Cascadia Research Collective

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FINAL REPORT

CENSUSES AND DISTURBANCE OF HARBOR SEALS AT WOODARD BAY AND RECOMMENDATIONS FOR PROTECTION

Prepared for

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EXECUTIVE SUMMARY

The Woodard Bay Natural Resource Conservation Area was purchased by the state of Washington. One of the important features of this site are the harbor seals that haul-out to rest and give birth to young on the log booms. This report summarizes research conducted by Cascadia Research and Washington Department of Wildlife on harbor seals at Woodard Bay (Henderson Inlet, Puget Sound) related to harbor seal abundance and disturbance and provides recommendations for management of the site.

Personnel with Cascadia Research and the Marine Mammal Investigations of the Washington Department of Wildlife (WDW) have studied harbor seals during 300 visits (681 hours) to Woodard Bay by land or air between 11 August 1977 and 31 December 1990. Most of the effort was in 1984 (131.5 hours during 65 visits) and 1990 (217 hours during 67 visits). Disturbances of harbor seals at Woodard Bay were recorded beginning in 1984. During 1990, we conducted observations to determine the distance at which seals entered the water in response to approaching vessels.

Harbor seals have used the log dump since at least the 1930s, though research on the seal numbers at this site began only in 1977. A number of factors were identified from the census data taken from 1977 to 1990 that influenced the number of seals at Woodard Bay in a statistically significant manner. These included: 1) time of day, 2) season, 3) year, 3) height of high tide, 4) rainfall, and 5) day of the week. These factors statistically accounted for over 50% of the variation in seal numbers observed throughout these historical censuses.

Counts were highest in August to October, coinciding with the latter half of the pupping season and the molt. Harbor seal numbers have increased dramatically at Woodard Bay since regular monitoring began in 1977. The pace of this increase was most pronounced between 1977 and 1985, probably because 1) seal populations were increasing more rapidly and 2) an increased use of the log booms as a result of the slowing and eventual elimination of commercial activity at the site. Though seal numbers appeared to stabilize between 1985 and 1989, the censuses in 1990 have revealed that seal use of this site is still increasing.

Pups are born at the Woodard Bay usually starting in early July, although viable pups were first seen in 1990 on 28 June. Births appeared to continue through early August when the maximum number of pups are seen. Births at Woodard Bay occurred on the log booms and especially on some of the areas that were covered with planks. The highest counts of pups made to date at Woodard Bay was 95 made on 7 August 1990. This high number indicates Woodard Bay is now approaching Gertrude Island as one of the most important pupping areas for harbor seals in Puget Sound.

Disturbances of seals (human activities causing seals to enter the water) were seen on 45% of our observation periods in 1990 at a rate of 0.33 disturbances per observation hour. Disturbance rates were highest during summer months, weekend days, and weekday evenings, reflecting the factors that influence the number of people out on the water and around the site. Disturbance rates were higher in 1990 than any other previous year at the site. The disturbance rate at Woodard Bay in 1984 as well as 1990 was more than twice as high as at other sites we monitored in Washington State.

The primary causes of disturbances of seals at Woodard Bay were people coming to the site in recreational motor boats, skiffs, and canoes or kayaks to observe the harbor seals. Most of the people who caused disturbances usually approached the seals without the apparent intention of disturbing or harassing the seals.

Seals entered the water on the approach of vessel at distances up to 246 m, although the average was 56 m (n=44, s.d.=44). The distances that seals were disturbed varied significantly by vessel type; seals entered the water at a greater distance in response to kayaks and canoes compared to recreational motorboats and skiffs. Seals entered the water in response to people on foot at up to 256 m although, on many occasions, we were able to pass less than 100 m from seals while maintaining a low profile without causing disturbance.

The impacts of disturbances on harbor seals have not been well studied though a number of possible effects have been identified by other researchers. These include: 1) change in behavior at site by altering haul-out times, 2) abandonment of preferred haul-out areas, 3) mother-pup separation during bond formation, 4) interruption of nursing, 5) increased stress during the molt, 6) potential stress during other seasons (e.g. mating), and 7) interruption of rest resulting in lower fitness and health.

Due to a high rate of disturbance noted in July 1990, the following actions were taken in August 1990 to reduce disturbances: 1) signs were posted warning people not to disturb the seals, 2) newspaper articles were published describing the problem with disturbance at the site, 3) the National Marine Fisheries Service was provided with information on potential violators of the Marine Mammal Protection Act, and 4) buoys and lines were used to close off the entrances to the interior of the log booms. These actions were extremely successful and there was an immediate dramatic decrease in the rate of disturbances after they were put in effect.

As part of this project for DNR, we have provided recommendations for long-term preservation of harbor seals at Woodard Bay. The most important recommendations are:

1) The most critical period for harbor seals at the site is July and August when pupping is occurring at the site and September to October when animals are molting. Activities that might disturb harbor seals should be avoided during these periods. Activities that are disruptive to seals are best conducted in early morning hours and during rainy days.

2) For the maximum seal numbers using Woodard Bay (possibly approaching 500 seals within the next few years), a minimum haul-out area of 1,250 m^2 and 500 m of water access is required. The current log boom area provides a surplus of space for seals using the site at this time. Two types of structures, log booms and floats, represent the best choices for replacement habitat at Woodard Bay because both are used commonly by harbor seals. Given the current surplus of haul-out space at Woodard Bay, replacement of haul-out structures do not need to be implemented until space available reached 2,000 m^2.

3) Protecting seals from disturbance represents the major challenge for insuring that public access to the site does not threaten the use of the site by seals. Vessels (motorized and non-motorized) as well as people on foot should not be allowed to approach closer than 150 m from the seal haul-out area. A public viewing area closer than 150 m from the seals could be used if it was shielded from the seals.

4) The harbor seals at Woodard Bay do provide a unique opportunity for educating the public and providing them with access to observe and understand marine mammals in a wild setting. An essential aspect of protecting marine mammals at Woodard Bay and other areas is to use this opportunity to allow people to see and learn about seals. Attempts to avoid disturbance of harbor seals do not need to prevent human access. Informing people on proper ways to observe marine mammals without causing disturbances can be an important educational value of their experience at the site.

5)Future research and monitoring on seals should focus on the effectiveness of measures to prevent disturbance of seals as the human traffic at the site increases, future changes in seal numbers, seal food habits and their role in the ecosystem, and conflicts between seals with shellfish production at the site.

INTRODUCTION

The Woodard Bay Natural Resource Conservation Area was purchased by the state of Washington under legislation passed in 1987. The area was purchased from Weyerhauser Company that operated a log unloading facility at the site for over 50 years. The site is managed by the Washington Department of Natural Resources. Major purposes of the natural resource conservations areas are to: 1) maintain, enhance or restore ecological systems, 2) protect outstanding scenic and ecological values, 3) maintain habitat for threatened, endangered, or sensitive species, 4) enhance sites for primitive recreation, and 5) provide opportunities for outdoor education.

One of the important reasons for the purchase of the Woodard Bay site was the harbor seals that haul out to rest and give birth to young on the log booms. The increasing number of harbor seals that use this site has made it one of the most important haul-out areas for seals in Puget Sound (Calambokidis et al. 1985, 1988).

This report summarizes research conducted by Cascadia Research and Washington Department of Wildlife on harbor seals at Woodard Bay (Henderson Inlet, Puget Sound) related to harbor seal abundance and disturbance. We also provide recommendations for management actions needed at the site. This report and the 1990 field work was conducted under a contract with the Department of Natural Resources.

METHODS

Observations were conducted at the Woodard Bay Natural Resource Conservation Area located in Henderson Inlet in southern Puget Sound (Figure 1). Observations were made by both land and air of the seals hauled out on the log booms or in the water in the vicinity.

Censuses

Census effort by Cascadia Research and the Marine Mammal Investigations of the Washington Department of Wildlife (WDW) is summarized in Table 1. A total of 300 visits (681 hours) to the study site by land or aerial survey were made between 11 August 1977 and 31 December 1990; most of the effort was in 1984 (131.5 hours during 65 visits) and 1990 (217 hours during 67 visits). This data set included counts reported by Calambokidis et al. (1978, 1985). Land-based observations were conducted on a railroad trestle that runs along the log booms that seals use to haul out. Spotting scopes were used to count seals. Censuses were generally taken at 30 to 60 minute intervals. Counts of seals in the water were made by scanning the water during each census count.

Land censuses through 1985 were primarily conducted by experienced Cascadia personnel. From 1986 to 1989, however, a majority of the censuses were by student interns working under the direction of Cascadia. Training of interns was conducted during multiple visits to the site and was verified using blind- replicate counts. Censuses in 1990 were conducted by both trained interns and experienced Cascadia personnel.

Aerial surveys have been conducted by both Cascadia Research and the Washington Department of Wildlife (Table 1). These were conducted from a single-engine high-winged aircraft at altitudes of 600-1,000 ft. Counts were generally made from photographs taken during the flight.

Census data from WDW contained the date, time, observation position, and total numbers of seals (both hauled out and in the water). WDW census data have been incorporated into a single database with Cascadia data and are included in the analyses reported here.

Weather and environmental information

Weather and tidal information were recorded for each survey. Tidal information from 1977-1983 was obtained from NOAA Seattle tide tables, and locally-published Seattle tide tables were used for post-1983 dates. Tide times were corrected for Woodard Bay. General weather information was collected in the field following each census count. NOAA Local Climatological Data for Olympia were used for additional weather information, especially for rainfall data.

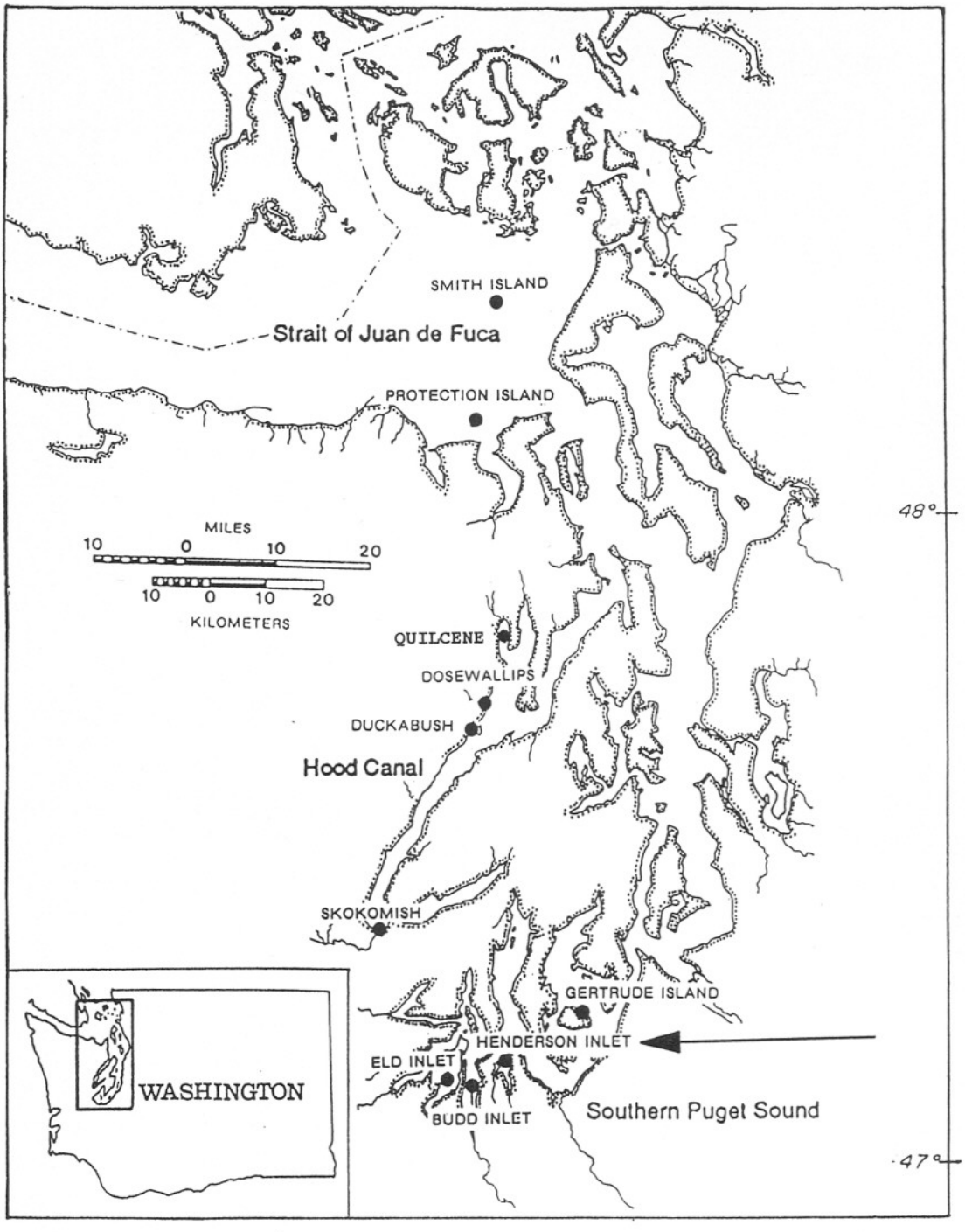

Figure 1. Location of Woodard Bay Natural Resource Conservation Area in Henderson Inlet. Dots mark locations of other harbor seal haul-out areas referred to in text.

