Variability in reactions of Pacific harbor seals, *Phoca vitulina richardsi*, to disturbance

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Abstract.–Disturbances to harbor seals, *Phoca vitulina richardsi*, during 1991 and 1992 pupping seasons were observed at Puffin Island, Clements Reef, and Skipjack Island in Washington state. Harassment (≥ one seal entering the water) of seals ashore was common (≥71% of survey days) and primarily caused by powerboat operators approaching to observe seals. Recovery (number of seals on a haul-out site returned to preharassment levels) following a harassment was less at Puffin Island (19%) than at Clements Reef (54%) and Skipjack Island (45%). Additionally, seals were more vigilant (P<0.003) at Puffin Island than at the other two locations. These results indicated that seals at Puffin Island were less tolerant of disturbance than seals at other sites. This could possibly be attributed to a greater (P<0.05) percentage of pups ashore (17%) than at Clements Reef (3%) and Skipjack Island (3%). Because of this, we expected that powerboats would disturb seals from greater distances at Puffin Island. To test this, we used a theodolite to determine distance between seals and an approaching vessel at Puffin Island and Clements Reef. There was, however, no significant (P>0.05) difference in distances at which disturbances occurred. The most notable difference in distance of disturbance was between initial and subsequent harassments during a haul-out period. Those seals remaining or returning to shore after a harassment were more tolerant of powerboats, allowing significantly (P<0.05) closer approaches than those initially harassed. Seals detected (head raised and oriented toward the potential disturbance) a powerboat at a mean distance of 264 m, and harassments occurred when boats approached, on average, to within 144 m. Results of this study exemplify the variability in reaction to disturbance and the necessity for considering these differences for minimizing disturbance.

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In many locations, disturbance is an important factor affecting the haul-out patterns of harbor seals, *Phoca vitulina*. Disturbance is defined as any activity that alters normal behavior. In the United States, disturbance of marine mammals by humans is regulated by the Marine Mammal Protection Act of 1972. In contrast to pelagic marine mammals, changes in the behavior of pinnipeds on haul-out sites related to disturbance is relatively simple to measure. Long-term effects of disturbance, however, are often difficult to assess.

The effects of disturbance may be quite mild or may cause displacement and even mortality. Bighorn sheep (*Ovis canadensis*) and white-tailed deer exposed to snowmobile traffic have shown increased heart rate but no visible change in behavior (MacArthur et al., 1982; Moen et al., 1982). Humpback whale (*Megaptera novaeangliae*) female-calf pairs in Hawaii have avoided nearshore areas of intense human recreational activities (Salden, 1988; Glockner-Ferrari and Ferrari[1]). Disturbance-related mortality in harbor seals can result from stampeding and pup abandonment (Johnson[2]). Disturbance from low-flying aircraft may have caused mortality of more than 200 (10%) harbor seal pups on Tugidak Island, Alaska, in 1976 (Johnson[2]).

In addition to aircraft, sources of disturbance include boats, seismic exploration, pedestrians, kayakers, and natural predators (Renouf et al., 1981; Laursen, 1982; Allen et al., 1984; Terhune, 1985; Richardson et al., 1995; Moss, 1992; Kroll, 1993; Johnson[2]; Murphy and Hoover[3]; Calambokidis et al.[4]; and others). Allen et al. (1984) reported that harbor seals on a haul-out site in Bolinas Lagoon, California were disturbed by humans on 71% of survey days; most disturbances were caused by nonmotorized boats (primarily canoes). Humans, primarily boat operators, were the most common cause of harassment to harbor seals on Pro-

[1] Glockner-Ferrari, D. A., and M. J. Ferrari. 1985. Individual identification, behavior, reproduction, and distribution of humpback whales, *Megaptera novaeangliae*, in Hawaii. Rep MMC-83/06 for Mar. Mamm. Comm., 42 p. [NTIS PB85-200772.]

[2] Johnson, B. W. 1977. The effects of human disturbance on a population of harbor seals. *In* Environmental assessment of the Alaskan continental shelf, p. 422–432. Annual. Rep. Princ. Invest., vol. 1. U.S. Dep. Commer., NOAA/OCSEAP, 708 p. [NTIS PB-280934/1.]

