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Co-occurrence of Pacific Sleeper Sharks *Somniosus pacificus* and Harbor Seals *Phoca vitulina* in Glacier Bay

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Abstract: We present evidence that Pacific sleeper sharks *Somniosus pacificus* co-occur with harbor seals *Phoca vitulina* in Glacier Bay, Alaska, and that these sharks scavenge or prey on marine mammals. In 2002, 415 stations were fished throughout Glacier Bay on a systematic sampling grid. Pacific sleeper sharks were caught at 3 of the 415 stations, and at one station a Pacific halibut *Hippoglossus stenolepis* was caught with a fresh bite, identified as the bite of a sleeper shark. All 3 sharks and the shark-bitten halibut were caught at stations near the mouth of Johns Hopkins Inlet, a glacial fjord with the highest concentration of seals in Glacier Bay. Using a bootstrap technique, we estimated the probability of sampling the sharks (and the shark-bitten halibut) in the vicinity of Johns Hopkins Inlet. If sharks were randomly distributed in Glacier Bay, the probability of sampling all 4 pots at the mouth of Johns Hopkins Inlet was very low ($P = 0.00002$). The highly non-random distribution of the sleeper sharks located near the largest harbor seal pupping and breeding colony in Glacier Bay suggests that these 2 species co-occur and may interact ecologically in or near Johns Hopkins Inlet.

INTRODUCTION

Glacier Bay National Park has had one of the largest breeding colonies of harbor seals *Phoca vitulina* in Alaska (Calambokidis 1987; Mathews 1995). However, the number of seals has declined steeply. In 1992, 6,200 seals were counted at haulouts during August surveys, but by August 2001 only 2,600 seals were counted at these same haulouts. Harbor seals in Glacier Bay have experienced one of the largest documented population declines in Alaska—a decline of 63% over 11 years within Johns Hopkins Inlet, a large glacial fjord, and a decline of 75% over 10 years at terrestrial resting sites (Mathews and Pendleton 2006). The cause of this population decline is not known, but increased mortality, possibly due to predation by Pacific sleeper sharks *Somniosus pacificus*, Steller sea lions *Eumetopias jubatus*, or killer whales *Orcinus orca*, is one of several proposed hypotheses (Mathews and Pendleton 2006). Sleeper sharks are known to feed on marine mammal carrion in the North Pacific (*S. pacificus*; Smith et al. 2002) and North Atlantic (*S. microcephalus*; Bigelow and Schroeder 1948; Compagno 1984); they may also be active predators on marine mammals (Crovetto et al. 1992), including seals (Bright 1959; Ridoux et al. 1998). Although there is no direct information on abundance or trend for Pacific sleeper sharks in Glacier Bay, significant increases were detected between 1984 and 1996 in the central Gulf of Alaska (Mueter and Norcross 2002). If the number of sleeper sharks in Glacier Bay has also increased, then it may help explain the seal declines observed. We present evidence that Pacific sleeper sharks co-occur with breeding harbor seals in Glacier Bay. We hypothesize that the co-occurrence may be caused by an overlap in prey species or that these sharks scavenge or prey on marine mammals.

METHODS

In July and August, 2002, top-loading conical Tanner crab pots were fished at 415 stations on a systematic grid throughout Glacier Bay to assess the distribution and relative abundance of Tanner crab *Chionoecetes bairdi* and red king crab *Paralithodes camtschaticus* (Figure 1). All locations and depths were sampled

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with a 24 h soak time. Pot depths ranged from 15 to 439 m. In addition to the target species, many other species were captured including Pacific sleeper sharks. Captured sharks were measured for straight-line length (distance from snout to the tip of the upper caudal, Compano 1984) and stomach contents were collected and retained for analysis after returning to the laboratory.