Table 1. Census effort at Henderson Inlet by Cascadia Research (CRC) and Washington Department of Wildlife (WDW).

Year	Total hours	No. visits	Begin date	End date	CRC visits		WDW visits	
					Land	Air	Land	Air
1977	13.7	12	11 Aug	13 Sep	11	1	0	0
1980	1.0	1	27 Apr	27 Apr	1	0	0	0
1981	6.3	3	28 Jun	29 Aug	3	0	0	0
1982	1.8	3	25 Aug	20 Nov	2	1	0	0
1983	29.2	19	22 Jan	16 Oct	19	0	0	0
1984	131.5	65	22 Jan	30 Dec	55	7	0	3
1985	81.7	40	7 Apr	8 Nov	32	0	3	5
1986	27.6	22	9 Jun	2 Dec	9	0	9	4
1987	29.0	12	9 Jan	8 Aug	9	0	1	2
1988	67.6	25	25 Jan	1 Dec	22	0	2	1
1989	74.3	31	6 Jan	10 Dec	30	0	1	0
1990	217.0	67	9 Jan	6 Dec	67	0	0	0
TOTAL	680.7	300			260	9	16	15

Disturbance observations

Seal disturbance were monitored during our regular censuses at sites in Puget Sound, Hood Canal, and northern Washington inland waters. Special emphasis was placed on monitoring disturbance at Woodard Bay.

Starting in 1984 a standardized disturbance datasheet was completed for each incident that resulted in seals entering the water. We recorded information on time and location, disturbance type, activity and intent of disturber, and number of seals that entered the water.

Distance calculations

During 1990 we conducted observations to determine the actual distance at which seals entered the water in response to approaching vessels. These observations were conducted from the railroad trestle using 3-4 observers and a Leitz DT5A theodolite. Height above water was measured prior to each set of observations to account for changing tide conditions. Computations to two reference locations (pilings) in the study area were used to verify the calculations and height measurements.

Methods for measuring the distance of disturbance were similar to those we have conducted in the past in other areas (Calambokidis et al. 1983, In prep.). When vessels approached the log boom area, multiple readings were made with the theodolite to track its position, speed, and course. Two or three other observers selected seal groups anticipated to be in the path of the approaching vessel. The position of each seal group was also determined with the theodolite. The time at which seals entered the water from a monitored group was noted and used to determine the vessel location and the distance between the seals and the vessel at the time of disturbance.

Haul-out area requirements

Photogrammetry data collected in 1984 (Calambokidis et al. 1985) were re-analyzed to determine the area and shoreline distances used by seals at haul-out sites in Puget Sound (Gertrude Island, Woodard Bay and Eld Inlet), Hood Canal (Skokomish and Duckabush Deltas and Quilcene Bay), and the Strait of Juan de Fuca (Smith and Protection Islands) by Calambokidis et al. (1990). Photogrammetric methods are reported by Calambokidis et al. (1985). From these measurements, the area used per seal in a haul-out group (m^2/seal) and length of shoreline (or waterline for human-made structures) available to the group (m/seal of shoreline) was determined. Additionally, seals groups on logs at Woodard Bay were measured using a theodolite.

RESULTS AND DISCUSSION

Harbor seal population sizes and trends

Harbor seal numbers at Woodard Bay have been studied primarily since 1977. Counts made between 1977 and the end of 1990 have varied widely ranging from 0 to 391 seals (Figure 2). As described below, a variety of factors were identified that were responsible for the variation in seal numbers.

Though historical information is limited, harbor seals used this area well before formal censuses began in 1977. Workers at the log dump in the 1970s reported seeing seals at the site throughout the period they had worked there, dating back to the 1930s. Newby (1971) reported counting 10 seals at the site in October 1970.

Factors affecting seal numbers

Analyses of seal numbers at Woodard Bay were complicated by the absence of a clear relationship between tidal state and seal numbers. This relationship is very pronounced at most other harbor seal haul-out areas in Washington. Most commonly, harbor seals use sand bars, rocky reefs and ledges, mudflats, and spits at low tide when maximal space is available. The consistency of this tidal-related cycle has provided a clear reproducible sampling time for these sites. This was not the case at Woodard Bay where the habitat availability was not regulated by the tide and observations did not reveal a clear cycle.

Analyses of the large amount of census data provided a statistical basis for evaluating the factors that have influenced seal numbers at this site. From multiple linear regression analyses, seven factors were identified that influenced number of seals in a statistically significant manner in multiple models. These are summarized below:

Time of day: Counts of harbor seals tended to increase through the day.

Month: Counts of harbor seals varied by season with highest numbers in July through October. This factor is discussed in more detail below.

Year: There have been significant increases in seal numbers by year. See below for details.

Height of high tide: Higher counts were found on days that had higher high tides, though surprisingly seal counts were independent of the time to high tide. This result is somewhat puzzling and we cannot find other evidence to justify this occurrence.

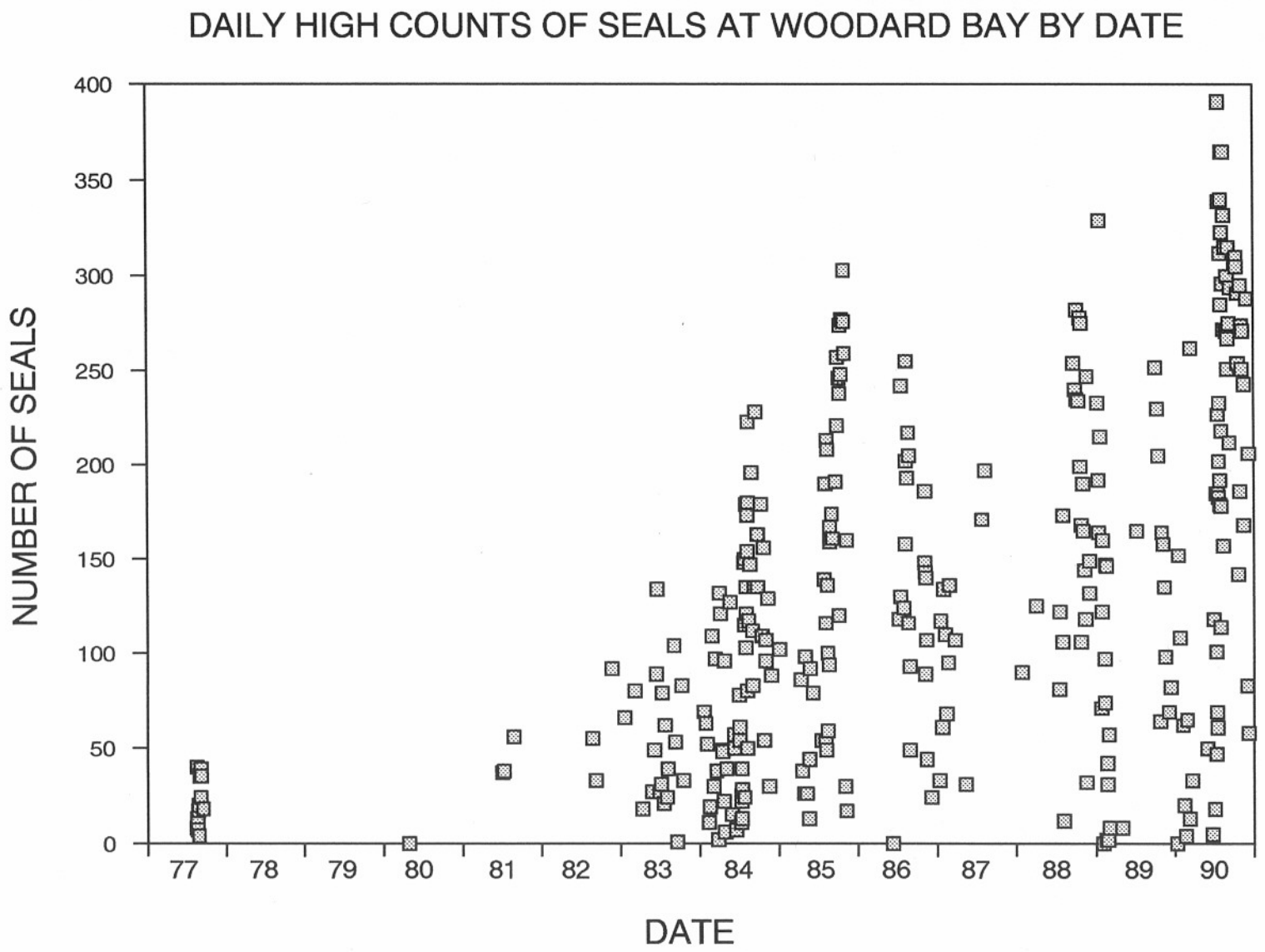

Figure 2. Daily high count of harbor seals made on the 300 visits to Woodard Bay from 1977 through 1990.

Rainfall: Rainfall significantly affected the number of seals in two ways. Seal numbers tended to be lower on days with more rainfall and tended to be higher after large amounts of rain on the previous day or week. This indicated that seals do not haul out as much in rain and also that they return to the site in larger numbers after not hauling out because of rain in previous days. One of the major roles of haul-out behavior is to rest and conserve heat loss. Clearly this advantage is reduced during rain because seals would remain wet.

Day of week: Significantly more seals tended to use the site on weekdays than on weekends during the summer. This pattern was not the case prior to 1984 when the site was used commercially, but has occurred since that time. This factor was not significant when all seasons were considered together. This pattern probably reflects the increase in disturbance by pleasure boaters at the site on weekends during summer months, which causes seals to enter the water and leave the area.

These factors statistically accounted for over 50% of the variation in seal numbers observed throughout these historical censuses. The large number of factors found to influence seal numbers indicated the complexities in evaluating seal numbers at Woodard Bay. Without incorporating the influence of other factors, it would be difficult to make an accurate assessment of the annual changes in numbers. Consideration of these factors should also be used in designing future monitoring programs of this site.

Somewhat surprisingly, several other factors were not found to influence seal numbers significantly. Seals numbers did not vary with time before or after high tide. Air temperature was an inconsistent factor that affected seal numbers and analysis of the influence of this factor was confounded by its covariation with seasonal influences.

Seasonal changes in seal numbers

Harbor seal numbers varied significantly by month of counts, though this variation is not large and seals were present in numbers throughout the year (Figure 3). The most complete data on seasonal patterns of use in a given year was in 1990 (Figure 4). Counts were highest in August to October, which coincides with the latter half of the pupping season and the molt.

The general pattern of highest counts in August to October is also seen in Figure 3 which shows daily high counts for all years. A large variation in numbers of seals in any one month is also apparent. One of the highest counts prior to 1989, for example, was made in January. Though the overall average counts in July are lower than in August to October, the maximal numbers of seals increase in July from the previous months, coinciding with the start of the pupping season.

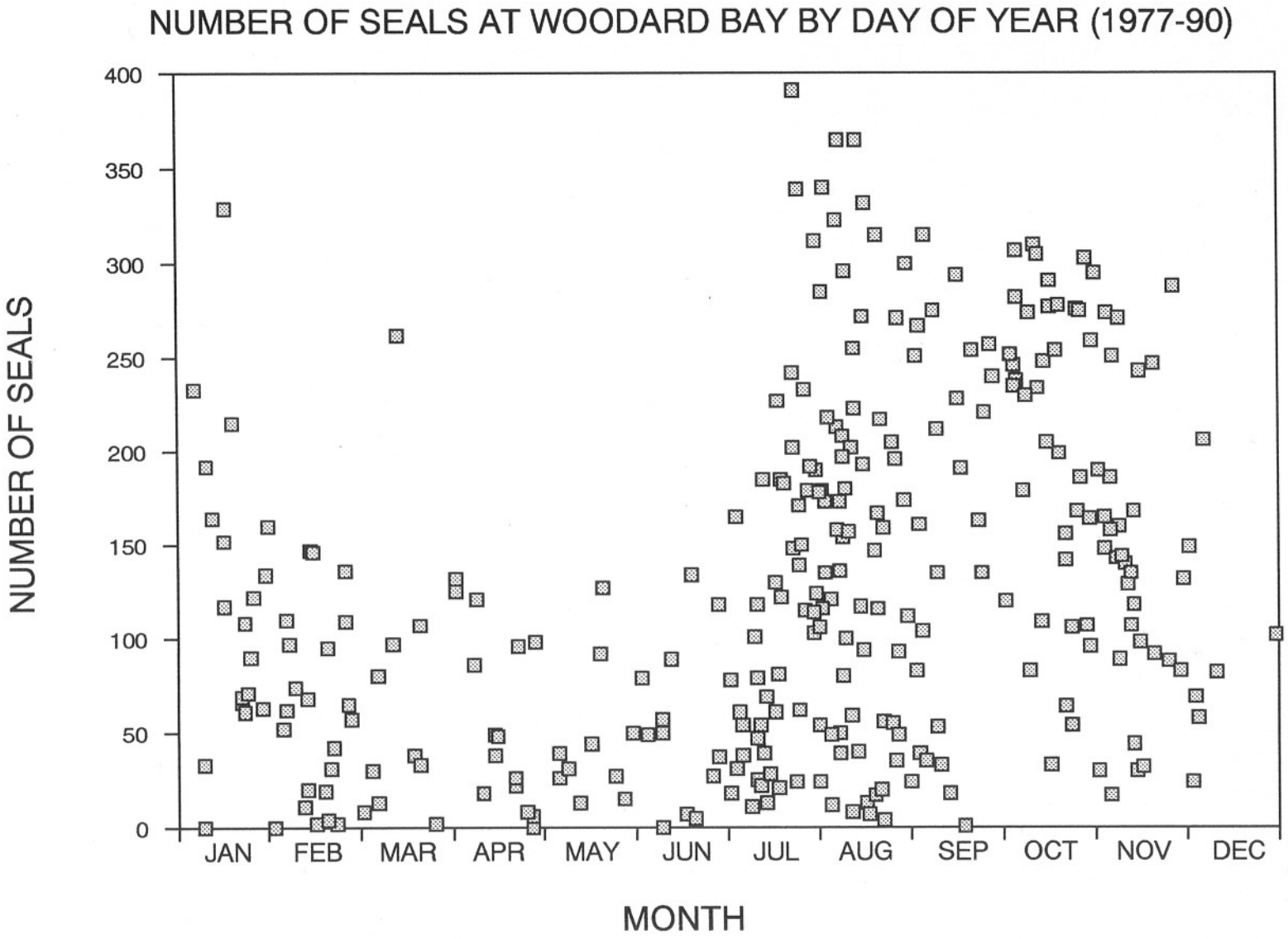

Figure 3. High counts of harbor seals at Woodard Bay by date through season. Includes counts for all years (1977-90).

