The Introduction, Increase, and Demise of Wolves on Coronation Island, Alaska

■ David R. Klein

Wolves were introduced to Coronation Island in the Alexander Archipelago of southeastern Alaska in 1960. The island was previously without wolves or other large mammalian predators and supported a high density of Sitka black-tailed deer. The introduced wolves (two pair) increased to a peak population of 13 animals in four years and caused a pronounced decline in deer density. The wolves then declined to a single animal in 1968, and deer persisted only in a few areas of rough terrain and dense habitat. Wolf scats consisted primarily of deer during the first five years following their introduction, with harbor seal of secondary importance. Deer remains in the scats declined during 1966-1968 to low frequency, whereas marine invertebrates, small rodents, and birds increased markedly, and wolf remains also appeared in the scats. As deer density declined, wolves fed opportunistically on whatever was available, even resorting to cannibalism.

Introduction

Wolves (*Canis lupus ligoni*) were introduced to Coronation Island (55°53'N, 134°14'W) in the Alexander Archipelago of southeastern Alaska in 1960 (Fig. 1). This 73.3 km^2 island lies on the western periphery of the archipelago and, before 1960, had a high density of small black-tailed deer (*Odocoileus hemionus sitkensis*) (Klein 1965a). Neither wolves nor black bears (*Ursus americanus*) occurred there (Klein 1965b).

The terrain of Coronation Island is irregular; Karst topography is common, and cliffs rise sharply from the sea on the south and west. More than 80% of the land area is below 300 m, although Needle Peak rises to nearly 600 m. The island is under strong maritime influence, with cool summers and mild winters. Vegetation is north temperate rain forest, dominated by western hemlock (*Tsuga heterophylla*) and Sitka spruce (*Picea sitchensis*). About 80% of the island is forested, 11% muskeg, 6% subalpine, and the remaining 3% alpine, exposed rock, alder slide, and water as reported by Klein (1965a) in a detailed description of the island, its climate, and vegetation.

The Island Prior to the Introduction of Wolves

Body condition of deer and their relationship to vegetation on Coronation Island were the focus of investigations from 1959 through 1961. The studies included comparison of deer and vegetation with those of Woronkofski Island, of comparable size and 120 km to the east (Fig. 1). Woronkofski Island is under weaker maritime influence and wolves were present (Klein 1962, 1964, 1965a). Woronkofski Island deer of every age class were larger than those of Coronation Island. At one year of age, they were 17% heavier, at two years 24%, at three years 31%, and at four years or older 37%. Quantitative analysis of vegetation on the two islands showed lower plant density and species richness on Coronation Island. Sustained heavy herbivory probably caused these differences. Vegetation was less affected by deer on Woronkofski Island where occasional severe winters of heavy snow accumulation, in combination with wolf predation, resulted in wide fluctuations in deer numbers.

I suspect that nutritional constraints produced the observed differences in deer body size on the two islands. Historically, Coronation Island populations were limited primarily by availability of forage plants rather than by wolf predation, hunting pressure, or extreme snow depths. Lower nitrogen and higher fibre content in the rumen contents of Coronation Island deer verified a qualitative difference in diet (Klein 1965a).

Deer density on Coronation Island was estimated by Merriam (1967) at 3.9/km^2 in 1961, but he later revised this upward to 5.8–7.8/km^2 based on comparable frequency of deer sightings with other areas in southeastern Alaska. Subsequent deer pellet group surveys on Coronation and other

