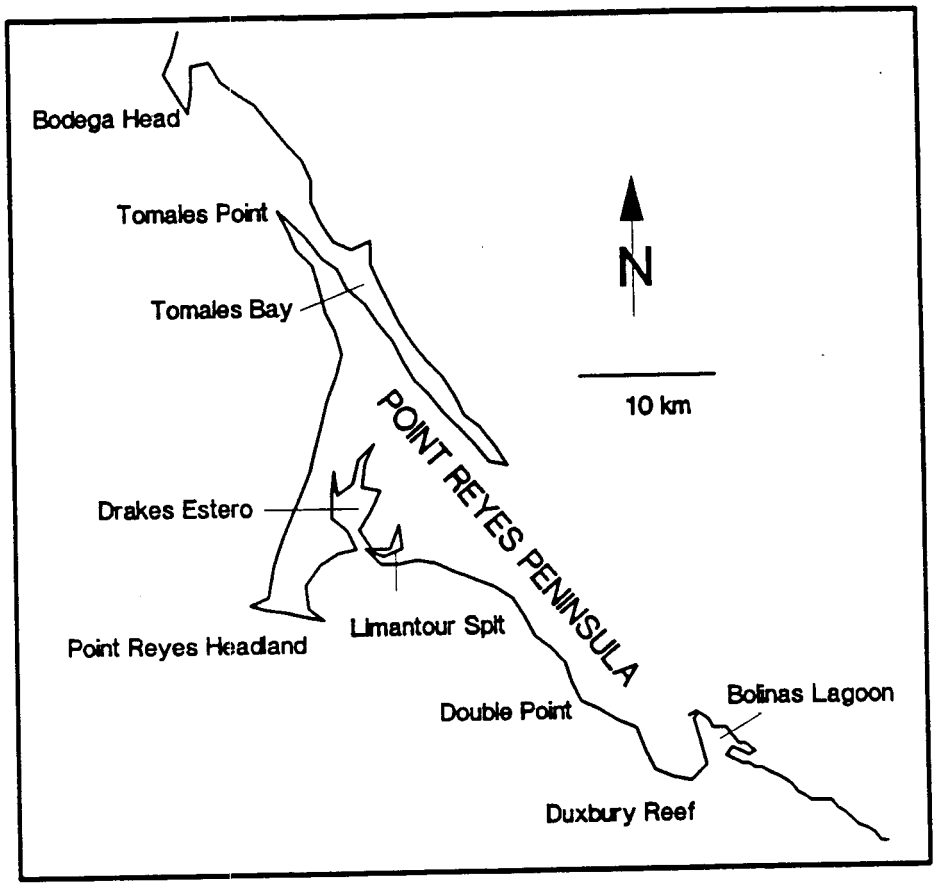

Figure 1. Haul-out sites of harbor seals along the Point Reyes coastline, Marin County, California.

Drakes Estero was selected as the study site because the capture technique chosen is only possible in an estuarine environment and because Drakes Estero is one of the main breeding locations in the Point Reyes area (Allen and Huber 1984a; Figure 2). Other estuaries along the Point Reyes coastline (Bolinas Lagoon and Tomales Bay) are exposed to substantial levels of human disturbance (Allen and Huber 1984b, Allen et al. 1985), and consequently, movement and activity patterns would likely be atypical there.

Drakes Estero is a system of drowned valleys invaded by the sea and is surrounded by low bluffs composed of a geologic formation described as the Drakes Bay Formation which includes fine-grained siltstone interbedded with mudstone (Galloway 1977). The embayment is 35.7 km^2 and is protected from ocean wave action by sandspits (Mudie and Byrne 1980). Tidal exchange occurs through a narrow inlet that is 1.5-3.0 m deep at mean low water. Siltation within the estero has escalated since the turn of the century when cattle ranching was established, and currently, a deep channel courses only half way up the estero (Mudie and Byrne 1980). Present human uses in and around the estero include recreational fishing and canoeing, commercial mariculture, and cattle ranching.

The climate is characterized by moderate temperatures and precipitation. The average annual precipitation at Point Reyes Lighthouse over a 64 yr period was 51 cm and the average annual temperature over 52 yrs was 20^{o} C (Galloway 1977). Fog and drizzle during the summer months are common resulting in a daily temperature mean difference between January and September of only 3^{o} C.

Seals haul-out in Drakes Estero on a number of tidal sand bars exposed at low to medium-high tides. The sand bar used most frequently by the seals is near the estero mouth (A) and is bordered by the main channel with a depth of 8 m. Seals also haul-out near the mouth of the estero on the tip of Limantour Beach (L) at all tide levels (Figure 2).

Capture

The method used to capture seals was conceived by personnel from the Washington Department of Game and the Oregon Department of Fish and Wildlife. We caught seals in a 130-m long gill-net, with 20-cm mesh, set off the haul-out site and then pulled ashore. The net had a lead line on the bottom which

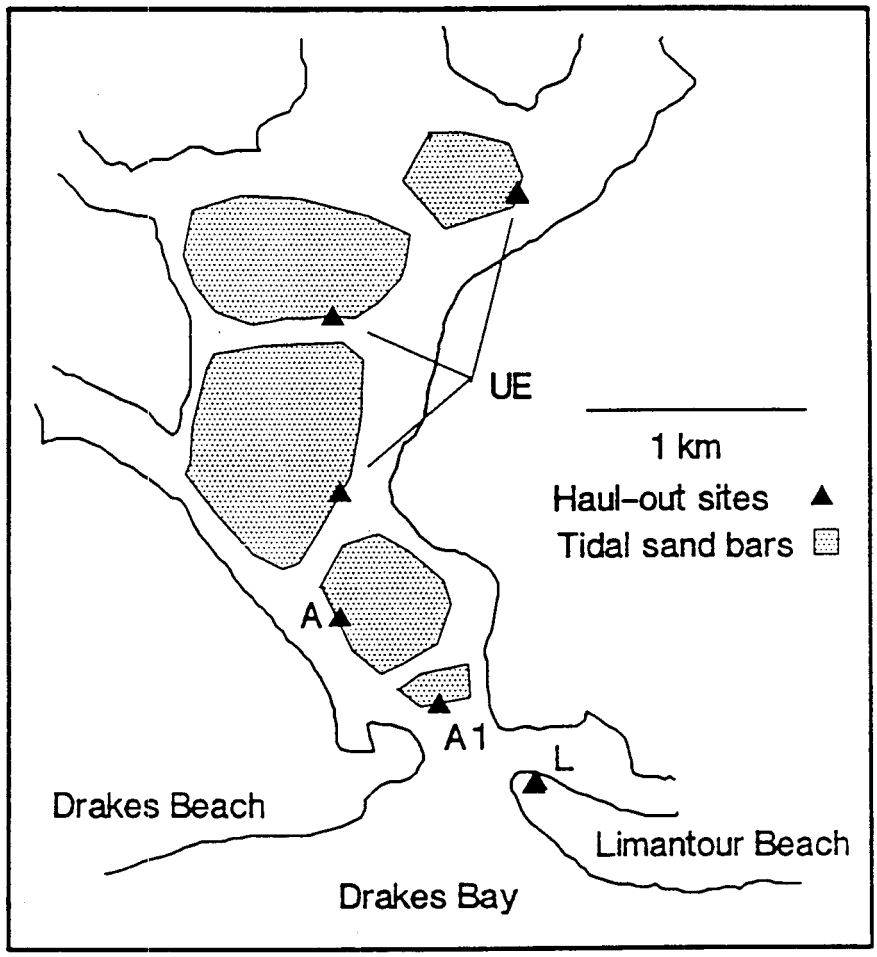

Figure 2. Harbor seal haul-out sites within Drakes Estero; A is the primary haul-out site, A1 is used during the breeding season, L is Limantour Beach, and UE are haul-out sites up the estero.

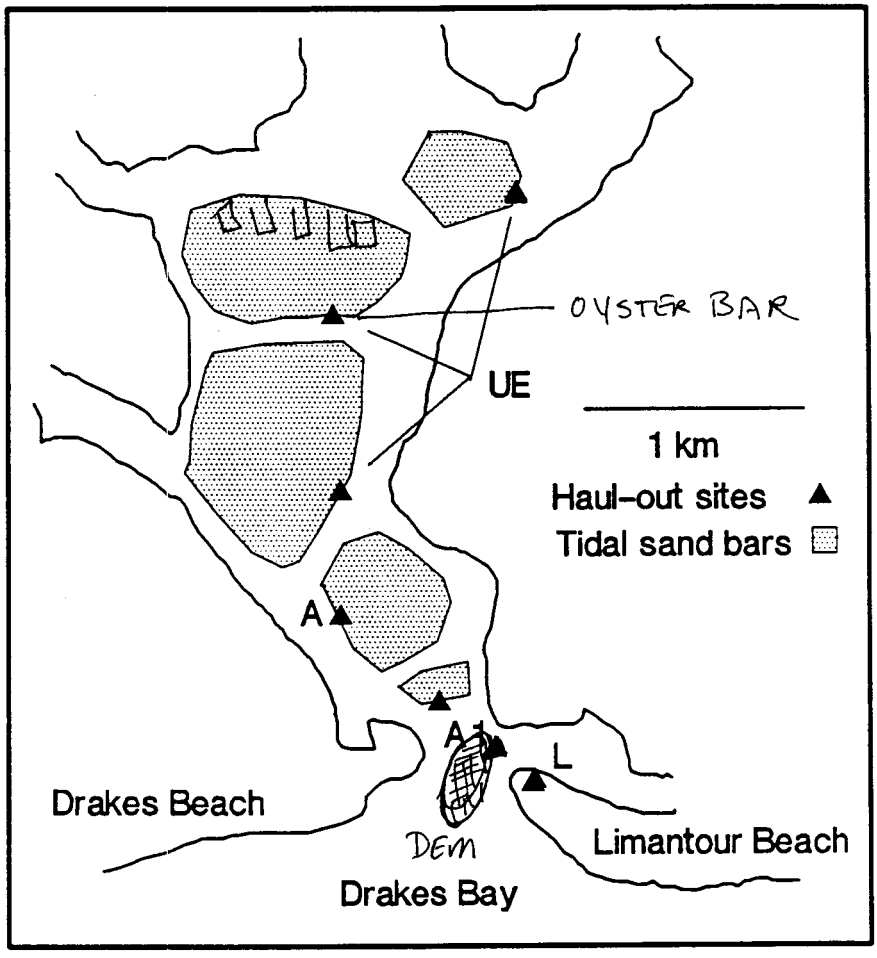

Figure 2. Harbor seal haul-out sites within Drakes Estero; A is the primary haul-out site, A1 is used during the breeding season, L is Limantour Beach, and UE are haul-out sites up the estero.

prevented seals from escaping underneath. Two power boats were used to deploy the net adjacent to the haul-out site. The lead boat carried the net on a platform set above the transom. This boat approached the hauled out seals at about 20 knots, set the net as the seals entered the water, and then landed on the far side of the sand bar. A second boat retrieved the other end of the net, landing on the near end of the bar. Seals were thus captured in a beach seine fashion. This method enabled the capture of a large number of seals over a short period of time, thereby minimizing the frequency of disturbance (Beach et al. 1985, Brown 1981, Jeffries et al. 1985).

Eighteen to twenty people were involved in the capture including personnel from Point Reyes National Seashore, Gulf of the Farallones National Marine Sanctuary, National Marine Fisheries Service, California Department of Fish and Game, Oregon Department of Fish and Wildlife, Washington Department of Fish and Game, the University of California, and Point Reyes Bird Observatory. In addition, a veterinarian monitored the condition of restrained seals and any seal deemed dangerously stressed was immediately released.

Capture periods were initially scheduled for late July to coincide with the pelage molt to maximize the length of transmitter attachment (see below). An additional capture period in March was scheduled because many transmitters had fallen off by February. No radio-tagged seals departed permanently from the estero during the week following the capture, and consequently, I assume that the capture technique did not disrupt the normal activity patterns of the seals.

Tagging Technique

Captured seals were weighed, measured (length and maximum girth), and sexed. All seals were marked with flipper-tags in the webbing of the hind flippers and with a neoprene patch on the dorsum (Figure 3). Certain seals were selected to be radio-tagged. We double flipper-tagged seals with plastic, lime green, "Riese" cattle ear tags in 1985 and lime green "Allflex" cattle ear tags (Veterinarian Supplies, Harbor City, California 90710) in 1986 and 1987. The "Allflex" tags had larger numbers which could be easily read in the field at a distance of 150 m. We attached a bright orange colored vinyl strip with 7.6 cm numbers to each flipper tag which further aided in identification of individuals. Two neoprene patches with an individual

number or symbol code were glued with "Lock-tight" Super Glue to the fur between the shoulder blades to provide an additional visual mark.

A radio transmitter manufactured by Advanced Telemetry Systems, Inc. (Isanti, Minnesota 55040) was glued to the fur on the posterior of the seal's head with "Devcon" 5-minute epoxy (Figure 3). Radio-transmitters were 9x3x3 cm, weighed 60 gms, had a 33 cm flexible antenna, and a life expectancy of 300 days. Each transmitter had a frequency within the range of 164-165 Mhz, transmitting 55 pulses per minute. Placement of the transmitter on the head allowed for tracking movements of seals while in the water when they surfaced to breathe. Radio signals could be monitored to 5 km from bluffs (50-100 m) along the coastline and to 16 km from aircraft (100-300 m).

Monitoring

Seals were monitored with an automated recording station, and by ground and aerial surveys. The automated recording station was established on a 30-m bluff overlooking Drakes Estero 150 m from the primary haul-out site and consisted of an "Esterline Angus", 20-channel, strip chart recorder, a programmable scanning receiver, a 12-volt marine battery, and a "Yagi" antenna. The receiving station recorded seals within a 4-km radius on a 24-hr basis. Each frequency was monitored by the scanning receiver for 32 sec and was scanned five to six times per hour. A seal was considered hauled out within a 1-hr period if the pen was triggered continuously for three consecutive 32-sec intervals; a seal was considered in the vicinity but in the water if the pen was triggered continuously for one 32-sec interval in conjunction with three 32-sec intervals that displayed discontinuous pen marks.

Frequencies were checked to determine if radio interference from nearby radio communication facilities (U. S. Coast Guard and RCA Global Communications Center) triggered pens. Interference did not hinder the recording of hauled out seals. However, radio interference on several frequencies prevented determining whether animals were in the water, and so strip chart data were not analyzed for the presence of these particular seals in the water. In addition, female seals with very young pups (less than 5 d) on occasion would rest in shallow water rolling and submerging the transmitter antenna. As a result, the strip chart recorder registered that the animal was not hauled out. Females with pups also on occasion would rest

vertically in the water with head raised above the surface and the recorder registered that the seal was hauled out. Consequently, haul-out times of females in this analysis may be biased for this period.

A beacon transmitter was placed in a PVC pipe at seal "head lift" level (31 cm above the ground) on the haul-out site to verify that the receiving system was functioning properly and to determine when the haul-out site was exposed during tidal cycles and therefore available to seals.

The station was in operation continuously from July 31 through September 5, and from October 25 through December 31, 1985; and from January 1 through April 30, 1986. It was again in operation from 23 July 1986 through 30 June 1987 except for intermittent periods when equipment malfunctioned.

The station was inspected and maintained a minimum of two times per week and almost daily during the 1987 breeding season. During visits all frequencies were scanned and checked for signal drift. Each signal was monitored for a period of five to ten minutes to detect seals in the water. The scan period was selected based on averaging dive times of radio-tagged seals during the first month of the project ($x = 3$ min, range 0.08 to 9.75 min, SD = 2 min, $n = 76$). Seals onshore were visually scanned for marks to check for flipper-tag or transmitter loss. At this time, information on female and pup behavior and on spatial distribution within the estero was recorded.

