Distribution and haul-out behavior of harbor seals in Glacier Bay, Alaska

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Over 5000 harbor seals haul out on icebergs calved from tidewater glaciers in Muir and Johns Hopkins inlets in Glacier Bay, Alaska. During June, these sites are used primarily by parous females and pups, and in August, by molting seals. The number of mothers and pups was higher than expected for the total number of seals in Glacier Bay, indicating an immigration of some parturient females from outside Glacier Bay. The number of seals counted varied throughout the day with greatest numbers around midday. In Muir Inlet the number of seals hauled out was positively correlated with percent ice cover. Ice that is suitable for hauling out may presently limit the abundance of seals in this area. The retreat of Muir Glacier has dramatically reduced the ice available to seals and, if it continues, will likely result in the elimination of drift-ice habitat in the near future. Seals from both inside and outside Glacier Bay apparently use ice habitat in Muir and Johns Hopkins inlets when giving birth, when nursing pups, and when moulting for protection from terrestrial and marine predators, and because it is relatively abundant and easily accessible at all tides and times.

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Plus de 5000 Phoques communs se réfugient sur les icebergs détachés des banquises dans les baies Muir et Johns Hopkins à Glacier Bay, Alaska. En juin, ces sites sont utilisés surtout par les mères et les petits et en août, par les phoques qui muent. Le nombre de mères et de petits s'est avéré plus élevé que prévu par rapport au nombre total de phoques à Glacier Bay, ce qui indique qu'il y a eu immigration de femelles parturientes venues d'ailleurs. Le nombre de phoques variait au cours de la journée, mais était maximal vers le milieu de la journée. Dans la baie Muir, le nombre de phoques sur les glaces était relié au pourcentage d'eau recouvert par les glaces. Les glaces dont la configuration convient à la montée des phoques limitent probablement la densité des phoques dans cette région. Le retrait du glacier Muir a considérablement réduit la quantité de glace disponible pour la montée des phoques et, si le phénomène continue, il est possible qu'il conduise à l'élimination des glaces flottantes dans un délai assez court. Les phoques de Glacier Bay et des autres régions utilisent les glaces des baies Muir et Johns Hopkins au moment de la mise-bas et de l'allaitement et, au moment de la mue, pour se protéger contre les prédateurs terrestres et marins et aussi parce que ces glaces sont relativement abondantes et facilement accessibles en tout temps et à toutes les marées.

[Traduit par la revue]

Introduction

Throughout most of its range, the harbor seal (*Phoca vitulina*) hauls out, gives birth, and nurses its young on land (Brown and Mate 1983; Scheffer and Slipp 1944; Bonner 1972; Boulva and McLaren 1979; Fisher 1952). The use of ice habitat has been described for the congeneric spotted seal, *Phoca largha* (Burns 1970), but only limited research has been conducted on the use of ice habitat by harbor seals (Streveler 1979; Murphy and Hoover 1981). One of the largest concentrations of harbor seals in southeastern Alaska occurs in the iceberg-filled northern reaches of Muir and Johns Hopkins inlets in Glacier Bay, Alaska (Streveler 1979). Glacier Bay has been changing rapidly as a result of the retreat of glaciers that covered the entire bay as recently as 200 years ago (Lawrence 1958). These ongoing glaciologic changes have dramatically reduced the number and extent of icebergs available to seals and, in the next few years, may result in the total elimination of this habitat in Muir Inlet.

Here we present data on the distribution and behavior of harbor seals in relation to ice conditions in Glacier Bay.

Methods

Research was conducted on harbor seals in Glacier Bay National Park, Alaska (Fig. 1) during the summers of 1982–1984 (Table 1). The primary study region was the iceberg-filled inlet off the face of Muir Glacier. Additional censuses were made in Johns Hopkins Inlet (off Johns Hopkins Glacier) and at land haul-out sites throughout the middle and lower portions of Glacier Bay where ice does not occur.

