THE INFLUENCE OF SALMON AVAILABILITY ON MOVEMENTS AND RANGE OF BROWN BEARS ON SOUTHWEST KODIAK ISLAND

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Abstract: Brown bear (*Ursus arctos middendorffi*) movements and seasonal range were examined in relation to the temporal and spatial distribution of salmon (*Oncorhynchus* spp.) on southwest Kodiak Island, Alaska, from 1983 to 1987. Salmon were available to bears from late June to mid-December and were utilized by all sex and age classes. From 50-89% of adult females fished at ≥2 separate areas of salmon abundance each year. Mean composite summer range of females tracked 2-5 yrs (108 km^2) was much greater than either spring (13 km^2) or fall (26 km^2) range. Annual summer range of 8 females tracked 4 consecutive years averaged 40 km^2; a smaller mean area of primary use (12 km^2) reflected a pattern of movement between areas of concentrated food. Females did not restrict their movement patterns in years they were accompanied by new (<1 yr) cubs. Males fished for salmon at the same sites used by females but traveled between those areas more often than females. Annual variation in movement patterns was due apparently to behavioral differences among individual bears as well as yearly fluctuations in berry production, salmon availability, and unknown factors. Important bear feeding areas in this region can be conserved by monitoring salmon escapements together with associated bear use, and by restricting human access at particular sites.

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Pacific salmon are an important component of brown bear habitat (Kistchinski 1972, Berns et al. 1980, Schoen et al. 1986, Hamilton and Bunnell 1987) as well as a valuable commercial and recreational resource. Shared use of the salmon resource and cohabitation of anadromous stream habitat by humans and bears present management problems such as depletion of fish stocks (Shuman 1950, Clark 1959, Gard 1971), safety to people (Meehan and Thilenius 1983, Miller and Chihuly 1986), and adverse impacts on bears from human disturbance (Archibald et al. 1987, Warner 1987).

Brown bears on Kodiak Island occur at high densities (Troyer and Hensel 1964, Barnes et al. 1988) and are highly sought after by trophy hunters. Increasing numbers of people visit the island to photograph or simply observe the animals. A major objective of the Kodiak National Wildlife Refuge, which encompasses most of the southern two-thirds of Kodiak Island, is to maintain high quality brown bear habitat for the enjoyment of both consumptive and non-consumptive users (U.S. Fish and Wildlife Service 1987:179). Identifying important bear habitat and the factors that influence use of that habitat is a key management strategy. In this paper, I examine brown bear movements and seasonal use in relation to the temporal and spatial distribution of spawning salmon. This work is part of a larger investigation of habitat use and census methodology.

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STUDY AREA

Kodiak Island is located in the Gulf of Alaska at 56-58° North latitude and 152-155° West longitude. The study area encompassed about 2,700 km^2 on southwest Kodiak Island (Fig. 1). The region has a cool, maritime climate characterized by cloudy days, summertime fog, and frequent wind. Summer temperatures usually range from 13 to 18 C and winter temperatures below -6 C are uncommon. Annual precipitation averages about 150 cm.

The western portion of the study area has wide, flat valleys, rolling foothills, and few ridges above 600 m. Topography becomes progressively more rugged in eastern parts of this area; steep valley walls are common and

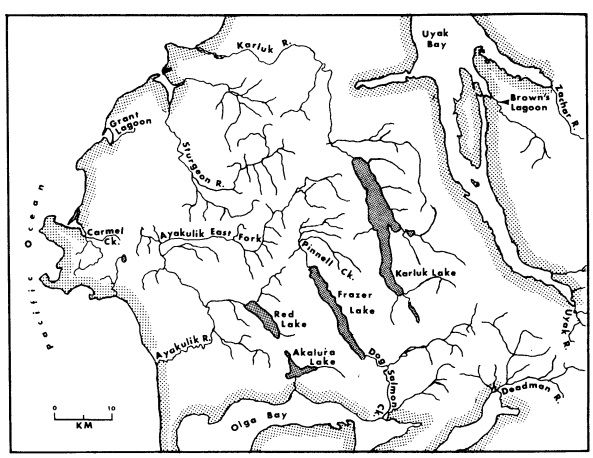

Fig. 1. Features of the study area in southwest Kodiak Island, Alaska.