Ten all-day censuses were conducted at Drakes Estero to compare the diurnal haul-out pattern of the herd with that of individually marked seals and to determine the accuracy of the equipment in distinguishing the presence or absence of seals. In addition, six seals were monitored for a 24-hr period on June 1, 1987, and their location and activities were recorded every 15 min. From this information, accuracy of the remote receiving station could be compared with field observations and local feeding areas could be identified.

To locate dispersing seals, semi-weekly aerial surveys along the central and northern California coast were scheduled. A Cessna 180, single engine, aeroplane was used for all flights, and Yagi receiving antennas were mounted on the wing struts (Mech 1983). An antenna was mounted on each side of the aircraft and pointed to the side so that the strongest signal is received from the side. With this arrangement, seals could be detected for a distance of 16 km on either side of the plane as it cruised along the coast. Typically, scheduled aerial surveys began at Drakes Estero and then proceeded north to Point Arena, south

to Half Moon Bay, and then into San Francisco Bay. Length of flight depended on success in locating all animals. However, if individual seals were not recorded for one month either by the remote receiving station or by ground surveys, then aerial surveys were extended north to the Oregon border or south to Point Conception.

Seals were monitored by two people using scanning receivers and frequencies chosen were continuously scanned for three seconds each. In this manner, much of the coastline was covered two times by two people thereby maximizing detection. When a seal was located, activity, time, and location were recorded. Flights were scheduled on weekdays around tides that were low to medium to maximize the likelihood of seals being hauled out. Under this sampling regime, I assumed that major shifts in location (both spatially and temporally) would be recorded but that local and short-term movements might be over looked.

Ground surveys were scheduled in addition to aerial flights to account for local, short-term movements along the Point Reyes Peninsula. Surveys were made once per week to locate animals absent from Drakes Estero. Typically ground surveys extended along the coastline from Limantour Beach to the north end of Point Reyes Beach. Feeding areas and movement to local haul-out sites were identified from this exercise. Uneven topography hindered the mobility necessary for obtaining several fixes for triangulation to determine precise locations of animals in the water (Tester 1971); however, seals on shore were easily located visually for confirmation of position.

Data Analysis

Radio-tagged seals were categorized by the amount of time and the season that they were present at Drakes Estero. Seals were defined as "resident" if they remained at Drakes Estero for most or all of the study period, "breeders" if they departed in the fall but returned during the following breeding season, and "transients" if they were present at Drakes Estero during the capture and shortly thereafter, but resided away from Drakes Estero during the rest of the study period. Movements greater than 25 km were defined as long distance and less than 25 km as local.

Seal behavior at Drakes Estero was classified as either hauled out or absent. Descriptive statistics were calculated for each behavior for each animal by season. The months December and March (winter) and April through June (spring) were chosen to illustrate seasonal differences in haul-out behavior. The months August, December and March were used for comparing year to year differences. A chi-square test statistic was used when comparing time of haul-out initiation and the length of haul-out bout; initiation time was categorized into four periods (0000-0500, 0500-01200, 1200-1700 and 1700-2400 hr) and length of haul-out bout was categorized into four periods (1-4, 4-8, 8-12, $\geq$ 12 hr).

The absolute abundance of seals using Drakes Estero in March 1987 was estimated with a modified Lincoln-Peterson Index mark-recapture model (Caughley 1977: 141). For this analysis, only seals marked in March 1987 were included to avoid sample bias of sex and age class representation and of tag loss from the previous year. Sixteen estimates were made but an estimate prior to the onset of the pupping season was selected to avoid violation of the closed population assumption. The probability of tag loss was estimated with the equation

$$p = B^1/(2B^2+B^1)$$

where p is the probability that an animal will lose one tag, B^1 is the number of animals counted with one tag and B^2 is the number of animals counted with two tags (Caughley 1977: 140).

All information recorded on the strip chart recorder was transferred to a "DBase III+" database. The "SPSS" statistical program for micro-computers was used for most analyses. Non-parametric statistical analyses including Mann-Whitney U test and Fisher's Exact test were used for comparing behaviors of gender and between-year differences in behavior. Wilcoxon matched-pairs sign-rank tests were applied to test seasonal differences in haul-out behavior when the same individuals were sampled over two different time periods. To test the null hypothesis for independence of location within the estero with sex, a chi-square test of independence was performed (Sokal and Rohlf 1981).

RESULTS

Between 1985 and 1987 during three capture periods, 109 seals were flipper-tagged, and of these, 51 were radio-tagged. In 1985 (July 31 - August 1), radio transmitters were attached to 17 adult seals and an

additional three were flipper-tagged (Table 1a); in 1986 (July 21 and 22), transmitters were affixed to 22 and flipper tags to eight (Table 1b); and on March 9 and 11 of 1987, 92 animals were captured and transmitters affixed to 12 and flipper-tags to 47 (Table 1c). During the March capture, many seals were released because of time constraints. One adult male seal died during handling procedures. A necropsy was performed and cause of death was likely related to respiratory failure due to shock (Beach et al. 1985).

On average, adult males weighed 24 kg more and were 16 cm longer than adult females in July 1985 and weighed 9 kg more than females in July 1986 (Table 2). Though females in 1985 weighed about the same as those in 1986, males on average weighed less in 1986. Adult males and females both weighed substantially more in March 1987 than in July 1986; the weight gain in females may be explained in part by pregnancy. Average length of adult males was not substantially different from that of females for all three periods. Immatures were about 35 cm shorter than adults, and on average, weighed 34 kg both in July 1986 and March 1987.

Tag Loss

An insufficient number of seals were tagged in 1985 or 1986 for analysis of flipper-tag loss, but in 1987, the probability of flipper tag loss was estimated to be 0.31 after four months (June 26) and 0.57 after five months (July 31). Consequently, resighting information on seals with "Allflex" flipper-tags was unreliable after four months. In contrast, the "Riese" flipper-tags attached in 1985 were still seen periodically on six seals as of June 1987. "Allflex" tags were square in shape and may have snagged on objects more easily than "Riese" tags; on one occasion, I observed fishing line hanging from an "Allflex" flipper tag.

Transmitter Life Span and Loss

Length of transmitter attachment affected analysis of movement patterns such that movements of seals absent from Drakes Estero were less likely to be documented after January for both years. The median length of attachment for 1985 was 221 d ($\bar{x}$ = 181 d, SD = 80, n = 17) and 1986 was 186 d ($\bar{x}$ = 194 d, SD = 81, n = 22; Tables 3a and 3b). In 1986 transmitters tended to remain on male seals longer than on females but the difference in days was not significant ($p = 0.08$; Mann-Whitney U test). All but two

Table 1a. Standard measurements of 21 adult harbor seals tagged at Drakes Estero, August 1985; SE is standard error.

Flipper Tag No.	Radio Tag No.	Sex	Length (cm)	Girth (cm)	Weight (kg)	Comments
229	024	F	146	98	63.5	
216	033	F	138	95	56.7	
225	092	F	148	96	55.8	
214	234	F	147	120	86.2	
206	313	F	145	103	63.5	
--	415	F	131	94	50.0	
232	491	F	121	94	56.7	
228	710	F	138	96	63.5	
--	047	M	150	108	74.8	
--	084	M	154	112	93.0	Old shark bite
224	124	M	148	125	77.1	
--	176	M	148	118	84.4	
204	256	M	146	105	74.8	Old shark bite
--	272	M	167	117	90.7	
218	435	M	168	106	79.4	
201	753	M	147	118	93.0	
210	974	M	163	114	90.7	
212		M	155	111	90.7	
222		M	144	107	77.1	
220		M	150	--	83.9	
		M	173	117	102.0	

Table 1b. Standard measurements of 30 harbor seals tagged at Drakes Estero, July 1986.

Flipper Tag No.	Radio Tag No.	Age*	Sex	Length (cm)	Girth (cm)	Weight (kg)	Comments
302	224	P	F	88	69	20.4	
304	419	A	M	146	106	70.3	
306	281	P	M	96	74	22.7	
308		A	M	149	--	67.6	
310	306	I	F	107	83	31.8	
312	137	A	F	140	104	63.5	Not pregnant
313		A	F	130	103	65.8	
316	531	A	F	141	104	65.8	
317		I	F	116	81	35.8	
320		A	M	145	105	73.5	
322	343	A	M	163	111	81.6	
324	198	A	M	158	--	88.5	
326	540	P	F	95	73	19.5	
328	616	A	F	162	--	90.3	Pregnant
330	590	A	M	138	104	68.5	
332		A	M	142	106	81.6	
334		A	M	170	115	77.6	
335		A	M	148	112	78.9	
338	482	A	F	139	105	64.4	Pregnant
340		A	F	145	104	64.4	
341	645	A	F	133	105	70.3	Shark scar/Preg
344	246	A	F	138	101	55.3	Pregnant
346	504	A	M	143	106	70.3	Shark scar
348	444	A	M	140	107	74.8	
350	325	I	F	114	82	36.3	
352	117	A	F	145	101	63.5	
354	362	A	F	134	98	59.8	Not pregnant
355	467	A	F	143	103	69.4	Pregnant
357	160	A	F	146	99	70.3	Pregnant
359	267	A	M	149	104	71.7	Shark scar

* A = adult, P = pup, and I = immature.

Table 1c. Standard measurements of 63 harbor seals tagged at Drakes Estero, March 1987.

Flipper Tag No.	Radio Tag No.	Age*	Sex	Length (cm)	Girth (kg)	Weight	Comments
--		--	F	--	132	105	
--		I	F	--	126	99	
--		I	F	118	86	40.8	
363		I	F	--	--	--	
371		I	F	--	--	--	
373		I	F	--	--	--	
386		I	F	99	77	30.8	
430		I	F	111	83	28.6	
434		I	F	103	75	38.6	RT540
436		I	F	115	85	40.8	
438		I	F	109	80	33.1	
440		I	F	107	90	33.1	
443		I	F	98	82	32.2	
445		I	F	98	78	28.6	
447		I	F	89	81	34.5	
449		I	F	112	80	34.9	
451		I	F	118	86	36.3	
--		I	M	115	87	40.4	
366		I	M	--	--	--	
368		I	M	--	--	--	
412		I	M	120	91	40.8	
416		I	M	114	86	32.7	
432		I	M	110	80	29.5	
365		A	F	135	115	84.8	Pregnant
374	432	A	F	137	128	112.0	Pregnant
378	026	A	F	150	126	104.3	Pregnant
380	046	A	F	143	128	106.6	Pregnant
384	844	A	F	165	127	109.8	Pregnant
387		A	F	138	123	78.9	Pregnant
3900	092	A	F	143	121	98.4	Pregnant
392	116	A	F	143	123	96.2	Pregnant
394		A	F	--	--	81.2	
396	856	A	F	153	--	113.4	Pregnant
398	874	A	F	143	122	94.4	Pregnant
400		A	F	136	119	89.4	Pregnant
410	622	A	F	159	139	116.6	Pregnant
418		A	F	154	121	102.9	Pregnant
419		A	F	137	109	70.8	Pregnant
421		A	F	143	125	87.1	Pregnant
424		A	F	149	115	83.0	Not pregnant
428		A	F	150	115	98.4	
441	821	A	F	151	134	--	RT234/Pregnant

453		A	F	156	133	--	
455		A	F	132	125	--	Pregnant
457		A	F	134	123	--	Pregnant
461		A	F	143	124	--	Pregnant
463		A	F	139	128	--	
465		A	F	146	119	--	Pregnant
467		A	F	153	111	--	Not pregnant
471		A	F	146	127	--	Pregnant
475		A	F	124	120	--	Pregnant
212		A	M	--	--	--	FT212
221		A	M	--	--	--	FT221
382		A	M	--	--	--	
402	894	A	M	163	126	102.1	
403		A	M	141	115	87.1	
406		A	M	145	110	78.0	
408		A	M	147	118	89.4	
413	060	A	M	174	128	116.6	
426		A	M	149	105	83.5	
459		A	M	153	112	--	
469		A	M	150	123	--	
473		A	M	150	112	--	

* A = adult and I = immature.

Table 2. Average standard measurements of seals tagged in 1985, 1986, and 1987; $\bar{x}$ is the average, SE is the standard error, and n is the number of seals.

		LENGTH (cm)	GIRTH (cm)	WEIGHT (kg)
1985				
Adult Males:	$\bar{x}$	154.8	113.2	85.5
	SE	2.8	1.7	2.5
	n	13	12	13
Adult Females:	$\bar{x}$	139.0	99.5	62.0
	SE	3.3	3.1	3.9
	n	8	8	8
Total Adults:	$\bar{x}$	149.0	107.7	76.6
	SE	2.6	2.1	3.3
	n	21	20	21
1986				
Adult Males:	$\bar{x}$	149.4	107.6	75.4
	SE	2.79	1.2	1.8
	n	12	10	12
Adult Females:	$\bar{x}$	141.3	102.5	66.9
	SE	2.4	0.7	2.5
	n	12	11	12
Immatures:	$\bar{x}$	112.3	82.0	34.6
	SE	2.7	0.6	1.4
	n	3	3	3
Pups:	$\bar{x}$	93.0	72.0	20.9
	SE	2.5	1.5	1.0
	n	3	3	3
Total Adults:	$\bar{x}$	145.3	104.9	71.2
	SE	0.5	1.1	1.2
	n	24	21	24
1987				
Adult Males:	$\bar{x}$	152.4	116.6	92.8
	SE	3.4	2.6	5.8
	n	9	9	6
Adult Females:	$\bar{x}$	144.5	123.08	96.0
	SE	1.8	1.4	3.1
	n	27	26	18
Immatures:	$\bar{x}$	110.8	85.1	34.7
	SE	2.5	1.8	1.1
	n	18	18	16
Total Adults:	$\bar{x}$	146.5	121.4	95.2
	SE	0.6	0.8	0.4
	n	36	35	24

Table 3a. Duration of radio-transmitter attachment on seals tagged in 1985 and last date seal was located visually or with receiver.

Seal	Date Attached	Last Date Attached	Days Attached	Date Last Observed
024	8/01/85	11/12/85	101	4/29/86
033	8/01/85	3/03/86	240	7/10/86
047	7/31/85	3/12/86	221	7/10/86
084	7/31/85	3/27/86	236	7/10/86
092	8/01/85	3/19/86	228	7/03/86
124	8/01/85	3/06/86	236	4/08/87
176	7/31/85	1/08/86	158	1/08/86
234	8/01/85	1/24/86	174	*
256	7/31/85	8/09/85	7	7/21/86
272	7/31/85	8/28/85	26	7/10/86
313	8/01/85	12/19/85	138	5/22/86
415	7/31/85	4/18/86	258	4/18/86
435	8/01/85	1/01/86	151	7/3/86
491	8/01/85	12/19/85	138	6/08/88
710	8/01/85	3/19/86	228	7/23/86
753	8/01/85	5/03/86	273	7/10/86
974	8/01/85	4/16/86	256	7/03/86
		Average	181	
		SD	80	

* Seal was retagged as RT821 in March 1987.

Table 3b. Duration of transmitter attachment on seals tagged in 1986 and last date seal was located visually or with receiver.