[3] Murphy, E. C., and A. A. Hoover. 1981. Research study of the reactions of wildlife to boating activity along Kenai fjords coastline. Final Rep. to Nat. Park Serv., Anchorage, AK, 125 p.

[4] Calambokidis, J., G. H. Steiger, J. R. Evans, and S. J. Jeffries. 1991. Censuses and disturbance of harbor seals at Woodard Bay and recommendations for protection. Final report to Washington Dep. Nat. Resources, Olympia, WA, 45 p.

tection Island (Kroll, 1993) and Woodard Bay (Calambokidis et al.[4]), Washington. Sources of disturbance to harbor seals ashore at Gertrude Island, Washington, were mainly unidentifiable; however, of detectable causes, human activities and coyotes were the most common (Moss, 1992).

Reaction to disturbance may vary among harbor seal groups within an area (Terhune and Almon, 1983) and according to disturbance sources (e.g. powerboats vs. canoes and kayaks; Calambokidis et al.[4]). This variability may be attributed to different levels of tolerance among age, sex, or reproductive status of harbor seals. Reaction to different causes of disturbance may vary with exposure to particular sources, eventually resulting in greater avoidance or tolerance. In any case, results of previous studies indicate that reaction to disturbances vary within and among regions, although little quantitative evidence exists.

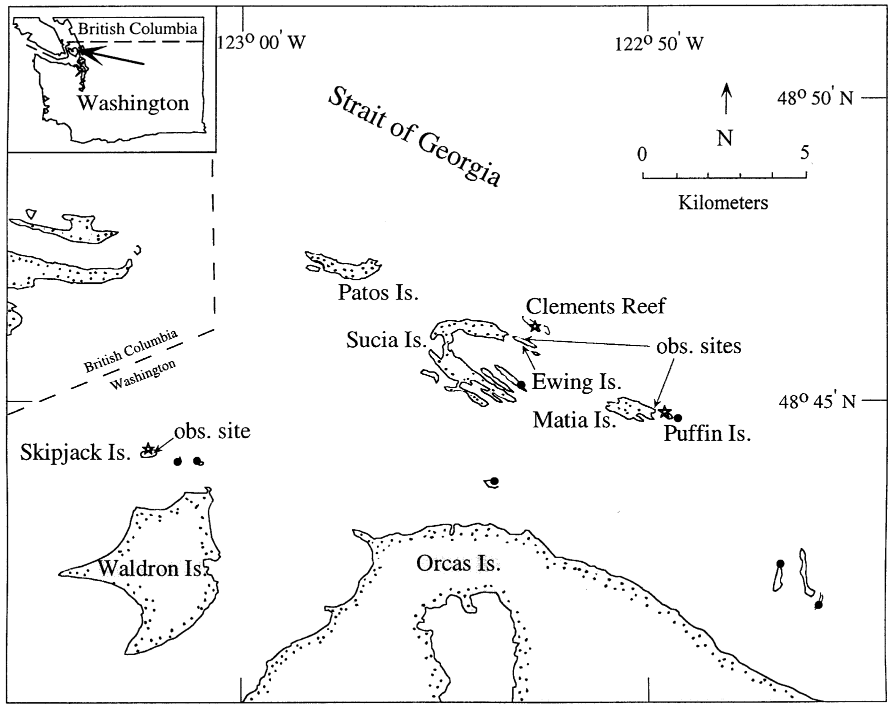

Figure 1

Locations (★) of harbor seal haul-out sites observed at Clements Reef, Puffin Island, and Skipjack Island during 1991 and 1992 pupping seasons in the San Juan Islands, Washington. Dots (●) indicate other haul-out sites in the area.

In this study, we collected data to evaluate the extent of disturbance to harbor seals at haul-out sites in the northern San Juan Islands. Our objectives were to determine 1) if human-related activities were the primary source of disturbance; 2) if recovery varied between flood and ebb tides and was similar among the three haul-out sites (one location was a pupping area); 3) if vigilance characteristics differed among haul-out sites; 4) if the response to harassment was similar for pups and for adults and subadults; and 5) if the mean distance between harbor seals and a boat causing a disturbance varied within and among haul-out sites and, if so, to determine potential causes of this variability.

