# DENNING ECOLOGY OF BROWN BEARS ON ADMIRALTY AND CHICHAGOF ISLANDS

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*Abstract:* From fall 1981 through fall 1985, 58 radio-collared brown bears (*Ursus arctos*) were followed to winter dens on Admiralty and Chichagof islands in southeast Alaska. One hundred twenty-one dens were located and their site characteristics described. Mean dates of den entry and emergence, 30 October and 2 May, varied between sexes and among years. Mean elevation and slope of 121 dens were 640 m and 35°, respectively. Dens were at higher elevations and on steeper slopes on Admiralty Island than on Chichagof Island. Females denned on higher and steeper slopes than males. Admiralty Island bears preferred subalpine and alpine/rock habitats and Chichagof Island bears preferred old-growth forest for denning. On Admiralty, rock caves were the most frequent den type; on Chichagof, bears excavated dens most frequently under large-diameter Sitka spruce (*Picea sitchensis*) or in the bases of large snags. Mine development on Admiralty Island may have caused bears to avoid certain denning areas. Industrial scale logging may reduce brown bear denning habitat in this region. Management recommendations for reducing the impact of human activity and resource development on denning brown bears are provided.

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A significant feature of brown bear and grizzly bear ecology is winter dormancy (see Folk et al. 1980, Nelson et al. 1983), which allows bears to spend 5–6 months of the year hibernating in a winter den. Predenning accumulation of energy stores and den site suitability are critical for successful denning.

Brown bear or grizzly bear dens and den site characteristics in Europe (Couturier 1954, Curry-Lindahl 1972), the Rocky Mountains (Craighead and Craighead 1972; Vroom et al. 1980; Servheen and Klaver 1983; Judd et al., in press), northern Canada (Pearson 1975, Harding 1976), and Alaska (Lentfer et al. 1972, Reynolds et al. 1976, Smith and Van Daele 1984, Miller 1985) have been described. There are, however, no published reports on the denning ecology of brown bears of the coastal rain forests of southeast Alaska or British Columbia. Human activity and resource development, particularly logging and mining, are increasing in this coastal region, which supports significant brown bear populations.

As part of a major investigation of brown bear ecology in southeast Alaska (Schoen and Beier 1986), we studied denning ecology from fall 1981 through fall 1985. Our objectives were to document denning chronology, delineate denning habitat, identify landscape variables important in den site selection, assess the availability of suitable den sites, and consider the potential influence of resource development on the denning ecology of brown bears in southeast Alaska. This paper summarizes our findings.

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## STUDY AREA

Southeast Alaska lies in a narrow band between the coastal mountains of British Columbia on the east and the Pacific Ocean to the west. It extends from Dixon Entrance at the Canadian border to Icy Bay 840 km to the north. Islands of the Alexander Archipelago compose much of the land area. Chichagof and Admiralty islands are the 2nd and 3rd largest islands in the archipelago, measuring 5,340 $km^2$ and 4,430 $km^2$, respectively. The 2 study sites were located on northern Admiralty and southeastern Chichagof islands at 57°–58° North latitude and 134°–136° West longitude.

The topography of the area is rugged with mountains rising from sea level to over 1,400 m. Vegetation is primarily of 2 major types: temperate rain forest and alpine tundra. Scattered throughout this area are steep avalanche slopes, poorly drained muskeg bogs, and tidal wetlands. A cool, maritime climate is characteristic of this region. Snow often accumulates at sea level during the winter, and elevations above 600 m are covered by snow for 6–9 months of the year. Annual precipitation averages about 140 cm, and January and July temperatures average −6 C and 13

C, respctively (Natl. Ocean. and Atmos. Admin. weather records).

Within southeast Alaska, brown bears occur only on the mainland and on islands north of Fredrick Sound, including Admiralty, Baranof, and Chichagof. Although wolves (*Canis lupus*) and black bears (*U. americanus*) occur on the southern islands and mainland, they are absent on these northern islands.

The Admiralty site is steeper and has more high-elevation alpine habitat than the Chichagof site. Logging activity has been minimal on the Admiralty site, although Chichagof has been extensively logged within the last 25 years. The Noranda Mining Company is now developing a major mine at Greens Creek in the center of the Admiralty site.

## METHODS

We captured and instrumented bears with radiocollars (all with mortality modes and many with motion sensors) in alpine areas, along fish streams, and on tidal grass flats (Schoen and Beier 1986). We then radio-tracked bears from fixed-wing aircraft, using a directional yagi antenna mounted under each wing. We flew 1 telemetry survey per week, weather permitting, from 1 April through mid-November. During the winter, we made surveys by air approximately once every 6 weeks. Habitat variables recorded from the air included habitat type, elevation, slope, aspect, terrain, percent canopy cover, percent spruce composition, and timber stand volume. Denning habitat preference was determined by comparing percentage use of these habitat variables with their availability with in the study area. All locations were plotted on U.S. Geological Survey 1:63,000 scale topographic maps.

Den entry and emergence dates were usually approximations based on observations made from consecutive flights. We defined date of den entry as the mean date between when a bear was last located out of the den and when its location became stationary. Similarly, the mean date of den emergence was the mean date between when a bear was clearly in a den and first located out of a den. Once a bear was out of the den during the spring emergence period, it was considered emerged even if it remained in the den vicinity.