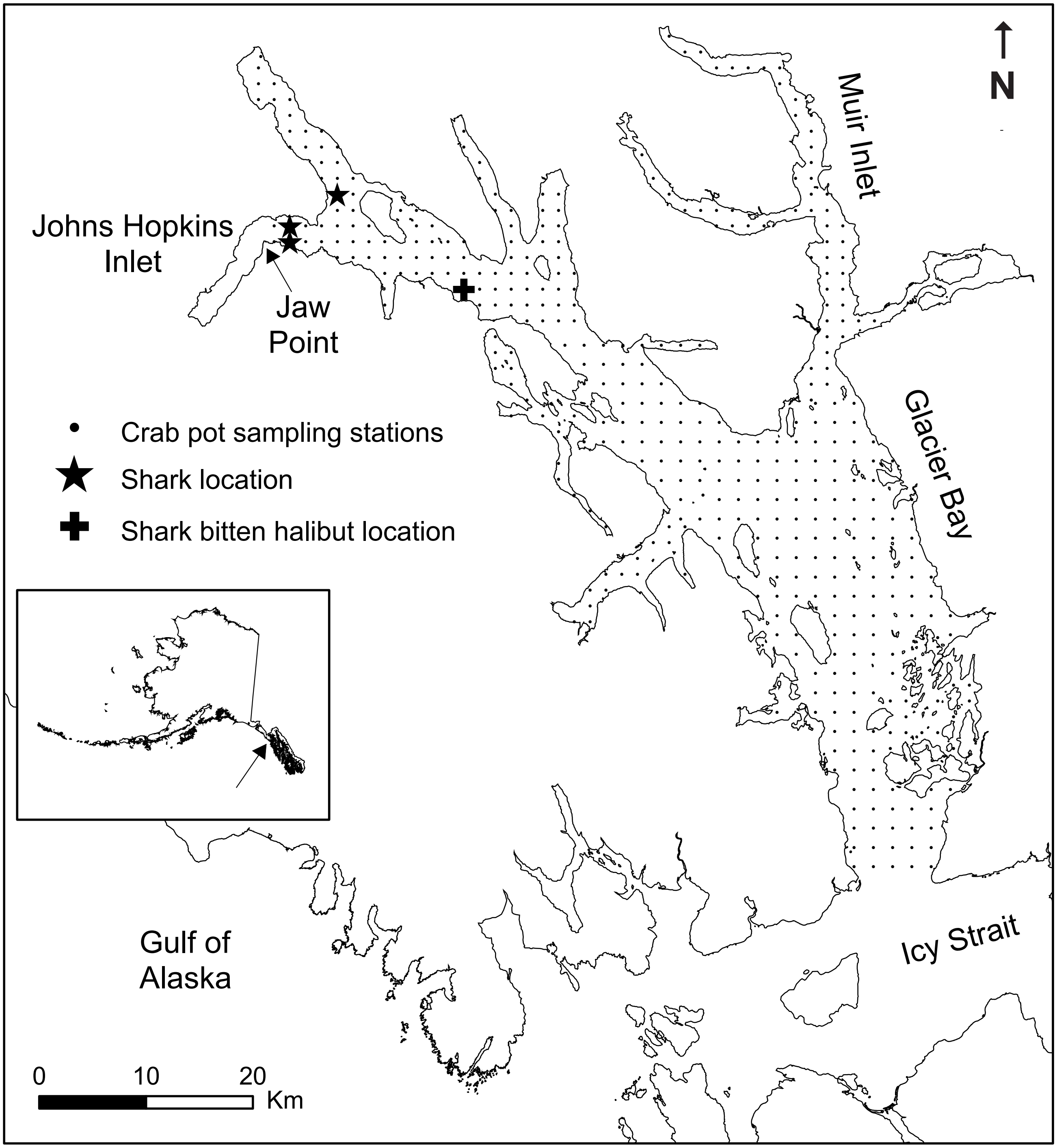

Figure 1. The 415 locations in Glacier Bay, Alaska, that were sampled with commercial Tanner pots. Stars indicate where 3 Pacific sleeper sharks were caught and a cross indicates where a halibut with a shark bite was captured. Johns Hopkins Inlet is a tidewater glacial fjord where close to 2,000 harbor seals—approximately two thirds of all seals in Glacier Bay—breed during summer months.