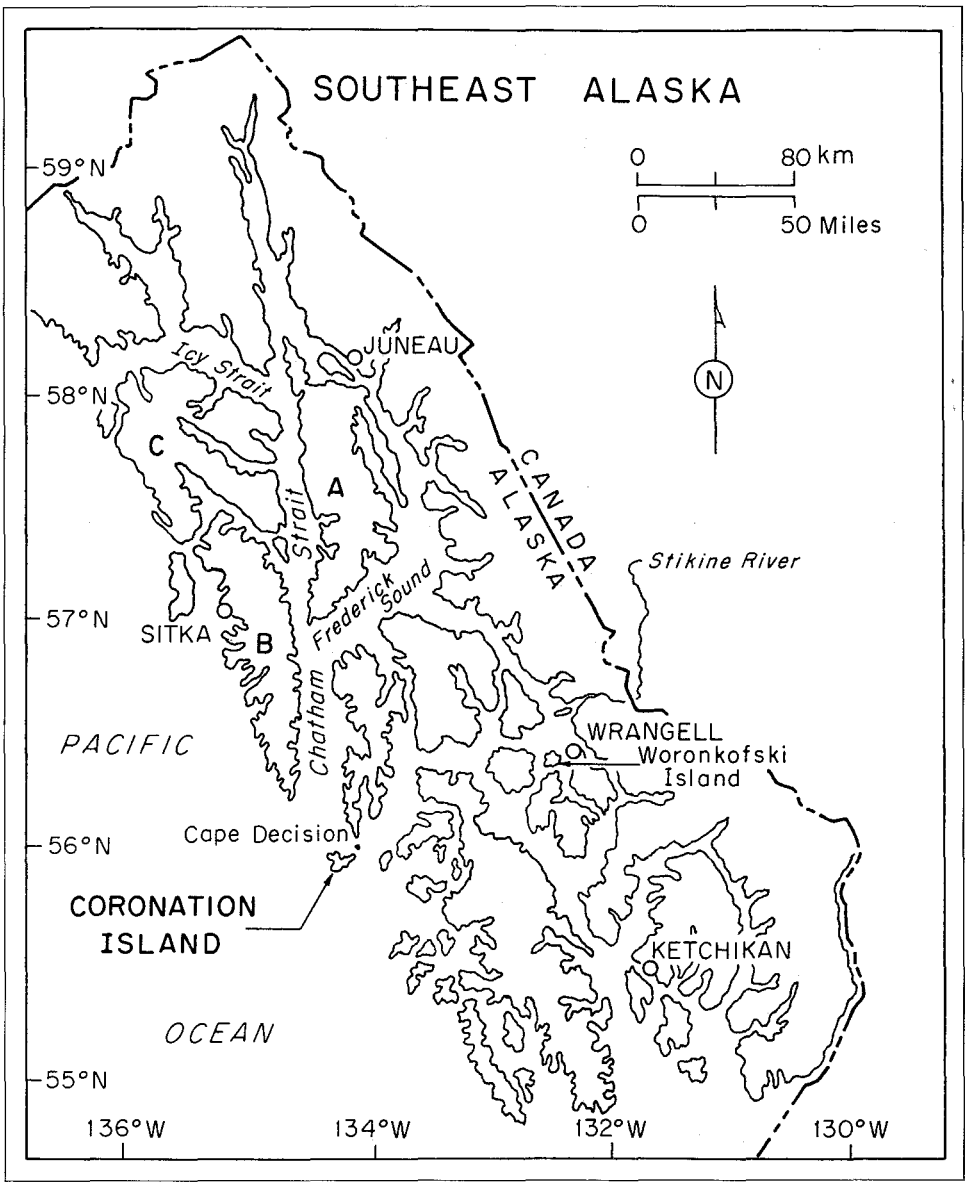

Fig. 1 *Position of Coronation Island in the Alexander Archipelago and other locations mentioned in the text. The natural distribution of wolves in southeastern Alaska includes the mainland and islands south of Frederick Sound with the exception of Coronation Island. Wolves have not established on Admiralty (A), Baranof (B), and Chichagof (C) and associated islands in the northern archipelago.*

islands in southeastern Alaska (Kirchhoff and Pitcher 1988) support this higher estimate.

The Wolf Introductions

After Klein (1964, 1965a) reported altered vegetation on Coronation Island because of foraging pressure by deer, and the associated suppressed phenotypic development of the deer, biologists of the Alaska Department of Fish and Game (ADFG) proposed introducing wolves to Coronation Island. The reason for the proposal was the belief that Coronation Island offered a unique opportunity to investigate relationships among vegetation, herbivores, and predators. These included: 1) the response of a food-limited deer population to wolf predation; 2) the growth and dynamics of a wolf population introduced to an island of limited area with a high deer density; 3) the response of vegetation following reduction of deer density; and 4) the possible changes in body condition of the deer as a consequence of their lowered density and subsequent recovery of vegetation.