We counted seals hauled out and in the water from points overlooking the study areas in Muir and Johns Hopkins inlets. The observation location in Muir Inlet in 1982, at 20 m elevation, was moved in 1983 and 1984 to a 300 m high site that provided a better view of the areas used by seals. Observations in Johns Hopkins Inlet were made from several locations ranging from 60 to 75 m elevation. Counts were made with spotting scopes or binoculars. Locations of seals and ice concentrations shifted daily at both sites, with seals occurring from 100 m to a maximum of 3 km from the observation site. In Muir Inlet we counted seals at 3-h intervals from 06:00 to 21:00 in 1983 and 1984 with a more variable schedule in 1982. In Johns Hopkins Inlet, where counts took longer, they were made between approximately 07:00 and 09:00, 12:00 and 14:00, and 20:00 and 22:00. During our survey we counted the total number of seals on icebergs and in the water, the number of pups, and the group size of seals on each iceberg, and we noted the weather conditions, including an estimate of the percent ice cover. Counts of seals in the water (generally an order of magnitude lower than counts of hauled seals) are minimums because submerged seals may have been missed. Unless otherwise noted, all counts include seals both hauled out and in the water. Counts at land haul-out sites were made opportunistically from land or, on a few occasions, from boats.

We monitored the movements of seals to and from the study sites in Muir and Johns Hopkins inlets by counting the seals entering and leaving the study area from an observation point down the inlet from the haul-out area. Observations were made every 15 min from 06:30 to 22:00 on 4 days and were summarized in 1-h blocks.

Results

A maximum of 1167 seals were counted in Muir Inlet in August 1984; variations in numbers of seals occurred among months and, to a lesser degree, among years (Fig. 2). The abundance of seals was greatest in mid-June, the peak of the pupping season, and in late August, when seals were molting.