Methods

Study area

The study area was located in the northern San Juan Islands, Washington (Fig. 1). This area is characterized by numerous islands, a tidal range of 3.6 m, strong currents (maximum of 7.7 km/h), and a rocky shoreline. Haul-out sites of harbor seals, which include reefs and rocky intertidal zones of islands, are numerous but typically are used by fewer than 100 animals. During this study, observations were conducted at Clements Reef, Puffin Island, and Skipjack Island (Fig. 1).

Observations of haul-out sites

Ground-based surveys of harbor seals were conducted at Clements Reef (n=13), Puffin Island (n=9), and Skipjack Island (n=8) from 2 July to 19 August 1991. In 1992, surveys were conducted between 24 June and 10 September 1992 at Clements Reef (n=21) and Puffin Island (n=18). Skipjack Island was not surveyed during 1992 to allow increased sampling effort at the other two sites. Seals at each location were observed at least twice a week (one observer per site). Seals at Clements Reef were viewed from Ewing Island (Fig. 1), approximately 0.55 km away. Seals on the northwest end of Puffin Island were viewed from the southeast corner of Matia Island, 0.38 km away (Fig. 1). Observer heights above zero tide level were 10 m at Clements Reef and 13 m at Matia Island. The observation point on the northeast side of Skipjack Island was directly above (23 m) the haul-out site (Fig. 1).

Observations of harbor seals began one to three hours before low tide and ended three to seven hours after low tide (when <50% of the maximum number of seals counted during that tide cycle remained ashore).

Seals were viewed with 22× and 15–60× spotting scopes. Scan surveys (Altmann, 1974) were conducted at ten minute intervals throughout the observation period. During each half-hour period, the first scan was a count of all seals, the second scan included size structure (number of harbor seal pups and subadults and adults), and the third scan was used to quantify vigilance of seals (head up, alert but not oriented toward a disturbance source) and sources of disturbance (within 1.0 km of the haul-out site). Counts of size structure included only those individuals that could be assigned a given category (e.g. seals were not included if only a flipper was visible as in the first scan).

Counts from these scans were used to determine how many seals entered the water following a disturbance and when recovery had occurred. Recovery was measured by the increase in number of harbor seals on the haul-out site after harassment. Recovery was divided into four categories: 1) full recovery (number of seals ashore after harassment returned to preharassment levels); 2) partial recovery (number of seals ashore increased after the harassment, but did not reach preharassment levels); 3) no recovery (number of seals ashore did not increase after harassment); and 4) no chance to recover (number of seals ashore never increased after harassment owing to repeated disturbances or rising tide washing over the haul-out site). Because animals were not marked, full recovery did not imply that individuals returning to shore were necessarily the same ones that were harassed, but partial and no recovery did indicate certain individuals did not return to the haul-out site.

Terhune (1985) and da Silva and Terhune (1988) reported that the number of vigilant harbor seals was dependent on group size. To eliminate the potential effect of group size on vigilance, the original data were subsampled to produce subsets of equal group sizes. Therefore, a single value is not presented for a site because it varies with each comparison.

Data were collected for every potential source of disturbance that approached the haul-out site. Sources were divided into the following categories; airplanes, powerboats (including sailboats under motor power), sailboats, kayaks and canoes, people, bald eagles (*Haliaeetus leucocephalus*), unknown, or other. Vessel speed was classified as underway fast (creating a breaking bow wake), underway slow (nonbreaking bow wake), and drifting (motor not in gear or turned off). Harbor seal reactions to a disturbance were categorized as 1) detection: ≥1 seal with head raised and oriented toward potential disturbance source; 2) alarmed: ≥1 seal moved from its resting place, but did not enter the water; and 3) harassed: ≥1 seal entered the water.