numerous peaks extend above 900 m. Poorly drained lowlands are vegetated by a mosaic of willow (*Salix* spp.) and herbaceous cover, while well-drained sites are commonly dominated by hummocks covered with heath (*Ericaceae*) and bluejoint grass (*Calamagrostis canadensis*). Mid-slope habitat consists of dense to scattered alder (*Alnus crispa*) patches interspersed with red elderberry (*Sambucus racemosa*); representative vegetation in openings includes bluejoint grass, sedge (*Carex* spp.), ferns (*Polypodiaceae*), fireweed (*Epilobium angustifolium*), cow parsnip (*Heracleum lanatum*), and salmonberry (*Rubus spectabilis*). Alpine habitat consists of low-growing willow, heath, herbaceous meadows, bare soil, and rock.

Six species of Pacific salmon spawn in the study area (Table 1). The Karluk and Ayakulik River drainages are the 2 largest watersheds on Kodiak Island and each supports significant runs of sockeye (*O. nerka*), chinook (*O. tshawytscha*), pink (*O. gorbuscha*), and coho (*O. kisutch*) salmon as well as steelhead trout (*O. mykiss*). Other major drainages (Table 1) support 2-4 important salmon runs and numerous little streams have small runs, usually of pink, chum (*O. keta*) or coho salmon. Except for sockeye in the Frazer Lake system, all of the salmon and steelhead runs are natural populations. A fish pass built in 1962 on Dog Salmon Creek allows an artificially established run of sockeye to migrate into Frazer Lake.

METHODS

Brown bears were captured by darting from helicopters during mid-May to late July from 1983 to 1987. All adults (≥5 yr) and selected subadults (<5 yr) were fitted with radio-collars; adult females were recaptured and fitted with new radio-collars at 2-3 year intervals. Capture effort was directed exclusively at adult females during 1983-1985, but included some adult males and subadults for population studies (Barnes et al. 1988) in 1986 and 1987. Bears were radio-tracked from fixed-wing aircraft at 7-10 day intervals from March through November and at roughly 2-3 week intervals during the remainder of the year. Bears were occasionally relocated ≥1 time per week during capture operations or while surveying bear concentrations during summer. Habitat type, elevation, activity, associated bears, and relative food availability were recorded at the time each bear was relocated. Locations were plotted on 1:63,360 scale U.S. Geological Survey topographic maps. These points were subsequently digitized for computer analysis with the map overlay and statistical system (MOSS) developed by the U.S. Department of the Interior.

Supplemental information on bear concentrations, bear activity, and salmon availability were recorded while conducting aerial stream surveys of bears and from camps established on ridges overlooking streams utilized by bears.

Table 1. Spawning escapements and seasonal availability of salmon species utilized by brown bear on southwest Kodiak Island, Alaska, 1983-1987.

	Average escapement (thousands), 1983-1987[a]					Seasonal availability[b]		
	Sockeye	Chinook	Chum	Pink	Coho	Spring	Summer	Fall
Karluk Lake System	701.2	7.4	<0.5	489.0	31.6			
River						—	SO,CI,PI	SO,CO
Lake						SO	SO	SO,CO
Ayakulik River	245.7	10.4	<0.5	243.9	17.6			
Main						—	SO,CI,PI,CO	CO
East Fork						—	SO,CI	CO
Red Lake						SO	SO	SO,CO
Frazer Lake System	182.4	<0.5	15.0	95.6	4.1			
Dog Salmon Ck.						SO	SO,CU,PI	
Pinnell Ck.							SO	
Sturgeon River	—	—	52.3	8.8	3.0	CU	CU	CO
Uyak River	—	—	12.9	116.2	Unk.	—	CU,PI	
Deadman River	—	—	17.7	113.6	Unk.	—	CU,PI	

[a] Weir and aerial survey data (Alaska Dep. Fish and Game and Kodiak Natl. Wildl. Refuge files).