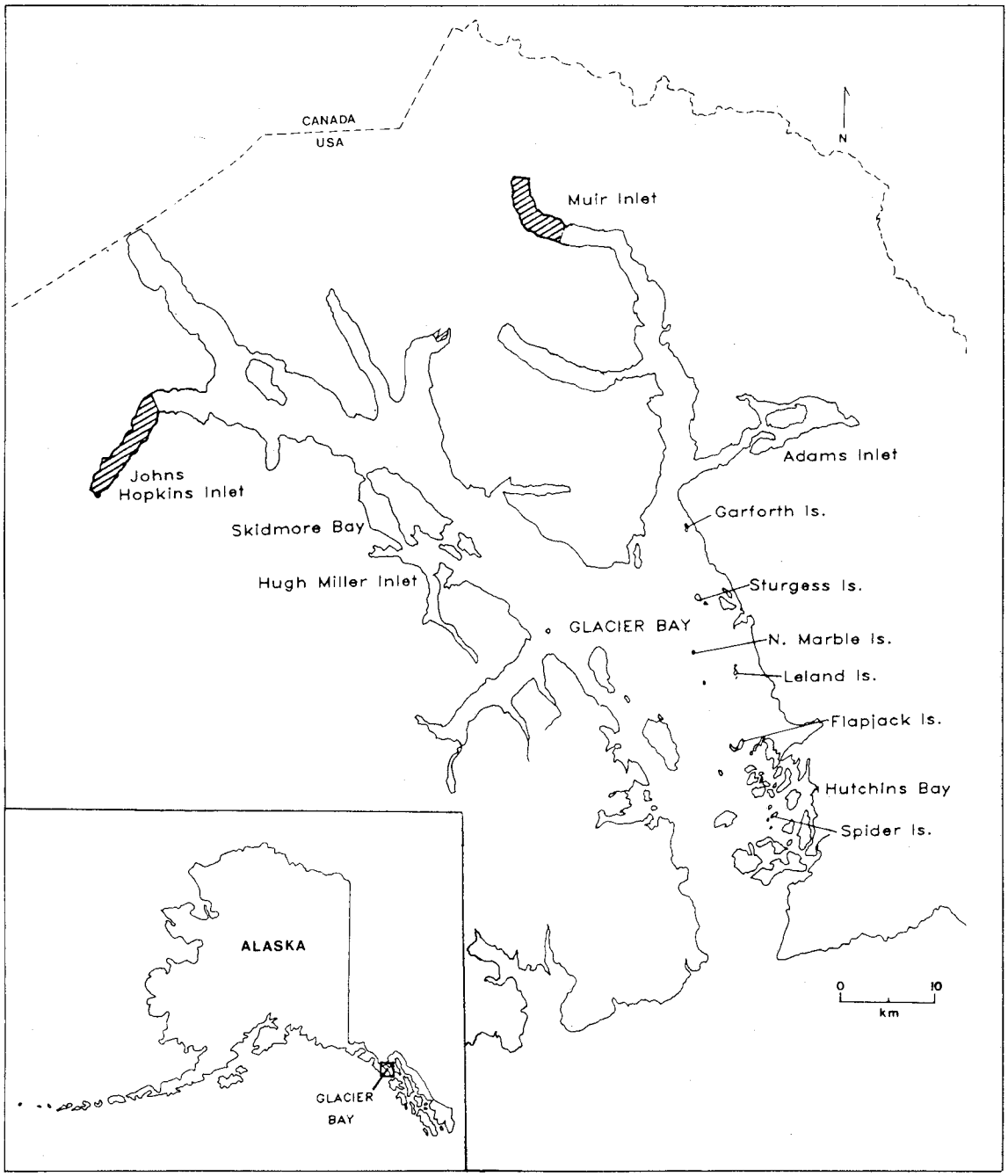

FIG. 1. Glacier Bay, showing principal study areas in Johns Hopkins and Muir inlets (shaded) and other monitored harbor seal haul-out areas.

TABLE 1. Number of days and range of dates during which censuses of harbor seals were made at study sites in Glacier Bay, Alaska

	Muir Inlet			Johns Hopkins Inlet			Land sites		
	No. of days	Start date	End date	No. of days	Start date	End date	No. of days	Start date	End date
1982	30	30 May	22 Aug.	—			20	26 June	10 Aug.
1983	30	19 June	19 Aug.	—			21	12 June	24 Aug.
1984	15	8 June	20 Aug.	10	10 June	16 Aug.	34	6 June	27 Aug.

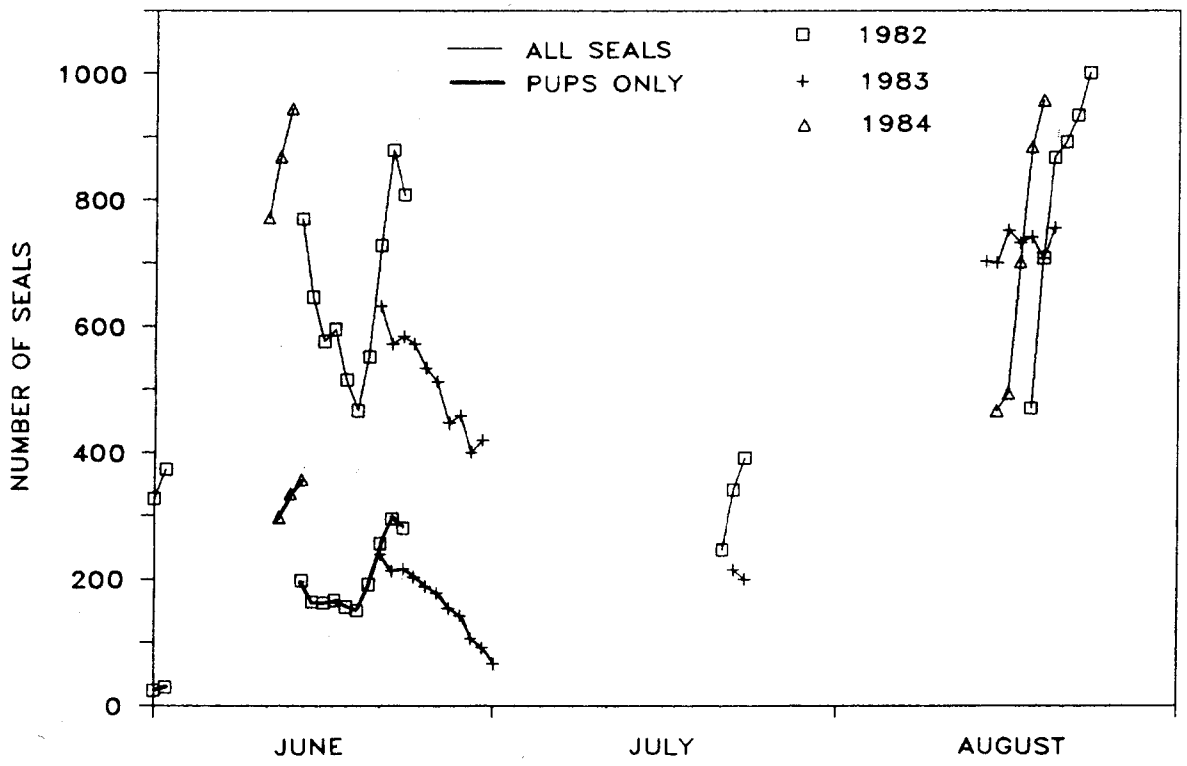

FIG. 2. Three-day running averages of daily high counts of total seals and pups in Muir Inlet for 1982–1984. Averages were used to moderate the effects of daily fluctuations in response to weather and ice conditions.