Seal	Date Attached	Last Date Attached	Days Attached	Date Last Observed
119	7/22/86	7/31/86	10	1/06/87
224	7/21/86	3/20/87	243	3/26/87
419	7/21/86	1/22/87	186	6/29/87
281	7/21/86	9/11/86	53	9/11/86
306	7/21/86	4/06/87	260	4/06/87
137	7/21/86	1/10/87	174	5/22/87
529	7/22/86	2/03/87	197	3/06/87
342	7/22/86	2/01/87	195	2/24/87
198	7/22/86	1/22/87	185	6/29/87
540	7/22/86	12/19/86	151	4/02/87
616	7/22/86	1/22/87	185	6/24/87
590	7/22/86	4/22/87	275	4/22/87
482	7/22/86	2/03/87	197	5/12/87
645	7/22/86	1/22/87	185	6/29/87
246	7/22/86	12/10/86	142	7/06/87
504	7/22/86	5/17/87	300	6/29/87
444	7/22/86	4/17/87	270	6/27/87
325	7/22/86	9/09/86	51	9/09/86
362	7/22/86	4/02/87	255	6/27/87
467	7/22/86	5/24/87	307	6/24/87
160	7/22/86	12/22/86	154	6/29/87
267	7/22/86	5/17/87	300	6/26/87
		Average	194	
		SD	81	

transmitters (88%) attached in 1985 remained on seals for a minimum of five months, nine (53%) for seven months, six (35%) for eight months, and one for nine months. Of 22 transmitters attached in 1986, 19 (86%) remained attached for a minimum of five months, 15 (68%) for six months, eight (36%) for eight months, and three (14%) for ten months. The maximum length of attachment was 273 d for seals tagged in 1985 and 307 d for those in 1986. All but one transmitter attached in March 1987 remained functioning for four months, i.e., until the molt in June (Table 3c).

All but one (RT176) of the seals radio-tagged in 1985 were located at least once every two weeks, either visually or with receiver, until April 1986. The radio-tags of two seals (RT256 and RT272) ceased functioning within the first month of study; however, both were observed periodically at Drakes Estero for the entire year. Of the seals radio-tagged in July 1986, all but three were located intermittently through February 1987. Two of these three were immature (RT281 and RT325) and one was an adult female (RT119) whose transmitter ceased functioning 10 d after attachment. All seals radio-tagged in March 1987 were located regularly until transmitters were shed in June.

Seals with transmitters that ceased functioning within two months of attachment were excluded from analysis of movement patterns; these included RT256 and RT272 of 1985, and RT119 of 1986. In addition, RT325 and RT281 were excluded from movement analysis because they could not be located after September. It is possible that these two missing seals may have been killed by sharks (Ainley et al. 1985, Stewart and Yochem 1984). A number of seals with fresh shark bites were noted in the fall of 1986. Three adult flipper-tagged seals (including RT119) and five untagged seals had fresh shark bites in September. The wound on RT119 raked the entire lower left flank. The other two flipper-tagged seals had minor bites (less than 30 cm across) and these scars healed within four months.

Movements

In 1985, eight (53%) radio-tagged seals were classified as residents, four (27%) as breeders, and three (20%) as transients (Tables 4a and 5a). Seven seals (5 females and 2 males) left within one month of the date of capture, and four of these returned the following breeding season. In 1986, most seals (90%) were classified as residents (Table 4b and 5b). Five of these were also recorded hauled out periodically at Point Reyes Headland (PRH) and two traveled distances greater than 25 km during the winter months but

Table 3c. Duration of radio-transmitter attachment on seals tagged in 1987 and last date seal was located visually or with receiver.

Seal	Date Attached	Last Date Attached	Days Attached	Date Last Observed
432	3/09/87	6/17/87	101	6/29/87
026	3/09/87	6/17/87	101	6/29/87
046	3/09/87	4/23/87	99	6/29/87
844	3/09/87	6/17/87	101	6/14/87
092	3/09/87	6/25/87	109	6/29/87
116	3/09/87	6/17/87	101	6/29/87
856	3/09/87	6/22/87	106	6/29/87
874	3/09/87	6/20/87	104	6/29/87
894	3/09/87	6/27/87	111	6/29/87
821	3/11/87	6/20/87	102	6/29/87
622	3/09/87	6/16/87	100	6/29/87
060	3/09/87	6/27/87	111	6/27/87
		Average	104	
		SD	4	

Table 4a. Data for trips over 25 km taken by seals radio-tagged in 1985; $\bar{x}$ is average for total and n is number of seals to take trips.

Seal	Status[a]	No. Moves	Average Distance (km)	Location[b]	No. Locations
Females:					
024	B	2	480	KR/DE	2
033	R	0	--	DE	1
092	B	2	210	MB/DE	2
234	R	0	--	DE	1
313	B	3	47	TB/SP/DE	3
415	T	2	58	SR/RR	3
491	T	3	24	DP/PRH/DP	3
710	R	2	48	TB/DE	2
	$\bar{x}$	2.3	128		2.1
	n	6			
Males:					
047[c]	R	0	--	DE	1
084	R	0	--	DE	1
124	T	4	18	PRH/DP/DE/DP	3
176	R	0	--	DE	1
435	R	2	20	BP/DE	2
753	R	0	--	DE	1
974	B	2	48	TB/DE	2
	$\bar{x}$	2.7	28		1.6
	n	3			

[a] Status of seal; R = resident, B = breeder, T = transient.

[b] Locations:

BP = Bolinas Point, Marin Co.
DE = Drakes Estero, Marin Co.
DP = Double Point, Marin Co.
KR = Klamath River, Del Norte Co.
MB = Monterey Bay, Santa Cruz Co.
RR = Russian River, Sonoma Co.
SP = Salt Point, Sonoma Co.
SR = Sea Ranch, Mendocino Co.
TB = Tomales Bay, Marin Co.

[c] Hauled out frequently at Point Reyes Headland (12 km).

Table 4b. Data for trips over 25 km taken by seals radio-tagged in 1986; $\bar{x}$ is average for total and n is number of seals to take trips.

Seal	Status[a]	No. Moves	Average Distance (km)	Location[b]	No. Locations
137	B	4	81	PSB/MB/DE	3
160	R	0	--	DE	1
198	R	0	--	DE	1
224	R	0	--	DE	1
246	R	2	48	TB/DE	2
267	R	0	--	DE	1
305	B	3	47	DR/TB/DE	3
342	R	0	--	DE	1
362	R	0	--	DE	1
419	R	0	--	DE	1
444	R	0	--	DE	1
467	R	0	--	DE	1
482	R	0	--	DE	1
504	R	2	410	PC/DE	2
591[c]	R	0	--	DE	2
540[c]	R	0	--	DE	2
590[c]	R	0	--	DE	2
616[c]	R	0	--	DE	2
645[c]	R	0	--	DE	2
	$\bar{x}$	2.8	144		1.6
	n	4			

[a] Status of seal; R = resident, B = breeder, T = transient.

[b] Locations:

DE = Drakes Estero, Marin Co.
DR = Duxbury Reef, Marin Co.
MB = Muir Beach, Marin Co.
PC = Prairie Creek, Humboldt Co.
TB = Tomales Bay, Marin Co.

[c] Hauled out frequently at Point Reyes Headland (12 km).

Table 5a. Location and behavior of seals that traveled from Drakes Estero recorded during aerial surveys, 1985-86.
Behavior is classified as A (active/swimming) and I (inactive/hauled out).

	Date																						
Seal	8/9	8/15	8/29	9/12	9/13	9/19	9/26	10/4	10/10	10/22	10/23	10/28	10/31	11/8	11/21	11/26	12/19	2/7	2/27	3/20	3/23	3/25	4/2	4/18
024	DE/I								KR/A					DE/I	DE/I					DE/I	DE/I	DE/I		
033				DE/I			DE/I		DB/A				DE/A	DP/A	DE/I			PRH/A	PRH/A					
047				PRH/A			DE/I		DE/A				DE/A	DE/I	DE/I	DE/I				DE/I	DE/I			
084						DE/A	DE/I	DE/I	DE/I												MB/I			
092	DE/I				MB/I						MB/I						DP/I							
124	PRH/A			DP/I				DP/I	DP/A					DE/I	DE/I	DE/I								
176				DE/I			DE/A		DB/A															
234			DE/I	DE/I			DE/I		DE/I				BH/A	TB/A		SP/I	SP/I							
313	DE/I		TB/A	TB/I				TB/A	TB/I								RR/I	RR/I		RR/I		RR/I	RR/I	RR/I
415							DE/I		SR/I			DB/A	BP/A	DE/I	DE/I									
435				DE/I													DP/I							
491	DE/I					DP/I	DP/A	PRH/A	DP/A					DE/I	DE/I				DE/A	DE/I				
710	DE/I			DE/I			DE/I	TB/A		DE/A									DE/I	DE/I	DE/I	DE/I	DE/I	DE/I
753							DE/I		DE/I			DE/A	DB/A		DE/I	DE/I						TB/I	TB/I	DE/I
974	DE/I	TB/I	TB/I	TB/I			TB/I	TB/I				TB/I	BH/A	TB/I	TB/I		TB/I	TB/A	TB/I					

Locations with linear distances (km) from capture site:

BH = Bodega Head	40	MB = Monterey Bay	210
BP = Bolinas Point	20	PRH = Pt. Reyes Head	12
DE = Drakes Estero	0	RR = Russian River	55
DB = Drakes Bay	<10	SP = Salt Point	65
DP = Double Point	16	SR = Sea Ranch	85
KR = Klamath River	480	TB = Tomales Bay	40

Table 5b. Location and behavior of seals that traveled from Drakes Estero recorded during aerial surveys, 1986-87. Behavior is classified as A (active/swimming) and I (inactive/hauled out).

	Date																	
Seal	7/29	7/30	8/31	9/9	9/21	9/22	9/30	10/13	10/14	10/30	11/10	11/28	12/10	1/8	2/7	2/23	3/24	4/6	5/18
137	DE/I	DE/I	DE/I	DB/I		PSB/I	MB/A	MB/A	MB/A			PSB/A	PSB/A	PSB/A					
160	DE/I	DE/I		DE/I	DE/I		DE/I			DE/I	DE/I	DE/I	DE/I						
198	DE/I	DE/I		DE/I			DE/I		DE/I	DE/I	DE/I	DE/I	DE/I	DE/I					
224		DE/I	DE/I	DE/I			DE/I			DE/I		DE/I	DE/I	DE/I	DE/I				
246	DE/I	DE/I	DE/I	DE/I			DE/I		TB/I	DE/I			DE/I						
267	DE/I	DE/I	DE/I	DE/I	DE/I				DE/I	DE/I	DE/I	DE/I	DE/I	DE/I	DE/I	DE/I	DE/I	DE/I	
281				DB/A															
306	DE/I		DR/A	TB/I	TB/I					TB/I	TB/I			DE/I				DE/A	
325	DE/I	DE/I		DB/A															
342	DE/I	DE/I		DE/I			DE/I		DE/I	DE/I			PRH/A	PRH/A					
362	DE/I	DE/I	DE/I	DE/I			DE/I		DE/I	DE/I	DE/I	DE/I	DE/I	DE/I	DE/I		DE/I	DE/I	
419	DE/I	DE/I		DE/I					DE/I	DE/I	DE/I	DE/I	DE/I	DE/I					
444	DE/I	DE/I	DE/I	DE/I			DE/I		DE/I	DE/I	DE/I		DE/I	DE/I			DE/I	DE/I	
467	DE/I	DE/I	DE/I		DE/I		DE/I		DE/I	DE/I	DE/I		DE/I	DE/I	DE/I		DE/I		
482	DE/I	DE/I	DE/I	DE/I			DE/I		DE/I	DE/I		DE/I	DE/I	DE/I					
504	DE/I	DE/I		PRH/A			DE/I		DE/I	DE/I	PC/I	DE/I	DE/I	DE/I			DE/I	DE/I	
529	DE/I	DE/I		DE/I			DE/I		DE/I	DE/I	DE/I	DE/I	DE/I	PRH/I	DE/I			DE/I	
540	DE/I	DE/I		PRH/A						DE/I		DE/I	DE/I	DE/I					
590	DE/I	DE/I		DE/I			DE/I		DE/I	DE/I			DE/I	DE/I		PRH/I	DE/I	PRH/I	
616				DE/I	PRH/I		DE/I		DE/I	DE/I	DE/I	PRH/A	PRH/A	DE/I					
645	DE/I	DE/I	DE/I	DB/A			DE/I		DE/I	DE/I	DE/I		DE/I	DE/I					
046																	PRH/A	DE/I	
060																		BL/A	DE/I
090																		DP/A	DE/I
432																			PRH/I
874																	PRH/I	DE/I	DE/I

Locations with linear distances (km) from capture site:

BL = Bolinas Lagoon	25
DE = Drakes Estero	0
DB = Drakes Bay	<10
DR = Duxbury Reef	22
MB = Muir Beach	38
PRH = Pt. Reyes Head	12
PSB = Pescadero State Beach	106
PC = Prairie Creek	410
TB = Tomales Bay	48

returned within one month to Drakes Estero. In contrast to 1985, only two (10%) seals were classified as breeders and none as transients.

Locations to which seals migrated ranged both north and south of Drakes Estero; however, most (8 of 13) seals traveled to northern sites, four journeyed to southern ones, and one seal traveled to sites in both directions (Figure 4). In all cases, seals traveled to documented harbor seal haul-out sites (Miller 1983). Seals were very individual, though, in location selected and no more than two seals traveled to the same site in a given year. The southern most haul-out site was at Hopkins Marine Station in Monterey Bay (210 km) and the northern most one was at the Klamath River (480 km; Tables 5a and 5b).

The maximum number of recorded haul-out sites used by an individual seal over a one-year cycle was three (Tables 4a and 4b). Five (33%) of the seals tagged in 1985 were recorded exclusively at Drakes Estero, six (40%) on two haul-out sites, and four (27%) on three haul-out sites. Ten seals (53%) of the those tagged in 1986 were recorded hauled out exclusively at Drakes Estero, seven (37%) on two haul-out sites, and two (11%) on three haul-out sites.

Distances traveled to alternate haul-out sites ranged from 12 km to 480 km. Long-range movements of greater than 25 km were recorded for seven of 15 seals in 1985 and four of 19 seals in 1986. In 1985, one female moved north to the Klamath River (480 km) and one traveled south to Monterey Bay (210 km). Both were observed without transmitter at Drakes Estero in April 1986. The seal at Monterey Bay was observed almost weekly hauled out in front of the Hopkins Marine Station from mid-August to mid-March (A. Baldridge, Hopkins Marine Station, CA; C. Deutsch, Univ. of Calif., Santa Cruz, pers. commun.). Five seals traveled to haul-out sites within Point Reyes; three to Tomales Bay and two to Double Point. In 1986, one female (RT137) resided throughout the winter at Pescadero State Beach (south 106 km) and returned to Drakes Estero the following spring. RT305 moved locally and to Tomales Bay (north 48 km) during the winter and also returned to Drakes Estero the following spring. One female (RT246) traveled north to Tomales Bay in October but returned to Drakes Estero by the beginning of November. One male (RT504) was recorded at Drakes Estero on November 5, north at Prairie Creek (410 km), Humboldt County, on November 10, and again at Drakes Estero on November 20.