During late winter, we marked some of the dens by dropping weighted flagging or a radiotransmitter from an aircraft. After the bears had left their dens, we returned to measure pertinent variables.

We recorded snow measurements at the den sites of 13 radio-collared bears in January and April 1983. Where open and forested areas were adjacent, we measured snow depths in both habitat types. For dens that could not be reached, we based estimates of snow depths on those at nearby locations, tree canopy cover, topographic features, and snow drift patterns. We based our subjective descriptions of snow characteristics on surface appearance and probing. Maximum-minimum thermometers were placed in the vicinity of 5 representative dens. In April, we examined snow profiles from the snow surface to the ground and measured moisture content and density by weighing core samples at 5 dens. We used snowfall data for 8 years (1977–85) from a 425 m elevation site at the Eaglecrest ski area on Douglas Island (12–20 km east of most dens) to predict the amount of snow cover at den sites during years of minimum and maximum snowfall.

Mann-Whitney U tests of significance were used for 2-sample comparisons and Kruskal-Wallis tests for multisample comparisons. Contingency tables were analyzed with chi-square.

## RESULTS AND DISCUSSION

From fall 1981 through fall 1985, we followed 58 brown bears (18 males, 40 females) to their winter den sites on Admiralty and Chichagof islands. One hundred twenty-one dens sites (86 on Admiralty, 35 on Chichagof) were described from the air, and 38 of those dens (29 on Admiralty, 9 on Chichagof) were located on the ground and described.

### Denning Chronolgy

Mean dates of den entry and emergence for radio-collared brown bears were 30 October and 2 May, respectively. Sex and reproductive status influenced both entry and emergence dates ($P < 0.001$, Table 1). Pregnant females and females with young entered dens earlier than single females or males (Fig. 1).

In general, females began denning by the 2nd week of October; by the end of October more than 70% were in dens. Males began denning the 3rd week of October, but by the end of October fewer than 50% were denned. By mid-November about 80% of the males and 95% of the females had denned. Several radio-collared males remained active until about mid-December. These bears, as well as other unmarked bears of undetermined sex, were observed feeding on

**Table 1. Mean dates of den entrance and emergence of radio-collared brown bears by sex and reproductive status on Admiralty and Chichagof islands, southeast Alaska, fall 1981 through fall 1985.**

| Sex & reprod. status | Mean date of den entrance | Range (days) | *N* | Mean date of den emergence | Range (days) | *N* |
|---|---|---|---|---|---|---|
| Females | | | | | | |
| Parturient | 22 Oct | 25 | 17 | 11 May | 72 | 18 |
| With young | 27 Oct | 44 | 23 | 16 May | 61 | 18 |
| Single | 5 Nov | 40 | 22 | 29 Apr | 52 | 16 |
| Males | 5 Nov | 58 | 30 | 19 Apr | 57 | 28 |

late salmon runs from November through much of December.

In spring, males were the 1st to emerge from dens. Next were single females and finally females with young (Table 1). Males began emerging in late March, and by the end of April, 67% had left their dens (Fig. 2). Females began emerging from dens in early April, and by the end on April 56% of single females had emerged compared to 13% of females with young. By the 3rd week of May, all males had emerged in contrast with about 80% of the females. Most females had emerged by the end of May; however, in 1985, following a late spring, several females remained in their dens through the 1st half of June.

Males spent an average of 165 days in winter dens compared with 194 days for females. Parturient females averaged 211 days, 46 days longer than males. Other investigators have described similar patterns of den emergence (Craighead and Craighead 1972; Pearson 1975; O'Pezio et al. 1983; Smith and Van Daele 1984; Judd et al., in press).

Following den emergence, many bears (particularly females with cubs) remained near the den site. The length of time varied from several days to several weeks for females with cubs.

Mean dates of den entry and emergence varied among years ($P < 0.005$ and 0.0001, respectively; Table 2). Winter snowpack and timing of spring snowmelt appear to be correlated with mean date of den emergence. The spring hunter harvest of brown bears on Admiralty Island, in turn, appears negatively correlated with den emergence (Fig. 3).

The winter of 1983–84 was relatively mild and the snowpack above 425 m at Eaglecrest on Douglas Island (about 15 km east of most Admiralty dens) was about 90 cm below the 8-year average. That spring, the mean day of den emergence for all radio-collared bears was 26 April. This was 9 days earlier than the mean (6 May) for the 4 years of study. This same spring was a near-record high spring bear harvest (39 bears, 17 more than the 25-year mean) for Admiralty Island.

The following winter of 1984–85 was one of near-record snowpack at higher elevations. The snowfall

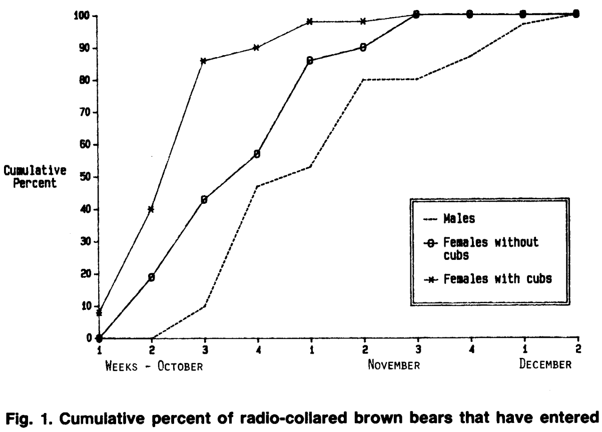


**Fig. 1. Cumulative percent of radio-collared brown bears that have entered dens on Admiralty and Chichagof islands, southeast Alaska, fall 1981–85.**

