THE EFFECT OF DISTURBANCE ON HARBOR SEAL HAUL OUT PATTERNS AT BOLINAS LAGOON, CALIFORNIA[1]

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ABSTRACT

We studied harbor seals at Bolinas Lagoon, California, from May 1978 to June 1979. Field observation and two time lapse motion picture cameras were used to monitor the numbers of seals and of disturbances, and to provide information on tidal height. Peak numbers occurred during the summer. During nonbreeding seasons, high numbers occurred at low tides, and during the breeding season they occurred in early afternoon except when haul out areas were flooded. Seals were disturbed by humans on 71% of days monitored; people in canoes were the primary source of disturbance. Human activities closer than 100 m caused seals to leave haul out sites more than activities at greater distances.

Several studies exist on the haul out patterns of harbor seals, *Phoca vitulina*, in undisturbed locations (Scheffer and Slip 1944; Venables and Venables 1955; Richardson 1975[4]; Pitcher 1977[5]; Loughlin 1978), but the effects of human activities on haul out patterns have been examined infrequently (Newby 1971; Paulbitsky 1975; Chapman 1979[6]). We report here how daily and seasonal haul out patterns of harbor seals can be modified by human activity in a small estuary, Bolinas Lagoon, Calif. The data also provide a baseline against which the effects of pending increased levels of human activity could be compared.

Since 1970, a state quarantine has reduced human activities in the contaminated waters of Bolinas Lagoon. Human use has been confined to bird watching, some boating, illegal clam digging, beach combing, and recreational bait fishing. When the quarantine is lifted, many of these activities will increase. Increased human activity could also result from provisions included in the General Management Plan of the Golden Gate National Recreation Area (June 1979) for a walk-in camp site and parking area along the lagoon.

Little information exists on harbor seals at Bolinas Lagoon. Carlisle and Alpin (1966, 1971) estimated numbers as part of a statewide aerial count, but their figures for Marin County were low compared with preliminary data collected by Gary W. Page (unpubl. data). More recently, Mate's (1977)[7] monthly statewide counts failed to detect any seals in Bolinas Lagoon.

STUDY AREA AND METHODS

Bolinas Lagoon, a 448 ha estuary 24 km north of San Francisco, is a Marin County Nature Preserve and is part of the Golden Gate National Recreation Area. Triangular in shape, it is bordered by paved roads, pasture land, the small community of Bolinas, and a 3 km long sand spit covered with houses. At the end of the spit there is a 60 m wide opening to the ocean. The major channel used by the seals passes by Kent Island (KI) and Pickleweed Island (PWI) and cuts north along the northeastern shore (Fig. 1). KI and PWI remain above water when tides exceed 1.7 m above mean low water level and are the two main seal haul out areas.

Movie cameras recorded the activity of seals and humans in the vicinity of KI and PWI. A Canon[8]

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[4]Richardson, D. T. 1975. Assessment of harbor seal and gray seal populations in Maine. Contract report to the U.S. Marine Mammal Commission, Washington, D.C., 37 p.

[5]Pitcher, K. W. 1977. Population productivity and food habits of harbor seals in the Prince William Sound - Copper River Delta area, Alaska. U.S. Department of Commerce, Final Report to Marine Mammal Commission, Contract No. MM4AC009, 37 p.

[6]Chapman, D. 1979. The effects of recreational activities on the harbor seal, *Phoca vitulina*. [Abstr.] American Mammal Association Annual Meeting, Corvallis, Oregon, June, 1979, p. 80.

[7]Mate, B. R. 1977. Aerial censusing of pinnipeds in the eastern Pacific for assessment of population numbers, migratory distributions, rookery stability, breeding effort, and recruitment. U.S. Dep. Commer., N.T.I.S. PB-265 859, 67 p.