[b] Species: SO = sockeye, CI = chinook, CU = chum, PI = pink, CO = coho; Season: Spring = late June, Summer = July - Sept., Fall = Oct. - Nov.

The extent that bears traveled in response to salmon availability was evaluated by recording the number of times they visited different fishing areas. These areas were subjectively chosen to represent exploitation of salmon in different drainages or feeding on a single species in distinct portions of the same watershed. In the Ayakulik River drainage, for example, bears feeding on chinook salmon in the river segment below the Red Lake subdrainage were classed separately from bears feeding on the same species in the Ayakulik East Fork. Similarly, for bears feeding on sockeye, the Red Lake system and the Ayakulik East Fork were considered 2 different fishing areas. However, a bear feeding on different salmon species at the same location, regardless of time, was considered to have visited only 1 fishing area. If bears were not fishing along or in a stream, they were not recorded as utilizing salmon unless spawning salmon and evidence of feeding on salmon (trails, beds, salmon carcasses) were apparent in the drainage where the bear was located.

I used program HOME RANGE (Samuel et al. 1985) to estimate seasonal ranges and areas of primary utilization. The 95% minimum convex polygon was used to estimate total range exclusive of outlier locations and the 95% harmonic mean contour was used to estimate the area most heavily utilized by bears. Because the 95% harmonic mean contour often excluded travel corridors, especially for wide-ranging animals, it generally enclosed an area smaller than the 95% convex polygon. For seasonal ranges, I defined spring, summer and fall as May-June, July-September, and October-November, respectively. Movements in April and December were omitted from analysis because substantial numbers of bear were denned in those months (Van Daele et al. 1990). For comparisons with other studies, I also determined home ranges using 100% minimum convex polygons.

The Kruskal-Wallis test of significance was used for comparisons of range size among seasons, years, and females of different maternal status. The Chi-squared statistic was used to analyze frequency distributions.

RESULTS

Seventy-one bears were radio-collared from 1983 to 1987, including 57 adult females, 7 adult males and 7 subadults. With the exception of 1 male captured at Karluk Lake, all the animals were initially caught west of the Karluk Lake and River watershed and north of Olga Bay (Fig. 1). Most (51%) captures were made in Sturgeon and Ayakulik East Fork River drainages, followed by the Pinnell Creek (18%), Red Lake (13%) and Dog Salmon Creek (8%) watersheds. Thirty-three adult females were tracked ≥2 consecutive years and 6 adult males were tracked for 1 to 2 years; the following results are based primarily on data associated with 2,529 relocations of these animals.

Patterns of Salmon Use

Bears fed on salmon at various sites in the study area from late June to mid-December. They began feeding on chum salmon in Sturgeon River, and on sockeye salmon in Dog Salmon Creek and Karluk and Red Lake drainages, from late June to early July (Fig. 1, Table 1). During July and August, bears fed extensively on chinook, sockeye, chum or pink salmon at numerous locations. From middle or late August to mid-September, bears used streams less and spent increasing time foraging for elderberries and salmonberries (Clark 1957, Berns et al. 1980). This pattern varied annually relative to berry production, but bears continued to feed on salmon to some degree regardless of berry abundance. Each year from late August to middle or late September, bears also congregated along streams at the head of Uyak Bay to feed on chum and pink salmon. In late August and early September of 1986, an unusual number (9) of radio-collared bears traveled to the lower Ayakulik River or to distant small streams (Carmel Creek, Grants Lagoon) to feed on chinook or pink salmon.