Positions of an approaching vessel were monitored by using a Nikon NT2A or Pentax TH20D theodolite. Bearings to the approaching vessel and seals exhibiting disturbance reactions were recorded. The distance from theodolite to vessel or seal was calculated by using the tangent of the vertical angle from the theodolite and height of the theodolite above the water. The distance between vessel and seals was calculated by using the Law of Cosines that incorporates distances between theodolite and vessel and theodolite and seals and by using the horizontal angle between the vessel and seals (from theodolite). Height of the theodolite above water was measured directly or estimated from a cosine prediction of tide height (San Juan Current and Tide Tables, published by Island Canoe, Bainbridge Island, Washington). The tidal constituent used was Port Townsend, Washington, with a correction for Echo Bay, Sucia Island (approximately 1 km from Ewing Island and 6 km from Puffin Island). The observation point at Ewing Island (for Clements Reef surveys) was near a vertical rock ledge, which allowed the observer to measure theodolite heights above water level (using a tape measure with float attached). Direct measurement of height above water was accurate to approximately 0.1 m. Direct measurement was not possible at Puffin Island; therefore, theodolite heights above water level were based on tide height predictions, which were accurate to approximately ±0.3 m. Error in theodolite locations was less than 10 m; accuracy was based on calibration with fixed objects (e.g. buoy or island).

Analyses

Results of statistical analyses were considered significant at $\alpha = 0.05$. Mean percentage of pups among the sites was compared by using analysis of variance (ANOVA) with arcsine transformation. A Tukey multiple comparison test was used for significant ANOVA results (Zar, 1984; Day and Quinn, 1989). To test whether pups were less tolerant of disturbance than adults, the frequency of positive and negative changes in the proportion of pups ashore before and after a harassment was compared by using a chi-square goodness-of-fit test (data were combined from all sites). Percentage of vigilant seals was compared between sites by using Mann-Whitney U tests (separate two-sample tests were conducted owing to random subsampling to control for group size). Differences in distance of disturbance among powerboat approach speeds were tested with Mann-Whitney, t, and Kruskal-Wallis tests. Significant differences in distance of disturbance among categories of detection, alarm, and harassment were detected with

Table 1

Summary of numbers of harbor seals using haul-out sites and primary disturbances occurring during the pupping season of 1991 and 1992 in the northern San Juan Islands, Washington.

	Puffin Island	Clements Reef	Skipjack Island
No. of seals (range)	50–125	125–275	50–125
% pups (SE)	17% (1.1)	3% (0.3)	3% (0.4)
% of days with harassment (*n*)	77% (27)	71% (34)	88% (8)
No. of harassments observed	64	91	24
% of harassments caused by powerboats	42%	76%	46%
Unknown[1]	19%	2%	38%
Bald eagle	16%	2%	0%

[1] No disturbance source was detectable by the observer.

ANOVA with square root transformation. Initial versus subsequent disturbances were compared within each disturbance categories with *t*-tests. Randomization statistics (Resampling Stats, Inc., 1995) were used in calculation of power to detect significant differences.

Results

Clements Reef was the largest haul-out site with the greatest number of seals. Puffin Island, however, had the greatest number of pups, the pups representing a significantly (F=97.6, P<0.01) greater percentage of the total number of seals ashore in comparison with Clements Reef (Table 1). The study area on Puffin Island appeared to be an important area for female-and-pup pairs and thus may explain some of the observed differences in reactions to disturbance.

Harassments of seals occurred during at least 71% of the survey days. The primary cause of disturbance was powerboats (Table 1). Most of these (74%, n=96) involved boat operators approaching haul-out sites to view seals. The second most common category of disturbance was unknown (no source was visible or audible to the observer) and was most prevalent at Skipjack Island. Bald eagles were the third most common cause of disturbance and were more frequent at Puffin Island than at other sites. In contrast with powerboats, sea kayaks were uncommon during the study and, therefore, caused fewer harassments (11% for all sites). Sea kayakers, however, were a greater potential disturbance to seals ashore than operators of powerboats. Fifty-five percent of kayakers (n=11) within 1 km of a haul-out site harassed harbor seals, whereas only 9% of powerboats (n=436) within 1 km caused harassment. This finding is a result of seals being less tolerant of kayaks and kayakers who generally travel closer to shore than do powerboaters.

Table 2

Percentage of harassments (*n*, excluding disturbances caused by bald eagles) that resulted in either full recovery, partial recovery, no recovery, or no chance to recover for harbor seals at Puffin Island, Clements Reef, and Skipjack Island, northern San Juan Islands, Washington, 1991 and 1992.