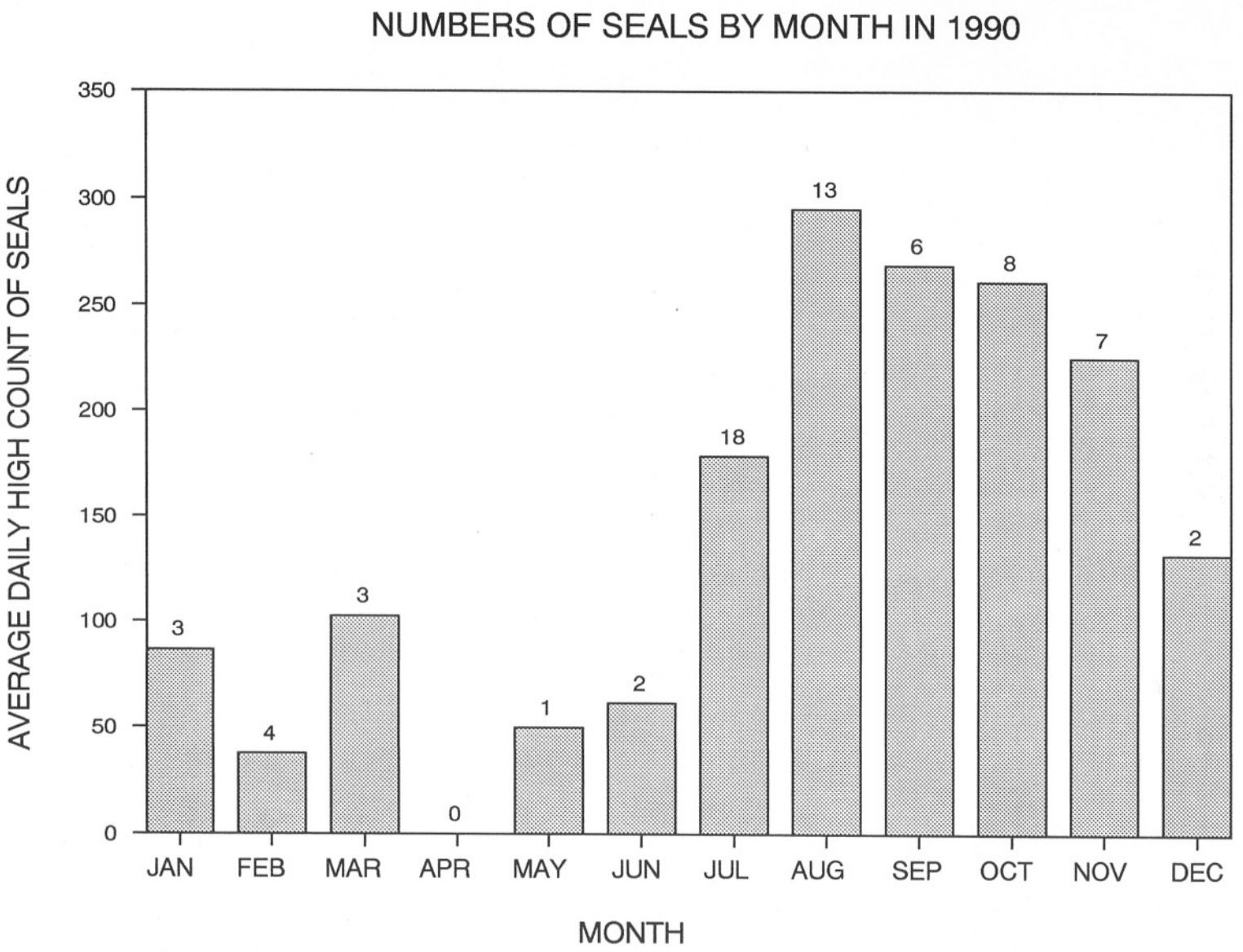

Figure 4. Mean daily high count of harbor seals by month during 1990. Numbers above bars indicate the number of counts made by month.

Numbers of seals remained high through the month of October then declined rapidly in November. The high counts in September and October, after the pupping season, represent the increased time seals spent hauled out during the molt.

Annual changes

Harbor seal numbers have increased dramatically at Woodard Bay since regular monitoring began in 1977. The pace of this increase was most pronounced between 1977 and 1985, which likely reflected 1) a higher rate of increase for the seal population and 2) an increased use of this site as a result of the slowing and eventual elimination of commercial activity at the site. Calambokidis et al. (1985) estimated a 31% annual increase in high counts, average counts, and pups born between 1977 and 1984. Increases in seal numbers have been occurring at other sites in Puget Sound (Calambokidis et al. 1985, 1988), however, the rate of increase at Woodard Bay was higher than any other site monitored and was higher than what could be attributed to a growing seal population.

Seal numbers at Woodard Bay have continued to increase based on counts conducted through the end of 1990. This is most clearly seen in the graph of average numbers of seals seen between July and October of different years (Figure 5). Though seal numbers appeared to stabilize between 1985 and 1989, the censuses in 1990 have revealed that the number of seals that use this site is still increasing.

The annual rate of increase of seal numbers varied depending on the method used. Regression analyses that incorporated the influence of the multiple factors discussed above indicated an annual increase of 20-30% in seal numbers between 1984 and 1990. The number of pups born at the site (measured for all years since 1984 except 1989) have increased at a rate of 11% per year since 1984 (Figure 6). In 1984, an unusually high proportion of mothers and pups were seen at this site as compared to what would be expected (Calambokidis et al. 1985). At the time of the high pup count in 1984, over 30% of the seals present were pups. This proportion had decreased to 26% in 1990. This change in proportion partially explains the lower annual increase revealed by pup counts compared to the total seal counts.

Harbor seal pups

The highest counts of pups made at Woodard Bay was 95 made on 7 August 1990 (Figure 6). This high number indicates Woodard Bay is now approaching Gertrude Island as one of the most important pupping areas for harbor seals in Puget Sound.

Pups are born at the Woodard Bay usually starting in early July, although the first viable pups were seen in 1990 on 28 June. Births appeared to continue through early August when the maximum number of pups were seen at the site. The timing of the

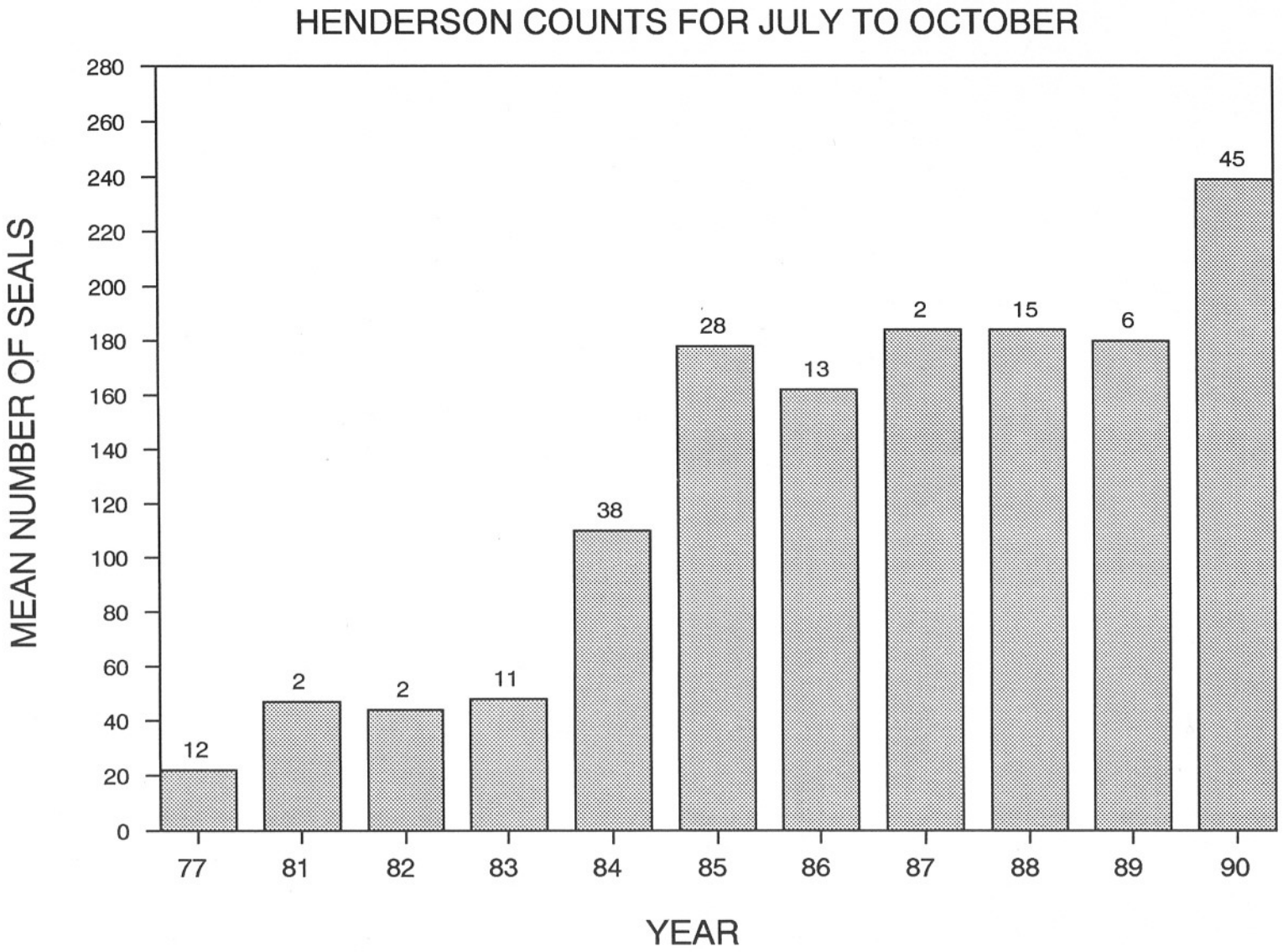

Figure 5. Mean daily high count of seals by year for 1977 through 1990. To minimize the effects of seasonal factors, only counts made in July to October are included. Numbers above bars indicate the number of counts made that month.