Coronation Island lies within the natural distribution of deer, wolves, and black bears, in contrast to islands to the north of Frederick Sound where only deer and brown bears (*Ursus arctos*) are present (Fig. 1) (Klein 1965b). Coronation Island, however, is exposed to the Pacific Ocean; its closest proximity to a wolf-occupied island is by way of the chain of small Spanish Islands and the 2.7-km-wide Decision Passage. Strong tidal currents and rough seas that characterize the passage may account for the failure of natural wolf dispersal to the island in recorded history. Although wolves swim water channels between islands in southeastern Alaska (Klein pers. obs.), these are more protected waters with relatively calm conditions. The absence of wolves from

Table 1. Frequency of food items in wolf scats from Coronation Island, 1961-1968.

		Percent Occurrence						
YEAR	Number Scats	Deer	Harbor Seal	Wolf	Bird	Rodent	Marine Invert.	Undetermined
1961	146	78	43	0	2	0	1	2
1962	18	89	48	0				11*
1963	45	89	53	0	0	1	2	27
1964	77	95	32	0	8	0	0	14
1965	213	97	8	7	5	3	3	17
1966								
Feb	110	53	18	10	30	1	28	66
Aug	7	0	14	29				57*
1967	44	0	57	0	25	18	23	5
1968	3	33	33	0	0	33	33	0

* Not examined for bird, rodent, or marine invertebrates.

northern archipelago islands with deer provides further evidence that, unlike deer, wolves are limited in their distribution by moderately wide or rough water crossings. These islands are separated from the mainland by water channels a minimum of about 2.5 km wide. Few potential prey species for wolves other than deer live on Coronation Island (Land and Young 1984). Mink (*Mustela vison*) and river otters (*Lutra canadensis*) are primarily occupants of the beach fringe; the former is much more common than the latter. Rodents include *Microtus coronarius* and *Peromyscus sitkensis*. Birds include the blue grouse (*Dendragapus obscurus*), passerine birds, a few shore birds and waterfowl nesting in muskeg areas, and large colonies of cliff-nesting sea birds on the west and south coasts. In winter, waterfowl, mostly diving ducks, and some seabirds are present in peripheral waters. Harbor seals (*Phoca vitulina*) occasionally haul out on the rocky shores. Other marine mammals commonly present in the surrounding waters are sea lions (*Eumetopias jubata*), sea otters (*Enhydra lutris*), porpoises (primarily *Phocaena romerina* and *Phocoenoides dalli*), and whales (primarily *Balaenoptera* spp., *Megaptera nodosa*, and *Orcinus orca*). In intertidal zones, mollusks and crustaceans are common. There are no significant salmon runs into the several small streams that drain the island.

A litter of seven wolf pups obtained from a den on Kupreanof Island in 1959 and reared by ADFG biologists was a source for introduction. While in captivity the two females grew to 29 kg and the five males to more than 37 kg at approximately one year (Garceau 1960). These weights are greater than those of wolves killed in southeastern Alaska during September 1960 to June 1961 (72.4 ±4.3 (SE) lbs (27 kg) for females and 88.0 ± 3.8 lbs (33 kg) for males) (Garceau 1961).

When about 1.5 years old, two females and two males from the captive litter were individually caged and transported by boat from Petersburg to Egg Harbor at Coronation Island. They looked well when released on 27 October 1960 after four days of close confinement. Five deer were shot, three at Egg Harbor and two at Aats Bay, to provide food for the wolves.

Growth of the Wolf Population and Decline of Deer

Garceau (1961) visited the island in May 1961 and reported evidence that these wolves, although inexperienced in killing deer, had acclimated to conditions on the island. He found tracks of at least one male and one female wolf (based on track size differences) on beaches, remains of several deer showing evidence of having been killed by wolves, and wolf scats containing deer bones and hair. In July 1961, a commercial fisherman who had anchored at Egg Harbor shot the two adult female wolves. One was reported to have been lactating and both were bearing ear tags (Garceau 1962). Later in the summer howling, tracks, and fresh scats indicated that both adult males were still alive. Garceau (1962) observed tracks of wolf pups several times in August. On 11 August, he saw a wolf pup estimated to weigh 15–19 kg near an apparent rearing area.

Seventy-eight percent of wolf scats (146) collected during spring and summer of 1961 contained deer remains, whereas 43% contained harbor seal (Table 1) (Garceau

1962). Of those scats containing deer, 26% included fawn remains. Remains of 23 deer killed by wolves included 16 adults, five fawns, and two undetermined. Bone marrow was dense and fatty in 11, the fat was depleted in two, and condition of 10 could not be determined because of insufficient skeletal remains. Garceau (1962) reported wolf tracks were common throughout the island. He saw 32 live deer and abundant deer sign, suggesting that deer remained at moderate density.