Heavy use of sockeye salmon continued through September in the Karluk and Red Lake basins as bears gradually shifted emphasis from fish spawning in tributary streams to those spawning along lake shores. Bears consistently fed on beach-spawning sockeye salmon through October in both areas; use declined in early November at Red Lake but some animals continued to feed along Karluk Lake shores until mid-December. Utilization of coho salmon began in September, peaked in October, and declined during November. Two adult males and 2 adult females continued to feed on coho salmon in tributaries of the Karluk River into December.

Migrating or spawning steelhead trout appeared to be only incidental prey of brown bears. Substantial movement of steelhead into the Karluk and Ayakulik Rivers did not occur until late September or early November (Chatto 1987) and at that time coho salmon were more widely distributed and abundant. Bear predation on spawning steelhead was noted as early as mid-May in the Upper East Fork of the Ayakulik River, but most spawning took place in larger riffle areas downstream where steelhead could better evade bears.

All radio-collared bears (including 6 subadults) monitored at least 1 summer season utilized salmon. Inter-

drainage movement of radio-collared bears was common as they responded to changes in salmon abundance or distribution. As the chum salmon run declined in Sturgeon River, bears usually traveled to Red Lake, Karluk Lake, or Pinnell Creek to feed on sockeye salmon. Often these animals returned to the Sturgeon River drainage to feed on berries, fish for coho salmon, and begin winter denning. Bears that fed on the early sockeye run in Dog Salmon Creek either remained there to fish for chum salmon, traveled to the Red or Karluk Lake area to exploit sockeye salmon, or moved to the Deadman River to feed on chum and pink salmon. Interchange between Karluk Lake and Pinnell Creek, and between Pinnell Creek and Red Lake, was frequently observed. Long distance movements to and from areas east of Karluk Lake were recorded for 2 females and 1 male.

Data were inadequate for most bears to determine movement patterns during periods <1 week. However, some insight was obtained from a female radio-collared in 1987 that yielded locations at 1- to 3-day intervals via satellite (Fancy et al. 1988). She and her 2, 2-year-old cubs utilized a small area along Sturgeon River the last half of July, remained along a tributary of Red Lake the first 8 to 10 days of August, moved to the lower Ayakulik River from 10-26 August and returned to the Sturgeon River by 29 August. She was observed fishing for chum, sockeye, and chinook salmon at the Sturgeon River, Red Lake, and Ayakulik River sites, respectively. Neither satellite nor conventional aircraft tracking indicated she moved back and forth between those areas during that period.

The mean number of different fishing areas individual females visited each year ranged from 1.6 (1983, 1987) to 2.6 (1986) and averaged 2.1 (Table 2). These figures provide a conservative measure of movement because some bears fished in the same area at 2 separate times interrupted by an excursion to fish at a distant site. Bears also moved to and from drainages where salmon runs were occurring simultaneously; the interval between most radio-tracking flights (≥1 week) probably allowed some movement to go undetected.

Table 2. Annual variation in number of salmon fishing areas used by radio-collared adult brown bears, southwest Kodiak Island, Alaska.

No. areas visited	Females					Males	
	1983	1984	1985	1986	1987	1986	1987
1	7	6	4	3	9	—	—
2	5	15	16	8	9	—	—
3	2	4	6	13	1	—	3
4	—	—	1	4	—	2	—
5	—	—	—	—	—	1	1

Causes of annual variability in the frequency that females used 1, 2, or ≥3 fishing areas were not clear ($X^2 = 30.8, P < 0.05$). A relatively sparse elderberry crop in 1986 may have contributed to high interchange among fishing areas that year. However, differences in behavior of individual animals as well as subtle fluctuations in abundance of salmon or other foods may also have influenced bear movements in 1986 and other years. Overall 73% of the radio-collared females annually used ≥2 fishing areas.

Limited data on adult males (Table 2) suggest they traveled more extensively during summer than did adult females. All 6 males fished ≥3 areas each year; the mean number of areas visited in 1986 and 1987, respectively, were 4.3 and 3.5 for a combined average of 3.9.