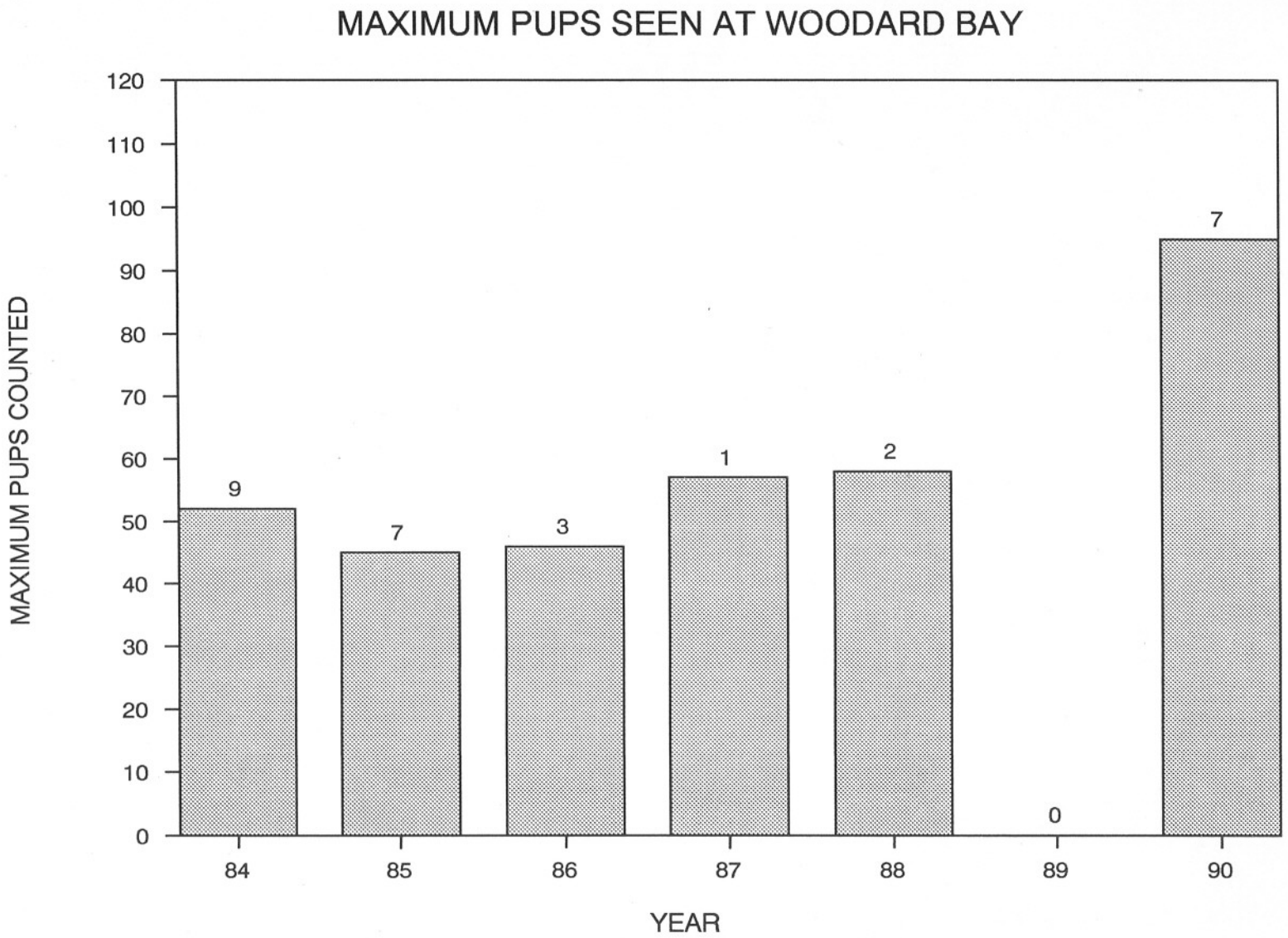

Figure 6. Maximum number of pups seen each year at Woodard Bay. Numbers above bars indicate number of visits made during period of peak pup numbers (27 July through 10 August).

pupping season at Woodard Bay is similar to that in Eld and Budd Inlets but is much earlier than the pupping season at Gertrude Island. Pups begin to be born at Gertrude Island, the largest haul-out site in southern Puget Sound, begin at the end of July and some are born as late as the end of September.

Births at Woodard Bay occurred on the log booms and especially on some of the areas that were covered with planks. Birth site locations have been examined in past years at this site through recovery of birth remains.

The number of pups at Woodard Bay, as a proportion of the total number of seals, is higher than at most other areas we have monitored in Puget Sound (Calambokidis et al. 1985). This suggests this area is particularly well suited for mothers and pups. Segregation of mother and pups away from other seals at other haul-out sites has been observed, apparently to protect the pup from harm or separation. The habitat at Woodard Bay may be ideal because it allows space for mothers and pups to separate from other seals and also is available at all tide heights. Unlike recreational floats in Eld Inlet, the log booms also are low enough to the water to allow pups to haul out even in the first few days after birth.

Disturbances of harbor seals

Harbor seals generally rest, give birth, and nurse young at haul-out areas (Scheffer and Slipp 1944). Many of these haul-out areas, especially near industrial and residential development, have been exposed to increasing human activities. The potential impact of disturbances from human activities on harbor seals has been a concern in a number of areas (Newby 1973, Allen et al. 1984, Johnson 1977, Paulbitsky 1979, Calambokidis et al. 1987).

Causes of disturbance

Disturbances from a variety of sources were noted at Woodard Bay from 1984 through 1990 (Table 2). The two primary causes of disturbances were recreational motor boats and skiffs, which together accounted for more than half (87 of 137) of the human-caused disturbances of harbor seals at Woodard Bay (Figure 7). Aircraft caused 12 disturbances (10 from non-military aircraft). Kayaks and canoes caused 24 disturbances. A few disturbances were also noted that were not caused by humans including those caused by deer, herons, and a natural tree-fall.

Causes of disturbances of seals at Woodard Bay in 1984 and 1990 show some differences (Figure 7). Pleasure boats caused more and small skiffs fewer disturbances in 1990 as compared to 1984. Kayaks disturbed seals more frequently in 1990 than 1984. Causes of disturbances of seals elsewhere in Puget Sound showed some differences from those at Woodard Bay (Figure 7). In the Hood Canal, people on foot

Table 2. Causes of disturbances at Woodard Bay documented in detail by observers from 1984 to 31 December 1990. The N reflects the number of disturbance observations where the number of seals disturbed was estimated.

Cause	Number of disturbances	Number of seals disturbed		
		N	Mean	SD
Person	7	7	50	69
Dog	2	2	35	21
Pleasure boat	59	53	22	37
Sailboat	4	4	14	21
Skiff	28	28	33	46
Kayak	15	13	24	32
Aircr. non mil.	10	10	42	70
Aircr. military	2	2	2	1
Logging vessel	2	1	25	
Working vessel	3	2	32	34
Deer	1	1	16	
Canoe	9	8	17	12
Bird	3	3	10	6
Unknown	2	2	23	18
Other	1	1	152	
Major categories				
Human	137	128	27	42
Animal	6	6	19	16
Unknown	1	1	152	

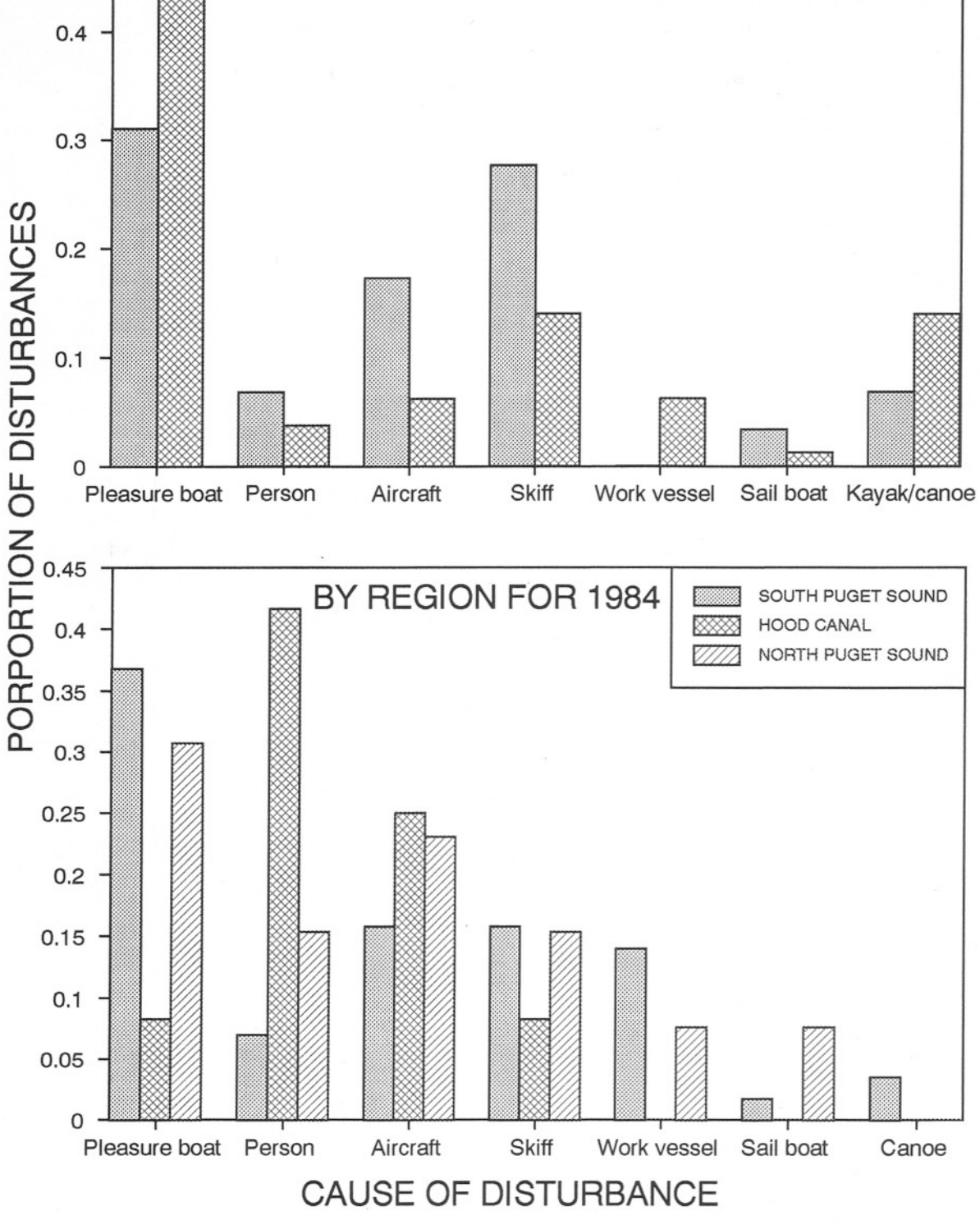

Figure 7. Causes of disturbances of seals at Woodard Bay (Henderson Inlet) in 1984 and 1990 and in regions of Washington State for 1984. Woodard Bay is included in lower figure as a part of southern Puget Sound.

were the most common cause of disturbance. This is reasonable because of the easy land access to some of the harbor seal haul-out sites in the Hood Canal.

Regardless of the type of disturbances, the primary activity of those causing the disturbance was observation or curiosity of boaters in the seals (Table 3). In about 70% of the human- caused disturbances it appeared the purpose of the trip into Woodard Bay was to observe harbor seals.

The people who caused the disturbances usually approached the seals without the apparent intention of disturbing or harassing the seals (Table 4). In nine instances, however, we judged that the people who caused the disturbance were attempting to harass the seals. In these cases, the average number of seals disturbed was more than three times higher than when harassment did not appear intended (Table 4). In the remaining cases, the people who caused the disturbance either appeared unaware of the seals or we could not determine their intention.

The causes of harbor seal disturbance reported in other areas include birds, domestic animals, earth slides, agonistic seal behavior (aggression between seals), all-terrain vehicles, boats, canoes, cruise ships, people attempting to photograph seals, hikers, clam-diggers, planes, and helicopters (Pitcher and Calkins 1979, Renouf et al. 1981, Johnson and Jeffries 1983, Calambokidis et al. 1983, Allen et al. 1984).

Allen et al. (1984) reported the proportion of disturbances of harbor seals in Bolinas Lagoon, California, by their source. The primary cause was non-power boats (55% of disturbances with known causes), primarily canoes. People on foot (17%) and power boats (13%) were the other major causes (calculated from Allen et al. 1984).

Rate of disturbance

Disturbances of seals (human activities causing seals to enter the water) were seen on 45% of our observation periods in 1990 at a rate of 0.33 disturbances per observation hour. A number of factors influenced the rate of disturbance at Woodard Bay. Most pronounced of these were season, year, time of day, and day of week. These factors reflect the obvious factors that influence the number of people out on the water and around the site.

The rate of disturbance in 1990 varied among seasons with summer and, secondly, spring having the highest rates of disturbance (Figure 8). The disturbance rate was lowest in winter when disturbances occurred five times less often than in summer. The monthly rates of disturbance show the above pattern in more detail (Fig. 9). Highest disturbance rates occurred during July and early August during the pupping season. The decrease in disturbance (apparent in Figure 9), after the actions taken on 10 August 1990 to warn boaters against disturbing seals, are discussed later in this report.

Table 3. Activity of sources of disturbances at Henderson Inlet documented in detail by observers from 1984 through 31 December 1990.

Cause	Number of disturbances	Number of seals disturbed		
		N	Mean	SD
Sport fishing	1	1	8	
Commer. fishing	5	5	92	80
Traveling	16	16	14	18
Seal Watching	101	97	19	23
Loggers working	7	6	20	21
Clamming	1	1	1	
Other/unknown	15	11	61	62

Table 4. Apparent intention in approaching seals by sources of disturbances at Henderson Inlet documented in detail by observers from 1984 through 31 December 1990.