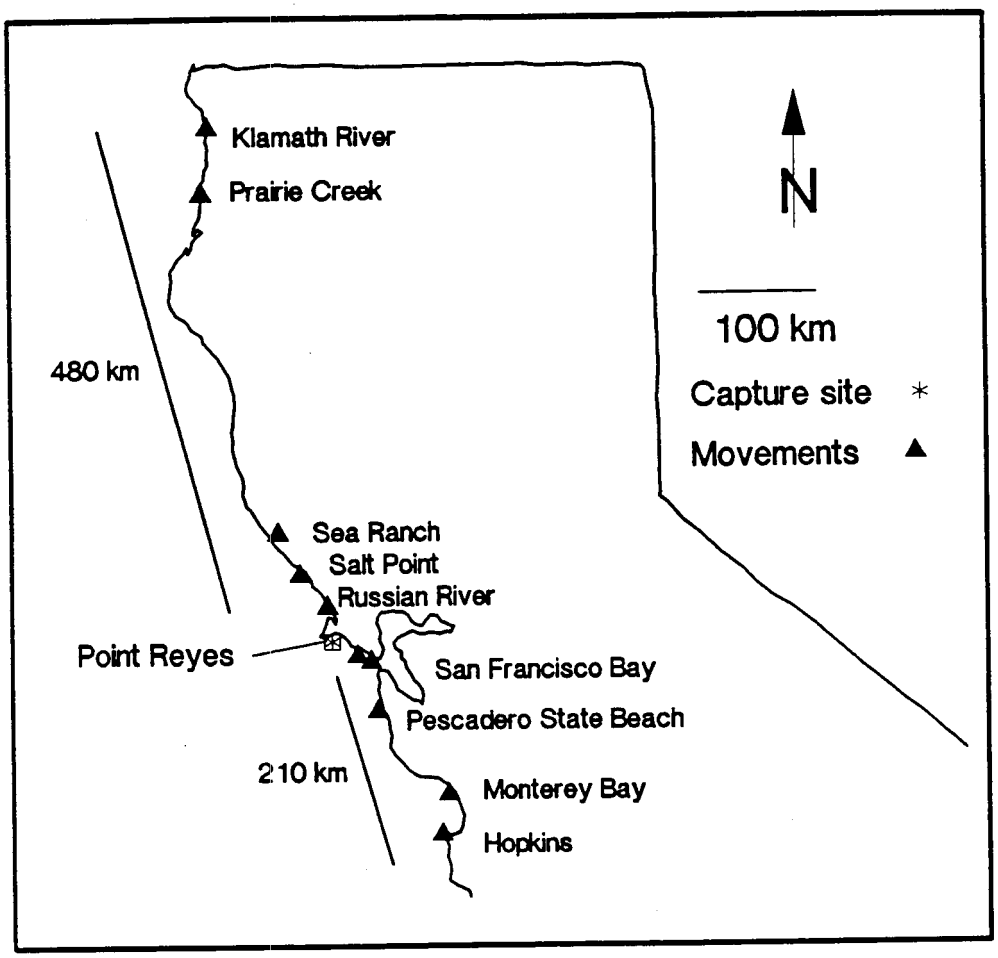

Figure 4. Capture site and resighting locations of harbor seals in California, 1985-1987.

The sample size was too small for comparing differences of movements by sex or age group in 1986, but in 1985 more females (6) traveled long distance than males (2) and females averaged longer distances than males (Table 4a). The pooled results for both years indicate that more movements occurred during the fall (16) than during the winter (5) or spring (6) and that the majority of movements were made by breeders; however, these results may be biased by the length of transmitter attachment (Table 6).

Short-range movements of less than 25 km occurred frequently throughout the study period. Most short-range movements were to Point Reyes Headland (PRH; 12 km) where seals were recorded primarily in the water. Five seals tagged in 1986 were recorded hauled out at PRH and two of these (an immature and adult male) spent more than half their time there. Two transient seals tagged in 1985 relocated to Double Point (16 km south). During both years, seals were also recorded feeding in Drakes Bay both north and south of Drakes Estero.

Two radio-tagged seals captured in March 1987 departed from Drakes Estero. One male (RT060) traveled to Bolinas Lagoon (25 km south) in early April and returned in early May just prior to the estimated weaning date of most pups (see below). One female (RT432) divided her time equally between Drakes Estero and PRH until April 20 when she returned to Drakes Estero and gave birth on April 22. She remained at Drakes Estero continuously until she weaned her pup on May 18 when she returned to PRH. She continued to spend equal amounts of time at PRH and Drakes Estero until her transmitter was shed in June. All other radio-tagged seals in 1987 were recorded at least once in the water around PRH but none hauled out there. In addition, individual seals identified by flipper-tags were recorded at Double Point (6), Bolinas Lagoon (1), and PRH (8) between March 15 and July 30, 1987.

Activity Patterns

All-day censuses at Drakes Estero were conducted to compare the diurnal haul-out pattern of the herd with that of individually marked seals. For both summer and winter in 1985, individual patterns were similar to those of the herd and there was a strong positive correlation between the proportion of tagged seals and the total number of seals hauled out ($r = 0.81$, $p < 0.01$, $n = 86$ counts; Table 7). Consequently, assumptions regarding herd haul-out behavior can be extrapolated from monitoring individuals. Seals

Table 6. Movements greater than 25 km of resident, breeding, and transient seals by year and by season.

	Resident	Breeder	Transient	Totals
Seals tagged 1985	8	4	3	15
Females	3	3	2	
Males	5	1	1	
Seals tagged 1986	17	2	0	19
Females	8	2		
Males	7			
Immatures	2			
No. moves by season:*				
Jul-Oct	4	8	4	16
Nov-Feb	2	2	1	5
Mar-Apr	0	6	0	6

* Combined results for both years.

Table 7. Diurnal haul-out pattern of harbor seals compared to that of radio-tagged individuals at Drakes Estero during summer and winter 1985; Herd is total number of seals hauled out, Tag is total number of tagged seals hauled out, and Prop is number of tagged seals hauled out per hour in proportion to the total number of resident, tagged seals.

Date		Time (PST) 0700	0800	0900	1000	1100	1200	1300	1400	1500	1600
						Summer					
Aug 6											
	Herd	453	397	429	462	365	259	81	36	17	21
	Tag	8	8	8	9	7	7	3	3	0	0
	Prop	0.6	0.6	0.6	0.6	0.5	0.5	0.2	0.2	0	0
Aug 13											
	Herd	387	378	325	94	24	106	89	173	192	70
	Tag	5	7	7	5	3	3	4	4	5	2
	Prop	0.5	0.7	0.7	0.5	0.3	0.3	0.4	0.4	0.5	0.2
Aug 20											
	Herd	389	427	261	372	316	51	1	0	0	6
	Tag	8	8	5	9	8	4	0	0	0	0
	Prop	0.8	0.8	0.5	0.9	0.8	0.4	0	0	0	0
Aug 27											
	Herd	257	241	174	56	60	72	211	248	265	157
	Tag	3	3	4	2	2	3	8	8	9	9
	Prop	0.3	0.3	0.4	0.2	0.2	0.3	0.8	0.8	0.9	0.9
Sep 3											
	Herd	100	230	355	252	210	48	0	0	3	24
	Tag	3	4	4	5	5	2	0	0	1	2
	Prop	0.3	0.4	0.4	0.6	0.6	0.2	0	0	0.1	0.2
						Winter					
Jan 1											
	Herd	190	266	404	467	467	497	192	70	66	0
	Tag	4	4	7	8	8	8	3	1	1	0
	Prop	0.5	0.5	0.9	1.0	1.0	1.0	0.4	0.1	0.1	0
Jan 7											
	Herd	0	0	0	0	157	329	419	497	498	506
	Tag	0	0	0	0	5	6	7	7	7	7
	Prop	0	0	0	0	.7	.9	1.0	1.0	1.0	1.0
Jan 15											
	Herd	309	364	413	456	462	451	229	110	0	0
	Tag	3	3	4	4	5	6	5	4	0	0
	Prop	0.4	0.4	0.6	0.6	0.7	0.9	1.0	0.6	0	0
Jan 18											
	Herd	--	212	210	165	79	64	100	100	110	110
	Tag	--	4	4	3	3	3	3	3	3	4
	Prop	--	0.6	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.6
Jan 20											
	Herd	0	0	14	124	310	372	464	476	467	445
	Tag	0	0	0	2	4	4	5	5	4	4
	Prop	0	0	0	0.3	0.6	0.6	0.7	0.7	0.5	0.6

exhibited distinct seasonal trends in haul-out behavior at Drakes Estero. In 1985, resident seals hauled out an average of 92% (SE = 3%) of the days from August through October, but only 77% (SE = 4%) of the days from November through February (Tables 8a and 9; $p = 0.008$, $n = 8$, Wilcoxon matched-pairs sign-rank test). In 1986, adult seals were hauled out an average of 90% of the total number of days monitored in July and 81% in August but only 74% in December (Tables 8b and 9). The difference between the months July and December was significant ($p = 0.02$, $n = 17$) but not between August and December ($p = 0.5$, $n = 17$, Wilcoxon matched-pairs sign-rank test). In March and April just prior to the breeding season, the percentage of days hauled per month was also low, and then during May, the percentage increased again to 92% ($p = 0.002$, $n = 14$, Wilcoxon matched-pairs sign-rank test). Immature seals hauled out on fewer days than adults; however, the sample size was too small to make meaningful comparisons. In 1985, females appeared to haul-out on fewer days than males in September and November; however, the sample size is too small for useful statistical comparison. There was no significant difference between the number of days that male and female seals were hauled out for the months July and October 1986 ($p > 0.05$; Kolmogorov-Smirnov two-sample test; Table 10). For all other months the percentages were similar.

In 1985, the percentage of tagged seals hauled out per day relative to the total number of tagged seals was also greater for August through October than from January through March (Table 10). For the seals tagged in 1986, the percentages were greater in May, June, and July than in August through April (Table 10). The percentage difference between years for August and September can be explained in part by the inclusion of immatures in the 1986 sample. If immatures are excluded from the analysis, the percentage increases to 76%. Immature seals appeared to haul-out on fewer days in August and September than adults.

When resident seals were not hauled out, they were either in the water within Drakes Estero or were absent from Drakes Estero. The length of time that seals were absent averaged 1.4 to 1.9 consecutive days per month in 1985 and 1.0 to 2.7 in 1986 and 1987 (Table 11). Combined data for both years averaged from 1.5 to 2.5 days per trip (Table 12). The longest absence was for seventeen days but most trips were one day. The average number of trips per month was greatest for February for both years and least for May 1987. Combined data for both years averaged from 2.7 to 5.2 trips per seal per month.

Table 8a. Percentage of days per month individual radio-tagged seals were present at Drakes Estero, 1985-86.

	Month							
Seal	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Females:								
033	90	100	100	90	73	76	58	74
234	90	60	86	52	50	67	*	
491	55	40	**					
710	90	80	86	48	93	73	63	63
Males:								
047	93	100	100	90	83	73	33	50
084	80	80	57	76	93	80	71	65
176	100	100	100	81	93	***		
272	85	*						
435	93	100	100	90	80	*		
753	93	100	100	90	90	80	88	90

* Transmitter ceased functioning.
** Seal no longer present at Drakes Estero.
*** Condition unknown.

Table 8b. Percentage of days per month individual radio-tagged seals were present at Drakes Estero, 1986-87.

	Month											
Seal	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Females:												
119	78	*										
137	67	23	**									
160	100	100	96	96	93	*						
246	100	100	100	23	33	0	*					
362	100	94	96	92	93	90	86	82	79			
467	100	97	73	65	60	79	86	100	50	83	100	*
482	100	90	92	69	67	59	61	*				
529	100	84	89	77	60	72	71	61	*			
616	33	36	31	57	33	48	50	*				
645	78	77	46	50	40	62	57	*				
024									83	60	100	94
046									61	58	*	
090									52	47	93	88
116									39	67	97	88
432									35	50	50	35
622									61	53	93	94
821									62	67	93	90
844									78	67	93	100
856									87	87	97	100
874									83	63	97	90
Males:												
198	100	94	92	96	83	93	96	*				
267	100	77	96	100	100	97	96	86	*			
342	100	48	46	54	20	62	64	*				
419	100	86	79	77	83	86	*					
444	100	94	89	100	87	83	68	50	71	*		
504	100	94	89	77	40	62	61	39	58	93	95	*
590	78	39	50	73	53	66	75	11	25	10	*	
060									78	0	86	66
893									100	100	100	100
Immatures:												
224	11	52	58	65	50	66	64	36	29	*		
281	44	42	8	***								
305	100	58	**									
325	100	19	19	***								
540	33	23	8	27	33	39	*					

* Transmitter ceased functioning.
** Seal no longer present at Drakes Estero.
*** Condition unknown

Table 9. Average percentage of days per month seals were hauled out at Drakes Estero by sex and age; $\bar{x}$ is the average, SE is the standard error, and n is the number of seals monitored.

	Month											
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Measurement period 1985-86												
Total Adults:												
$\bar{x}$		87	84	91	77	82	75	63	68			
SE		3.9	7.3	5.4	6.2	5.2	2.0	9.0	6.6			
n		10	9	8	8	8	6	5	5			
Females:												
$\bar{x}$		81	70	91	63	72	72	61	69			
SE		2.9	4.0	8.6	2.9	2.7	2.3	16.3	11.7			
n		4	4	3	3	3	3	2	2			
Males:												
$\bar{x}$		91	92	91	85	88	78	64	68			
SE		0.0	0.1	0.1	0.0	0.0	0.0	0.2	0.1			
n		6	5	5	5	5	3	3	3			
Measurement period 1986-87												
Total Adults:												
$\bar{x}$	90	81	78	74	63	74	73	61	67	63	92	86
SE	4.6	5.6	5.9	5.6	6.7	4.0	4.0	8.0	5.0	6.7	3.4	5.8
n	17	15	15	15	15	14	12	7	18	17	14	11
Females:												
$\bar{x}$	86	85	78	66	60	70	69	81	64	64	91	87
SE	7.1	7.5	9.2	8.3	8.5	5.6	5.4	6.9	5.2	12.6	4.7	6.6
n	10	9	8	8	8	7	6	3	12	11	10	9
Males:												
$\bar{x}$	97	76	77	82	67	78	77	47	73	62	94	83
SE	3.2	8.8	6.5	11.0	11.1	5.6	6.4	15.5	11.3	18.7	2.9	17.0
n	7	7	7	7	7	7	6	4	6	6	4	2
Immatures:												
$\bar{x}$	58	39	23	46	42	53						
SE	18.1	7.7	11.9	19.0	8.5	13.5						
n	5	5	4	2	2	2						

Table 10. Average percentage of radio-tagged seals hauled out per day by month relative to the total number of radio-tagged seals (seals relocated to other haul-out sites are not included); SE is standard error, and n is number of days monitored.

	Month											
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Measurement period 1985-86												
No. Seals		14	8	8	8	8	7	5	5	--	--	--
$\bar{x}$		86	86	88	81	74	65	63	70	--	--	--
SE		3.4	2.8	0.0	4.3	5.2	3.9	5.6	8.0	--	--	--
n		30	5	7	21	30	29	24	21	--	--	--
Measurement period 1986-87												
No. Seals	22	21	20	17	17	17	16	10	19	17	14	11
$\bar{x}$	83	67	64	70	61	69	64	52	64	68	92	87
SE	1.6	2.1	2.0	1.5	2.6	3.3	2.8	3.2	1.7	2.9	2.4	1.9
n	9	31	26	26	30	29	28	26	23	20	27	20

Table 11. Number of consecutive days seals were absent from Drakes Estero, excluding seals that relocated to other sites, for the years 1985-86, and 1986-87. Insufficient data were available for September and October, 1985; n is the number of seals monitored per month, Seal is the number of seals that took trips each month, $\bar{x}$ is mean, and SE is standard error.