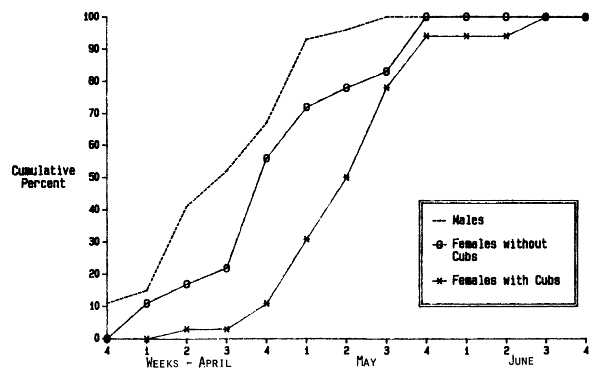


**Fig. 2. Cumulative percent of radio-collared brown bears that have emerged from dens on Admiralty and Chichagof islands, southeast Alaska, spring 1982–85.**

**Table 2. Mean annual dates of den entrance and emergence of radio-collared brown bears on Admiralty and Chichagof islands, southeast Alaska, 1981–86.**

| Year | Mean date of den entrance | Range (days) | *N* | Mean date of den emergence | Range (days) | *N* |
|---|---|---|---|---|---|---|
| 1981–82 | 20 Oct | 15 | 4 | 15 May | 22 | 5 |
| 1982–83 | 3 Nov | 33 | 15 | 29 Apr | 43 | 17 |
| 1983–84 | 28 Oct | 66 | 29 | 24 Apr | 64 | 28 |
| 1984–85 | 30 Oct | 38 | 31 | 11 May | 74 | 34 |
| 1985–86 | 2 Nov | 31 | 27 | — | — | — |
| Total mean | 30 Oct | 68 | 107 | 2 May | 95 | 84 |

at Eaglecrest was about 240 cm above the 8-year mean, and the mean date of den emergence for all radio-collared bears was 14 May. This was 8 days later than the 4-year mean and 17 days later than the mean emergence date the previous year. The 1985 spring bear harvest on Admiralty was 15 animals (7 fewer than the 25-year mean).

Late den emergence of brown bears from the Susitna Basin of south-central Alaska has also been associated with late spring conditions (S. Miller, pers. commun.), as has late emergence of black bears from the Susitna Basin and Kenai Peninsula in Alaska (Schwartz et al., this volume).

The denning chronology of brown bears in southeast Alaska differs from that of grizzly bears in the Rocky Mountains (Craighead and Craighead 1972; Servheen and Klaver 1983; Judd et al., in press) and brown bears in south-central Alaska (Miller 1985). Some southeast Alaska brown bears den later (primarily males) and emerge later (mostly females) than grizzly or brown bears from the Rocky Mountains and interior Alaska.

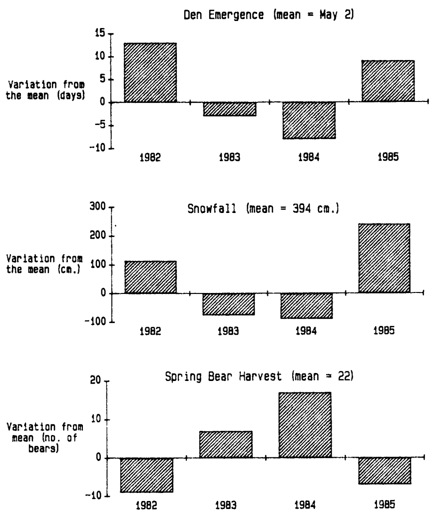


**Fig. 3. Relationship between spring den emergence of radio-collared brown bears, winter snowfall at 425 m, and spring bear harvest on Admiralty Island, 1982–85.**

Several possibilities may account for these differences. The bears we observed denning late (December) had access to late-fall salmon runs that provided abundant nutrient-rich food. December denning of male brown bears has also been described on Kodiak Island, where late salmon runs occur (Smith and Van Daele 1984; V. Barnes, pers. commun.). Bears in the Rocky Mountains or interior Alaska do not have a late seasonal abundance of food resources comparable with those found in southeast Alaska. The earliest denning of brown bears or grizzly bears has been reported from the eastern Brooks Range of Alaska (Reynolds et al. 1976), where winter comes early and late fall food resources are scarce.

What triggers bears to enter their winter dens is not clear. Craighead and Craighead (1972) postulated that environmental conditions such as the 1st winter snowfall trigger grizzly bears to move simultaneously into their dens in Yellowstone Park. In our study, denning did not occur with the 1st snowfall. We speculate that the disappearance of abundant high-quality food determines time of den entrance. Food availability can vary substantially among geographical localities. It is interesting to note that zoo bears, when fed throughout the winter, do not den.