Some fishing areas consistently attracted high numbers of marked and unmarked bears (Table 3). The Red Lake system was visited by an average of 43% of the females and all males under study each year. Twenty-seven (69%) of 39 adult bears fished in Red Lake and/or its tributaries at least once during the study. One 6.5 km stream received particularly heavy use; peak counts of aerial surveys of the stream averaged 38 bears from 1984 to 1987. Observers at ridge-top camps identified a minimum of 86 and 49 individual bears (including young) using the stream during 4-day periods in early August of 1986 and 1987, respectively.

The upper stretches of Sturgeon River also sustained heavy and consistent use by bear; 23-41% of the radio-collared females fished in the river each year (Table 3). Fifteen (45%) of 33 females and 3 of 6 males fished the Sturgeon River at least once during the study. Peak aerial counts of this stream averaged 43 bears during 1984-87.

Movements and Seasonal Range

Movements of most (85%) adult females tracked ≥2 years were confined to a core area that was bounded by the Karluk River and Dog Salmon Creek drainages on the east, Olga Bay on the south, and the Pacific Coast on the west (Fig. 1); all of them denned within that area. Mean annual range (95% minimum convex) of these 29 females was 52 km^2 and only 1 had a mean annual range >80 km^2. A contrasting pattern of movement was evident for 4 other females that denned east or southeast of this core area. In 14 of 16 bear-years they were tracked, these 4 animals fished at 1 or more sites in the core area and then traveled east to areas in which they eventually denned. Three of them also fed on salmon in the drainages where they denned. The 4th female may have fed on coho

Table 3. Annual use of fishing areas by adult radio-collared brown bears, southwest Kodiak Island, Alaska.

Fishing area	Females					Males	
	1983 (n = 14)	1984 (n = 25)	1985 (n = 27)	1986 (n = 28)	1987 (n = 19)	1986 (n = 3)	1987 (n = 4)
Red Lake System[a]	3	5	14	18	8	3	4
Sturgeon River	3	9	8	12	6	1	2
Pinnell Creek	4	5	7	8	3	3	1
Karluk Lake System[b]	4	7	8	6	1	1	1
East Fork Ayakulik River	3	7	6	7	3	1	3
Deadman/Uyak Rivers, Combined	2	4	3	4	4	—	—
Karluk River	—	3	3	4	1	2	2
Dog Salmon Creek	2	4	4	2	2	—	—
Other Areas Combined	2	5	5	13	2	2	1

[a] Red Lake system includes the lake, 2 tributaries into the lake, and 1 outlet tributary.
[b] Karluk Lake system includes Karluk, Thumb, and O'Malley Lakes and tributaries flowing into these lakes.

salmon near her Zachar River denning area, but she typically fished in Sturgeon River in early summer and then ranged in the Karluk Lake basin into November. Mean annual ranges of these 4 females ranged from 100-461 km^2 and averaged 211 km^2.

Although annual ranges (95% minimum convex) of adult males ($\bar{x}$ = 185 km^2, SE = 42, n = 6) exceeded that of adult females ($\bar{x}$ = 71 km^2, SE = 20, n = 33), only 1 male traveled outside the core area. In September 1986, that animal traveled from the Red Lake area to Brown's Lagoon (24.5 km), where a congregation of bears was feeding on chum salmon, and then returned to the Sturgeon River drainage in early October.

Interdrainage movement by bears during summer was predominantly associated with foraging on salmon and it contributed to relatively large ranges during that season (Table 4, Fig. 2). Because number of non-den locations of bears was often limited in spring and/or fall of some years, seasonal ranges were compared by pooling data for individual bears by season over all years they were tracked. This approach resulted in composite seasonal ranges that were larger than annual seasonal ranges, but should not bias the relative difference in movement patterns between seasons. Mean composite summer range of females, as well as mean area of primary use during summer, was at least 3 times larger (H = 44.5 and H = 37.1, respectively, $P < 0.05$) than either spring or fall range (Table 4). Most females emerged from dens during late April to early May (Van Daele et al. 1990) and tended to remain in the same drainage of the den sites for at least 2-3 weeks. From mid-May through June they spent most of their time in mid-slope habitat feeding on emergent vegetation (Clark 1957, Smith and Van Daele 1988). Except for animals that denned in the headwaters of Uyak, Deadman, and Zachar Rivers, substantial movement between drainages to feed on salmon did not begin until late July or early August. By late September or early October, most females had returned to those locales in which they would eventually den. Exceptions were females that remained at Karluk Lake in October and November to feed on sockeye salmon.