Cause	Number of disturbances	Number of seals disturbed		
		N	Mean	SD
Approached intentionally	104	101	19	28
Disturbed intentionally	9	8	59	48
Unaware	10	9	7	9
Unknown	25	19	67	74

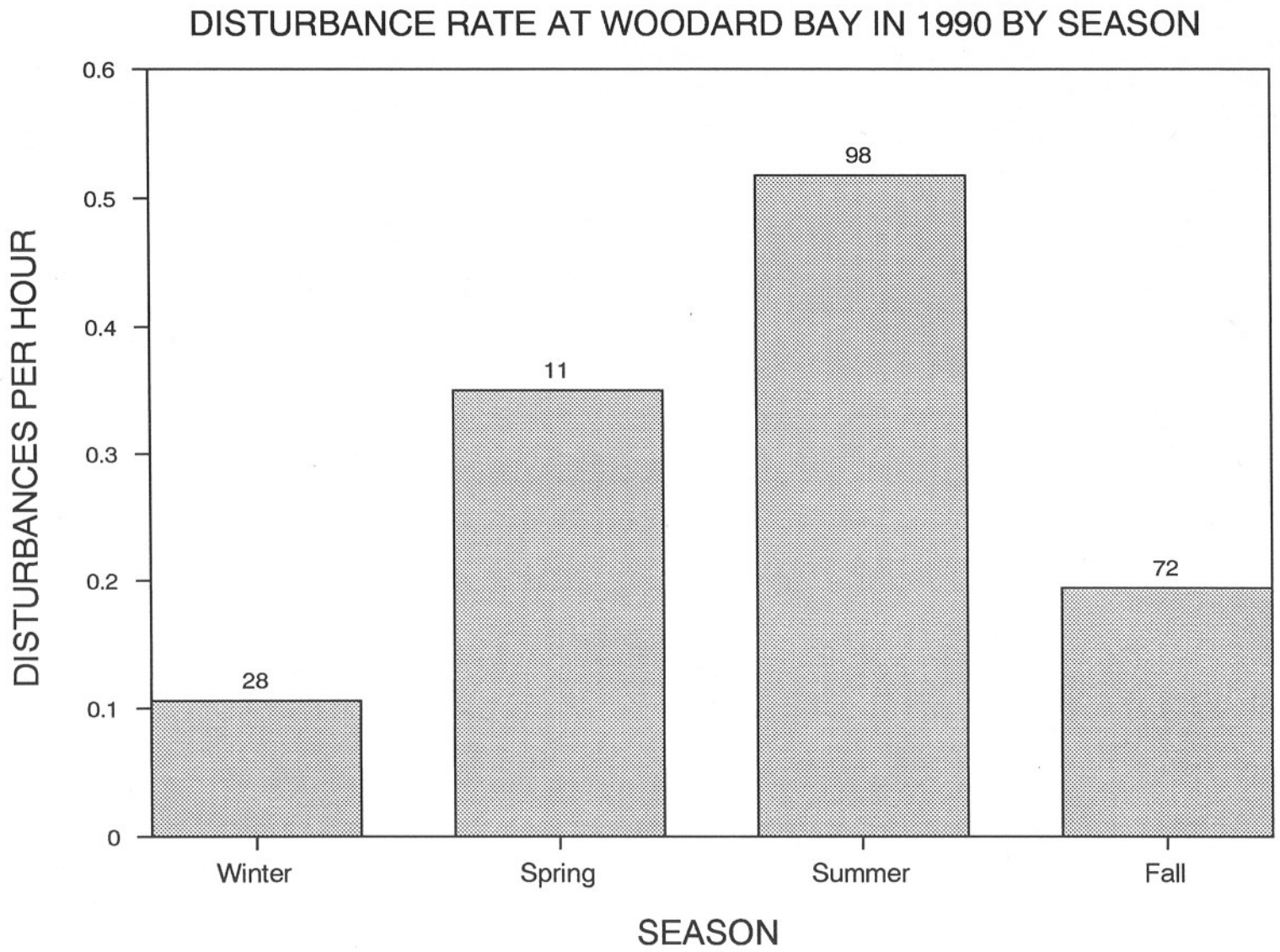

Figure 8. Frequency of human-caused disturbances of seals at Woodard Bay by season for 1990. Numbers above bars indicate hours of observation.

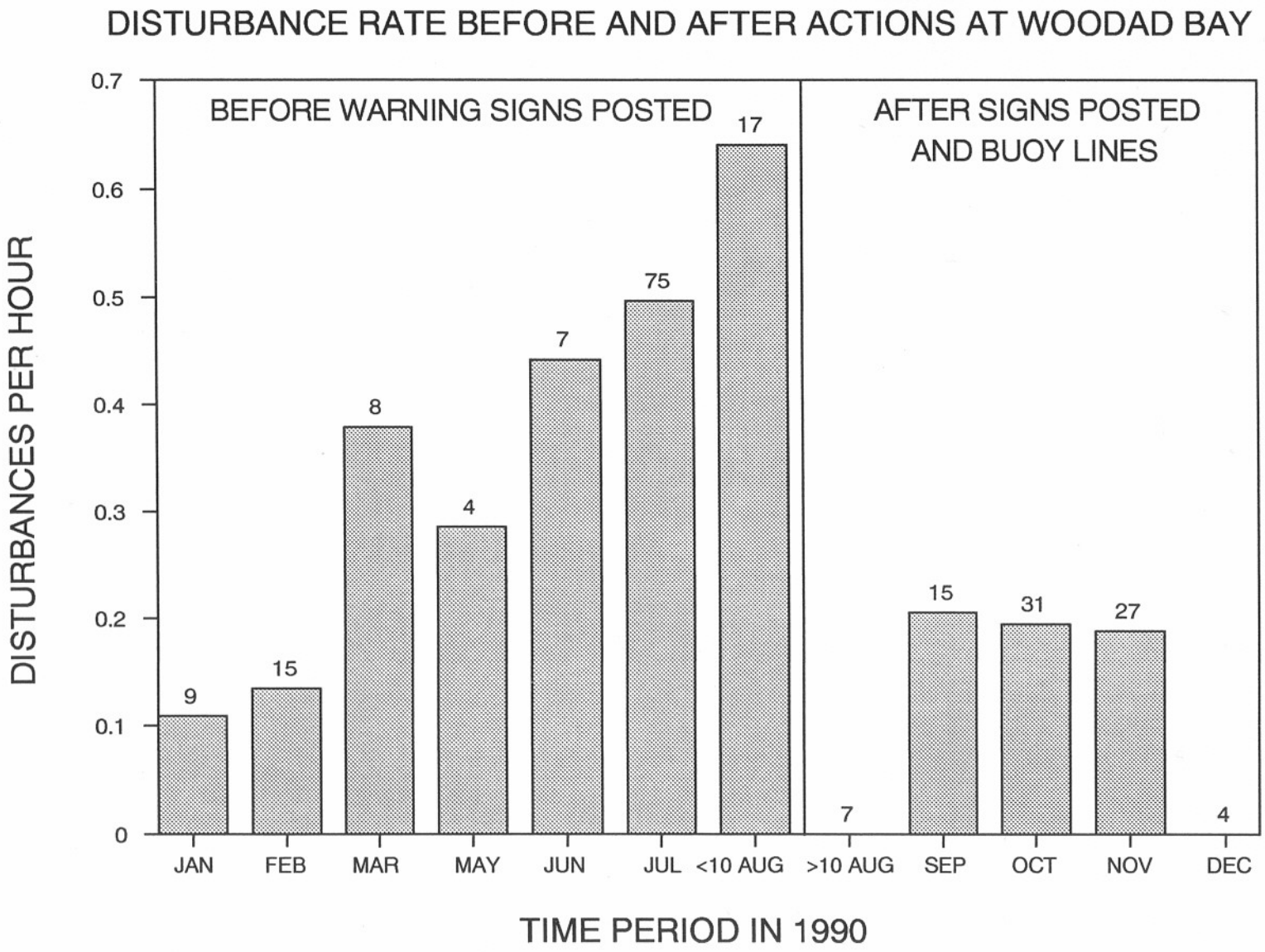

Figure 9. Frequency of human-caused disturbances of seals at Woodard Bay by month for 1990. August is divided based on the date when actions were taken to reduce disturbance (see text). Numbers above bars indicate hours of observation.

Annual rates of disturbance were affected by differences in the season, day of week, and time of day of observation in different years. Disturbance rates in 1990, compared only for July to September among the years, were higher than any other year (Figure 10). Somewhat surprisingly, disturbance rates in 1984 were next highest after 1990, though this may be partly the result of the lower observer effort in other years.

The frequency of disturbance was more than twice as high on Saturdays than any other day of the week. High rates of disturbances were also noted in late afternoon and evening hours of weekdays, especially on Friday. In both cases, this is a reflection of the increased recreational boating during these time periods.

The disturbance rate at Woodard Bay in 1984 as well as 1990 was more than twice as high as at other sites in Washington State (Figure 11). Comparative figures for other sites around Washington State were only gathered in the summer if 1984. Besides Woodard Bay, disturbance rates were next highest in the San Juan Islands and in Budd Inlet in southern Puget Sound, both areas of heavy recreational boat traffic.

The rate of disturbance of harbor seals in Woodard Bay is also higher than rates reported in studies conducted in California. Allen et al. (1984) reported the mean number of actual disturbances (when the source was known) at 1.1 and 0.6 disturbances per day for two haul-out sites in Bolinas Lagoon. The frequency these disturbances was higher in summer at both sites (1.5 and 0.7 disturbances per day)(Allen et al. 1984).

Distances of disturbances

We monitored the distance at which seals entered the water upon the approach of three types of vessels. These consisted of pleasure motorboats (n=22), skiffs (n=11), and kayaks/canoes (n=11). The mean distance that seals entered the water in response to these vessels was 56 m (n=44, s.d.=44). Most commonly seals were disturbed when vessels were 26 to 50 m, though only above 125 m was there a sharp decrease in the proportion of groups disturbed (Figure 12). The maximum disturbance distance was 246 m; this was substantially higher than any other disturbances we monitored.

The distances at which seals were disturbed varied significantly between the three vessel types, (ANOVA, p=0.038). The mean distance for each type ranged from 40 m to 84 m (Figure 12). Seals entered the water in response to kayaks and canoes at almost twice the distance of the other two types of vessels.

We also observed seals being disturbed by people on the trestle. These sometimes involved groups of seals more than 100 m from the people and on one occasion, two people on the trestle caused 5 groups of seals to enter the water at distances ranging from 84 to 256 m. At other times, however, seal researchers (keeping quiet and maintaining a low profile) were able to pass less than 100 m from seals without causing disturbance.

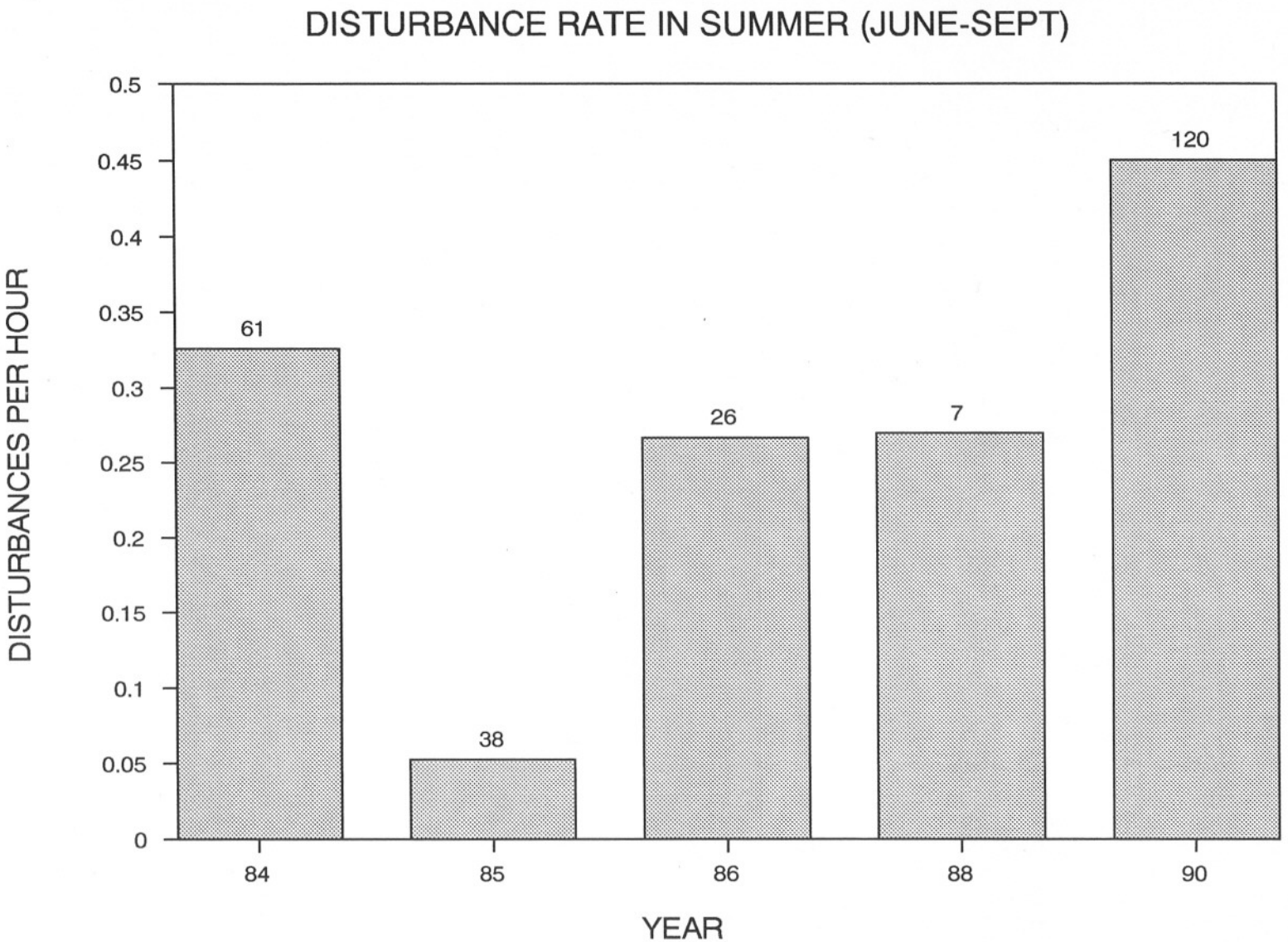

Figure 10. Frequency of human-caused disturbances of seals at Woodard Bay by year for summer months (June to September). Numbers above bars indicate hours of observation.