## Den Site Characteristics

The mean elevation of 121 brown bear dens located in this study was 640 m; the mean slope was 35° (Table 3). Dens on Admiralty were at higher eleva-

**Table 3. Elevation and slope of brown bear dens by area, sex, and distribution on Admiralty and Chichagof islands, southeast Alaska, 1981–85.**

| Den category | $N$ | Elevation (m) | | | | Slope (degrees) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $\bar{x}$ | SE | Min | Max | $\bar{x}$ | SE | Min | Max |
| All | 121 | 640 | 21 | 6 | 1,190 | 35 | 1.0 | 5 | 75 |
| Admiralty | 86 | 713 | 23 | 6 | 1,190 | 36 | 1.2 | 5 | 60 |
| Chichagof | 35 | 460 | 25 | 210 | 760 | 31 | 1.8 | 20 | 75 |
| Male | 29 | 535 | 47 | 6 | 915 | 30 | 2.0 | 5 | 45 |
| Female | 85 | 658 | 23 | 240 | 1,190 | 36 | 1.2 | 10 | 75 |
| Coastal[a] | 42 | 674 | 28 | 370 | 1,110 | 34 | 1.6 | 10 | 60 |
| Interior[a] | 18 | 848 | 41 | 460 | 1,190 | 42 | 2.0 | 20 | 55 |

[a] Distribution status of Admiralty Island females.

tions and on steeper slopes than those on Chichagof ($P < 0.001$), reflecting differences in habitat availability. All dens of females (and those of 2 subadult males) were at higher elevations and on steeper slopes ($P < 0.05$) than dens of adult males. The security provided by high, steep terrain may be more important to females with cubs than to other bears.

On Admiralty Island, most females spend part of the year in coastal areas feeding on spawning salmon, although some females spend the entire year in interior regions of the island without access to spawning salmon (Schoen et al., in press). Interior females den at higher elevations and on steeper slopes than do coastal females ($P < 0.01$, Table 3). This probably reflects the higher elevational distribution of interior bears throughout the year.

On both Admiralty and Chichagof islands, bears preferred den sites above 300 m elevation (Fig. 4). This is comparable to den site selection by brown bears on Kodiak Island (Lentfer et al. 1972, Smith and Van Daele 1984) and the Alaska Peninsula (Lentfer et al. 1972).

Radio-collared brown bears on Admiralty and Chichagof islands preferred den sites on moderate-to-steep slopes (Fig. 5). The preference for steep, high-elevation denning habitats observed in southeast Alaska is similar to elsewhere in Alaska (Lentfer et al. 1972, Reynolds et al. 1976, Miller 1985), the Yukon (Pearson 1975), and the Rocky Mountains (Craighead and Craighead 1972; Servheen and Klaver 1983; Judd et al., in press). Several of these authors have speculated that bears seek out remote, isolated areas and sites that will accumulate enough snow to insulate them from cold winter temperatures. Snow is probably less important for insulation in south coastal Alaska, where winter temperatures rarely fall below −20°C. Instead, we suggest that bears need dry cold sites where temperatures generally remain below 0°C and free-flowing surface water is rare. In southeast Alaska, torrential winter rain storms frequently occur below 300 m. This may explain why bears avoid den sites below that level.

More bears in this region chose southerly exposures than any other. Forty-four percent of the dens had southerly exposures, 29% had northerly exposures, and 27% had east or west exposures. Southern exposures are the last to accumulate deep snow in the fall and the 1st to be snow-free in the spring. In other regions, bears appear to prefer slope exposures accumulating the greatest snowpack, which insulates the den chamber (Craighead and Craighead 1972, Vroom et al. 1980). As described previously, we consider the insulating value of snow to be less important

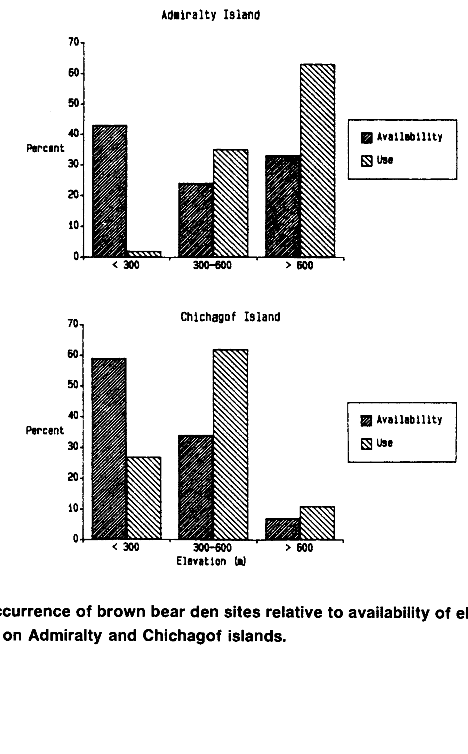


**Fig. 4. Occurrence of brown bear den sites relative to availability of elevation intervals on Admiralty and Chichagof islands.**

in southeast Alaska than in other areas with colder winter temperatures.

Sixty-five percent of all dens were in areas of highly dissected terrain. Although greater use of rugged terrain occurred on Admiralty, we suggest that steep, rugged country is generally preferred by bears in both areas.

Of the 5 habitats used for denning, bears chose old-growth forest most frequently (Table 4). Bears on Chichagof denned twice as frequently in old growth as bears on Admiralty (Fig. 6). On Admiralty, 39% of the dens occurred in higher-elevation subalpine and alpine/rock habitat. The differences in habitat types selected for denning between study areas are probably due to differences in habitat availability. Half of the coastal females on Admiralty denned in old-growth habitat types; none of the interior females did so.