Data on adult males suggest they also traveled over wider ranges in summer than in other seasons (Table 4). Composite summer ranges of males and females were comparable, but males had a larger mean area of primary use. This may reflect a tendency of males to travel extensively throughout their range whereas females were inclined to remain in particular drainages for longer periods of time.

Among females (n = 33), annual summer ranges and areas of primary use during summer averaged 34 km^2 (SE = 6) and 12 km^2 (SE = 4), respectively. For the 2 years adult males (n = 6) were monitored, mean areas of annual summer range and primary use were 85 km^2 (SE = 45) and 21 km^2 (SE = 6), respectively. The disparity in size of mean annual ranges and primary use areas during summer appeared to reflect a pattern of movement between areas of concentrated food supply.

Mean annual summer range of females varied among years (H = 21.4, $P < 0.05$), ranging from 15 km^2 in 1983

Table 4. Mean seasonal ranges (95% minimum convex) and areas of primary use (95% harmonic mean) of adult female and male brown bears on southwest Kodiak Island, 1983-1987.

	Seasonal range (km²)						Primary use (km²)					
	Spring		Summer		Fall		Spring		Summer		Fall	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Females (n = 33)	13	2	108	22	26	10	14	2	63	8	23	3
Males (n = 3)	27	21	103	60	—		30	27	99	76	—	

to 61 km² in 1986. Because unequal sample sizes among years may have contributed to this variation, I compared the annual summer ranges of 8 females that were continuously tracked from 1984 through 1987 (Table 5). Although mean summer range was larger in 1986 than in other years, variation among years was not significant ($H = 2.1, P > 0.05$). This suggests variation among individual bears had a greater influence on size of summer ranges than annual fluctuations in food availability.

Restricted movements might be expected in years that females travel with new cubs (Pearson 1975, Miller 1987) and certainly they limit movement during the immediate post denning period (Smith and Van Daele 1988, Van Daele et al. 1990). However, in this study 2 females made their longest excursions when traveling with new cubs. In 1 case a female with 1 cub moved 21 km outside her normal summer range to feed on pink salmon and then returned within 3 weeks. In September, another female, also with 1 cub, traveled 27 km outside her normal range for an undetermined reason. Three other females with unusually large annual ranges ($\bar{x}$ = 246 km²) traveled long distances between spring and summer range, as well as during the summer period; minimum straightline distances they traveled with new cub litters were 23, 31, and 46 km.

Maternal status apparently had little effect on summer movements or range of females. To examine the effect of litters on size of summer range, I compared ranges of 17 females with data in each of 3 maternal categories. Mean summer ranges for females without cubs ($\bar{x}$ = 26 km², SE = 7, n = 25), with new cubs ($\bar{x}$ = 36 km², SE = 11, n = 19) and with older (≥1 yr) cubs ($\bar{x}$ = 38 km², SE = 8, n = 30) were similar ($H = 1.2, P > 0.05$), as were areas of primary use ($\bar{x}$ = 11-12 km², SE = 2, $H = 0.1, P > 0.05$).