	Month											
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Measurement period 1985-86												
n	--	7	--	--	7	7	5	4	3	--	--	--
Seal	--	6	--	--	4	6	4	3	3	--	--	--
$\bar{x}$ days/trip	--	1.5	--	--	1.4	1.9	1.0	1.8	1.4	--	--	--
SE	--	0.3	--	--	0.3	0.6	0.0	0.5	0.2	--	--	--
mode	--	1	--	--	1	1	1	1	1	--	--	--
range	--	1-3	--	--	1-4	1-10	1	1-4	1-2	--	--	--
$\bar{x}$ trips/mo	--	1.7	--	--	2.3	2.7	3.3	4.3	2.7	--	--	--
SE	--	0.5	--	--	0.6	0.6	0.9	1.2	0.9	--	--	--
range	--	1-4	--	--	1-4	1-5	1-5	1-6	1-4	--	--	--
Measurement period 1986-87												
n	21	20	17	16	15	15	13	7	15	13	11	10
Seal	7	17	16	14	14	11	13	6	11	11	3	4
$\bar{x}$ days/trip	1.8	2.5	2.2	2.1	2.7	1.4	1.7	2.0	2.1	1.4	1.0	2.0
SE	0.3	0.3	0.3	0.3	0.3	0.1	0.1	0.3	0.5	0.1	0.0	0.5
mode	1	1	1	1	1	1	1	1	1	1	1	1
range	1-5	1-7	1-12	1-17	1-15	1-13	1-4	1-7	1-7	1-3	1	1-4
$\bar{x}$ trips/mo	1.9	3.5	3.8	4.1	4.7	4.8	4.5	5.3	2.6	2.7	1.0	1.8
SE	0.3	0.5	0.7	0.5	0.6	0.9	0.5	0.9	0.4	0.4	0.0	0.8
range	1-3	1-9	1-8	1-7	1-9	1-11	1-7	1-8	1-5	1-5	1	1-4

Table 12. Combined data on number of consecutive days seals were absent from Drakes Estero, excluding seals that relocated to other sites, 1985-87; **n** is the number of seals monitored per month, **Seal** is the number of seals that took trips each month, $\bar{x}$ is average, and **SE** is standard error.

	Month					
	Aug	Nov	Dec	Jan	Feb	Mar
n	22	20	22	17	10	19
Seal	18	16	16	16	8	14
$\bar{x}$ days/trip	2.0	2.5	1.5	1.5	1.8	1.7
SE	0.2	0.3	0.2	0.1	0.2	0.4
mode	1	1	1	1	1	1
range	1-3	1-15	1-13	1-4	1-7	1-7
$\bar{x}$ trips/mo	2.7	4.0	3.9	4.3	5.2	2.8
SE	0.5	0.6	0.7	0.5	0.7	0.4
range	1-9	1-9	1-11	1-7	1-8	1-5
Days absent ($\bar{x}$ days/trip times $\bar{x}$ trips/month):						
	5.4	10.0	5.9	6.3	9.2	4.9

Seals spent more time away from Drakes Estero on foraging trips during the months from September through February, and this trend was most pronounced in November and February (Table 12). For all months except May, June, and July, more than 50% of the seals left the estero at least once. Immature seals appeared to take more trips ($x = 4.3$; 22 of 60 trips) than adults in August; however, the average length of trip was the same as for adults. When seals were absent for more than three days, they often hauled out at PRH.

When seals were present in Drakes Estero, the haul-out pattern was strongly diurnal and most seals hauled out during mid-day regardless of season. The percentage of tagged seals hauled out over a 24-hr period was largest between 0600 and 1600 hr for all months; the percentages hauled per hour, however, varied between months (Figures 5 through 8). Greater than 50% of radio-tagged seals hauled out between 0600 and 1400 hr in May and June 1987. Tide level also influenced the diurnal haul-out pattern. The sand bar where most seals hauled out within Drakes Estero was awash on average 5.1 hrs per 24-hr day ($SD = 1.4$, $n = 13$) and was submerged during tide levels greater than 1.4 m above the mean low except when winter storms would push water levels higher. In the event that sand bars were underwater, seals often hauled out at Limantour Spit which was exposed at all tide levels.

On average, seals hauled out for a total of 7 hrs per day during winter months in both years (Tables 13a and 13b). Seals hauled out for an average of 9 hrs per day during the breeding season (April, May, June) and 11 hrs per day in July during the molt (Table 13b). Seals hauled out for significantly more hours per day during the breeding season than the nonbreeding season ($p = 0.002$, $n = 13$, Wilcoxon matched pairs signed-rank test;comparing March and May). The averages were not significantly different between August and December in 1985 ($p = 0.88$; Wilcoxon matched-pairs sign-ranks test). Males appeared to be on shore for more hours per day than females in 1985, but the sample size was small. In 1986, males also appeared to haul-out for more hours per day; however, the difference was not significant ($p = 0.12$, Mann-Whitney U test, for October). Small sample size restricted testing differences between adults and immatures; however, there appeared to be no difference between the months August and September (Table 13b).

Seals would often come onshore more than once per day. The average number of haul-out bouts was around 1.5 per day for all months except May (Table 14). Seals averaged 2.4 haul-out-bouts per day

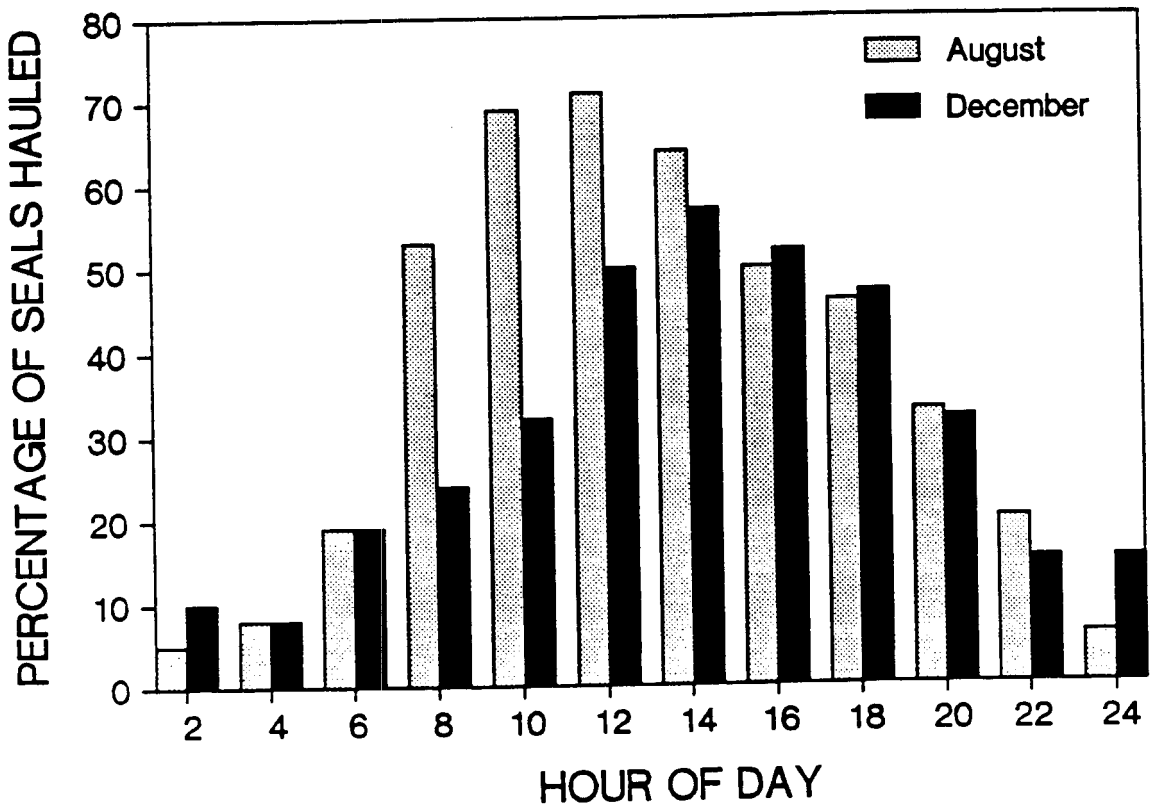

Figure 5. Percentage of radio-tagged seals hauled out by hour of day for August and December, 1985.

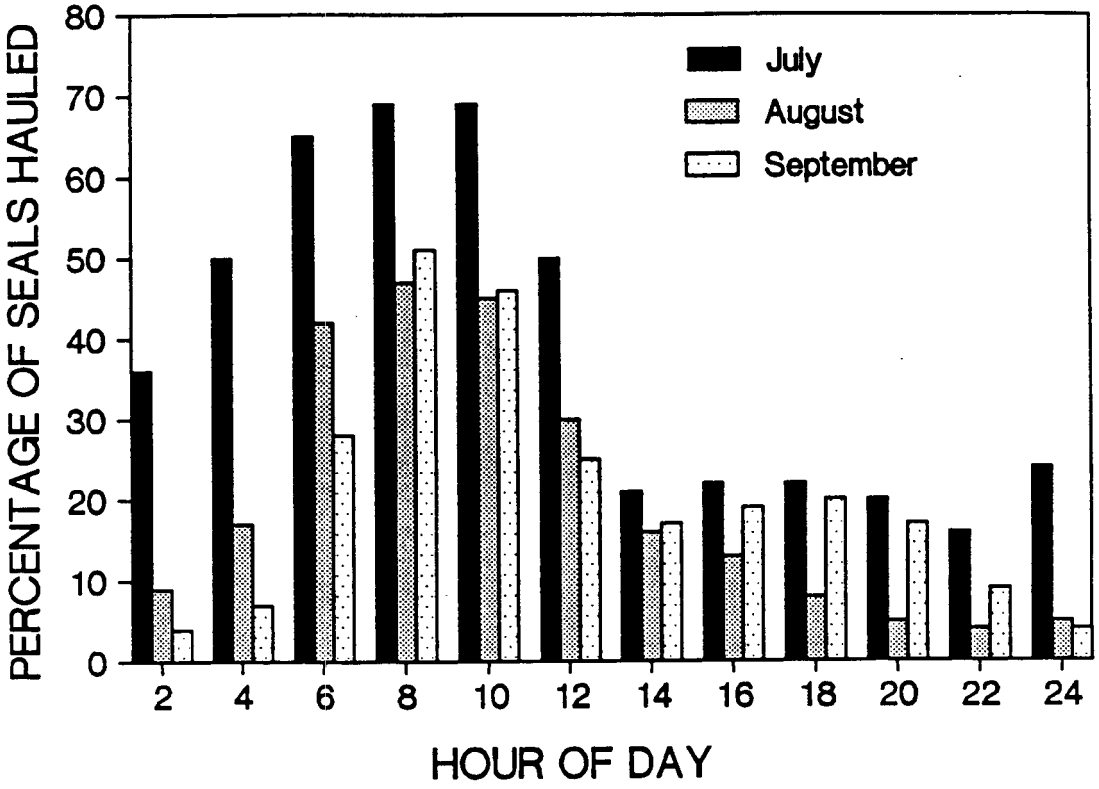

Figure 6. Percentage of radio-tagged seals hauled out by hour of day for summer months, 1986.

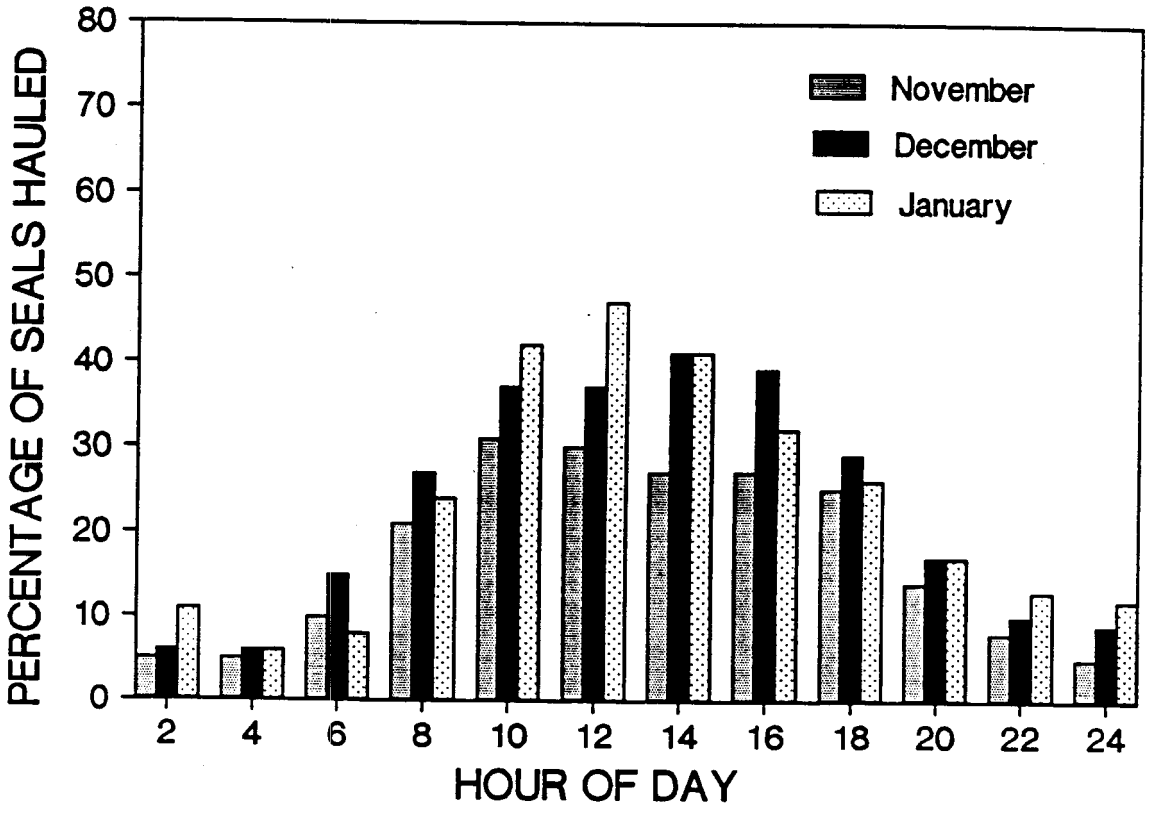

Figure 7. Percentage of radio-tagged seals hauled out by hour of day for winter months, 1986-87.