The first births occurred at the end of May and most pups were born in mid-June. Births and birth sites (blood, placenta, and fetal hair) were frequently seen on icebergs in the study area.

In Johns Hopkins Inlet we counted 4250 seals on 11 June 1984 and up to 5208 seals during the period from 9 to 16 August 1984. These counts may underestimate the maximum number of seals present in Johns Hopkins Inlet because of the large area over which seals haul out and the limited number of days that censuses were made.

Most seals present in both Muir and Johns Hopkins inlets in June were parous females and their pups. Pups represented 40% of all seals observed in mid-June in Muir Inlet. A similar proportion of pups (37%) was seen on 11 June in Johns Hopkins Inlet. At these times about two-thirds of all seals (excluding pups) were females with suckling pups.

Numbers of seals using Muir Inlet did not appear to change dramatically among years (Fig. 2). Counts made in July and August were similar among years (ANOVA, $p > 0.05$). There was some difference among years in the June counts (ANOVA, $p < 0.005$), primarily as a result of low numbers of seals in 1983. This difference, however, may reflect the later portion of the month sampled in 1983 or differences in environmental conditions during the census period. Counts of both total seals and pups appeared to reach a peak earlier in 1984 than in 1982 and 1983.

Diel patterns

The number of seals (hauled out and in the water) in the study area varied throughout the day at both Muir and Johns Hopkins inlets (Fig. 3). At both sites the number of seals counted as a proportion of the daily high count varied significantly by time of day (ANOVA, $p < 0.01$), with greatest numbers at 09:00 and 12:00 at Muir Inlet and at 13:00 at Johns Hopkins Inlet.

The 12:00 count in Muir Inlet appeared to be altered by the 11:30 arrival of a daily tour boat that caused varying numbers of seals to enter the water (up to 184 counted). Because seals in the water are undercounted, the disturbance by the vessel tended to bias the 12:00 count downward. Figure 3 shows the counts of seals during 5 days when the vessel did not enter the study area. Though the sample size is small, these five counts may more accurately represent the diel haul-out pattern of seals in an undisturbed habitat.

The diel pattern of seals was also apparent in the movement of seals arriving and departing from the study areas in Muir and Johns Hopkins inlets (Fig. 4 for Muir Inlet). During morning hours, seals were primarily seen swimming up the inlet towards the study area. By evening this pattern had reversed with the majority of seals swimming down the inlet away from the study area.

Harbor seals in Muir and Johns Hopkins inlets appear to use these areas primarily to haul out and not to feed. Almost all animals seen in the water were actively swimming up or down the inlet or circling icebergs. We saw very few seals engaged in activities that suggested feeding. Feeding activity was observed frequently, sometimes by groups of over 100 seals, in Adams and Hugh Miller inlets, 40 km away from the haul-out areas in Muir and Johns Hopkins inlets, respectively. Few seal scats were seen during either censuses or boat searches of more than 100 icebergs in Muir Inlet. On all but two occasions when fecal remains were found, they consisted of either meconium stool (containing traces of fetal hair) or milky remains that appeared to be from pups; in the two remaining cases they contained