Using a bootstrap technique (Efron and Tibshirani 1986), we estimated the probability of capturing sharks in the vicinity of Johns Hopkins Inlet if the sharks were randomly distributed throughout Glacier Bay. We measured the through-water distance from each pot containing a shark—or that contained evidence of a shark—to Jaw Point (located inside Johns Hopkins Inlet near the eastern edge of the area where seals rest and raise their pups; Figure 1) and summed the distances of these pots. The sum of the distances between Jaw Point and each of the pots that captured a shark—or contained evidence of a shark—was then compared to the sum of the distances between Jaw Point and an equal number of randomly selected pots in 50,000 bootstrap simulations (Resampling Stats Excel add-in version 3.0, Blank et al. 2001). A *P*-value was calculated as the proportion of the randomly selected trial sum distances that were less than the sample sum distance.

RESULTS

Three of the 415 crab pots contained Pacific sleeper sharks and a fourth pot contained a large (104 cm) Pacific halibut *Hippoglossus stenolepis* with a fresh bowl-shaped bite, which we identified as the bite of a sleeper shark. All 3 sharks were caught in pots set at the mouth of Johns Hopkins Inlet (Figure 1), a tidewater glacial fjord used by at least 1,700 harbor seals during late summer 2002 (Mathews and Pendleton 2006). The 3 pots with sharks in them and the shark-bitten halibut were fished within 2.4, 2.5, 10.1 and 19.3 km, respectively, from the mouth of Johns Hopkins Inlet (Figure 1). If sharks were randomly distributed in Glacier Bay, the probability of sampling all 4 sharks at the mouth of Johns Hopkins Inlet would be extremely low ($P=0.00002$).

The lengths of the 3 sleeper sharks captured near the entrance of Johns Hopkins Inlet were 3.0 m, 1.9 m and 1.6 m, and we examined the stomaches of all sharks. Seven, 36, and 76 cephalopod beaks were collected per stomach from the 3 specimens, respectively. Combined stomach contents included shrimp, teleost fishes, and tapeworms. The largest shark also contained cetacean tissue in its stomach.

DISCUSSION

The sample size of sleeper sharks in this study was very low and the catchability of the Pacific sleeper sharks in crab pot gear is unknown. However, the systematic sampling of a large area and the non-random distribution of the sleeper sharks located near the largest harbor seal breeding area in Glacier Bay suggest that Pacific sleeper sharks and harbor seals may co-occur in or near John's Hopkins Inlet.

A possible explanation for the co-occurrence of sleeper sharks and harbor seals is that they both feed on prey concentrated in Johns Hopkins Inlet. Stomach analyses demonstrate that there is overlap in their preferred prey. Pitcher (1980) examined 351 harbor seal stomachs from Alaska and most often found (in decreasing order of occurrence) walleye pollock *Theragra chalcogramma*, cephalopods, capelin *Mallotus villosus*, and flatfishes. In the Gulf of Alaska and the Bering Sea, cephalopods were the most common prey found in stomachs of 161 Pacific sleeper sharks; flatfishes and walleye pollock were among the top 7 prey items (Orlov 1999; Yang and Page 1999). Walleye pollock was the most common prey found in 19 harbor seal fecal samples collected in Johns Hopkins Inlet during August from 1996 to 2001 (Mathews, personal communication)—the same month when sleeper sharks were sampled. Cephalopod remains were not found in feces of seals in Johns Hopkins Inlet, but fecal analyses can be biased against cephalopods because seals regurgitate cephalopod beaks (Pitcher 1980). The stomach contents of the 3 sleeper sharks captured at the mouth of Johns Hopkins Inlet contained predominately cephalopod beaks. Our results, combined with the findings from other studies, support the hypothesis that there could be overlap in diet between harbor seals and sleeper sharks.

In addition to overlap in diet, harbor seals and Pacific sleeper sharks also overlap in their depth distribution. Hasting et al. (2005) attached satellite-linked time-depth recorders to 108 harbor seals in 3 regions of Alaska, including 34 seals in southeastern Alaska. Although the majority (50%–90%) of all dives were < 50 m, a portion (6%–16%) of adult and subadult seals in southeastern Alaska dove to depths between 50 m and 100 m during the breeding season. In addition, a maximum dive depth of 508 m for all 108 seals was recorded for 2 adult males (Hasting et al. 2005). At the mouth of Johns Hopkins Inlet, where we found sleeper sharks, the deepest water is 375 m. Sleeper sharks are known to range in depth from 2008 m (Anderson 1979) into the littoral zone (Compango 1984) and surface waters (Bright 1959). Hulbert et al. (personal communication) measured the vertical movement behavior of 22 Pacific sleeper sharks in the Gulf of Alaska using depth data collected from archival satellite-linked transmitters attached to the sharks. They found that the sharks changed depth nearly continuously, and ascents to within 100 meters of the surface were common. The overlap in diet and potential overlap in vertical distribution of these 2 species could mean that both species are attracted to areas with high prey densities.