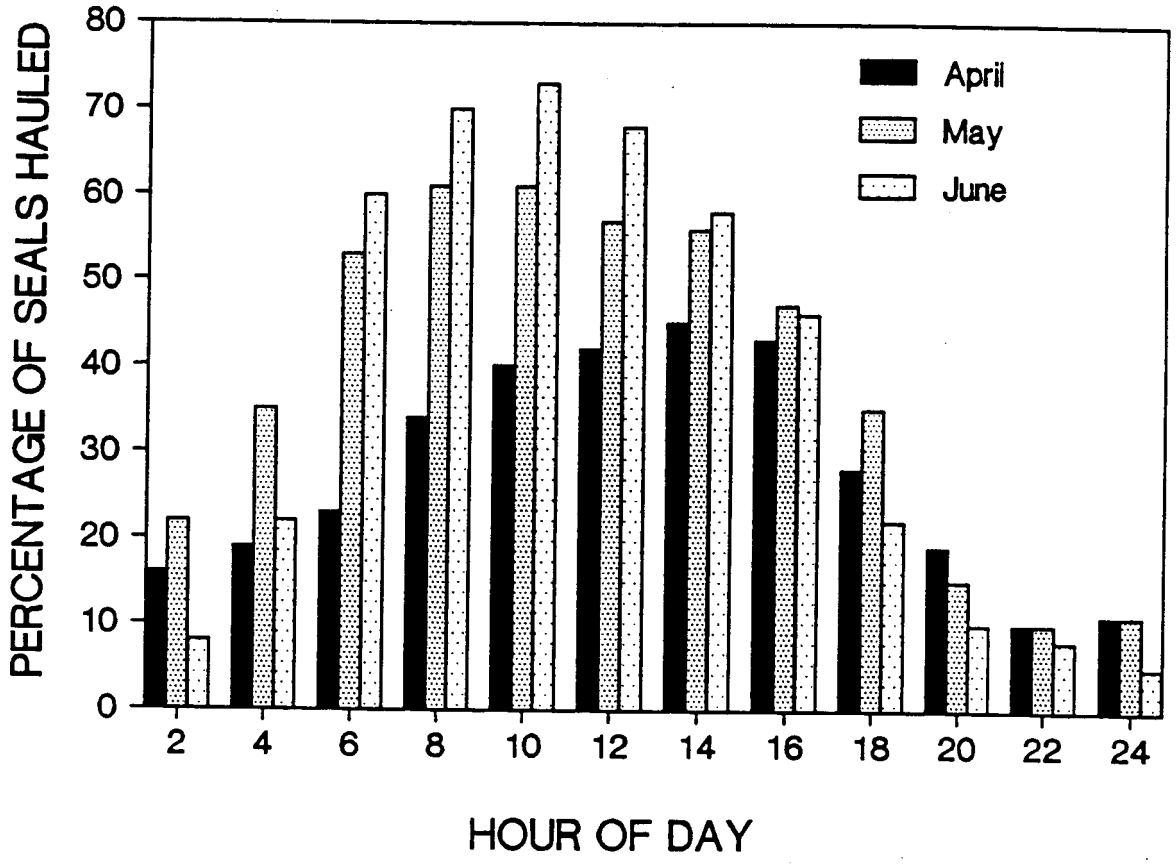

Figure 8. Percentage of radio-tagged seals hauled out by hour of day for spring months, 1987.

Table 13a. Average number of hours per day seals were hauled out at Drakes Estero by month and by sex and age class, 1985-86; $\bar{x}$ is the average, SE is standard error, and n is number of seals monitored.

	Month		
	August	December	March
All seals:			
$\bar{x}$	7.5	7.3	6.9
SE	0.2	0.3	0.3
n	10	8	5
Females:			
$\bar{x}$	7.3	6.0	6.6
SE	0.4	0.5	0.4
n	4	3	2
Males:			
$\bar{x}$	7.6	7.9	7.2
SE	0.3	0.3	0.4
n	6	5	3

Table 13b. Average number of hours per day seals were hauled out at Drakes Estero by month and by sex and age class, 1986-87; $\bar{x}$ is the average, SE is standard error, and n is number of seals monitored.

	Month											
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
All seals:												
$\bar{x}$	11.2	6.9	6.8	7.2	6.6	7.2	7.4	7.9	7.5	8.9	9.7	9.5
SE	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.6	0.4	0.4	0.6	0.4
n	21	14	14	14	14	13	13	7	18	15	14	11
Adult females:												
$\bar{x}$	10.4	6.5	6.5	6.4	6.1	6.4	6.6	6.8	7.1	8.7	9.9	9.5
SE	0.6	0.7	0.7	0.5	0.7	0.5	0.7	0.2	0.3	0.4	0.7	0.4
n	11	7	7	7	7	6	6	4	12	11	10	9
Adult males:												
$\bar{x}$	12.5	7.3	7.2	8.0	7.1	7.9	8.0	9.7	8.5	9.7	9.2	9.5
SE	0.6	0.7	0.5	0.5	0.4	0.4	0.4	0.5	0.8	1.1	1.5	1.0
n	5	7	7	7	7	7	7	3	6	4	4	2
Immatures:												
$\bar{x}$	10.5	6.8										
SE	0.8	0.3										
n	5	5										

Table 14. Length and number of haul-out bouts by month ; $\bar{x}$ is average, SE is standard error, and n is number of seals monitored.

	Month						
	Jul	Aug	Dec	Mar	Apr	May	Jun
			Measurement period 1985-86				
n		8	8	6			
$\bar{x}$/length		4.8	5.6	6.1			
SE		0.2	0.2	0.4			
range		1-34	1-17	1-13			
$\bar{x}$/number		1.6	1.4	1.2			
SE		0.1	0.1	0.1			
range		1-4	1-4	1-4			
			Measurement period 1986-87				
n	21	19	16	19	15	14	11
$\bar{x}$/length	7.9	5.5	5.7	5.7	5.25	4.5	5.8
SE	0.4	0.2	0.3	0.2	0.2	0.2	0.3
range	1-37	1-27	1-20	1-17	1-34	1-19	1-21
$\bar{x}$/number	1.3	1.5	1.4	1.4	1.7	2.2	1.6
SE	0.0	0.1	0.0	0.1	0.1	0.1	0.1
range	1-3	1-4	1-3	1-5	1-6	1-6	1-4

(n = 139, SE = 0.06,) between the median birthing and the median weaning dates, but only 1.5 per day (n = 142, SE = 0.06) in April two weeks prior to the median birthing date.

Haul-out bouts averaged around 5 hrs for all months except July, when they averaged 8 hrs (Table 14). The length of a haul-out bout was not significantly different between August and December 1985 ($p = 0.84$; Wilcoxon matched-pairs sign-rank test) but did differ between July and August 1986 ($p = 0.0002$; Wilcoxon matched-pairs sign-rank test). Twenty percent of all haul-out bouts were 2 hrs or less; over 90% were 12 hours or less, regardless of month. Maximum length of haul-out bout occurred during the molt (37 hrs) and during the early phase of the birthing season (34 hrs). There did not appear to be a difference in behavior between age classes for the months July and August or between sexes for any month.

Though seals initiated haul-out bouts at all hours of the day, most initiations occurred during daylight hours and before 1200 hr during both years (Figures 9, 10, 11). In April, May and July, however, many initiations occurred between 0100 and 0400 hr. The difference may be explained in part by females hauling out to nurse pups; however, males also initiated haul-outs then. In May, the cumulative percentage for female initiations between 0100 and 0400 hr was 27% and for males was 21%. In June, though, the cumulative percentage for female initiations declined to 14% between 0100 and 0400 hr but for males remained about the same (22%).

The length of haul-out bout was affected by the time of initiation for all months tested except December 1985. Seals that first hauled out between 0000 and 1200 hr were on shore longer than seals that initiated a haul-out bout between 1200 and 2400 hr (July: $X^2 = 80.9$, $df = 9$, $p < 0.001$; August: $X^2 = 59.3$, $df = 9$, $p < 0.001$; December: $X^2 = 69.8$, $df = 9$, $p < 0.001$; May: $X^2 = 80.2$, $df = 9$, $p < 0.001$: June: $X^2 = 58.4$, $df = 9$, $p < 0.001$). For all months, more than 80% of the haul-out bouts lasting for more than 12 hr occurred between 0100 and 1200 hr and less than 10% occurred after 1700 hr.

On June 1 and 2, 1987, I monitored six radio-tagged seals (4 females, 2 males) for 24 hrs beginning at 0900 hr, locating and recording activities every 15 min. The average number of hours hauled was 9.4 (SE = 2.6); however, the range was from 1.3 to 18.5 hr. Three seals hauled out two times during this 24 hr period, two three times, and one once. A seal that hauled for 18.5 hr was the only one to haul-out at night, and coincidentally had just returned from hauling out for several days at PRH. Because seals could haul-out

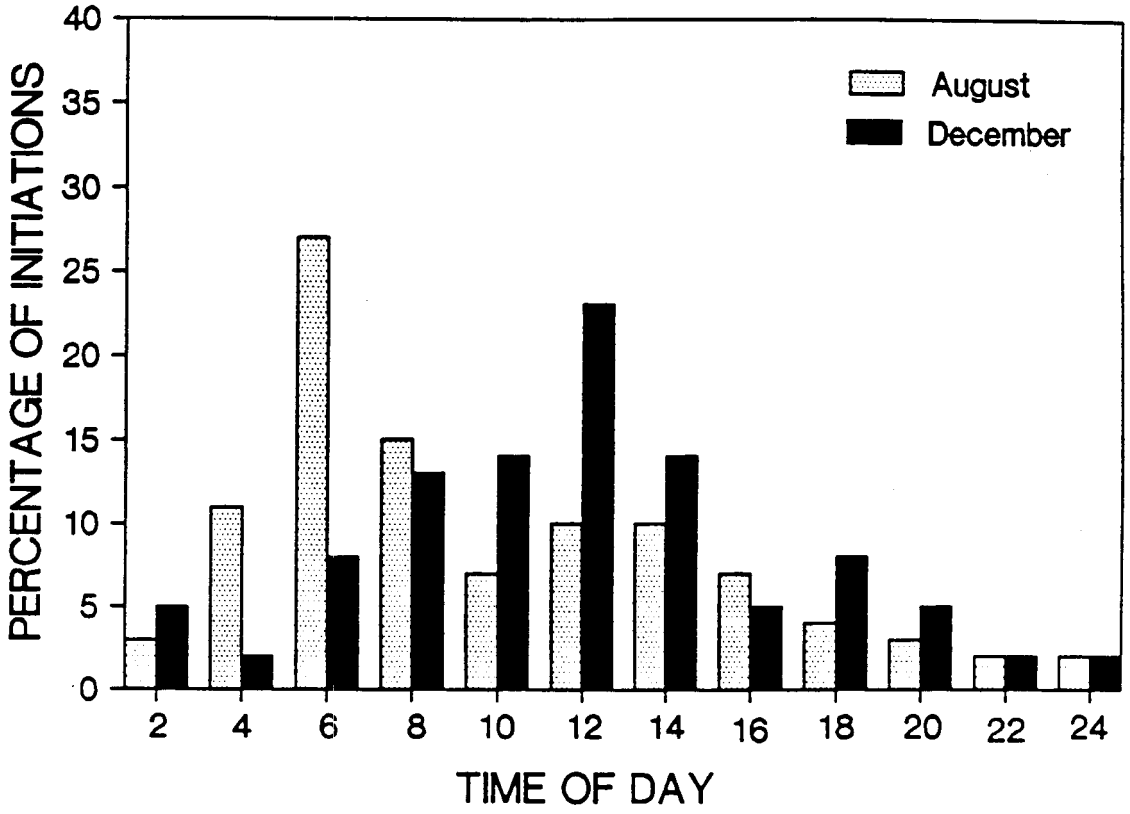

Figure 9. Initiation of haul-out bouts by hour of day for the months August and December, 1985.

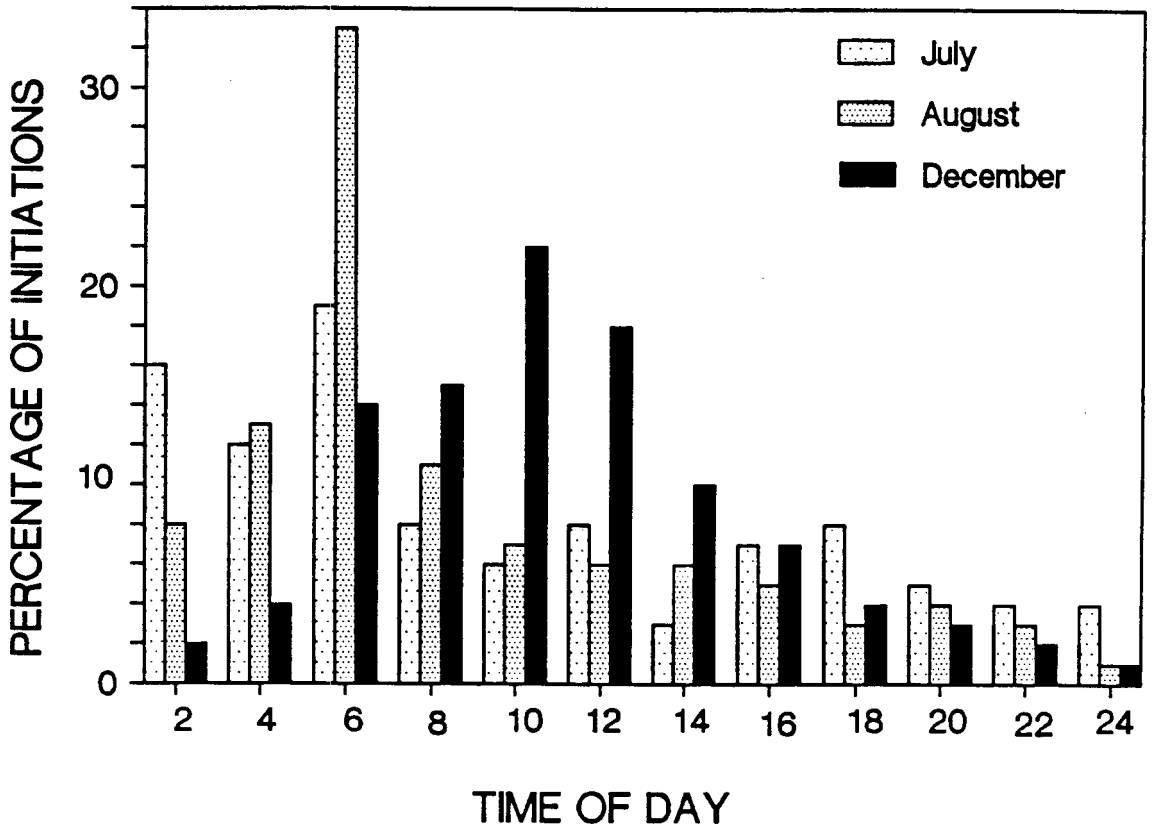

Figure 10. Initiation of haul-out bouts by hour of day for July, August, and December, 1986.

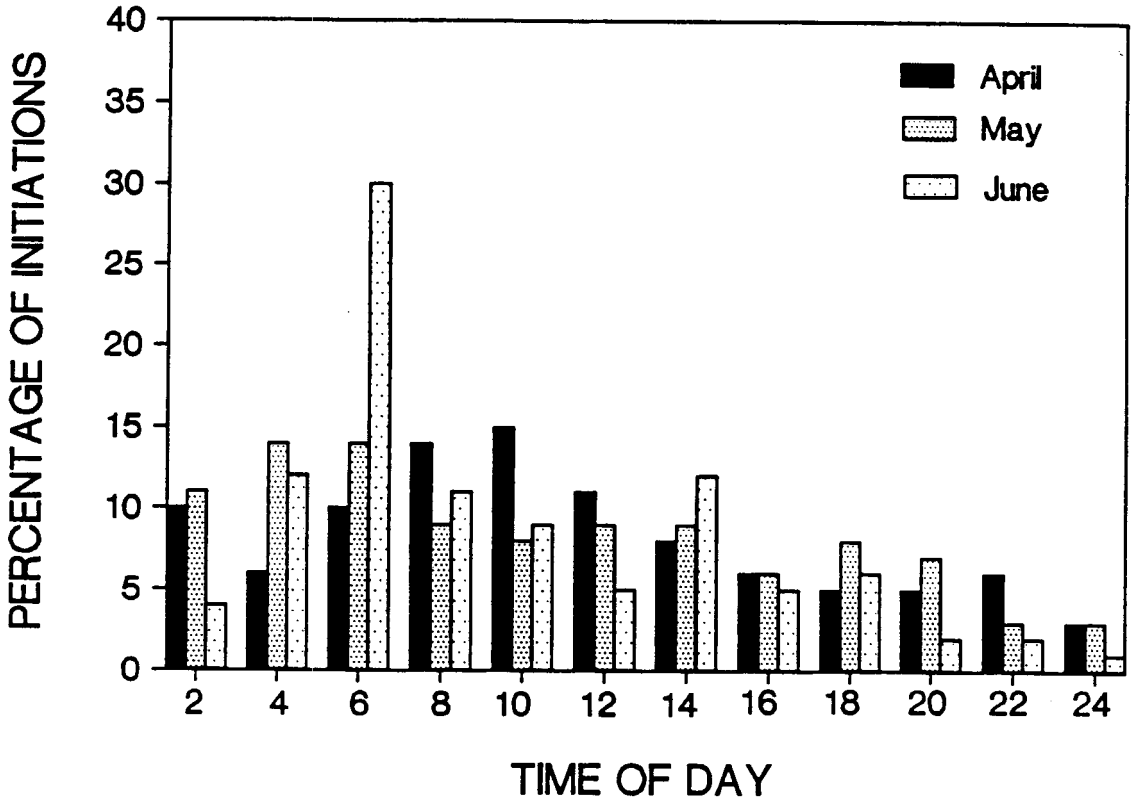

Figure 11. Initiation of haul-out bouts by hour of day for spring months, 1987.

at Limantour Spit at all tide levels, tide did not appear to influence the haul-out pattern. When sand bars in Drakes Estero were awash with rising tides, seals moved to Limantour Spit.