Although we suspect that high-elevation alpine/rock habitat may be preferred if it is available (Fig. 6), 52% of all dens we located occurred in old-growth forest habitat. An important caveat when determining habitat preference from use and availability data is that the importance of abundant habitat categories may be underestimated. If we assume that a brown bear is intimately familiar with its home range, then the actual use of habitat may, in itself, be an important indicator of habitat preference (McLellan 1986). Thus, in both sites, old-growth forest, followed by alpine/rock and subalpine forest, provide important denning habitat for brown bears in southeast Alaska. Craighead and Craighead (1972), Vroom et al. (1980), and Judd et al. (in press) also identified forested habitat as an important component in grizzly bear den site selection.

For 63 den sites in old-growth forest habitat, spruce composition was 29%. This is higher that the average composition of less than 20% and may reflect a preference for denning under spruce compared to hemlock (*Tsuga heterophylla*). Eighty-eight percent of old-growth forest dens occurred in commercial timber stands: 33% in low-volume (8,000–20,000 board feet/acre), and 8% in high-volume (> 30,000 board feet/acre) stands. Noncommercial sites were used less and mid-volume sites more than their availability within the study area. Noncommercial forest sites were probably avoided because they occur on poorly drained sites with standing water.

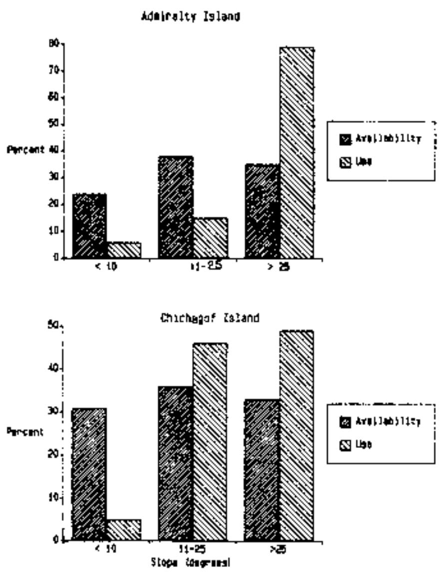


Fig. 5. Occurrence of brown bear den sites relative to availability of slope categories on Admiralty and Chichagof islands.

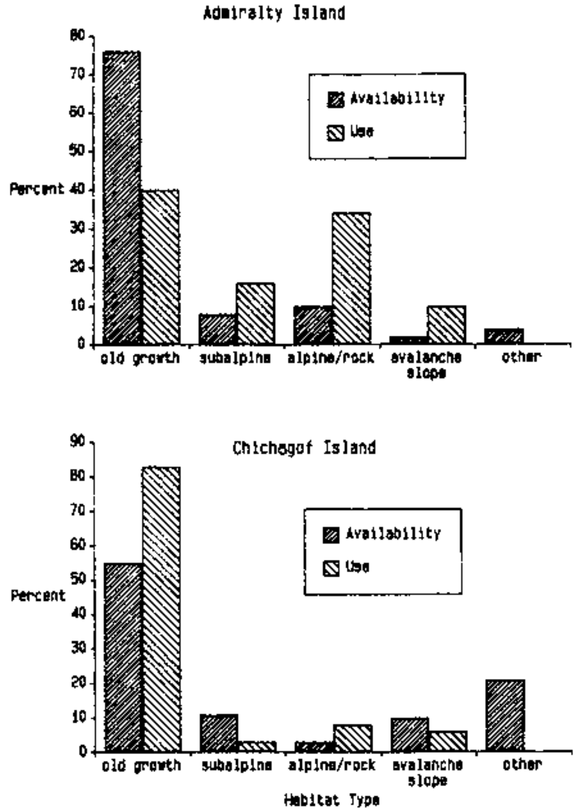


Fig. 6. Occurrence of brown bear den sites relative to availability of habitat types on Admiralty and Chichagof islands.

**Table 4. Frequency of habitat types for brown bear dens by area and distribution on Admiralty and Chichagof Islands, southeast Alaska, 1981–85.**

| Den category | *N* | Habitat type (%) | | | | |
|---|---|---|---|---|---|---|
| | | Old-growth forest | Avalanche slope | Subalpine forest | Alpine | Rock |
| All | 121 | 52 | 9 | 13 | 13 | 13 |
| Admiralty | 86 | 40 | 10 | 16 | 15 | 19 |
| Chichagof | 35 | 83 | 6 | 3 | 8 | 0 |
| Coastal[a] | 42 | 52 | 7 | 17 | 10 | 14 |
| Interior[a] | 18 | 0 | 17 | 11 | 33 | 39 |

[a] Distribution status of Admiralty Island females.

## Den Types

We visited and classified 38 dens to type. Twenty-four (63%) occurred in natural rock cavities, 8 (21%) were excavated in or under live trees or snags, 3 (8%) were excavated in earth, and 3 were surface beds.

On Admiralty Island, rock cavities were the most common den (79%), whereas on Chichagof Island only 1 of 9 dens (11%) was in a rock cavity. Rock cavities varied from large caves 7.5 m deep to small crevices under boulders. Several had more than 1 entrance. Some rock cavities had been slightly modified by digging. We suspect most rock dens had been used in prior years; some had probably been used for centuries. There appeared to be an abundance of acceptable rock cavities on the Admiralty study site but not on the Chichagof site.