[8]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

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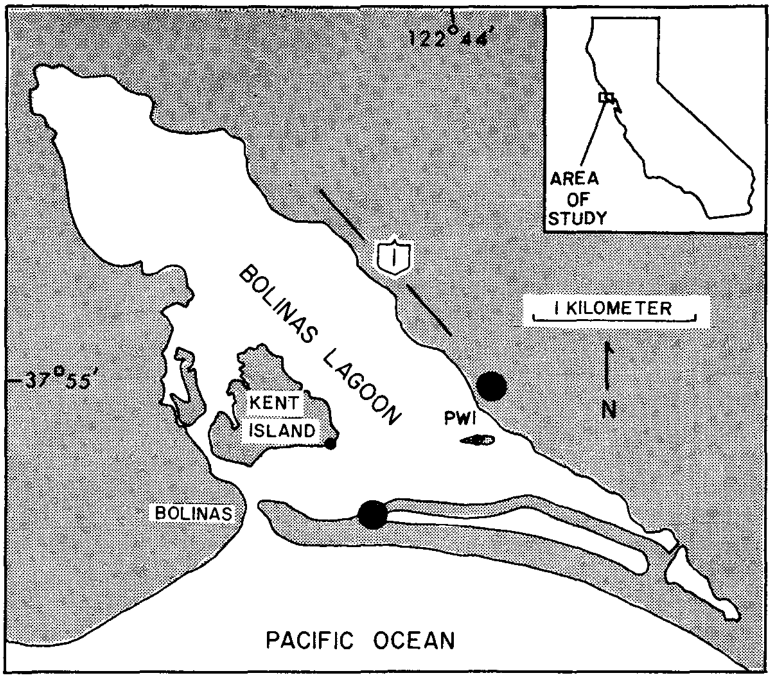

FIGURE 1.—Study area showing the two major haul out sites, Kent Island (KI) and Pickleweed Island (PWI), Calif., (small solid circles), and the location of the two cameras (large solid circles).

"814 XL Super 8" with a 7.5 to 60 mm zoom lens was focused on KI from a private residence on the sand spit about 400 m away. A photocell activated the camera at day break and deactivated it at sundown; an intervalometer exposed one frame of film every minute. Another camera, a Eumig "880 Super 8" with a 7 to 56 mm zoom lens, positioned in a weatherproof box on private property along State Route 1, was focused on PWI, about 300 m away. The built-in intervalometer also triggered 1 frame/min. An electrical timer activated the camera during daylight hours. The film used (Kodachrome ASA 40) contained 3,000 frames/roll and lasted a week except during summer, when film was changed every 4 d due to increased day length.

We used a Kodak "Moviedeck model 475" projector to analyze film. We noted time, tide level, and the number of seals once every hour of photographic time. Any major change in seal numbers within the 1 h interval was also noted, as well as any disturbance. A stake marked with 0.3 m increments was placed near the major channel by KI and in line of the Canon's viewfinder. This provided a photographic record of tidal change. Actual time for the first frame each day was extrapolated from tables for sunrise and sunset; on several mornings and evenings we compared these times with the actual time that camera operation began or ceased. Extrapolated times were accurate to within 1.0 h.

Twelve (once per month) day-long watches and 211 (124 breeding, 47 summer, and 40 winter) incidental sightings validated camera counts, detected sources of disturbance outside the camera field, estimated disturbance distance from the herd, identified additional haul out sites, and accurately counted pups, which were difficult to detect on film.

When analyzing data, the year was divided into three seasons: winter (November through February), breeding (March through June), and summer (July through October); seasonal averages are expressed with ±1 standard deviation. Correlation coefficients were calculated to compare camera and field counts as a test for camera reliability, and to examine the relationship of seal numbers to tide level within each hour (Snedecor and Cochran 1967). For daily use per season graphs of hourly means were compared; the "runs up and down test" (Bradley 1968) was used to test the sequence of hourly means for randomness.

All human activities (including dogs off leashes) in the area were divided into two types: actual disturbance and zero-seal disturbance. Actual disturbances, or any activity occurring when at least one seal was present, were further subdivided into type I, where at least one seal left the area, and type II, where no seals left the area. A zero-seal disturbance was any activity occurring in the area when seals were not hauled out but which may have prevented seals from doing so.

To investigate the effect of actual disturbance on the seals at KI, disturbances were classified by four criteria: 1) seal response (yes, at least one seal left; no, no seals left); 2) distance between the seals and the disturbance source (≤100 m, 101-200 m, 201-300 m); 3) day of week (weekend/holiday, weekday); and 4) disturbance type (person/dog, nonpower boat, power boat). Due to the low number of disturbances during the breeding and winter seasons, season was not used as a variable. Only the 156 instances where disturbance type and distances were known were used in the analysis. The result was a $2 \times 3 \times 2 \times 3$ contingency table. We used log-linear models to examine the effects of 2, 3, and 4 (explanatory variables) on 1 (response variable). Log-linear models are used to analyze multidimensional contingency tables and can be used to study two- and three-way interactions between variables (Bishop et al. 1975). We asked the question: "Is seal response independent of the other variables?" We then asked: "If not, what variables affect seal response?" Exploration of models was done by backward and forward selection of models (models were fit with iterative proportional fitting). Both methods produced the same final model; only the backward selection method is presented in the paper.