	Puffin Island (n=27)	Clements Reef (n=28)	Skipjack Island (n=11)
Full recovery	19%	54%	45%
Partial recovery	30%	32%	18%
No recovery	44%	7%	36%
No chance to recover	7%	7%	0
For all recoveries			
no. of harassments before low tide	10	11	5
no. of harrassments after low tide	17	17	6

The extent of recovery following harassments (excluding those caused by eagles) of harbor seals was less at Puffin Island than at Clements Reef and Skipjack Island (Table 2). Disturbances caused by eagles were excluded from this comparison because eagles were potential predators of pups (eagles were observed approaching and disturbing pups) and could affect recovery. Recovery was related to whether the harassment occurred before or after low tide (74% of full recoveries occurred before low tide, whereas 75% of partial and 89% of no recoveries occurred after low tide). This finding corresponds with total numbers of seals ashore typically decreasing one to two hours after low tide, independent of disturbance. For comparison of recovery among sites, the proportion of disturbances occurring before and after low tide was similar and likely did not influence results (Table 2).

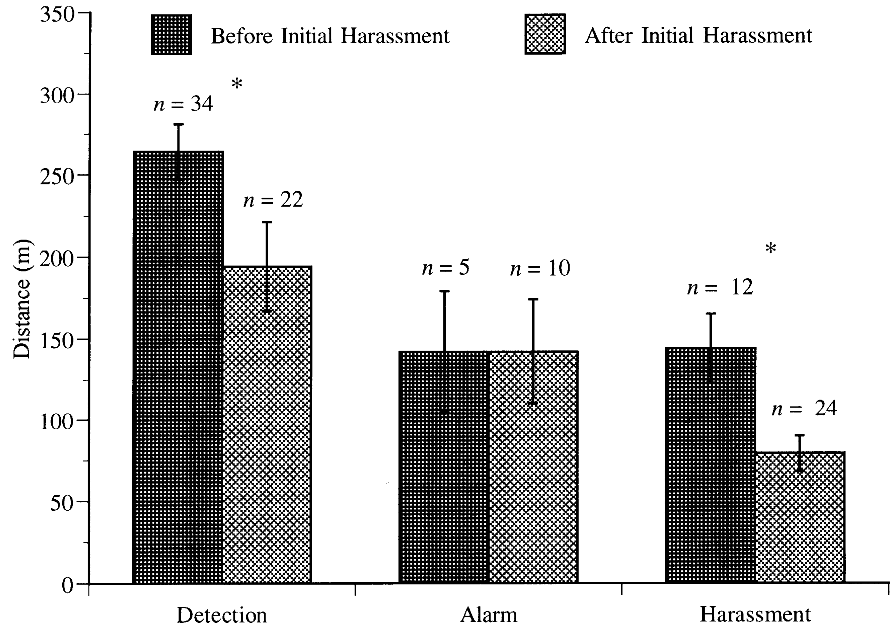

Figure 2

Mean distance (±SE) between harbor seals and powerboat for disturbances occurring before and after the initial harassment during a haul-out period. An asterisk (*) indicates a significant ($P<0.05$) difference between before and after initial harassment data for that disturbance category.

There was no apparent difference in the proportion of harbor seal pups onshore before and after harassments ($\chi^2=0.183$, $n=27$, $P>0.50$). Pups did not appear to be affected disproportionately to subadults and adults.

The percentage of vigilant harbor seals varied with each comparison (due to random subsampling of data to control for group size), hence there was no single value for percentage of vigilant harbor seals at each haul-out site. The percentage of vigilant harbor seals was significantly greater at Puffin Island compared with Clements Reef ($P=0.003$) and Skipjack Island ($P=0.002$; Table 3). This finding is likely due to the greater percentage of female-and-pup pairs at Puffin Island and, in addition to lower recovery, indicated seals were more susceptible to disturbance.