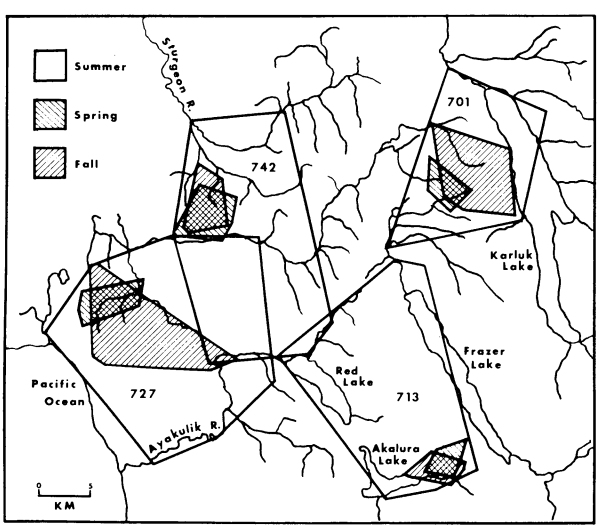

Fig. 2. Composite seasonal ranges (95% minimum convex polygons) of 4 adult females radio-tracked 4 to 5 consecutive years during 1983-1987, southwest Kodiak Island, Alaska.

DISCUSSION

Several studies have documented habitat use and movement patterns of coastal brown bears (Berns et al. 1980, Glenn and Miller 1980, Schoen et al. 1986, Hamilton and Bunnell 1987, Smith and Van Daele 1988 and others); collectively they revealed how utilization of salmon varied between bear populations. Brown bears in British Columbia ranged widely in search of several berry species and then restricted movements while feeding on salmon (Hamilton and Bunnell 1987). On the Alaska Peninsula (Glenn and Miller 1980), bears moved proportionately greater distances in spring than in summer and fall. Bears traveled to the coastal plain in spring to feed on marine mammal carcasses and ungulate prey; movements were relatively small in summer when bears were concentrated along salmon streams. Schoen et al. (1986) discovered that a portion of the Admiralty Island population did not feed on salmon in coastal streams but instead foraged in interior alpine and subalpine habitats. On Admiralty Island, females that fed on salmon usually remained on individual streams and consequently had a

Table 5. Annual summer ranges (95% minimum convex) and areas of primary use during summer (95% harmonic mean) for 8 adult females tracked 4 entire years, 1984-1987, on southwest Kodiak Island, Alaska.

	Summer range (km²)		Primary use (km²)	
	$\bar{x}$	SE	$\bar{x}$	SE
1984	37	19	12	2
1985	38	11	16	4
1986	52	22	14	4
1987	34	23	9	2

small average home range (19 km²); males frequently moved between several streams and had a larger mean home range (115 km²).

Brown bears on southwest Kodiak Island traveled more extensively in summer than in spring and fall, and their summer movements were directed primarily toward concentrations of salmon available at various sites and/or separate time periods. Compared to the study areas referred to above, southwest Kodiak apparently offered a more diverse salmon resource in terms of distribution, abundance, and species diversity. Conversely, other resources such as alpine forage (Atwell et al. 1980, Smith and Van Daele 1988), berries, and ungulate prey were less diverse on southwest Kodiak. The salmon-oriented movement patterns observed in this study, however, do not diminish the importance of other forage. Vegetative items are an essential component of the bear diet in the study area (Clark 1957).

Movement and habitat use patterns evaluated concurrently in this study and in the Terror Lake region of northern Kodiak Island (Smith and Van Daele 1988) revealed contrasting forage strategies for 2 essentially contiguous areas. Although bears in the Terror Lake area were attracted to salmon during summer, phenology of various vegetative communities was most predictive of movement patterns. Emerging herbaceous species were important spring foods in both areas. During July and early August, though, bears typically grazed on alpine vegetation in the Terror Lake area while bears in southwest Kodiak were congregating along salmon streams. Alpine habitat comparable to that found near Terror Lake is uncommon in southwest Kodiak and salmon do not become abundant in the Terror Lake area until August. Salmon abundance declined after mid-September in the Terror Lake area and bears spent increasing time in mid-slope habitats feeding on berries. A less pronounced shift to mid-slope habitat was evident in southwest Kodiak and salmon continued to hold or attract bears to lowland areas into late fall (Berns et al. 1980, this study).