Backward selection starts with a model that fits the data. All interaction terms that are found to be not significantly different from zero by using a conditional likelihood ratio test (Fienberg 1981) are removed from the model. The final model is found when all nonsignificant terms are deleted. Models were adjusted for marginal zeros (Bishop et al. 1975: Ch. 3), and are displayed here using a shorthand notation (Fienberg 1981). For example, seal response independent of all other variables is denoted [1] [234], and seal response dependent on one of the variables, such as distance, is denoted [12] [234]. Once the final model is selected, weights or "u-terms" are calculated from the data, and are given to each of the levels of each variable included in the final model. The sign of the weight indicates the effect of the explanatory variable [2, 3, or 4] on the response variable [1]. The relative magnitude of the weight indicates the importance of the explanatory variable.

The average time it took for seals to recover from disturbance was based on the elapsed time between when the seals were flushed to when 50% of the original number had rehauled. A chi-square test determined the significance of tide level on the ability of seals to recover from disturbance at KI (Snedecor and Cochran 1967). Correlation coefficients were used to detect the importance of PWI as an alternate haul out site.

RESULTS

Camera Reliability

A correlation of KI camera counts with field counts revealed that the camera was not a reliable indicator of the actual number of seals present but was reliable for information on daily trends. Correlation coefficients by season were as follows: winter, $r = 0.92$, $n = 19$; breeding, $r = 0.55$, $n = 40$; summer, $r = 0.75$, $n = 28$. Discrepancies between the two count methods were caused by seals shifting along the haul out area and, therefore, out of the camera's viewfinder, the inclination of females with pups to haul out on the fringe of the herd, and the difficulty in identifying pups. On the other hand, the camera was very reliable at PWI for the summer ($r = 0.94$, $n = 25$) and breeding ($r = 0.97$, $n = 13$) seasons because seals could not shift out of viewfinder range. Also, this camera was slightly elevated, allowing for better detection of seals hauled out close together. During much of the winter season the PWI camera was broken. Both cameras readily detected boats and people on foot disturbing seals, but could not detect aircraft. Dogs were seen on film twice and on 13 occasions during field counts.

Seasonal and Spatial Use Patterns

Seals used the lagoon on 95-100% of the days each month. More seals hauled out on KI during the breeding and summer seasons than during winter. Numbers on field counts averaged 31.2 ± 28.1 seals during the breeding season (range 0-101, $n = 78$), 53.5 ± 28.5 during the summer (range 0-105, $n = 48$), and 19.6 ± 19.3 during the winter (range 0-58, $n = 28$). The same trend was apparent from field counts on PWI; the number of seals averaged 10.6 ± 15.1 for the breeding season (range 0-77, $n = 107$), 10.0 ± 18.4 for summer (range 0-48, $n = 41$), and 7.7 ± 12.5 for winter (range 0-55, $n = 43$). The PWI means were much lower than those for KI, indicating that KI was the preferred haul out site.

During the breeding season, mother-pup pairs hauled out on PWI and on exposed sand bars along the major channel, but on 83% (125 d) of 150 camera monitoring days, seals were present on KI. Ten and 12 pups were counted in 1978 and 1979, respectively. After the breeding season in July, seals were present on 97% (111 d) of 114 camera days. By contrast, seals were counted on PWI on 56% (54 d) of 96 camera census days during the breeding season and 73% (74 d) of 102 d in the summer. After October, when the population declined, the level of use was still high at KI with seals present on 81 of 92 camera census days.

Daily Use

Peak numbers of seals usually occurred in early afternoon at both sites except at KI during winter when a constant number were present until late afternoon (Table 1, Figs. 2, 3). All the daily trends were significantly different from randomness except for PWI during winter [$P = 0.02$ for KI winter, $P = 0.008$ for KI breeding, $P = 0.007$ for KI summer; $0.24 < P < 0.06$ for PWI winter, and $P < 0.001$ for PWI breeding and summer ("runs up and down test")]. The greater use of KI during the summer and breeding seasons is also reflected in the elevated hourly means (Fig. 2).