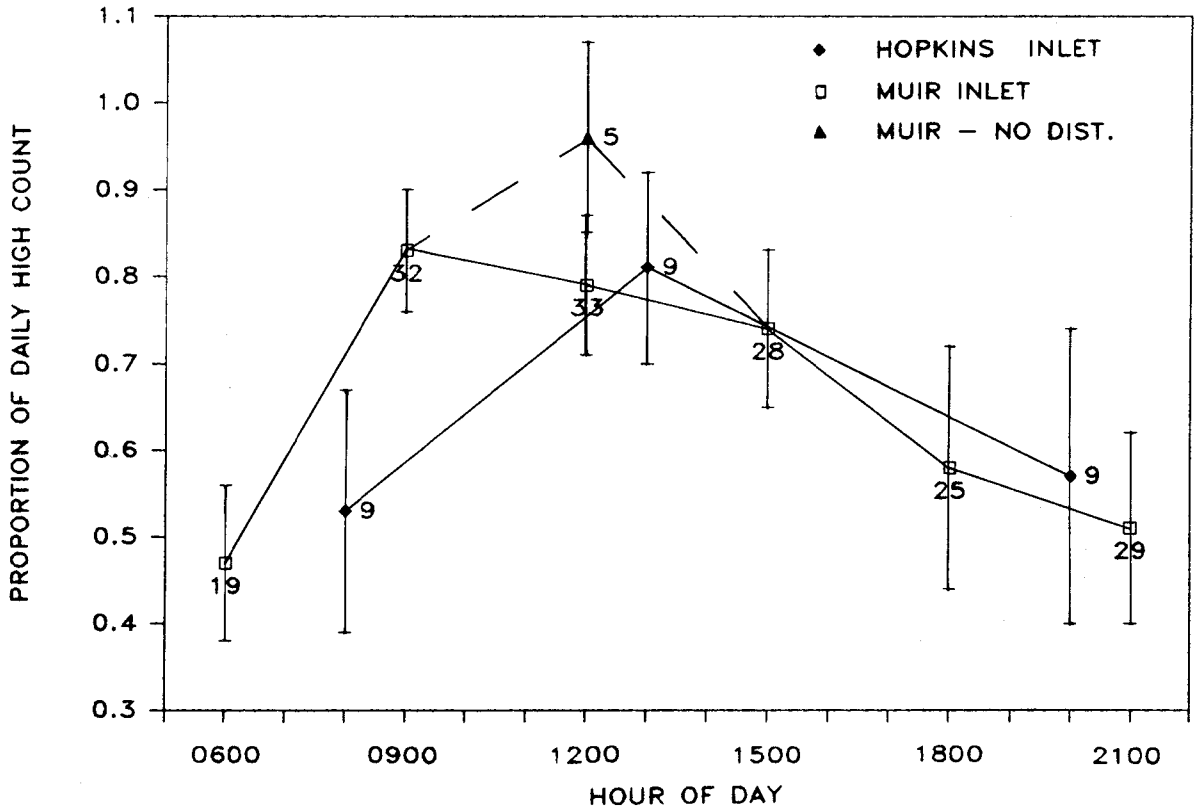

FIG. 3. Number of seals (calculated as a percentage of the daily high count) by time of day for Muir and Johns Hopkins inlets, 1983 and 1984. Censuses conducted in Muir Inlet at 12:00 on 5 days when there was no tour boat disturbance at 11:30 are shown separately. Numbers refer to sample sizes and bars show 95% confidence intervals.