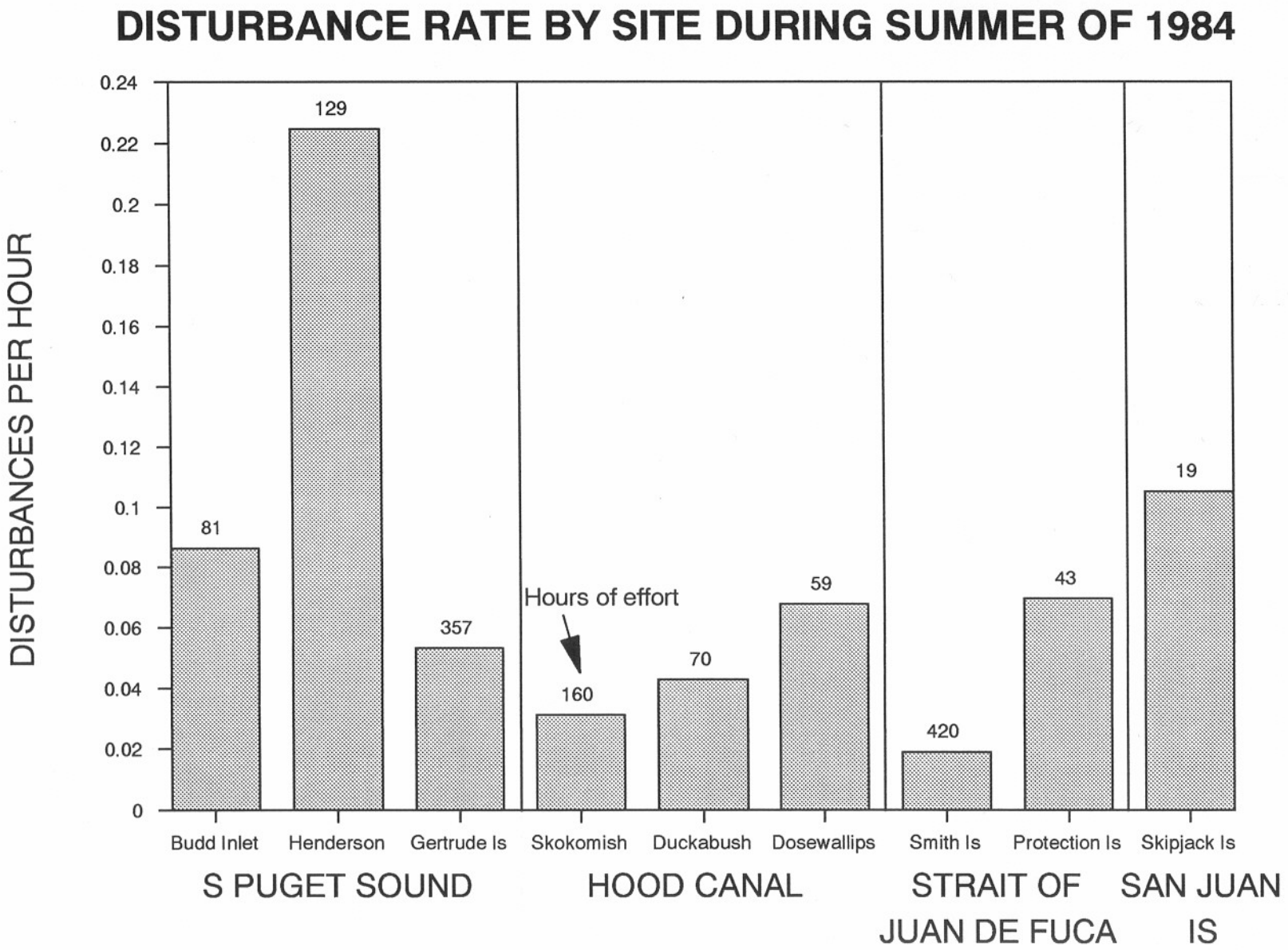

Figure 11. Frequency of disturbances of seals at different sites in the Puget Sound area in 1984. Numbers above bars indicate hours of observation.

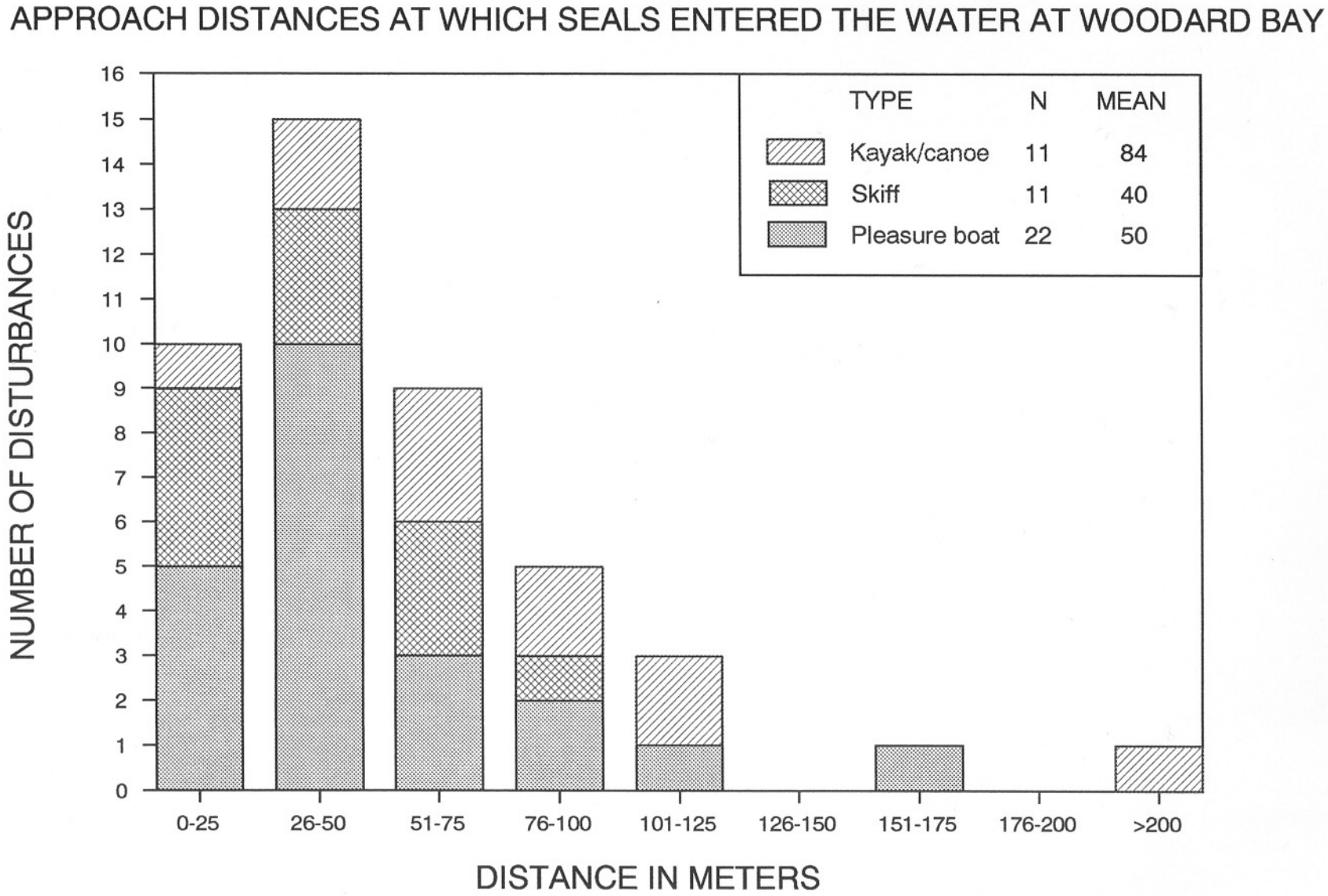

Figure 12. Distances at which harbor seals entered the water on the approach of vessels. Sample size and average distances by vessel type are given in the upper right corner.

Other studies of disturbances of harbor seal have only estimated the distance at which disturbance occurs. Johnson and Jeffries (1983) reported that the entire group of harbor seals would enter the water if boats approached as close as 100 yards; small aircraft below 500-600 ft would have the same impact. Allen et al. (1984) reported that disturbances usually occurred within 100 m of a haul-out site, however some were caused from more than 200 m distances.

The actual distance of disturbance was closer at Woodard Bay than was found in Glacier Bay, Alaska, in a study using similar methods (Calambokidis et al. 1983, In prep.). The mean distance of disturbance, when a disturbance caused at least 50% of the seal group to enter the water, was 167 m (n=90, s.d. 112).

Similar to this study, the reaction distance of harbor seals varied significantly by vessel type in Glacier Bay (Calambokidis et al., In prep). The mean distance was 134 m (n=47, s.d.=88) for tour boats, 277 m (n=17, s.d.=148) for cruise ships, 169 m (n=17, s.d.=75) for pleasure boats, and 130 m (n=9, s.d.=87) for kayaks.

Some other studies reported that weather factors affected disturbance distances. Seals tended to react at closer distances on overcast and rainy days compared to sunny days (Calambokidis et al., In prep). However, Johnson (1977) reported that seals reacted to low flying aircraft at greater distances on calm days compared to "noisy days" with strong winds, rough seas, or rain.

Number of seals disturbed

It was not always possible to determine the total number of seals that enter the water with each disturbance. Our estimates indicated most human disturbances caused at least 26 seals to enter the water. Of the common types of disturbance, kayaks tended to disturb more seals than other types. This is likely because: 1) kayakers often came to the area as a group (which we treated as a single unit) and then dispersed thereby disturbing seals in many different areas and 2) the greater distance at which seals reacted to kayakers.

Impact of disturbances

Harbor seals are considered the most wary of the pinnipeds as an instinctive reaction from hunting and land predators. There has been surprisingly little research documenting the impacts of disturbance on harbor seals. Most impacts discussed in the literature are speculative. Seal disturbance has been discussed to have a number of potential effects:

1) change in behavior at site by altering haul-out times

2) abandonment of preferred haul-out areas

3) mother-pup separation during bond formation

4) interruption of nursing

5) increased stress during the molt

6) potential stress during other seasons (e.g. mating)

7) interruption of rest resulting in lower fitness and health.

Some reports have suggested that harbor seals may alter their haul-out patterns at a site in response to human disturbance. Seals haul out at night and early morning at some sites in Puget Sound (Calambokidis et al. 1978) and San Francisco Bay (Paulbitsky 1975), presumably to avoid disturbance.

However, repeated disturbance may cause seals to abandon their haul-out sites completely and move to less-preferred areas. Kenyon (1972) reported that repeated disturbances caused Hawaiian monk seals (Monachus schauinslandi) to leave preferred habitat. Gerrodette and Gilmartin (1990) showed that monk seal numbers declined at haul-out sites after the Coast Guard built and operated loran stations; pup mortality increased and few subadult seals were seen. Conversely, numbers of seals increased at another haul-out site when a loran station was closed.

A major disturbance of harbor seals during the pupping season could cause separation of the mother and pup which would result in the death of the pup. Pitcher and Calkins (1979) reported an observation of a radio-tagged mother that separated from its newly-born pup when they fled to the water when a helicopter flew overhead. Pitcher and Calkins (1979) suggested that separation occurs if the disturbance is during within the first few hours of birth and a strong mother-pup bond has not formed. Johnson (1977) speculated that pup mortality due to disturbance may be as high as 10% of the pups born at Tugidak Island, Alaska. Separation is probably less likely at Woodard Bay because the seals are more dispersed that at most seal haul-out areas.

Repeated disturbances during nursing could affect the survivorship of the pup. The nursing period of phocid seals is very short and followed by a period of abrupt weaning (Oftedal et al. 1987). For harbor seals, nursing lasts for 4-6 weeks, during which time the pup grows from 10 to 24 kg (22 to 53 pounds)(Bigg 1969). The pup's survival depends on it's fat reserve, survival rates in other seal species have been correlated with weaning size (Gerrodette and Gilmartin 1990, Coulson and Hickling 1964). Repeated interruptions of nursing probably decreases the amount of milk the pup receives and therefore affects its chances for survival after weaning.

Disturbance may have a greater affect on seals when they are molting. Physiologically, molting is a stress (Geraci and Smith 1976) and haul-out conditions are

important for warming the skin and promoting growth of epidermal cells (Feltz and Fay 1966). Harbor seals haul out for longer periods during this time (Cascadia Research, unpubl. data). When seals enter the water frequently because of repeated disturbances, this process is interrupted and the stress is likely enhanced.

Actions taken to reduce disturbance

Due to a high rate of disturbance noted in July 1990, actions were taken in cooperation with DNR, tHe Woodard Bay NRCA Advisory Committee, and the National Marine Fisheries Service. These disturbances occurred during the peak of the annual pupping season of harbor seals, the most critical time when disturbances may have the most serious impact.