Correlation coefficients revealed a positive correlation between low tides and seal numbers (Table 2). The daily temporal use pattern (Table 1) was affected by tide level during winter (range of $r = 0.54 - 0.75$) and summer (range of $r = 0.49 - 0.69$) for KI and to a lesser extent during the summer for PWI (range of $r = 0.11 - 0.62$). No tidal effect was apparent at either site during the breeding season.

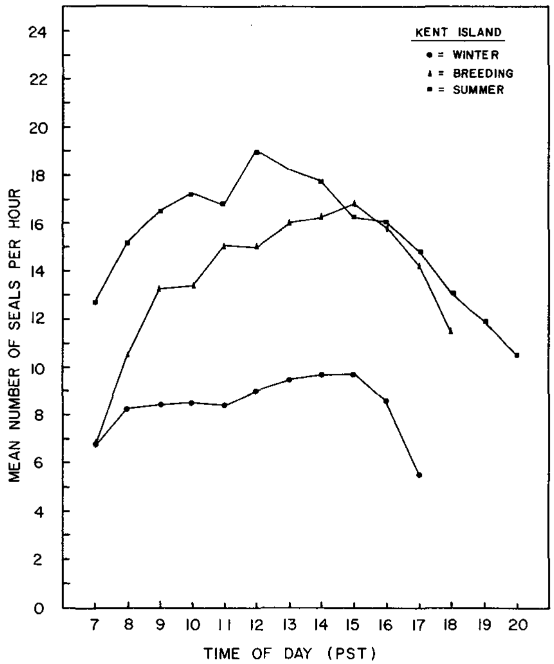

FIGURE 2.—Graph of time of day and the mean number of seals hauled out per time period for winter, breeding, and summer seasons at Kent Island.

Disturbance

Camera and field observations of KI recorded 539 actual and zero-seal disturbances. Of those with identifiable cause, 33.1% were nonpower boats, 10.0% people on foot, 7.8% power boats, 3.4% clam diggers or bait harvesters, 2.8% dogs, and

TABLE 1.—The relationship between time of day and the number of seals hauled out per season on Kent Island (KI) and Pickleweed Island (PWI); $\bar{x}$ is the mean number of seals per hour, SD is the standard deviation, and n is the sample size.

Season			Time													
			0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
Winter																
	KI	$\bar{x}$	6.8	8.3	8.4	8.5	8.4	9.0	9.5	9.8	9.8	8.7	5.6			
		SD	9.5	11.6	11.9	11.6	11.7	11.4	12.0	12.5	12.0	11.5	8.9			
		n	84	83	84	84	87	88	87	88	87	87	12			
	PWI	$\bar{x}$	0	0.8	3.5	6.9	6.3	5.5	6.2	5.4	2.2	2.2				
		SD	0	2.1	4.9	6.7	6.2	6.6	6.8	6.0	3.9	3.6				
		n	9	8	10	10	11	11	10	10	10	10				
Breeding																
	KI	$\bar{x}$	6.9	10.6	13.3	13.4	15.1	15.1	16.1	16.4	16.9	15.9	14.3	11.6		
		SD	10.2	13.8	16.5	16.0	16.8	16.3	16.8	16.1	16.5	16.2	15.3	13.8		
		n	105	108	112	114	118	119	118	119	116	116	116	94		
	PWI	$\bar{x}$	1.2	1.9	2.6	3.3	4.0	4.2	4.7	4.9	4.9	3.8	3.3	0.1		
		SD	3.1	4.8	5.8	6.6	7.3	8.0	8.3	8.4	8.5	7.3	6.5	0.3		
		n	87	89	86	89	91	89	92	91	91	90	83	37		
Summer																
	KI	$\bar{x}$	12.7	15.2	16.5	17.3	16.8	19.1	18.3	17.8	16.4	16.1	14.8	13.1	12.0	10.6
		SD	14.4	15.9	17.4	17.7	16.5	18.0	18.2	18.2	17.8	16.8	15.3	14.9	15.1	15.3
		n	77	83	92	98	104	102	101	105	105	103	86	51	27	
	PWI	$\bar{x}$	0.4	1.2	2.1	3.5	4.7	5.4	5.0	4.5	3.6	2.4	1.3	0.8	0.6	0.7
		SD	1.0	4.0	5.5	9.2	10.8	12.0	12.8	11.1	10.6	7.4	3.9	3.0	2.5	2.2
		n	91	90	91	94	101	101	99	99	98	98	98	92	70	14