In April 1963, an additional adult female wolf, trapped on Kupreanof Island, was released on Coronation Island (Merriam 1963–1968). During four days on the island, Merriam saw one wolf, tracks of two others, and heard a wolf howling. During the first two weeks of August 1963, Merriam (1963–1968) found fresh wolf tracks in all of the bays on the island. Five wolves were seen, and on the basis of wolves observed and tracks, he believed that there were at least four adults and three pups present on the island. In July 1964, during eight days on the island, Merriam (1963–1968) saw 11 adult wolves and tracks of two pups. He estimated that there were at least 13 wolves present and noted that three litters of young had been born since the introduction. Remains of 13 deer had fatty bone marrow in all but one. Before the introduction of wolves to Coronation Island bone marrow of deer dying of natural causes was predominantly without fat (Klein 1963). Fresh wolf scats (Table 1) continued to contain mostly deer, but seal and clam (*Clinocardium nuttallii*) were also present. Deer were greatly reduced and rarely seen, although tracks were present throughout the island. Pronounced regrowth from root suckering of blueberry and huckleberry (*Vaccinium* spp.) and rusty menziesia (*Menziesia furruginea*) was noted by Merriam (1963–1968), presumably as a result of the reduced foraging pressure by deer.

In July 1965, Merriam (1963–1968) spent 10 days on Coronation Island. He observed tracks of two pups and abundant adult tracks on all beaches. Deer sign, however, was absent from the north side of the island, but fresh tracks occurred on steep slopes on the south side of the island and on the higher peaks. Merriam equated these locations with escape terrain, where rough terrain and dense vegetation provided the best opportunity for deer to escape from wolves. He suggested that deer were able to survive under the high wolf density (0.18/km^2) only in such areas. He visited the Spanish Islands, separated by less than a kilometre of open water from Coronation Island, and reported no evidence of wolves. Deer sign and the overbrowsed condition of the vegetation were comparable to Coronation Island before the introduction of wolves. In 1963, vegetation transects on Coronation Island revealed that density of most deer food species had more than doubled in two years. Forbs showed the greatest increase. Merriam (1963–1968) saw one of the originally introduced male wolves close enough to recognize its ear tag, verifying its age at six years. In 201 wolf scats collected, deer continued to be the major food. Wolf hair present in 75% of the scats was probably from grooming, but may have resulted, in part, from cannibalism. Other food items included birds, mink, mice, crabs, chitons, and clams. By August 1965, on the basis of tracks, Merriam (1963–1968) believed there were 10 wolves on Coronation Island.

In February 1966, Merriam (1963–1968) observed only three wolves, and tracks suggested they were the only individuals present. Six of 110 wolf scats collected contained wolf remains only. The percentage of scats containing deer was less than half that of the previous spring. Birds, seals, marine invertebrates, and small mammals constituted the major food items. Using leg snares, Merriam and a colleague attempted to capture the remaining wolves to evaluate their body condition. They caught and tagged one wolf immediately after their arrival on 3 February as it attempted to raid their meat cooler on the porch of the Egg Harbor cabin. This male, in poor condition, weighed 24 kg and showed little fear. The absence of tooth wear indicated it was a young animal. After recapturing it three times, they tied it to a tree for several days so that trapping for additional wolves could continue. A second male was caught on 10 February, weighing 37 kg and was in excellent condition. In August 1966, Merriam (1963–1968) observed less evidence of wolves than at any time since the introduction. Two wolves were present and the possibility of a third was suggested, but there was no evidence of pups. Trails made and previously used by wolves were becoming overgrown with vegetation. Only seven wolf scats were collected in August of 1966, in contrast to 201 in a comparable period of the previous year. Three fresh deer tracks were observed, all on the higher peaks of the island.

In a week on the island in early May 1967, Merriam (1963–1968) found tracks of only two wolves and collected 44 scats, none with deer remains present (Table 1). Seal was the predominant food item, although birds, marine invertebrates, and rodents collectively made up most of the scat contents. He found only one fresh deer track, and that was on the south side of the island. On a visit to the island in January 1968, Merriam (1963–1968) heard one wolf howling and saw one old track. He found no scats and no deer tracks on the north side of the island. In mid-July several areas had tracks of a single wolf. No fresh deer tracks were observed, but there was evidence of winter browsing on some blueberry shrubs (*Vaccinium ovalifolium*). In December, with new snow and good tracking conditions, there was evidence of only one wolf, indicated by urination marks to be a female. No deer tracks were seen. Three wolf scats collected contained deer in one, seal in another, and rodents and chitons were in the third. Merriam (1971) spent 10 days on Coronation Island during June and July 1970, visiting all beach areas. He saw fresh tracks of a single wolf but no fresh deer tracks. Evidence of winter browsing by deer was present and he found one deer pellet group.