During the 24-hr period, all but one seal were located continuously. Four seals traveled both north and south of the estero but stayed within an 8 km radius, one seal never left the estero, and one seal traveled north out of range for 9.5 hrs. All seals spent a considerable amount of time in the channel of the estero or near the mouth, presumably feeding. Sunrise was at 0600 hr on June 2, and two tagged seals promptly hauled out along with several non-tagged seals. By 0800 hr, two more tagged seals hauled out, and the seal that had remained out all night retreated to the water. At the time of my departure (0900 hr), five seals were in identical locations as recorded at 0900 hr the previous day; four were hauled out at Limantour Spit and two were in the water at the mouth of the estero.

Estimates of Abundance

Direct counts of seals at Drakes Estero indicated that monthly maxima occurred in May, June, and July both in 1986 and 1987 (Figure 12). These numbers, though, are substantially lower than estimates derived from mark-recapture data. From a sample of 16 days between March 16 and April 15, an estimated 949 seals (95% confidence interval: LL 692 and UL 1206) used Drakes Estero (Figure 13). On sample day 4 (March 24), 30 marked animals were hauled out among a herd of 409 seals (18 adults and 12 immatures). On sample day 6 (March 26), the first pup was observed at Drakes Estero. From that date on, the assumption of a closed population was violated and estimates and confidence intervals fluctuated considerably. A population estimate for the same day derived from the expected maximum proportion of seals hauled out mid-day for March (0.455) was 899 (95% confidence interval: LL 769 and UL 1029).

Breeding Season

The first pup was observed at Drakes Estero during the last week of March during both 1986 and 1987. Maximal pup counts were made on April 30 in 1986 (255), and May 6 in 1987 (224). The proportion of pups to total number of seals censused was 0.30 and 0.32, respectively. By the end of May, it became increasingly difficult to distinguish pups from immature seals and few mother-pup pairs were recorded.

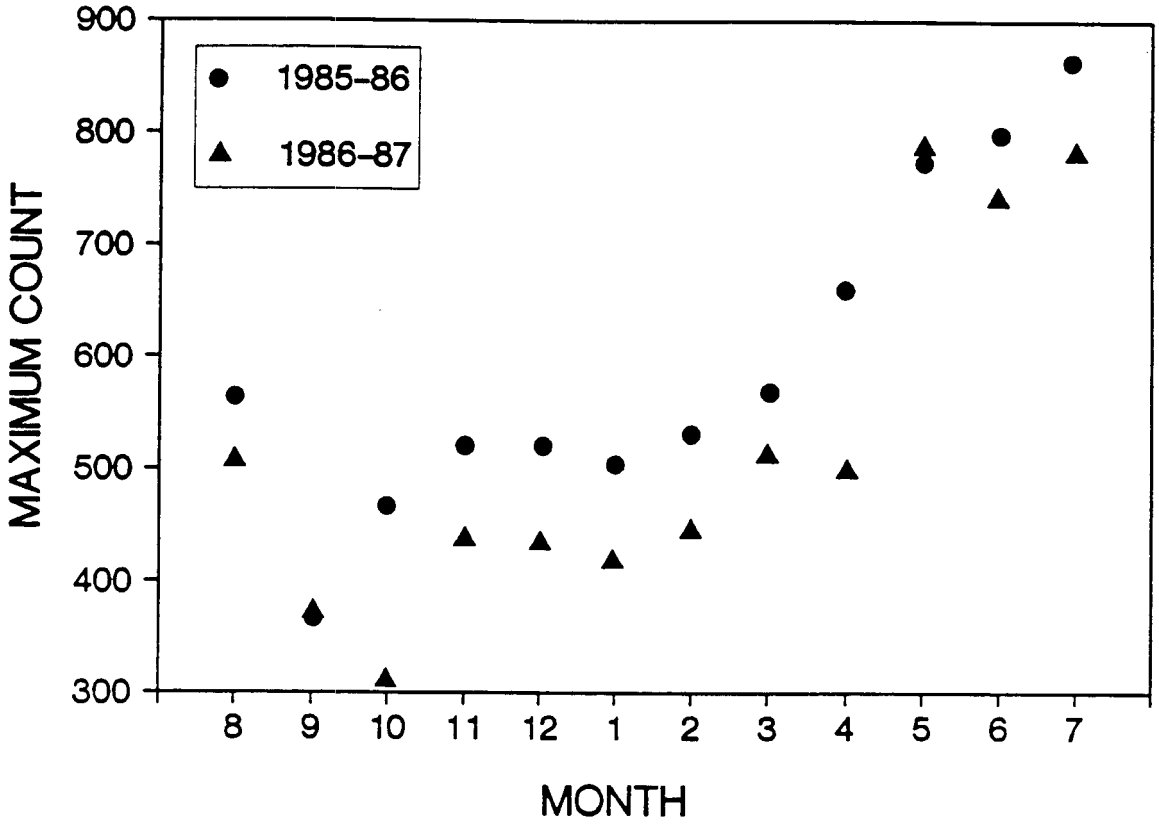

Figure 12. Monthly maximum number of seals counted at Drakes Estero between August 1985 and July 1987.

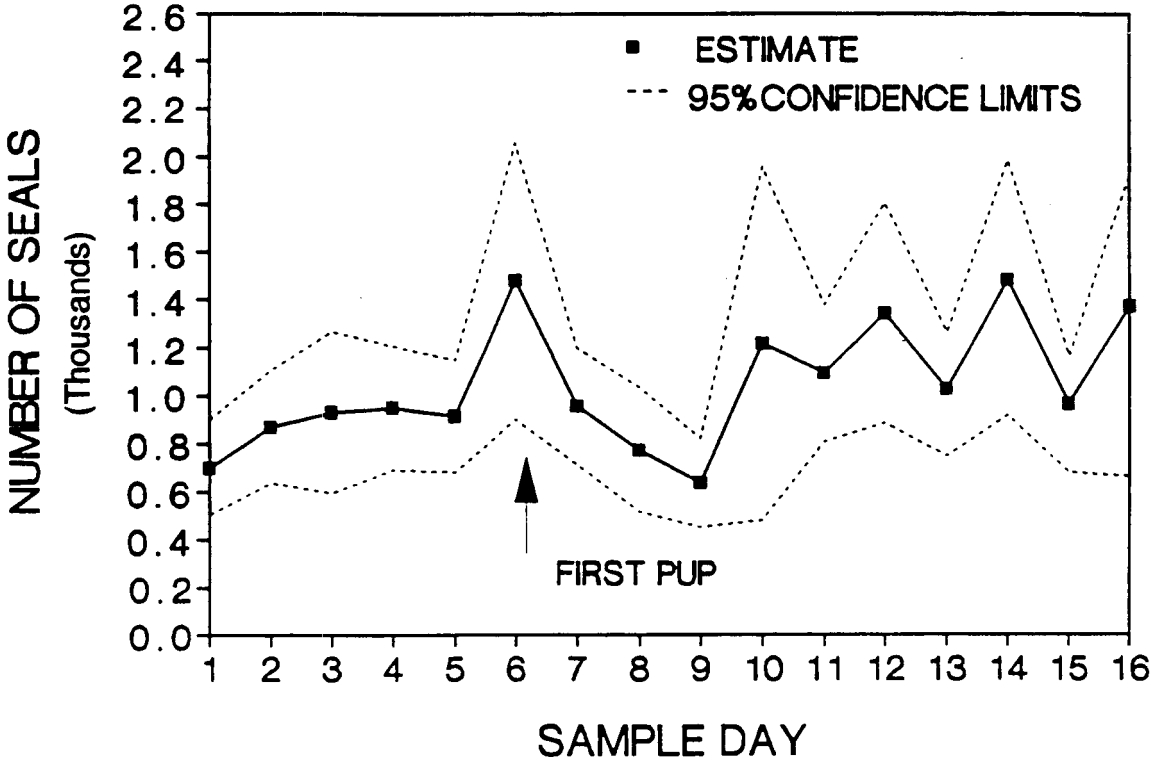

Figure 13. Estimates of absolute abundance of seals at Drakes Estero for March 1987.

Twenty of 28 adult, female seals (71%) tagged in March of 1987 were seen at least once with a pup. In addition, five of ten female seals (50%) tagged in July 1986, were seen with pups. Fifteen tagged seals were closely monitored throughout this season. The median pupping date for these females was April 23, and by April 28, 80% had given birth (range: April 16 to April 30). The median weaning date was May 25, and by May 28, 80% of the pups had been weaned (range: May 14 to May 30). The average number of days that females were seen with pups was 31 (SE = 0.6, n = 15; Table 15). Of the radio-tagged seals, only one (RT821) was observed separated from a pup; 24 days after giving birth, she was seen without pup and searching throughout the estero for two hours. On two subsequent days, she was again observed searching intermittently. All other females were seen in constant attendance with pups until the date of weaning. Weaning appeared to be abrupt. Characteristically, females departed for a minimum of one day from the estero on the day of weaning, and one female (RT432) relocated to PRH.

For the first two weeks after giving birth, females stayed exclusively within the estero, but after that time, they began to depart for an increasing number of hours during the night. Whether pups accompanied females on these excursions is not known. Spatial distribution of seals during the breeding season also changed with increasing use of several additional sites (Figure 2). Twenty-five percent of observations were of radio-tagged seals hauled out at sand bars up the estero, 33.6% at sand bar A1, 28.7% at sand bar A, and 13.4% at Limantour Spit (n = 261 observations). During the winter, though, 91.7% of the observations were of seals at sand bar A and only 8.3% at Limantour (n = 109 observations).

Though spatial segregation by sex was not absolute, the difference between spatial distribution of females with pups and males was significant ($X^2 = 33.55$, df = 3, $p < 0.0001$; Table 16). Females with pups tended to haul-out on sand bar A1 and to avoid Limantour Spit, which males tended to haul-out. During the winter, however, gender differences were not significant ($X^2 = 2.86$, df = 1, $p > 0.05$). Seven of ten females with pups also were remarkably site specific, hauling out at the same location on a subsite during more than 50% of the ground surveys conducted between April 29 and May 27. Female site tenacity was also demonstrated by a radio-tagged female (RT821) observed searching for her pup one day. Over a two-hour period, she investigated pups at two other subsites but returned each time to the locus on sand bar A where she had been seen with pup five times previously. Only one of three male seals expressed a preference

Table 15. Birthing and weaning dates of pregnant females radio- and flipper-tagged in July 1986 and March 1987.

Seal	Estimated Birthday	Estimated Wean Day	Days w/Pup
Radio-tagged			
024	4/28	5/26	30
090	4/30	5/28	29
116	4/28	5/28	31
432	4/22	5/18	27
467	4/27	5/30	39
821	4/26	5/19	24
844	4/23	5/22	30
856	4/21	5/23	33
874	4/23	5/25	33
Flipper-tagged			
RT046*	4/22	5/27	33
T365	4/16	5/14	29
T465	4/19	5/21	33
T454	4/28	5/25	28
RT645*	4/30	5/30	31

* Radio tag had ceased functioning.

Table 16. Spatial distribution of radio-tagged seals hauled out within Drakes Estero by sex and by season, 1986-87. Locations were identified during ground surveys. Number given is the number of days that individual radio-tagged seals were located at each site. A, A1, and U refer to specific sandbars, and L refers to Limantour Spit (see Figure 2).

	Breeding Location				Winter Location			
Sex	A	A1	L	U	A	A1	L	U
Female	55	76	14	52	48	--	3	--
Male	20	9	21	14	52	--	6	--
	$X^2 = 33.55$				$X^2 = 2.86$			
	$p < 0.0001$				$p > 0.05$			

for a location on a haul-out site during the breeding season; however, during the nonbreeding season several male and female seals showed a preference for a particular spot on a haul-out site, and one seal (RT821) continued using the same spot that she had used during the nonbreeding season and the previous breeding season.

During the first two weeks with pup, radio-tagged females hauled out for an average of 13.3 hrs per day (SE = 0.8, n = 10), and for the first couple of days after giving birth, females often hauled out for more than 20 hrs. Unexpectedly, males also hauled out for more hours between the median birthing date of April 23 and the median weaning date of May 25 (x = 13.1, S = 2.4, n = 3). For two weeks after pups were weaned, the average total number of hours hauled was 8.0 (SE = 0.7, n = 8) for females (from estimated weaning date to 14 d) and 6.2 (SE = 0.9, n = 4) for males (for period May 12 to May 27). Since mating occurs in the water, it is not surprising that males would spend less time hauled out during the weaning period; however, the difference between the sexes was not significant (p = 0.27, n = 12, Fisher's Exact Test).

DISCUSSION

The decline in seal numbers during winter months at Drakes Estero is related to both seasonal emigration and a reduction in the proportion of days that resident seals haul-out. Movements of greater than 25 km occurred more often in 1985 than in 1986, and instead, seals relocated for brief periods at Point Reyes Headland. The observed differences between years may be attributed to different individual preferences, to greater local food availability, or to some unknown factor. Similar to results in Orkney, Scotland (Thompson 1987), in Alaska (Pitcher and McAllister 1981), on San Nicolas Island in California (Yochem et al. 1987), and in Oregon (Harvey 1987), seals expressed a high level of site fidelity, using no more than three sites. All movements were to well established seal haul-out sites in estuaries, at river mouths, and at coastal sites (Miller 1983, Hanan et al. 1987). Use of more than three sites may have occurred and was not identified, if seals that relocated outside of the Point Reyes Peninsula visited other sites between aerial flights.

In 1985, the majority of long-range movements occurred just prior to the breeding season and after the molt, but in 1986, they occurred during all months except the height of the breeding season. At the

Klamath River, California, Herder (1986) observed that seals traveled significantly more times during the fall and winter and exhibited the greatest local movement during the period April to June. In Orkney, Scotland, Thompson (1987) also found that harbor seals (Phoca vitulina vitulina) made longer trips outside of the study area during the nonbreeding season. In my study more local movement occurred prior to the median birthing date and after the median weaning date, but virtually no movement occurred between those dates. Two of 12 seals (one adult male and one adult female) radio-tagged in March 1987 relocated to other haul-out sites prior to the breeding season but both returned within a few days of the median birthing date. Both Thompson (1987) and Beach et al. (1985) also noted daily attendance during the breeding season.