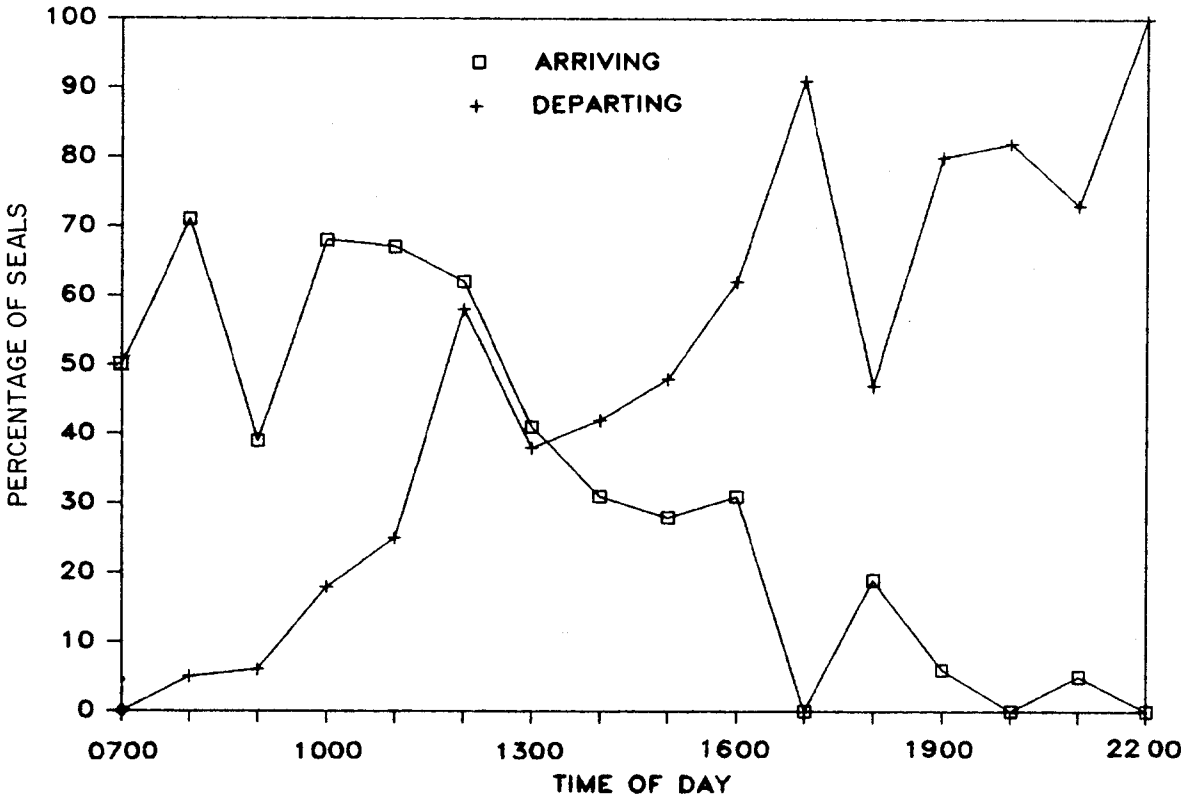

FIG. 4. Proportion of seals arriving and departing from study area in Muir Inlet by time of day.

TABLE 2. Average number of harbor seals hauled out per iceberg in Muir and Johns Hopkins inlets, Glacier Bay, Alaska

	No. of censuses	Seals/iceberg	
		Mean	SD
Muir, June 1983	56	2.8	0.9
Muir, July 1983	45	2.7	1.1
Muir, Aug. 1983	58	2.5	0.6
Muir, Aug. 1984	47	2.6	2.1
Johns Hopkins, Aug. 1984	27	1.4	0.2

TABLE 3. High counts of harbor seals at land haul-out sites in Glacier Bay, Alaska, during June to August 1982 to 1984

	No. of seals			Max. no. of pups
	June	July	Aug.	
Spider Is.	233	366	536	28
Hutchins Bay	88	97	—*	10
Leland Is.	43	66	280	2
Sturgess Is.	28	40	103	2
Adams Inlet	170	276	224	10
Hugh Miller	—*	140	121	—*
Other sites	153	18	177	11

*No counts made.

shrimplike crustacean remains. Harbor seal fecal samples were seen on most searches of tidally exposed land haul-out sites.

Relationship to ice conditions

The abundance of icebergs (ice cover) appeared to be a limiting factor affecting the number of seals in Muir Inlet. The number of seals hauled out on icebergs during censuses was strongly correlated with the percent ice cover ($n = 159$, $r = 0.46$, $p < 0.001$). Ice cover was also inversely correlated with the proportion of seals in the water ($r = -0.48$, $p < 0.001$) and the average number of seals per iceberg ($r = -0.23$, $p < 0.001$). These results indicate that when ice cover is low (*i*) fewer seals are hauled out, (*ii*) a greater portion of the animals are in the water, and (*iii*) those that are hauled out are more concentrated on the few remaining icebergs. Percent ice cover did not vary significantly in relation to time of day (ANOVA, $p > 0.05$), indicating that the diel pattern in seal numbers was not the result of diel changes in ice conditions.

Ice cover and seal group size varied between Muir and Johns Hopkins inlets. Ice cover in the portions of Johns Hopkins Inlet used by seals generally exceeded 50% while ice cover in Muir Inlet rarely exceeded 15%. The mean group size of seals (seals/iceberg) was significantly smaller in August in Johns Hopkins Inlet compared with the same period in Muir Inlet (ANOVA, $p < 0.01$, Table 2). This smaller group size on icebergs in Johns Hopkins Inlet is consistent with the pattern of smaller group size with increasing ice cover seen in Muir Inlet.

Harbor seal occurrence at land sites

The number of seals using haul-out sites on land in Glacier Bay was much smaller than the number using ice habitat in Muir and Johns Hopkins inlets (Table 3). A few additional sites, not included in Table 3, were also used by seals in Glacier Bay though these generally involved fewer seals than the sites we monitored. There were fluctuations in the numbers of seals seen at some of the land haul-out sites during June to August (Table 3).

The proportion of pups seen at land haul-out sites in June (Table 3) was relatively low (approximately 10%). Fewer seals used these sites for parturition and nursing young than they used the icebergs in Muir and Johns Hopkins inlets.