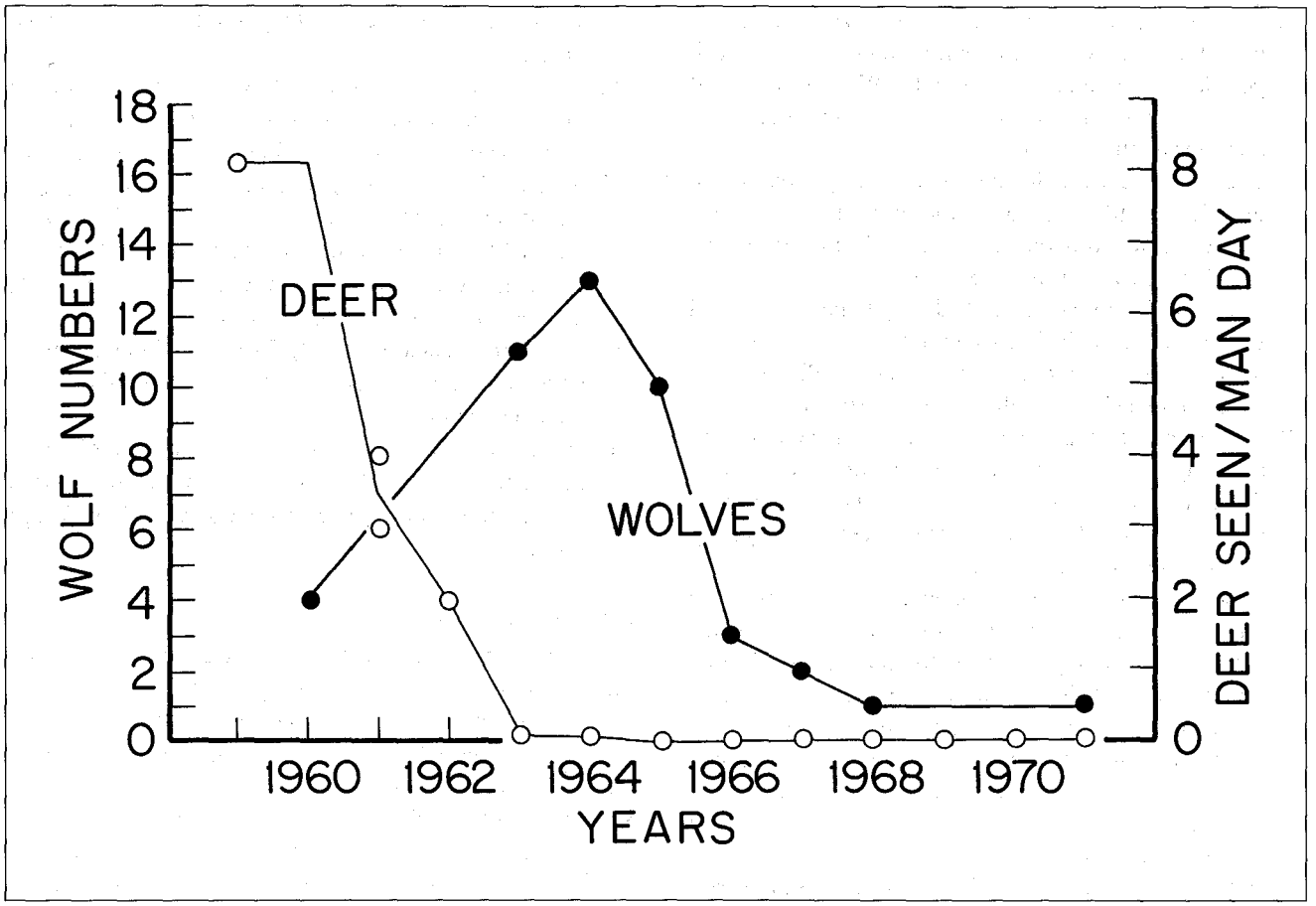

Fig. 2 *Increase and decline of wolves following their introduction to Coronation Island in 1960 and relative deer densities.*