The following actions were taken in August 1990 to reduce disturbances:

Posting of temporary signs: Most boaters appeared unaware that access to the site was restricted, that their activities may harm the seals, or that harassing seals was in violation of the Marine Mammal Protection Act. Signs were designed, manufactured, and posted on 10 August 1990 (Figure 13). The signs were posted on pilings along the perimeter of the site and on posts at the edges of the log booms.

Newspaper article: A newspaper article on the problem with disturbance was published by the Daily Olympian. This article had the risk of informing additional people about the site, however, this risk was small given how well known the site appeared to be among boaters.

NMFS enforcement: National Marine Fisheries Service enforces the Marine Mammal Protection Act. We have relayed information to NMFS about disturbances that appear to be severe enough to be a violation of the MMPA provision that forbids harassment. NMFS has pursued prosecution of several of these instances at Woodard Bay.

Closing off of the log booms: The most serious disturbances of harbor seals occurred when vessels entered the area in between the log booms. This resulted in disturbance of not just the animals along the perimeter but those on internal booms. A floating line marked with buoys was placed around the log boom openings on 10 August 1990. This did not present a large physical barrier, however, it required a more blatant action on the part of the boater to cross the barrier and disregard the warning signs.

The above actions were extremely successful in discouraging disturbances of seals by boaters. There was an immediate dramatic decrease in the rate of disturbances after the signs were posted and the buoy lines installed (Figure 9). This indicated that, for

DO NOT APPROACH SEALS

PLEASE KEEP 100 YARDS FROM SEALS ON LOG BOOMS. DO NOT CAUSE THEM TO ENTER THE WATER.

It is illegal to harass or disturb harbor seals and other marine mammals under the Marine Mammal Protection Act of 1972, enforced by the National Marine Fisheries Service with fines up to $10,000.

Contact DNR 753-2400 or Cascadia Research 943-7325

Figure 13. Format of sign posted around the perimeter of Woodard Bay on 10 August 1990.

the most part, boaters were ready to be cooperative and avoid disturbances if adequate information and warnings were provided.

Habitat requirements of seals

Use of human-made habitats

In Puget Sound, a variety of human-made structures are used by harbor seals to haul out. They include recreational floats, log rafts and booms, oyster rafts, fish net pens, marina floats, and breakwaters (Table 5). Log boom structures such as those at Woodard Bay are one of the most commonly used human-made habitats in Puget Sound.

Size of haul-out areas per seal

To determine the amount of haul-out space required by seals, we estimated the density of seals in a haul-out group at land and human-made haul-out sites. Results of this work were reported in more detail in Calambokidis et al. (1990). Among land (or "natural") sites, the density of seals hauled out were similar. The mean density of seals in groups was 1.9 m^2/seal and ranged from 1.0 to 3.1 m^2/seal (n=13)(Table 6) at sites examined.

At human-made haul-out areas, the area used by seals (Table 6) tended to be slightly larger but more variable than natural habitats. The two lowest measurements of area per seal were at a float in Eld Inlet (0.66 m^2/seal) and on a single log-boom stick at Woodard Bay (0.65 m^2/seal) where seal bodies hung over the edge of the platform.

One reason for the slightly larger area per seal at human- made habitat may be because of differences in group size. Group sizes were smaller at human-made haul-out areas (Table 6). We found a significant inverse correlation between the number of seals in the group and the area per seal (Figure 14) at Woodard Bay ($n=44$, $p<0.05$), where we had the largest sample and a wide range of group sizes. This relationship indicates that seals are more widely spaced from other animals (in their group) when there are fewer of them.

The area per seal measurements were highest at Woodard Bay where a larger area is available for seals to use than at the other human-made haul-out areas. The log-boom sticks available to seals in the summer of 1990 provided 9,900 m^2 of haul-out space (about 25 m^2/seal for 500 seals) and 12,950 m of water-line distance (about 33 m/seal). The existing space available at this site is far greater that is currently required by the seals.

Table 5. Types of human-made habitat and fallen trees used by harbor seals to haul out at some sites in Puget Sound.

Habitat	Location	Maximum count of seals
Log rafts	Budd and Henderson Inlets Port Gamble, plus others	>200
Log booms	Quilcene, Henderson	391
Fallen trees	Dosewallips and Duckabush deltas	77
Recreational float	Eld and Totten Inlets, Hood Canal	55
Oyster rafts	Quilcene, Totten Inlet	100
Fish net pen	Quilcene	115
Marina floats	Drayton Harbor	50
Breakwater	Hamma Hamma	20

Table 6. Areas used by defined groups of seals at land sites in Puget Sound and adjacent waters. Areas determined through aerial photogrammetry by Calambokidis et al. (1990) or with theodolite readings. Seals were considered part of a group if they were within 3 m of another seal in the group.

Habitat	Location	Number of groups measured	Avg. group size	Area(m2/seal)				Shoreline distance(m/seal)			
				mean	s.d.	min	max	mean	s.d.	min	max
Sand spit	Gertrude Island	2	259	1.5	0.02	1.5	1.5	0.38	0.07	0.32	0.45
	Smith Island	4	165	2.2	0.04	1.9	2.9	0.53	0.08	0.46	0.65
	Protection Island	1	180	1.4	-	-	-	0.38	-	-	-
	TOTAL	7	194	1.9	0.48	1.4	2.9	0.47	0.10	0.32	0.65
Salt marsh	Skokomish Delta	4	26	1.6	0.59	1.0	2.5	0.95	0.22	0.66	1.3
	Duckabush Delta	2	59	2.5	0.60	1.9	3.1	0.88	0.19	0.70	1.1
	TOTAL	6	37	1.9	0.73	1.0	3.1	0.93	0.21	0.66	1.3
Log booms	Henderson Inlet	44	11	2.4	0.97	0.65	5.1	3.0	1.2	1.7	6.4
Floats	Eld Inlet	25	7	2.8	2.7	0.66	14.	3.5	3.1	1.0	15.
Fish pen	Quilcene Bay	1*	115*	-	-	1.7	-	-	-	3.1	-

* Only single measurement of maximal count and area of entire structure used.

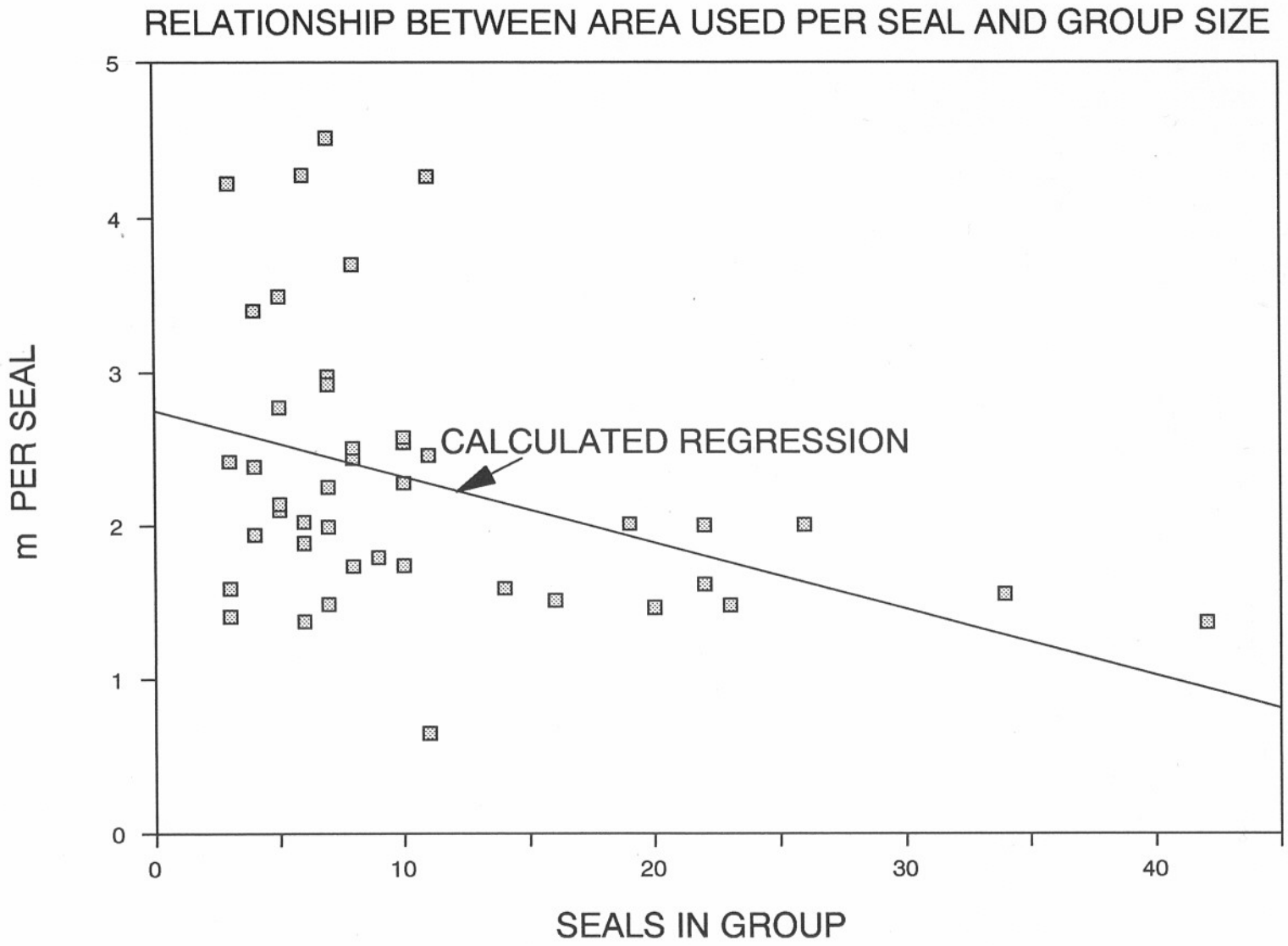

Figure 14. Relationship between average haul-out area space per seal and the number of seals in the group at Woodard Bay in 1990 (n=44, r=0.44, p<0.05).

Shoreline (water access) requirements

At harbor seal haul-out areas on land, the mean shoreline distance (the distance of shoreline or water access for a group of seals) was 0.5 m/seal (n=7, range 0.32-0.65) at sand spit sites and 0.9 m/seal (n=6, range of 0.66-1.28) at salt marsh sites examined (Table 6)(Calambokidis et al. 1990).

Unlike the haul-out density measurements, the length of shoreline available to seals at the sites examined differed significantly between human-made structures and natural habitats ($p<0.001$). The lower shoreline area used by seals at the sand spit reflects the way seals bunch together above the water line. The dramatically higher shoreline areas at human-made habitats probably reflects the large amount of water access provided by log booms as well as the association with group size (significantly inversely correlated at Woodard Bay ($n=44$, $p<0.05$)).

Platform height above water

The platform height above water for human-made structures used by seals, including log booms, floats, and a fish net pen, ranged from 12 to 54 cm (Table 7). Log booms at Woodard Bay were the lowest in the water (range 12 to 28 cm).

Newborn harbor seals require the lowest platforms to haul out. From previous observations of pups at recreational floats in Eld Inlet, we have seen pups make attempts to haul out on floats that were too high. In some cases, the mother that was hauled out would lower here posterior end off the edge of the float and the pup could nurse from the water, although it appeared that the pup expended more energy nursing in this manner. In 1984, pups were first seen in the water on 16 July but were not seen hauled on floats until 22 days later (7 August). From our observations at Woodard Bay, it appears that mothers with pups haul out on logs that tend to be lower in the water (<20 cm).

Table 7. Height of haul-out platform above the water at different human-made sites in Puget Sound determined by Calambokidis et al. (1990). Number of measurements (n) and height above water (cm) are given.

Habitat type	Location	n	Height above water (cm)		
			avg	low	high
log boom sticks	Henderson Inlet	10	19	12	28
recreational floats	Eld Inlet	18	34	17	54
fish net pen	Quilcene Bay	1	33	-	-
trial float	Dosewallips Delta	1	25	-	-

RECOMMENDATIONS

As part of this project for the Department of Natural Resources, we are providing recommendations for long-term preservation of harbor seals at Woodard Bay.

Timing of activities

Activities by DNR to make changes to the Woodard Bay site to the conservation area that will be disruptive to seal use of the area should be conducted between November and June and avoided between July and October. The most critical period for harbor seals at the site is July and August when pupping is occurring at the site. Secondarily, September and October is when the most animals are molting and some of the highest numbers of seals consistently use the site.

Activities that are disruptive to seals are best conducted in early morning hours and during rainy days. Harbor seal use of the site generally increases through the day and is highest when there is no precipitation

Replacement of haul-out habitat

Area: The current log boom area provides a surplus of space for seals using the site at this time. If the population continues to grow (and is allowed to grow), it will likely number up to 500 animals within the next 5 years. Space and shoreline (waterline) area requirements were considered assuming up to 500 animals might use the site. At a minimum, there needs to be 2.5 m^2 of haul-out space per seal (including a margin for spacing between seal groups) and at least 1 m of water access per seal. Water access is less of a limiting factor here because the haul- out designs discussed below meet this requirement easily. In total, the haul-out requirements for 500 seals would be 1,250 m^2 area and 500 m of water access.