Cave denning by brown or grizzly bears is generally atypical in North America (Craighead and Craighead 1972, Lentfer et al. 1972, Pearson 1975, Vroom et al. 1980, Servheen and Klaver 1983, Miller 1985). Although Couturier (1954) and Curry-Lindahl (1972) described cave denning by European brown bears, only Reynolds et al. (1976) and Judd et al. (in press) have described more than occasional cave denning by brown or grizzly bears in North America. We believe that many brown bears on Admiralty Island prefer rock caves or crevices for denning. We have no reason to believe that cave dens are inferior to earth-excavated dens as postulated by Judd et al. (in press); however, we recognize that winter temperatures in southeast Alaska are not as cold as in the Rocky Mountains.

Three dens were excavated in the earth and 8 were excavated under or in trees and snags. Six of the 7 excavated dens on Chichagof were associated with large-diameter spruce trees or snags. On Admiralty, 2 of 4 excavated dens were under live trees. The mean diameter at breast height of these trees and snags was 99 cm (SE = 9.9, range 61–152 cm). Tree ages were estimated at well over 200 years. Grizzly bear dens excavated under the bases of trees have been described as typical by Craighead and Craighead (1972) and Judd et al. (in press).

Our sample of visited dens was biased toward high-elevation, nonforested sites that were relatively easy to reach, but we did examine 14 dens within old-growth forest. Of those, 8 (57%) were excavated under the roots of old, large-diameter Sitka spruce trees or were excavated within the bases of snags with well-developed heart rot. We strongly suspect these are typical den sites within old-growth habitat.

In areas where bears den predominantly in old growth, extensive timber harvesting, particularly on steep slopes (>20°) and at elevations above 300 m, could reduce the availability of suitable denning habitat. In this region where soil depth is shallow and torrential rainfall common, trees and snags may be important elements of excavated dens. It is unlikely that the second-growth stands replacing old growth would provide the large diameter trees and large snags with heart rot which brown bears prefer for forest den sites. Judd et al. (in press) also found that grizzly bears in Yellowstone Park denned under large trees and also suggested that logging could destroy some den sites.

Three bears in this study, excluding animals that moved to new dens in midwinter, apparently denned on the surface of the ground or in snow dens. One was a young male that spent the winter on the ground at the base of a large tree in the beach fringe forest at 6 m above sea level. This was atypical and the lowest denning elevation recorded. We found surface den sites of 2 other bears, both females, in old-growth forest at about 400 m elevation. We suspect that these bears dug snow dens as described by Lentfer et al. (1972) in southwest Alaska. One of these females denned with 2 cubs-of-the-year, which she apparently lost over winter.

The mean dimensions of dens measured in this study were entrance height × width = 72 by 79 cm ($N$ = 31), chamber height × width = 107 by 121 cm ($N$ = 28), and total length = 272 cm ($N$ = 28). These measurements are similar to those described by Craighead and Craighead (1972), Lentfer et al. (1972), Vroom et al. (1980), and Servheen and Klaver (1983).

We found nest material, including conifer branches, alder (*Alnus* sp.) branches, a variety of deciduous shrubs, heather (*Cassiope* sp.), and rotten wood, in most dens. The type of material used reflected what was available in the immediate vicinity.

### Spatial Distribution and Reuse of Dens

Most dens were located on the periphery of bears' annual home ranges. On Admiralty Island, little overlap in male and female denning areas was found. In several instances, however, both males and females denned within 0.4–1.0 km from one another on Chichagof Island.

The mean distance individual bears denned from a previous year's den site was greater ($P < 0.001$) for males (8.8 km) than females (3.5 km); however, these data suggest some degree of fidelity to a general denning area for both sexes. The difference between males and females reflects the larger size of male home ranges. Annual home range sizes for males and females were approximately 100 $km^2$ and 25 $km^2$, respectively.

It was uncommon for individual bears to reuse the same den in subsequent years. Although we do not have proof of den reuse by the same individual, we suspect that 2 females used their dens (rock caves in both cases) for 2 and perhaps 3 consecutive years. All other bears used different dens in consecutive years. Our summer visits to the den sites may have inhibited reuse; we did not visit the dens of the 2 bears that may have reused their dens until the last year of the study. However, numerous dens we did not visit on the ground were not reused by instrumented bears in subsequent years.

### Den Mortality and Den Abandonment

Overwinter den mortality was documented in 1 case and was strongly suspected in 2 other cases. In the 1st instance we found the remains of 2 yearlings in a rock cave den following the long winter of 1984–85.

That same year another radio-collared bear, which denned with her 2 cubs, was observed the next spring without young. This bear spent the winter in a surface nest or perhaps in a snow den.

In winter 1983–84, a radio-collared female entered her rock cave den in the fall with 1 cub. In March, she abandoned her den and moved to a site 2.9 km away. She was alone when first observed after emergence. We presumed her cub either died in the den and she abandoned it or it was lost as she traveled to the new den site. We were unable to examine either den. An additional case of winter den abandonment was by an old female without young who moved in midwinter to a new site 0.4 km away.