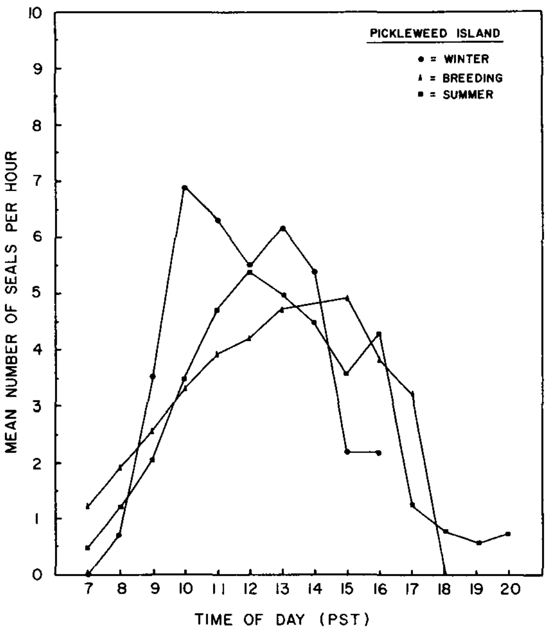

FIGURE 3.—Graph of time of day and the mean number of seals hauled out per time period for winter, breeding, and summer seasons at Pickleweed Island.

0.7% helicopters. The camera did not record the cause in 40% of the disturbances. During December, January, and February, commercial bait harvesters accounted for 25.7% of the disturbances. Disturbances from aircraft were detected only in field observations. The seals were disturbed at least once on 71% of 356 d when the KI camera was functioning, and during these days, 72.7% of 539 disturbances caused the seals to disperse (Table 3). On 211 d during which the PWI camera was functional, seals reacted to 57% of 236 disturbances (Table 3). The frequency of actual disturbances per day averaged highest during the summer for both KI and PWI.

Of the actual disturbances of known cause, most occurred within 100 m of the KI site and resulted more from nonpower boats than from any other source (Table 4). The deletion of terms [13] and [14] from the log-linear model in backward selection, however, indicated that only the distance of a disturbance significantly affected seal behavior (Table 5). Seals did not react differentially to any disturbance type and did not react more to disturbances during weekend/holidays than during weekdays. The relative magnitude of the weights associated with the distance/seal response interaction term [12] denoted that seals responded to

TABLE 2.—Correlation coefficients between tide level and the number of seals hauled out at hourly intervals per season at Kent Island (KI) and at Pickleweed Island (PWI), from camera data; n = number of censuses. Insufficient data were available for PWI during the winter. A positive correlation indicates a positive relationship between seal number and low tide, and a negative correlation indicates a negative relationship between seal number and high tide.

	Winter	Breeding		Summer	
Time	KI (n = 27)	KI (n = 26)	PWI (n = 16)	KI (n = 24)	PWI (n = 21)
0800	0.54**	0.35	0.23	0.49**	0.36
0900	0.75**	0.34	0.17	0.69**	0.20
1000	0.67**	0.42*	−0.17	0.55**	0.62**
1100	0.71**	0.31	−0.30	0.57**	0.52**
1200	0.64**	0.14	0.06	0.68**	0.48*
1300	0.65**	−0.12	0.34	0.54**	0.45*
1400	0.58**	−0.15	0.42	0.62**	0.37
1500	0.55**	0.001	0.22	0.67**	0.23
1600		0.20	0.11	0.67**	0.11

* Significant at P = 0.05.
**Significant at P = 0.01.

TABLE 3.—The frequency of disturbances on Kent Island (KI) and Pickleweed Island (PWI) by season; n is the number of days the camera was functional, A is the number of actual and zero-seal disturbances combined, $A1$ is the number of actual disturbances type I, A/n is the mean number of all disturbances per day, and $A1/n$ is the mean number of the actual disturbances per day.

	KI					PWI				
Season	n	A	$A1$	A/n	$A1/n$	n	A	$A1$	A/n	$A1/n$
Breeding	150	216	158	1.4	1.1	96	101	54	1.1	0.6
Summer	114	215	167	1.9	1.5	102	121	75	1.2	0.7
Winter	92	108	67	1.2	0.7	13	14	6	1.1	0.5
Totals	356	539	392	1.5	1.1	211	236	135	1.1	0.6

TABLE 4.—Data from the Kent Island camera used in log-linear model analysis (Bishop et al. 1975). The numbers in the table are the number of disturbances where seals were present for each category. Y = response (at least one seal left site); N = no response (no seals left site).