By summer 1966, vegetation on the island showed marked response to release from foraging pressure associated with the previous high deer density. Merriam (Alaska Dept. Fish and Game, pers. commun.) established seven point-intercept, vegetation transects [100-foot (30.5-m) with points at 1-foot (.305-m) intervals] at Egg Harbor, Aats Bay, Alikula Bay, and Gish Bay in 1963. He relocated these in 1966 and reran them. From 1963 to 1966, the transects showed a 63% increase in occurrence of forest floor forbs. These included trailing bramble (*Rubus pedatus*), lace flower (*Tiarella trifoliata*), and dwarf dogwood (*Cornus canadensis*), which are forage species favored by deer. There was a 34% increase in woody shrubs and tree seedlings.

Over several weeks in 1983, Land and Young (1984) surveyed fauna on the island but saw no evidence of wolves. From 1987 and 1988, Lewis (1992) spent six months on the island in both summer and winter during a study of vegetation and deer. He found no evidence of wolves.

Discussion and Conclusions

The wolves introduced to Coronation Island increased to a density of 1/5.64 km^2 (0.18 wolf/km^2). Deer at their peak density in 1959 (5.8-7.8 km^2 = 425-572 deer), before the introduction of wolves, outnumbered wolves at their peak density in 1964 (13 wolves) by 32–43 to one. Deer density, however, was much reduced by 1964 after wolves were introduced. The potential rate of increase of wolves, assuming an even sex ratio and average litter size of six (Rausch 1967), far exceeds that of deer. There were obviously constraints on wolf reproduction that most likely included limitations in the capability of the deer population to sustain itself under the level of wolf predation that existed. Potential social inhibitions to reproduction among the wolves may also have been a factor. Although the two pair of wolves initially released were from the same litter, it is doubtful that inbreeding was a factor in limiting reproduction and survival. Shields (1983) points out that a moderate level of inbreeding is a normal consequence of wolf sociality and their disjunct distribution. At least four litters of young were produced on Coronation Island. The early removal of the two original adult females, who were litter mates, and their replacement by another wild-trapped female increased genetic diversity in the population.

Specific conclusions from this study of a wolf introduction to an island populated by deer are as follows:

1) Wolves introduced to a 73 km^2 island with moderately high deer density increased within four years to a peak population of about 13 animals. Wolves produced young at two years of age and at least four litters were born during this period.
2) Deer declined markedly during this same period to such low density that they were rarely seen. Deer forage species showed pronounced regrowth from the previous sustained heavy herbivory by deer.
3) Most deer killed by wolves had fatty bone marrow and were presumed to be in good condition, whereas before the introduction of wolves most deer that died were in a malnourished state without bone marrow fat.
4) As the wolf population declined over the next four years to a single animal, deer were no longer seen and their few tracks were restricted to steep slopes on the south side of the island and to the higher peaks. No young wolves were born after 1965.
5) Food consumed by wolves changed from primarily deer during their increase phase to a diversity of items apparently obtained opportunistically during the decline phase. They included harbor seal, marine invertebrates, birds, rodents, fish, mink, and river otter. Wolf hair commonly appeared in wolf scats, apparently ingested during grooming, but during the rapid decline to three wolves in 1966, six of 110 scats collected contained only wolf remains.
6) Wolves failed to cross the 900 m of water to the adjacent Spanish Islands where deer densities remained moderately high throughout the study.
7) When the wolves had declined to three individuals in 1966, of two males captured and released, one was in poor condition weighing 73% of the mean for adult males killed throughout southeastern Alaska. The other was in excellent condition weighing 14% more than the mean.
8) Recovery of deer forage species following the decline in deer density was most rapid for forbs of the forest floor. Woody shrubs responded more slowly and continued to increase throughout the study period.
9) At the low density, when deer on the island had been reduced by wolves during the eight years of the study, it was not possible for the deer to increase, even during the marked decline in wolf numbers.
10) Coronation Island with only 73.3 km^2, although favorable deer habitat, is too small to sustain populations of both deer and wolves.
11) Wolves in areas of strong maritime climatic influence in southeastern Alaska have the potential to suppress deer numbers below the carrying capacity of the forage resource.

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Ecology and Conservation of

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