During the winter of 1986, December and January had near-record mild temperatures and heavy rainfall. By early February 1986, 30% of 33 radio-collared bears abandoned the dens they entered in October and November and moved into new dens. This is a minimum estimate of the number emerging, because some bears may have come out during the mild weather and returned to their original dens. Nevertheless, these data indicate that a substantial number of bears may abandon their dens during mild weather conditions. We suspect that some of these bears may have left their dens because of wet conditions caused by thawing and rain. During the same time period R. Smith (pers. commun.) reported about the same percentage of radio-collared bears abandoning dens on Kodiak Island during wet, mild conditions.

Increased energy expenditure and difficulty in finding a new den site are problems bears that abandon dens in midwinter may encounter. Den abandonment could also pose problems to newborn cubs. Blix and Lentfer (1979) reported that polar bear cubs have no internal thermoregulatory mechanism, depending instead on the mother's milk to maintain body heat throughout the 1st several months of life. If brown bears are similar, den abandonment and relocation could be particularly stressful or perhaps fatal to cubs-of-the-year. Excavating a den or finding a suitable rock cavity would be difficult in midwinter. Thus, some bears might be forced to dig snow dens (Lentfer et al. 1972) of perhaps inferior quality.

### Snow Characteristics at Winter Den Sites

Snow measurements were recorded at or near the winter den sites of 13 radio-collared bears during January and April 1983. Snow depths at dens ranged from 0.1 to 2.7 m ($\bar{x}$ = 1.3 m, SE = 0.17) in January and from 0 to 2.2 m ($\bar{x}$ = 1.4 m, SE = 0.23) in April.

In January, surface snow ranged from light and dry to heavy and moist to hard-packed and dry, depending on air temperature and wind conditions at the site. Probing to obtain depth measurements indicated an occasional hard layer. Snow was consistently denser and contained more moisture in April than in January. Mean snow density in April, based on measurements from 5 den sites, was 0.42 g/cc (SE = 0.04, Table 5).

One or 2 layers of consolidated ice occurred in 3 of 5 locations where snow profiles were examined (Table 5). Whether such conditions could restrict gas exchange to the extent that respired carbon dioxide would concentrate within the den and make oxygen levels inadequate is unknown. Hock (1960) reported hibernating black bears consume from 0.5 to 0.1 as much oxygen as active bears. If brown bears are similar, this would reduce the problem of oxygen consumption in dens affected by ice layering. Following a long winter such as 1984–85, however, bears in small dens overlain by layers of ice could conceivably encounter respiratory difficulties.

Ten sets of snow depth measurements were obtained in open areas and in adjacent areas with forest cover in the vicinity of 7 dens which occurred in both open and forested areas. Mean snow depths, based on all measurements, were 1.5 m (SE = 0.08, $N$ = 55) in open sites and 0.9 m (SE = 0.07, $N$ = 55) in forested sites ($P < 0.05$).

Winter 1982–83 had below average snowfall. Using an 8-year average from the 425 m elevation Douglas Island site as a standard, the 1982–83 snowfall was 79% that of the 8-year average. As an additional comparison, the minimum snowfall in 1980–81 was 60% that of 1982–83 while the maximum snowfall in 1984–85 was 200% of the 1982–83 snowfall. These figures suggest that snow depths at the den sites measured could possibly range from 0 to 5.4 m. It should be recognized, however, that this is an 8-year average and not representative of the extreme snowfalls that might occur.

In this study, bears denned over a wide range of snow depths (0.1–2.2 m). The shallow snow accumulation at some dens contrasts to studies in other areas where deep snow conditions were considered important (Craighead and Craighead 1972, Lentfer et al. 1972, Vroom et al. 1980). Snow cover as insulation for the den chamber is likely more important in colder interior areas such as the Rocky Mountains

**Table 5. Snow characteristics and air temperatures (C) at selected brown bear den sites, north Admiralty Island, southeast Alaska, winter 1983.**

| Den no. | Date | Elevation (m) | Aspect | Snow depth (m) | Snow density | No. ice layers | Snow temp. (C) | Air temp. Jan–Apr | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Min. | Max. |
| 48 | 22 Apr | 366 | S | 0.4 | .45 | 1 | — | −7 | 9 |
| 95 | 23 Apr | 396 | W | 0.4 | .45 | 0 | — | −9 | 16 |
| 37 | 23 Apr | 479 | W | 1.4 | — | — | — | −10 | 8 |
| 56 | 19 Apr | 823 | W | 2.7 | .53 | 0 | 4 | −22 | 13 |
| 14 | 22 Apr | 854 | W | 1.4 | .38 | — | — | — | — |
| 59 | 22 Apr | 945 | S | 1.4 | — | 2 | 4 | −9 | 5 |
| 6 | 22 Apr | 1,128 | E | 1.5 | .31 | 1 | 4 | — | — |

than in southeast Alaska, where the maritime climate moderates winter temperatures.

### Effects of Resource Development and Disturbance

Craighead and Craighead (1972) suggested that grizzly bears seek isolated den sites far from developed areas and human activity. Our observations suggest this may also be the case for brown bears in southeast Alaska. Resource development and human activity can affect denning environment through disturbance and habitat loss.

Frequently, bears instrumented with motion sensor transmitters became active as we flew over their dens at an altitude of about 150 m. These flights were in small, fixed-wing aircraft, which are much quieter than helicopters. Thus, in an area that receives intensive aircraft traffic, especially helicopter traffic, bears could be negatively affected by disturbance.