	Weekday						Weekend/holiday					
Distance:	<100 m		101-200 m		201-300+ m		<100 m		101-200 m		201-300+ m	
	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
People/dog	12	0	1	0	0	0	12	0	2	0	0	0
Nonpower boat	35	2	8	5	1	7	32	1	5	1	1	6
Power boat	7	1	3	3	1	0	8	0	0	1	1	0

TABLE 5.—Backward selection of log-linear model using data in Table 4; model variables are 1 (response), 2 (distance), 3 (day of week), and 4 (disturbance type). An asterisk indicates a term that is significantly different from zero.

Model	G	df	P	Term deleted
[12] [13] [14] [234]	11.15	8	>0.10	
[12] [13] [234]	15.4	13	>0.25	[14]
[12] [14] [234]	12.18	9	>0.25	[13]
[13] [14] [234]	57.52	14	<0.01	[12] *
[12] [234]	16.91	14	>0.25	[14]
[14] [234]	58.98	11	<0.01	[12] *
[1] [234]	70.38	16	<0.01	[12] *
Final model = [12] [234]				

disturbances at ≤100 m more than at distances 101-200 m and 201-300 m, and were least reactive to disturbances at 201-300 m (Table 6).

TABLE 6.—Weights associated with the distance/seal response interaction term [12] of the log-linear model that fits the data in Table 5. Relative magnitude of weight indicates importance of the variable. Sign of the weight indicates direction of effect (+ is more, − is less).

Distance (m)	Seal response	
	Yes	No
0-100	[1]1.116	−1.116
101-200	−0.201	0.201
201-300	−0.915	[2]0.915

[1]Seals were most reactive to disturbance.
[2]Seals were least reactive to disturbance.

After actual disturbances (type I), the number of seals that eventually rehauled was always lower than the original number. On KI, the average time it took seals to rehaul regardless of season, was 28 ± 20.8 min (range 5-100, n = 187). In 96 instances, no seals rehauled, primarily due to tidal height. During rising tides, they rehauled only 16.2% of the time (n = 37 disturbances), at low slack tide, 55.6% of the time (n = 124), and on falling tides 61.5% of the time ($n = 26$; $\chi^2 = 13.82$, $P < 0.001$).

Disturbances were of short duration and seals rehauled after the disturbance source had left the area, except for disturbance from commercial bait harvesters, who remained in the vicinity for entire low tide cycles. Bait harvesters likely prevented seals from hauling out at all (zero-seal disturbance). During December, January, and February, we recorded the presence of the harvesters on 13 d. After being disturbed, seals did not return to the haul out site on eight of those days. They were disturbed briefly by the harvesters and then rehauled on 3 d, and there was no change in seal numbers on 2 d.

PWI apparently was not an important alternative site when KI was disturbed. A weak correlation between seal numbers at PWI after they were disturbed from KI existed during the winter ($r = -0.42$, $n = 7$) and summer ($r = -0.40$, $n = 152$), but not during the breeding season ($r = -0.14$, $n = 123$). In 45 of these instances, however, (winter 3, breeding 14, and summer 28), disturbances occurred simultaneously at KI and PWI, thereby precluding seal movement to PWI. During field observations, the movement from KI to PWI after disturbance was actually observed on 11 occasions.

DISCUSSION

The population of harbor seals at Bolinas Lagoon is much higher than previously recognized, and in contrast to seasonal peaks during the breeding season at other seal haul out sites (Fancher 1979; Johnson and Jeffries 1977[9]; Loughlin 1978; and Allen and Huber 1983[10]), the peak at Bolinas Lagoon occurred during summer after the pupping season. The peak at Bolinas may be caused in part by an influx of seals, possibly from San Francisco Bay, only 24 km south, or from Double Point, 10 km north, where numbers decline after the pupping season (Risebrough et al. 1978[11]; Allen and Huber 1983 footnote 9). The summer increase also coincides with a marked increase in fish abundance in Bolinas Lagoon and Bolinas Bay; fish abundance and species diversity are greater in the lagoon from May to September than from November to February (J. Gustafson[12]). Scheffer and Sperry (1931), Spalding (1964), and Pitcher (1977 footnote 5), suggested that harbor seals are opportunistic, preying primarily upon small schooling fish. In a study by Brown and Mate (1983), peak abundance of seals in Netarts Bay, Oreg., also occurred in the fall and coincided with the seasonal abundance of chum salmon. Movement to Bolinas Lagoon at a time of high food availability may be a consequence of the seal's opportunistic feeding strategy.