A second hypothesis for the overlap in distribution of sharks and seals is that sharks may be scavenging or preying on marine mammals. In addition to the cetacean tissue found in the stomach of one shark from this study, a 1.8-m Pacific sleeper shark was caught on a longline in Muir Inlet, Glacier Bay, in 1995; the shark regurgitated harbor seal tissue when it was brought onboard the research vessel. During that same longline study, 2 other sleeper sharks were caught (2.2 m and 2.4 m); they were released, however, without examining the stomach contents (S. J. Taggart, personal communication). Pinniped and cetacean tissues have been found in sleeper shark stomachs in other parts of Alaska (Bright 1959; Orlov 1999; Hulbert et al. 2001) and off the Chilean coast (Crovetto et al. 1992). A 3.45-m female sleeper shark caught in Kachemak Bay, Alaska, contained the remains of at least 3 harbor seals (Bright 1959). Pacific sleeper sharks are one of the predominant scavengers of whale carcasses on the seafloor (Smith et al. 2002), and Greenland sleeper sharks have been observed around whaling stations "greedily" devouring whale meat and blubber (Bigelow and Schroeder 1948).

In addition to feeding on marine mammal carrion, sleeper sharks may also be active predators of marine mammals. A 3.6-m female Pacific sleeper shark was captured in Chilean waters with a fetus from a southern right whale dolphin *Lissodelphis peronii* and the genital area of an adult female in its stomach. The ventral location of the bite and freshness of the specimen strongly argue for active predation on a pregnant female dolphin (Crovetto et al. 1992). In addition to marine mammals, other large, fast prey have been found in the stomachs of Pacific sleeper sharks, including salmon (Gotshall and Jow 1965; Orlov 1999; Yang and Page 1999), squid (Gotshall and Jow 1965; Ebert et al. 1987; Orlov 1999; Yang and Page 1999), albacore tuna (Ebert et al. 1987), and Pacific halibut (Gotshall and Jow 1965). Remarkably, even giant squid have been found in the stomachs of Greenland sleeper sharks (Cherel and Duhamel 2004).

The evidence for sleeper sharks eating marine mammals and fast prey in other regions supports the hypothesis that Pacific sleeper sharks may be preying on harbor seals in Johns Hopkins Inlet and may be a factor in the seal population decline. At Sable Island in Nova Scotia, where shark predation on harbor seals has been linked to population declines, harbor seal pup production declined dramatically from 1980 to 1997 and shark-inflicted mortality climbed from 10% to 46% during the same time period (Lucas and Stobo 2000). Dead seals were found washed up on the beach with shark bites, and the shape of the bites was consistent with Greenland sleeper shark attacks (Z. Lucas, Biologist, Sable Island, Nova Scotia, personal communication). In contrast, dead harbor seals with shark wounds have not been observed in Glacier Bay. Sable Island is a large sandbar with gradual sloping beaches and onshore currents that could transport dead animals ashore (Lucas and Stobo 2000), whereas much of Glacier Bay is a deep fjord (approximately 300–400 m) with steep submarine walls, which would likely prevent or limit shoreward transport.

The co-occurrence of sleeper sharks and harbor seals, the potential overlap in diet of the 2 species, and clear evidence from this and other studies that sleeper sharks consume marine mammals including harbor seals, suggests that an ecologically important interaction may be occurring between these 2 species. These factors, combined with the recent decline in harbor seals, are consistent with the hypothesis that sleeper shark predation on seals may be contributing to the seal decline in Glacier Bay. The observations, however, are too few to be conclusive and this hypothesis warrants further testing.

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