Powerboat speed did not significantly influence distance of disturbance. Lack of statistical significance was likely due to small sample sizes after subdividing data by approach speed and initial versus subsequent harassments. There was also no significant difference in distance of disturbance between sites (data were not collected at Skipjack Island). Given the large variability of the data and small effect size, greater than 450 observations would be required for a power of 0.80 to detect a significant difference between sites. Data, therefore, were pooled for further analysis. Twenty-five percent of harassments occurred when vessels were <100 m from seals, 50% occurred at 100–200 m, and 25% at 200–300 m. After detection by seals, powerboats were able to approach significantly closer ($F=10.51$, $P<0.001$) before causing alarm or harassment of seals (Fig. 2). Interestingly, we found that distances of initial disturbance were significantly greater than subsequent disturbances (Fig. 2). This indicated that seals remaining or returning to shore following the first harassment were less easily disturbed.

Discussion

Many islands in the San Juan Archipelago are state parks or have resort harbors that attract numerous boaters during the summer. Clements Reef is located near (0.6 km) Sucia Island, which is the most heavily visited state park in the northern islands. It was not surprising, therefore, that most disturbances at Clements Reef were caused by boaters. Relatively few kayakers ventured out to Clements Reef, Puffin Island, or Skipjack Island. Kayakers typically travel along the shoreline and have been shown to cause

Table 3

Mean percentage of vigilant harbor seals at Puffin Island versus Clements Reef and at Puffin Island versus Skipjack Island when no potential disturbance source was within 1 km of haul-out site. Two means (±SE) and separate statistical tests are presented for Puffin Island due to random subsampling to control for group size of each comparison.

	Mean (%)	SE	*n*	Mann-Whitney *U*	*P*
Puffin Island	4.43	0.44	17		
Clements Reef	2.41	0.47	17	*U*=229	0.003
Puffin Island	6.40	1.13	21		
Slipjack Island	2.46	0.75	21	*U*=343	0.002

harassment of harbor seals at a greater distance than do operators of powerboats (Calambokidis et al.[4]); therefore, as sea kayaking becomes more popular, there is a greater potential for disturbance of harbor seals ashore.

The differences in occurrence of unknown causes of disturbance among haul-out sites was possibly a result of haul-out site topography. Harbor seals on Clements Reef had a 360° view of potential sources of disturbance compared with roughly a 270° view for Puffin Island and 180° for Skipjack Island. A disturbance of unknown origin at Skipjack Island would often begin by several harbor seals looking toward the rocky cliff of the island, then entering the water. A high incidence of disturbances of unknown origin have also been documented at Gertrude Island (77%; Moss, 1992) and Protection Island (43%; Kroll, 1993), Washington. The relatively high occurrence of harassments by bald eagles at Puffin Island may have been due to a nearby bald eagle nest and the high percentage of harbor seal pups (immature eagles were observed harassing female and pup pairs). Skipjack Island also had an active bald eagle nest, but eagles were not observed harassing harbor seals.

Overall, only 39% of all harassments resulted in full recovery, indicating seals often remained in the water or moved to a different site. Allen et al. (1984) reported that the number of harbor seals that returned to a haul-out site after a disturbance in Bolinas Lagoon, California, was always less than the original number, and in most cases, harbor seals did not move to a nearby reef. Murphy and Hoover[3] reported that harbor seals off the Kenai fjords, Alaska, often searched for a new haul-out site after harassment. Disturbance to harbor seals, therefore, may have considerable impact where haul-out space is limited (Murphy and Hoover[3]). Although haul-out sites in the San Juan Islands are numerous, alternate sites for female and pup pairs, similar to Puffin Island, may not be readily accessible (particularly since there tended to be less recovery of seals at Puffin Island).

Terhune (1985) compared aggregation behavior and vigilance of harbor seals with flocking behavior of avian species—a behavior that allows individuals to decrease their surveillance without decreasing the probability of detecting a predator (Caraco, 1979; Studd et al., 1983). Da Silva and Terhune (1988) identified group size as the only factor accounting for variation in time taken to scan for predators. Renouf and Lawson (1986) suggested that only males increased scanning time as mating season approached, and scans were related to important events in their mating system, not predators. Results of our study indicated that increased vigilance may be related more to potential "predators" (loosely defined as any source of disturbance, human or animal). We found that seals at an area with a greater percentage of female-and-pup pairs scanned more frequently than those at other locations. Other researchers have described increased vigilance of females with pups. Stein (1989) reported female harbor seals rested alert significantly more frequently when their pups were one to nine days old than when pups were older. Newby (1973) reported a female harbor seal with a pup is "constantly alert and nervous."