Design: If current structures used by seals are replaced in the future, they should contain the same essential elements currently available at the site. Current habitat consists of both single logs and platform space created by logs tied together or areas with planking. Harbor seals should be provided space that allows both grouping of animals (generally the case) and spacing of animals (needed by pregnant females and mothers and pups).

Two types of structures, log booms and floats, represent the best choices for alternate habitat at Woodard Bay. Both are used commonly by harbor seals and present different advantages and disadvantages (Table 8). The current design of the log structures at Woodard Bay represent an ideal design (Figure 15). The most compact and ideal float structure would be an open-cell float structure (Figure 16). A combination of both logs and floats would provide the best habitat for harbor seal haul-out habitat. Phasing in new structures gradually over time would allow an evaluation of their effectiveness.

Table 8. Relative advantages and disadvantages of different structures for use as seal haul-out.

Criteria	Floats	Log booms
Initial cost	High, likely \$20 ft^2	Approx. 1/3 cost
Maintenance	Low for concrete	Higher, ends need reaugering
Size	Relatively compact	More dispersed
Use for haul-out	Good	Good
Use for birthing	Excellent	Poor w/o platform Good w/ platform
Use by pups	Poor w/o low ramp Good w/ ramp	Excellent

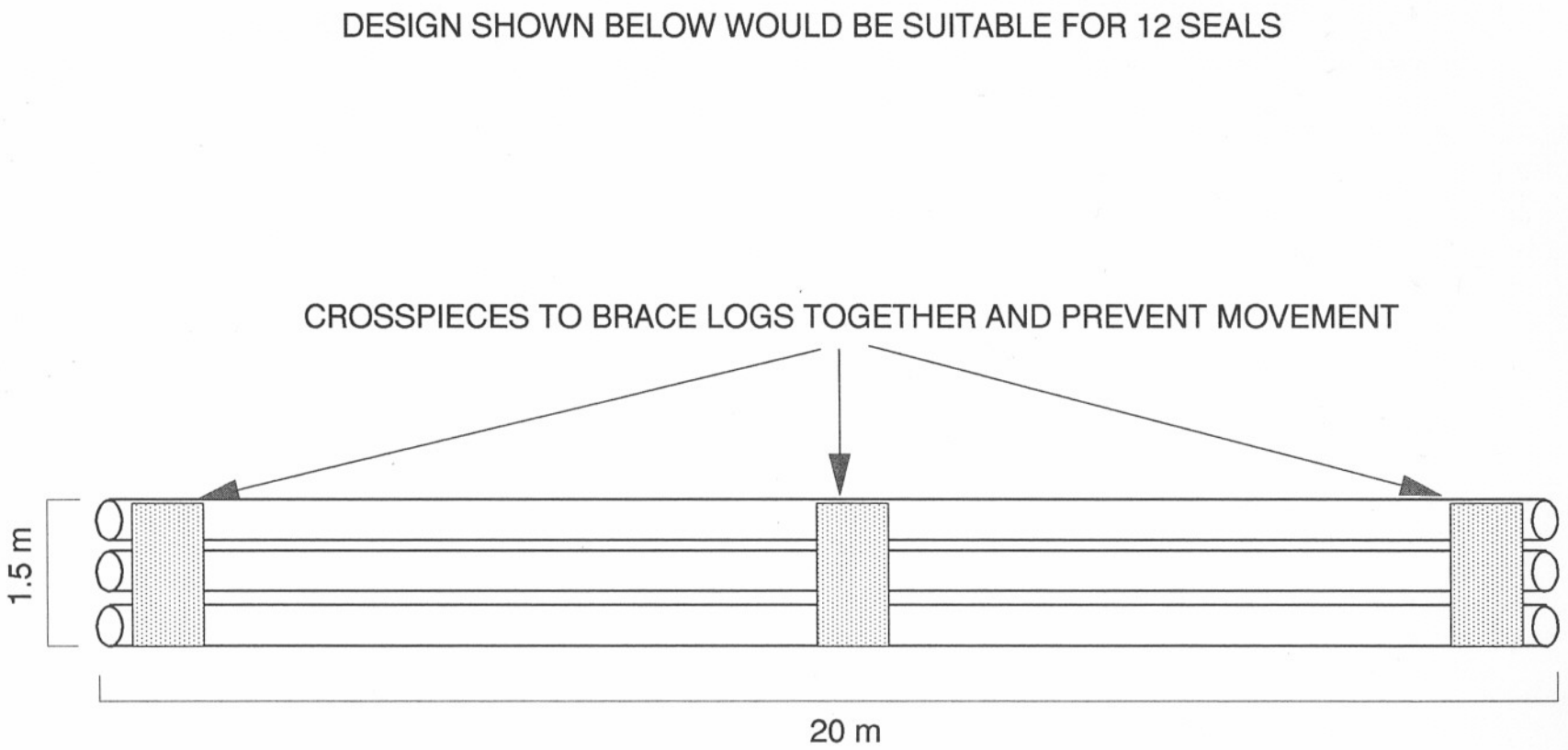

Figure 15. Design of float structures usually used by harbor seals at Woodard Bay. Under typical conditions this size structure would hold up to 12 seals.

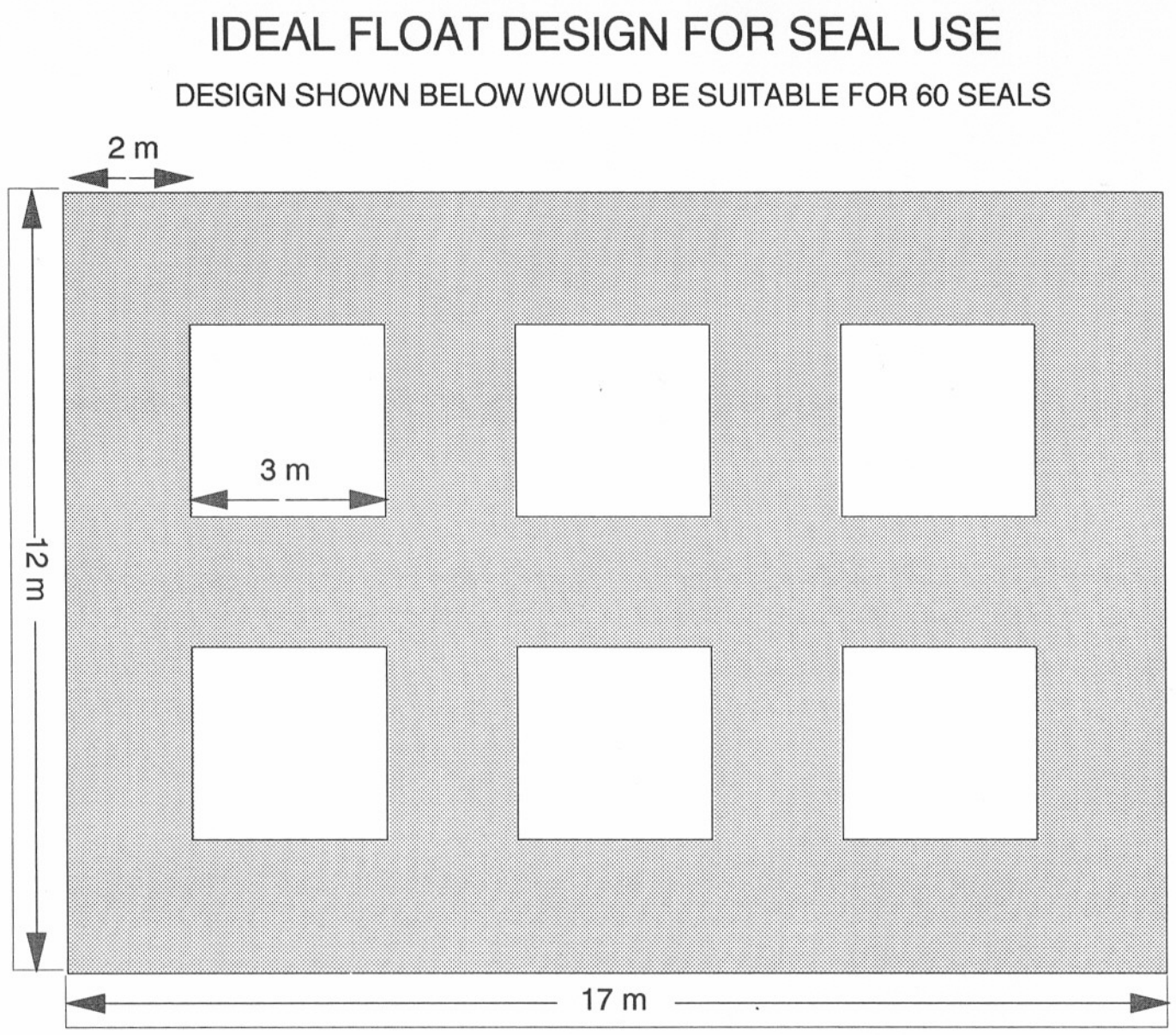

Figure 16. Example of ideal and compact float structure for seals. Open cells allow access to water from center areas. Design shown is suitable for 60 seals.

Placement: Haul-out structures should be placed so that they remain accessible to deep water at all tides. They should also remain in areas where they can be protected from disturbance (see below).

Implementation: Given the current surplus of haul-out space at Woodard Bay, replacement of haul-out structures does not need to be implemented until the space available reached as low as 2,000 m^2. This is above the minimum space requirement for 500 seals listed above. Below this figure, the available habitat would approach the minimum space required for seals. We recommend action be taken at that time to insure that delays in replacing haul-out structures would not allow the area available to seals to reach the minimum space required.

Seals may take some time to get used to using new structures that replace existing habitat at Woodard Bay. We recently examined if seals would readily use a recreational-type float off the Dosewallips Delta, a site where they usually haul out on the salt marsh (Calambokidis et al. 1990). Seals did use the new float regularly, but only after it had been deployed for almost two months. Although seals at Woodard Bay already use log boom structures to haul out, any other type of structures used should be installed at least two months before critical periods, such as the onset of pupping (by early May).

Protection from disturbance

Protecting seals from disturbance represents the major challenge for insuring that public access to the site does not threaten the use of the site by seals. This has been a major problem already (see previous sections) and will only increase with development at the site for human use. Steps that will need to be in place include:

A designated area that the seals use where vessel (motorized or non-motorized) or people on foot are not allowed.

A clearly marked barrier that prevents boaters and people on foot from approaching closer than 150 meters (165 yards) from the seals. This barrier should be made out of something other than floating logs that seals will use as a haul-out habitat.

Walkways for people on foot should also be kept at a distance of at least 150 m from the seal haul-out areas. Closer approach would be possible if a visual barrier was constructed to make the people less visible to the seals.

Permanent warning signs informing people about the seals, why they should not be disturbed and the potential legal consequences. These signs should be placed at the perimeter barrier for the site so that they are legible before people get within 150 m of the seals.

Training of personnel at the site on violations of the Marine Mammal Protection Act and how to proceed in such an event.

Education and public access

The harbor seals at Woodard Bay do provide a unique opportunity for educating the public and providing them with access to observing and understanding marine mammals in a wild setting. There remain many misconceptions about marine mammals from both their supporters and detractors. Educational signs, displays, and reading material can provide a better understanding.

Attempts to avoid disturbance of harbor seals does not need to prevent human access. Informing people on proper ways to observe marine mammals without causing disturbances can be an important educational value of their experience at the site. The placement of spotting scopes at the site would allow people to get close views of seals without needing to get close.

Compatibility with other uses

The harbor seal use of this site may pose some conflicts with other human uses of the site. Some of the recommendations above reflect the need to limit human activities that may disturb seals in the immediate vicinity of the haul-out area. Additionally, harbor seal fecal contamination in the immediate vicinity of the haul-out area may not be compatible with shellfish harvesting. Research conducted by Cascadia Research in other areas indicates this problem occurs only at the haul-out area itself and does not appear to affect surrounding waters used by seals for feeding (Calambokidis et al. 1989).

Harbor seals may also interfere with recreational fishing at the Woodard Bay site. Harbor seals prey on fish caught with hook and line in other areas and a similar problem could develop at the Woodard Bay site.

Future research and monitoring

We recommend a continued monitoring and research program on harbor seals at Woodard Bay. Reasons for continuing this research include:

Research and monitoring is needed to provide accurate educational information to visitors of the site.

The large number of harbor seals, especially mothers and pups that use the Woodard Bay site make it important to the regional seal population.

This species is already one of the major attractions bringing people to the site.

Harbor seals are vulnerable to human disturbance and are also dependent on management of the haul-out habitat.

There are a number of potential conflicts that have not been examined between a growing seal population and human uses including fishing and shellfish production. These are also reasons why the growing seal populations are controversial and information on these issues would be important for education of visitors at the site.

The primary objectives of future research and monitoring should be:

Monitor future changes in seal populations using the site. Seal numbers using this site have changed dramatically over the last 15 years and this may continue in the future.

Monitor human disturbance and impacts on harbor seals to provide managers with information on the effect of development of the site and the effectiveness of the management actions to protect the seals. This monitoring is most important during the summer and early fall.

Examine harbor seal food habits at the site and whether harbor seals feed on prey that conflict with recreational or commercial fisheries. This would also allow an assessment of how harbor seals fit into the marine ecosystem in this region.

Examine how harbor seal use of the area conflicts with use of the site for commercial shellfish production as has been proposed.

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