Time of day and tide were important factors that influenced daily haul out patterns of seals. The peak in numbers during early afternoon is consistent with studies on the Farallon Islands (Ainley et al. 1977[13]) and in San Francisco Bay (Fancher 1979). Though seals were seen hauled out on KI at night on 10 occasions, the sharp drop in numbers during late afternoon suggests that diurnal hauling out is preferred. The diurnal pattern may also

[9]Johnson, M. L., and S. J. Jeffries. 1977. Population evaluation of the harbor seal (*Phoca vitulina richardi*) in the waters of the State of Washington. U.S. Dep. Commer., N.T.I.S. PB-270 376, 27 p.

[10]Allen, S. G., and H. R. Huber. 1983. Pinniped assessment in the Point Reyes/Farallon Islands National Marine Sanctuary, 1982-83. Annual Report to U.S. Department of Commerce, Sanctuary Programs Office, 64 p.

[11]Risebrough, R. W., D. Alcorn, S. G. Allen, V. C. Alderlini, L. Booren, R. L. DeLong, L. E. Fancher, R. E. Jones, S. M. McGinnis, and T. T. Schmidt. 1978. Population biology of harbor seals in San Francisco Bay, California. U.S. Dep. Commer., N.T.I.S. PB81-107963, 67 p.

[12]J. Gustafson, Environmental Consultant, Resources and Ecology Projects, Mill Valley, CA 94941, pers. commun. August 1979.

[13]Ainley, D. G., H. R. Huber, R. P. Henderson, T. J. Lewis, and S. H. Morrell. 1977. Studies of marine mammals at the Farallon Islands, California, 1975-76. U.S. Dep. Commer., N.T.I.S. PB-266 249, 32 p.

be related to seal feeding habits as discussed by Antonelis and Fiscus (1980) and Spalding (1964) who noted that seals fed primarily in the late afternoon. The weak inverse correlation between tide level and seal numbers during the breeding season is likely related to the tendency of females with pups to haul out at irregular times to nurse.

These patterns were interrupted by disturbance from boats, pedestrians, dogs, and aircraft. People in nonpower boats were the greatest source for disturbance possibly because they are more mobile than people in power boats or on foot. Distance of disturbance, however, rather than type or season was the significant element at KI since at distances >100 m seals tended not to leave the hauling out site. The response of seals at distances >100 m may have been precipitated by the nature or unpredictability of the disturbance source. For example, a boat advancing directly toward the seals or lingering nearby caused flight more often than a boat moving by.

The source of current disturbances is a small but stable resident and tourist human population; however, a variety of changes in the seal's behavior may be expected if disturbance levels increase. Both Paulbitsky (1975) and Woodhouse[14] documented a change from diurnal to nocturnal hauling out patterns in seals at Strawberry Spit, Tiburon, and at Atascadero State Beach, Morro Bay, Calif., which was believed to be a response to an increase in the local human populations. The response of seals to the prolonged activities of commercial bait harvesters on Bolinas Lagoon is indicative of the potential disruption of seal haul out patterns.

Excessive disturbance may also lead to increased pup mortality. According to Kenyon (1972), 7 of 18 Hawaiian monk seals, *Monachus schaunislandi*, died before weaning on heavily disturbed pupping grounds on Midway Atoll, Hawaii. In contrast, for harbor seals at a relatively undisturbed pupping ground in British Columbia, Bigg (1969) estimated that pup mortality was only 12%. We do not know to what extent disturbance is affecting pup mortality rates at Bolinas Lagoon. In 1979, 3 of 12 pups were found dead; at least 1 of those 3 was killed by a dog.

Site abandonment is a third possible response to increased disturbance. Newby (1971) attributed harbor seal abandonment of a site in Puget Sound in part to increased disturbance from recreational boating. Kenyon (1972) postulated for the monk seal that site abandonment results in overall population losses because other traditional haul out sites probably cannot absorb the emigration. The same could apply to harbor seal populations in Marin County, if other sites are currently filled to capacity.

[14]C. Woodhouse, Santa Barbara Museum of Natural History, 2559 Puesta del Sol, Santa Barbara, CA 93105, pers. commun. May 1977.

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