Discussion

Harbor seals throughout their range, including most haul-out areas in Alaska, use terrestrial sites for parturition and to haul out (Bishop 1967; Pitcher 1977; Pitcher and McAllister 1981; Everitt and Braham 1980). Ice habitat is not available to harbor seals in most areas during the summer months. Glacier Bay contains both land and ice habitats that are used by harbor seals. The proportion of mothers and pups using icebergs in Muir and Johns Hopkins inlets is more than twice as high as found at land sites in Glacier Bay, as well as other terrestrial haul-out areas (Boulva and McLaren 1979; Venables and Venables 1955; Calambokidis *et al.* 1985; Bishop 1967). Pitcher (1977) also reported a high proportion of mothers and pups hauling out on glacial ice floes in Prince William Sound.

The proportion of mothers and pups in Glacier Bay, if both terrestrial and ice sites are pooled, is still higher than predicted for typical harbor seal population structures (Bigg 1969). Annual movement of tagged parturient females between two areas in Oregon and Washington has been reported by Beach *et al.* (1982), though this movement does not result in as dramatic a segregation of mothers and pups as reported here. The selective use of Muir and Johns Hopkins inlets by large numbers of parturient and parous females and their young makes it of potential regional significance for harbor seals.

The only previous research reported on harbor seals in Glacier Bay was conducted from 1973 to 1978 (Streveler 1979). Since that time, (*i*) the harbor seal haul-out area in Muir Inlet has shifted 10 km up the inlet matching the retreat of Muir Glacier; (*ii*) the number of seals has decreased in Muir Inlet and increased in Johns Hopkins Inlet and at land haul-out sites in central and lower Glacier Bay; and (*iii*) the proportion of parous females and pups at Muir and Johns Hopkins inlets in June has increased.

The diel haul-out pattern of harbor seals in Muir and Johns Hopkins inlets is different from that usually reported for harbor seals at haul-out sites on land. Harbor seals at most land sites haul out in greatest numbers at low tide (Allen *et al.* 1984; Bonner 1972; Vaughan 1971; Johnson and Jeffries 1977; Schneider and Payne 1983; Calambokidis *et al.* 1978), though high tide and nocturnal patterns have also been reported (Calambokidis *et al.* 1978; Risebrough *et al.* 1979). These patterns are usually the result of sites (sandbar, tidal reef, spit) being accessible to seals during only a portion of the tidal cycle. Ice habitat, however, is accessible to seals during all tides. A diurnal haul-out pattern, independent of tide, has been reported for harbor seals in the Channel Islands, California, where space is available to haul out at all tides (Stewart 1984).

An advantage of iceberg habitat is the avoidance of land and marine predators. Land predators such as the coyote are a major cause of death of harbor seal pups at one site in Puget Sound, Washington (Calambokidis *et al.* 1985; Steiger *et al.* 1985). Native Americans of the west coast of North America have traditionally hunted hauled-out harbor seals (Elmendorf 1960). Hunting of harbor seals in Glacier Bay by Tlingit Indians continued through 1973 (Streveler 1979). Avoidance of land predators would be critical during the pupping season in June when newborn pups are most vulnerable and during the molt when harbor seals haul out for longer periods. Killer whales are the major marine predator of harbor seals in Glacier Bay. We

observed killer whales preying or attempting to prey on harbor seals near land haul-out sites on two occasions and additional instances of predation were reported by others. Lopez and Lopez (1985) reported over 500 observations of killer whales preying on pinnipeds at land haul-out sites in Patagonia, Argentina. Killer whales, frequently seen in the central and lower portions of Glacier Bay, were not seen in the ice-filled northern reaches of Muir and Johns Hopkins inlets. These circumstances all indicate that seals would be more protected from predation in the ice habitat of Muir and Johns Hopkins inlets than on land haul-out sites in other areas.

Predicted changes in the ice conditions in Muir Inlet will likely jeopardize the future use of this area by seals. Muir Glacier has been receding for the last 200 years (Field 1947; Brown *et al.* 1982). If this retreat continues, the terminus of the glacier will be in shallow water, which would result in a decrease in the ice-calving rate and the icebergs produced by calving (Brown *et al.* 1982). Since ice availability already may be a limiting factor for seals in Muir Inlet, further declines in the abundance of icebergs will reduce the habitat available to seals. This will require seals either to use land haul-out sites in Muir Inlet (currently used only by a small number of seals) or to move to other locations outside of Muir Inlet.

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