Herder (1986) and Pitcher and McAllister (1981) observed that immature harbor seals traveled greater distances than adult animals, but in my study, maximal distances were recorded for adults. Immature seals also did not appear to engage in exploratory migration (Baker 1978); however, our sample size was small. One first-year seal rarely departed from Drakes Estero and another relocated intermittently at PRH; one immature traveled to Duxbury Reef and Tomales Bay. Adult females made more long range movements than males in 1985, as was noted by Herder (1986); however, this tendency was not repeated in 1986. Harvey (1987) found no sexual difference in the distance moved by harbor seals in Oregon.

The observed movements indicate that Drakes Estero is an important breeding area for seals ranging as far south as Monterey Bay and north to the Klamath River, an overall distance of 690 km. Movements also indicate that there is substantial social mixing among harbor seal colonies both locally and at distances greater than 25 km; however, mixing did not appear to take place during the breeding season implying that genetic mixing may not be occurring. Brown and Mate (1983) and Herder (1986) also recorded movements of seals between sites in Oregon and Washington, and between colonies in the Klamath River and Alsea Bay, Oregon, respectively. Stewart and Yochem (1983), though, found that inter-island movement of seals on the southern Channel Islands was the exception but that considerable exchange occurred between sites within an island.

Maximum distances traveled by seals in this study were greater than those recorded by Herder (1986) of 300 km from the Klamath River to Alsea Bay, by Boulva and McLaren (1979) of 190 km from Sable Island to Nova Scotia, Canada, or by Beach et al. (1985) of 300 km from the Columbia River to Coos

Bay, Oregon. One seal, though, tagged in Netarts Bay, Oregon, traveled 550 km south to Humboldt Bay, California (Brown and Mate 1983).

In general, movements appeared to be motivated by a group preference for breeding and molting at Drakes Estero, and by an individual preference for feeding areas. Migrant seals were highly individual in distance of movement and final destination. Individual preference may be influenced by past experience and current food availability. Seals do not appear to be responding to a single prey item as was a suggested explanation of winter movements of seals in northern California, Oregon and Washington (Brown and Mate 1983, Beach et al. 1985, Herder 1986, Harvey 1987), but instead, individuals may be expressing a preference for location based on past experience, including foraging success. Fourteen percent of seals radio-tagged over two years, though, visited Tomales Bay during winter when Pacific herring (Clupea harengus) spawn (Spratt 1981). Herder (1986) also observed seals traveling to areas where herring were spawning in Crescent City Harbor, California. The fact that one seal (RT504) traveled great distances (and presumably expended considerable energy) but promptly returned, suggests that past experience may have motivated the initial movement, but that food availability then influenced where it subsequently spent the greater proportion of its time.

Seals that remained at Drakes Estero were hauled out on more days and in higher proportions of total animals during the breeding season (April and May) and the molt (June and July) than during other months of the year. Peak abundance during these periods have been documented for harbor seals in other areas (Stewart and Yochem 1983, Beach et al. 1985, Harvey 1987, Thompson 1987) and for other phocid seals (e.g. northern elephant seals Mirounga angustirostris (Le Boeuf and Panken 1977), grey seals Halichoerus grypus (Bonner 1981), and Weddell seals Leptonychotes weddelli (Thomas and DeMaster 1983).

The average percentage of total radio-tagged seals hauled out on any given day per month in this study was substantially higher than figures derived by most other researchers studying harbor seals with radio telemetry. Harvey (1987) estimated similar figures for seals radio-tagged in Oregon, hauled out in June (82%) and July (100%) but his percentages for all other months were less than 55%. Stewart and Yochem (1983) calculated that seals hauled out on San Nicolas Island, California, an average of 58% of the days in June and 41% in July. For seals in the Klamath River, Herder (1986) computed an average of 56% of days

in April and 65% in May, and for seals on Tugidak Island, Alaska, Pitcher and McAllister (1981) calculated seals were hauled out on an average of 50% of the days in June.

Dissimilarity between studies is partly explained by differences in sampling techniques and by months chosen for analysis. Harvey (1987) and Yochem et al. (1987) included nonresidents in their analysis, whereas Pitcher and McAllister (1981) eliminated nonresidents. Harvey (1987) argued that by eliminating nonresidents the data may be biased toward resident seals that may rest on shore for longer periods; however, I believe that if the location of nonresidents can be ascertained, then more accurate assessments of time spent ashore for seals in the immediate area can be obtained.

As did Yochem et al. (1987), I calculated the proportion of tagged seals onshore at intervals over 24-hr periods; however, their percentages (11-19%) were still lower than those for Drakes Estero (4-41%) during winter. The difference may be attributed to the larger number of immature animals tagged on San Miguel Island versus the larger number of adult animals tagged in this study (Stewart and Yochem 1983). The percentage of days per month that immature seals were hauled out at Drakes Estero was similar to figures derived by Stewart and Yochem (1983).

The decline in seal numbers onshore at Drakes Estero during the winter is partly a function of a reduction in the total number of hours per day that seals are hauled out. For all months except during the breeding and molt periods, seals spent 29% (7 hr) of each day resting onshore. During the molt, the change is explained by an increase in the duration of a haul-out bout; during the breeding season, though, the increase is due to seals hauling out more frequently. The increase in time spent ashore during the molt is likely related to physiological requirements. The proliferation of epidermal cells is greatly enhanced by maintenance of higher skin temperatures as has been demonstrated in vitro (Feltz and Fay 1966).

Stewart and Yochem (1983) observed seals hauled out for a higher proportion of the day (8.9 hr), than I recorded at Drakes Estero (7 hr). Differences may be attributed to more exposure to disturbance from humans at Drakes Estero; though Limantour Spit is exposed at all tide levels, seals there are more frequently subjected to human disturbance (Allen and Huber 1984b). Yochem et al. (1987) determined that time of initiation of a haul-out bout did not influence the length of the bout; however, I found that during all

months except December 1985, seals hauled out for longer periods when bouts were initiated between 0100 and 1200 hr than for other time periods during day or night.

Sexual differences in activity patterns associated with seasonal reproductive requirements were minimal. Harvey (1987) also found no significant difference in attendance patterns of male and female seals in Oregon during the breeding season; however, his sample size for females with pups was small (3). Intuitively, though, one would expect adult males to spend less time ashore during the breeding season since mating primarily occurs in the water (Allen 1985), and post-lactating females spend less time ashore after weaning pups to replenish fat layers. Thompson (1987) observed this pattern in Orkney, Scotland. At Drakes Estero, the percentage of days hauled out in March, April, and June and the total number of hours hauled per day were not significantly different between the sexes. Males appeared to spend slightly more time in the water immediately after the median weaning date than females, thereby maximizing the opportunity of mating with females either departing from or arriving at a haul-out site. Frequently I observed one radio-tagged male (RT894) resting alone at the mouth of a channel to a haul-out site attended by females with pups. Often he would enter the water and remain at the mouth of the channel.

Preference for location of haul-out was the only significant difference in haul-out behavior between males and females. Herd segregation by sex and age class has been documented by others during the breeding season (Knudtson 1977, Thompson 1987, Allen et al. 1988) and during the nonbreeding season (Sullivan 1979, Payne and Schneider 1984). Site fidelity of individuals within a haul-out site, though, has only been documented by Sullivan (1979) and Heinonen (1985) for adult male seals on offshore rocks in Humboldt and San Mateo Counties, respectively. At Drakes Estero, females with pups exhibited within site fidelity. A primary advantage for this behavior would be to maximize the opportunity for reunion of females with pups should they become separated. During the nonbreeding season, several seals, both male and female, also could often be located at the same position on a given haul-out site. Sullivan (1979) believed that adult males were expressing dominance over females and immatures by selecting rocks to haul-out on which were higher in the supralittoral zone; however, there is no such advantage for seals on sand bars where ample haul-out space is available. Instead, seals may simply be habituated to hauling out at the same

location or to hauling out in proximity to other individual seals, as has been reported by Wilson (1978) for seals in Maine.

The strong diurnal haul-out pattern documented at Drakes Estero previously (Allen and Huber 1984), and shown by many other researchers (e.g. Boulva and McLaren 1979, Fancher 1979, and Stewart 1984), was further confirmed by this study. Though seals hauled out at all hours, peak abundance, based on the percentage of tagged seals, occurred from early morning to mid-day. Yochem et al. (1987) found that 7 of 17 seals preferred hauling out at night and suggested that this behavior could influence estimates of abundance. We identified 4 of 21 seals (3 pups and 1 adult female) in August and 4 of 15 (2 pups and 2 adult females) in December that preferred hauling out at night. In May, higher percentages of seals hauled out at night, but in most cases, these were females with pups that also hauled out for extended periods during daylight hours. Thompson (1987) found that seals in Orkney, Scotland, hauled out primarily during the day and foraged at night during the breeding season; during the nonbreeding season, though, time of day ceased to be a factor in the haul-out pattern. Thompson (1987) speculated that this difference was related to seals foraging for longer intervals during the nonbreeding season. I also established that foraging trips were on average more numerous during the nonbreeding season but that seals were strongly diurnal regardless of season.

Harbor seals may chose to forage at night because of a preference for bottom dwelling fishes that migrate to the surface at night. From stomach content analysis, Jones (1981) determined that harbor seals in northern California foraged primarily on bottom dwelling fish. Families of fishes that are active at night (Moyle and Cech 1986) and that are eaten by harbor seals (Jones 1981, Harvey 1988) include Clupeidae, Scorpaenidae, Embiotocidae, Hexagrammidae, and Sciaenidae. Fishes that are active day and night and are eaten by seals include Salmonidae and Pleuronectidae.

Absences of resident seals from Drakes Estero averaged from one to two days suggesting absentees were foraging close by; local movement patterns observed during aerial and ground surveys also support this conclusion. All recorded foraging activities and movements of seals during aerial surveys were limited to within 3.2 km of shore. Though offshore movements of greater than 10 km by harbor seals have been recorded by others (Spaulding 1964, Wahl 1977, Pitcher and McAllister 1981), nearshore feeding may be

more typical of seals at Point Reyes. Immatures in this study appeared to take more trips than adults in August and September, but there are no comparable data for other months. Once female seals had given birth in 1987, seals of both sexes were present daily in Drakes Estero until pups were weaned.

A more reliable schedule for conducting surveys and minimizing biases is possible once seasonal attendance and activity patterns are understood (Ribic et al. 1986). California Department of Fish and Game has been conducting aerial statewide surveys of harbor seals since 1982 to detect trends in distribution and abundance (Hanan et al. 1987). Attention to population trends has been particularly important during recent years because of an increased incidence of marine mammal - fishery interactions resulting in seal mortality and damage to commercial fishing gear (Beach et al. 1985, Diamond et al. 1986, Harvey 1987). Correction factors, therefore, are desirable to adjust direct counts acquired during aerial surveys.

Boveng (1988) discussed several difficulties in correcting counts due to errors of heterogeneity and to violation of the assumption of a closed population. He considered the most serious problem for estimating total abundance from proportion of seals hauled resulted from sex- and age-specific differences. Ribic et al. (1986) defined several variables requiring correction factors including season, time of day, tide, and sex and age class. Field studies have not yet confirmed sexual or age related differences in attendance patterns (Pitcher and McAllister 1981, Harvey 1987, Thompson 1987, Yochem 1987, Allen et al. 1988). In the Drakes Estero study, the sample size was insufficient for testing age-related differences in behavior but immatures tended to haul-out for fewer days than adults in the fall. Deviations associated with gender were not significantly different except for movement patterns in 1985. Yochem (1987) noted sexual differences in molt sequence and Thompson (1987) demonstrated sexual and age related differences in molt completion dates which may influence the peak abundance for each class. I was unable to acquire reliable data on molt sequence of individuals because of tag loss at the time of molt (transmitters were shed and flipper tag loss was nearing 0.6). Adult females, though, shed transmitters on average 8.6 days earlier than males.

The best strategy for surveying seals in the Point Reyes area would be to census seals midday at the peak of the molt during late June or early July. Seals hauled out for significantly more days per month and more hours per day then than for any other period of the year. Peak abundance occurred between 0600 and 1400 hr which represented between 60% and 73% of the estimated number of seals at Drakes Estero. Ribic

et al. (1986) determined that July counts had lower coefficients of variation and were generally more stable than those for other months of the year. Based on the above and as suggested by Boveng (1988), a correction factor of 1.4 times the total number of animals hauled out could be applied for estimating adult animals at Drakes Estero. This figure, though, would likely underestimate the total population because the attendance patterns of immatures and pups have not been satisfactorily documented during the molt. From studies of immature seals of other species during the molt, one would expect their behavior to be very different from adults (King 1983).

To improve current population estimates, in light of the deficiencies delineated above, future radio-telemetry studies should be designed to include larger sample sizes of each age and sex class. Additionally, research should address biases associated with annual variation. Most telemetry studies are funded for one or two years, and as was demonstrated at Drakes Estero, movement patterns were very different between two years. Between year differences could have been due to different seals sampled or to variation in food availability.

CONCLUSIONS

Results of this study fulfilled the primary objectives delineated in the introduction. The apparent decline in seal numbers during the winter was a function of both migration and a reduction in the frequency of the haul-out pattern. During the nonbreeding season, seals hauled out on fewer days per month and for fewer total hours per day than during the breeding/molt season. The destination of departing seals was detected during most aerial surveys, and movements ranged over a 690 km distance between Monterey Bay and the Klamath River, California. More seals traveled to haul-out sites >25 km from Drakes Estero in 1985 than in 1986; however, several seals relocated intermittently at Point Reyes Headland in 1986.

Results affirm that haul-out behavior of seals varied with time of day and time of year. Seals exhibited a strong diurnal haul-out pattern, regardless of season, with most seals resting onshore mid-day and foraging at night. The amount of time that seals spent onshore, though, varied seasonally. During the nonbreeding season, seals spent about 30% of the day hauled out and 70% either traveling to feeding areas or engaged in foraging activities; during the breeding/molt season, though, they were hauled out 38 to 46%

of the day. During the breeding season, the increase was due to an increase in the frequency of haul-out bouts and during the molt to an increase in the duration of a single haul-out bout.

Age and gender accounted for some of the variation in seal haul-out behavior. Assessment of the influence of age on variation was limited by a small sample size; however, data collected during the fall indicate that immature seals hauled out on fewer days than adults. Once onshore, though, the length of a haul-out bout was no different between age classes. Immatures did not appear to travel longer distances or more frequently than adults. Sexual differences in activity patterns were not significant regardless of season. The total number of hours per day, the length of a single haul-out bout, and the proportion of days hauled out per month were similar for males and females. In 1985 more females migrated and traveled longer distances than males but this trend was not repeated in 1986. Preference for location of haul-out site was the only significant difference in haul-out behavior between males and females and segregation occurred only during the breeding season.

Recommendations for improvement in research design center around determining age-related differences in movement and activity patterns. This can be accomplished in future projects by radio-tagging equal numbers of immatures and adults and increasing the sample size for both. Additionally, a better method of attachment of transmitters and a longer lasting transmitter should be investigated so that individuals can be monitored through the molt and for multiple years. Currently, CDFG statewide aerial surveys occur during the molt; however, all transmitters in this study were shed about two weeks prior to the molt and no telemetry data have been collected through the entire cycle. Nevertheless, major changes in seal haul-out behavior occur during the molt. Attendance patterns during the molt may vary significantly between age and sex classes as was noted by Thompson (1987) and Yochem (1987). Research for several consecutive years would ascertain whether annual differences in movement patterns, as were observed in this study, are typical.

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