The greater vigilance of harbor seals at Puffin Island than at Clements Reef and Skipjack Island and the lack of recovery from a harassment indicated that seals at a pupping location were affected more by disturbance. We therefore expected that seals at Puffin Island would enter the water when powerboats were farther away, in contrast with harbor seals at Clements Reef. This was not the case, there were no significant differences between sites. We cannot, however, conclude that seals at pupping locations tolerated boats to approach just as closely as seals at nonpupping sites without harassment because of differences in geographic characteristics of haul-out sites, unreplicated sites, and lack of power to detect a statistically significant difference.

Bishop (1967) observed that a nucleus of harbor seals, which usually included several very large animals, remained ashore unless danger became imminent. Although we also observed certain groups of harbor seals (often small-size groups) entering the water well before others during a harassment, there was no significant trend. Terhune and Almon (1983) also noted that not all groups of harbor seals reacted to disturbances in the same manner.

The most notable difference in distance of disturbance was the decrease between initial and subsequent harassments. There are two plausible explanations for this: 1) seals became more tolerant of powerboat approaches; or 2) seals that were less tolerant of disturbance did not return to the haul-out site after the initial harassment. Based on lack of full recovery following initial harassments, our results support the latter possibility.

Allen et al. (1984) reported that boats advancing toward, or remaining near, harbor seals ashore at Bolinas Lagoon, California, caused seals to leave the haul-out site more often than a boat simply moving past seals. Boats that traveled slowly, parallel to the haul-out site, and made no abrupt move or changes in speed approached harbor seals at Clements Reef and Puffin Island with minimal disturbance. Greater sample sizes probably would have resulted in significant differences among distances of disturbance for various approach speeds and angles recorded during this study.

Additional potential factors affecting the distance at which seals were disturbed included time of day for haul-out period or location of haul-out site. Harbor seals may more readily enter the water toward the end of the haul-out period, if air temperature is high (Watts, 1992), or during rain. These considerations were not addressed in this study. Harbor seals also may become accustomed to close approaches (<15 m) by boats in areas of high boat traffic (authors' pers. obs.). In Woodard Bay, Calambokidis et al.[4] reported powerboats were able to approach to an average of 40 m before harbor seals entered the water. This area near Seattle, Washington, undoubtedly gets more year-around recreational traffic than the northern San Juan Islands which may explain why disturbance distances were over a third less than those observed during our study.

Most harassments in our study were caused by people approaching to view harbor seals. It is important therefore to distribute information and guidelines for wildlife viewing to the general public. An effective solution may be to include information with vessel registration.

Direct mortality of harbor seals or long-term abandonment of haul-out sites (greater than one haul-out period) because of harassment by humans was not observed during this study. Long-term impacts of harassment of harbor seal populations, however, are difficult to assess. Cases where marine mammals remain in heavily disturbed areas are easy to detect; therefore, cases of partial or complete abandonment of disturbed areas may be more common than evidence indicates (Richardson et al., 1995). Harassments increase energy expenditure of harbor seals by decreasing duration of haul-out period. Increased energy requirements likely have the greatest impact on harbor seal pups during nursing and on adult and subadult harbor seals during molt when access to haul-out sites is important. Brasseur et al. (1996), however, demonstrated that captive harbor seals may need to haul-out even outside these "critical" periods. Richardson et al. (1995) noted that occasional disturbance probably has little effect on harbor seal populations; repeated disturbance, however, may have significant negative effects especially at haul-out sites used for pup rearing.

Results of this study quantify the variability in response to disturbance among individuals and locations. We also demonstrated the potential bias in sampling animals that remain after an initial disturbance, or in areas of regular boat traffic. Distance at which powerboats caused harassment were variable, ranging from 28 m to 260 m. Boating regulations near harbor seal haul-out sites should address activity of vessel (speed and approach angle) in addition to distance from harbor seals. Boating precautions are particularly important near harbor seal pupping areas such as Puffin Island.

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