The Noranda Mining Company has a major development at Greens Creek in the middle of the Admiralty study area. The project is inactive during midwinter, but helicopter traffic occurs during fall and spring when bears are in dens or entering or emerging from dens.

To assess the effect of helicopter traffic on denning, we selected 6 female bears that had denned within 4 km of the mine site in upper Greens Creek. Because of their proximity to the development area, we assumed these bears were most influenced by mine site activities, including intensive helicopter traffic. The mean distance these bears denned from the mine sites the 1st year of observation was 3.4 km. They denned significantly farther from the mine site the next year ($\bar{x}$ = 11.7 km, $P < 0.05$).

We further assessed this relationship by comparing the mean distance among subsequent years' den sites for the 6 radio-collared females mentioned previously with that of 11 radio-collared females that denned outside the area of mine influence. The mean distance among den sites in subsequent years was significantly greater ($P < 0.05$) for the 6 bears that initially denned closest to the mine (10.4 km) than for the 11 bears outside the mine's influence (1.9 km). None of the radio- collared males denned near the mine site or within the Greens Creek drainage.

These findings suggest that intensive development, including aircraft traffic, may reduce an area's suitability as brown bear denning habitat. Reynolds et al. (1976) described 5 cases of den site abandonment after bears were tracked to dens with a helicopter shortly after den construction. Reynolds et al. (in press) found increased heart rate and movements of instrumented grizzly bears in dens in northern Alaska in response to disturbances related to seismic surveys. During that study, aircraft overflights shortly before den emergence also disturbed denned bears.

Three types of development, hydroelectric, mining, and logging, have the potential to reduce denning habitat in southeast Alaska. Mining and hydroelectric development are relatively site-specific and will probably not be widespread in the near future. Site-specific impacts of hydroelectric development on brown bears are being assessed elsewhere in Alaska (Smith and Van Daele 1984, Miller 1985). Industrial-scale logging, however is a major industry in southeast Alaska and, with passage of the Alaska National Interest Lands Conservation Act in 1980, 450 million board feet or approximately 7,000 ha of old-growth forest are scheduled for harvest annually on the Tongass National Forest.

## MANAGEMENT IMPLICATIONS

Since 1933, the known sport harvest of brown bears on Admiralty, Baranof, and Chichagof islands has averaged 55 bears annually (Alaska Dep. Fish and Game harvest records, Johnson 1980). Seventy percent of the harvest, of which males comprise 70%, occurs in the spring (Johnson 1980).

During spring, hunting has generally been most productive beginning about 20 May, whereas the 1st 2 weeks of September have been the most productive period of the fall season. Since 1967, skull size and age of bears has remained constant, suggesting that an annual harvest rate of about 60 bears has had little impact of the overall population. This harvest level was incorporated into a brown bear management plant for Admiralty, Baranof, and Chichagof islands in 1981.

In 1975 and 1976 and again in 1984, the harvest increased to over 100 bears. To prevent the high harvest that occurred during the mid-1970s, the season was altered to eliminate the most productive hunting periods in late spring and early fall. These restrictions successfully reduced the harvest and remain in effect today; however, the early spring of 1984 still resulted in a higher harvest than desired.

Denning chronology of brown bears in southeast Alaska varies annually and among sex and reproductive classes. The spring bear harvest may vary substantially among years in relation to the amount of spring snowpack, which influences the timing of emergence from dens. Following a late spring with higher than average snowpack above 400 m, fewer bears, particularly females, are likely to be harvested.

The data obtained from this study offer managers additional flexibility for maintaining harvest levels within prescribed limits. Based on a knowledge of spring snow depth at or above 400 m, managers could adjust spring bear seasons corresponding to a predictable pattern of den emergence. The season could be extended if snow depths were above average and reduced if snow depths were below average.

Brown bears generally den at high elevations and on steep slopes. In southeast Alaska, where high mountains are common, brown bears prefer den sites in subalpine and alpine/rock habitat above 600 m elevation on rugged slopes greater than 25°. In these sites, natural rock caves, if available, are preferred for denning. In more forested and less mountainous areas, preferred den sites are mid-volume, old-growth forest habitat above 300 m elevation on slopes greater than 20°. In these areas, large diameter (>75 cm dbh) Sitka spruce trees and large snags with heart rot are preferred for denning.

Under natural conditions, availability of denning habitat does not appear to be a limiting factor for brown bear populations in southeast Alaska. Mining and logging are the 2 major land use activities in southeast Alaska today. Although mining is relatively localized, industrial scale forestry affects thousands of hectares annually in southeast Alaska and, in some areas, has the potential to reduce suitable denning habitat for brown bears. To minimize loss of denning habitat as a consequence of logging, we recommend avoiding logging on mid-volume, hemlock-spruce stands on slopes greater than 20° at elevations above 300 m in or adjacent to areas of brown bear concentrations.

Brown bears and grizzly bears prefer remote denning areas isolated from human activity and development (Craighead and Craighead 1972). Human activity near den sites, including noise from machinery, blasting, or aircraft (particularly helicopters), appear to disturb denning bears and may force some to avoid the area for future denning. Where development or major activity is unavoidable in denning areas, use of heavy machinery, blasting, and aircraft traffic should be minimized during the denning period, particularly during den entry (Oct through mid-Nov) and den emergence (Apr–May). Helicopter traffic, in particular should be routed away from denning areas during periods of den entry and emergence.

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