Brown bears in both the Terror Lake and southwest Kodiak study areas have adapted foraging patterns that allow them to exploit available resources successfully. Variation in the type, abundance, and distribution of foods resulted in dissimilar movement patterns and seasonal distributions in the respective areas. Use of vegetative communities in the Terror Lake area often involved movement along an elevational gradient with little travel between drainages. Additionally, movement between streams to feed on salmon occurred less frequently and over a shorter time span than in southwest Kodiak (Smith and Van Daele 1988). As a result, annual ranges (100% minimum convex) of adult females ($\bar{x}$ = 28 km²) and males ($\bar{x}$ = 133 km²) in the Terror Lake study (Smith and Van Daele 1990) were much smaller than comparable ranges on southwest Kodiak (female $\bar{x}$ = 92 km²; male $\bar{x}$ = 219 km²). However, the 2 areas supported comparable densities (1 independent bear/4.5 km², Terror Lake vs. 4.7 km², southwest Kodiak; Barnes et al. 1988). Thus, variation in size of annual ranges between the areas probably reflected differences in availability and exploitation of habitat resources rather than overall habitat quality.

It is unclear why home ranges reported by Berns et al. (1980) for the Karluk Lake drainage (female $\bar{x}$ = 11-14 km², male $\bar{x}$ = 24 km²) were less than those recorded in this study. Because most data in the earlier study were collected during the fall season, it is possible that some movement to and from Karluk Lake was not detected. Also, some bears may range entirely within the Karluk Lake drainage because the area provides an unusual diversity of forage, cover and denning habitat (Berns et al. 1980).

Females in southwest Kodiak usually occupied annual ranges <80 km²; during summer they tended to congregate in areas where salmon were abundant. For several animals, consecutive locations in particular stream drainages indicated limited movement while they were fishing that stream. Although some females were observed to move back and forth between distant fishing sites in periods of <10 days, the data suggest this pattern was less common.

Maternal status apparently did not affect general movement patterns of females during summer; mean summer ranges were similar during years they were alone, with new cubs, and with 1- or 2-year-old cubs. Five of 17 females had largest summer ranges when they were accompanied by new cubs. However, females with new cubs probably altered diel movements or selected specific fishing sites to avoid interactions with other bears (Stonorov and Stokes 1972, Mattson et al. 1987).

When observed for extended periods from ground camps, they tended to separate themselves from other bears and fish at times when the fewest bears were along streams or shores.

Data on adult males revealed patterns somewhat similar to those of females but with more extensive travel. They fished at the same sites used by females and in the same time periods. They were often observed fishing or bedded within 30 m of other single bears or family groups. Mean annual summer range of adult males exceeded that of females; the data indicated that males traveled between streams more frequently and were less inclined to remain along particular streams for extended periods.

Four adult females ranged over unusually wide areas and generally followed a pattern described by Berns and Hensel (1972) as use of separate activity areas. Female No. 722, for example, denned in the same rock cavity above Uyak River for 5 consecutive years; in late June or early July of each year, regardless of maternal status, she traveled to Dog Salmon Creek and/or Karluk Lake to feed on sockeye salmon and then in mid- to late August returned to the Uyak River to feed on pink and chum salmon. Similar although less consistent movement patterns were followed by 2 animals that denned in the Deadman River drainage and 1 that denned in the Zachar River watershed; each of these animals traveled to the core study area during summer and fished for salmon at various sites. Because chum, pink, and coho salmon, as well as alpine forage, were readily available in the Uyak, Deadman, and Zachar drainages, movement of bears from those drainages into the core study area apparently was not motivated by food availability. It is more likely the animals were following traditional movement patterns established by several generations of maternal females.

Consistent year-to-year use of specific fishing sites by individual bears, regardless of annual range size, implied that learned behavior played an important role in locating salmon. However, deviation from what appeared to be established patterns occurred often enough to suggest that bears may also explore their ranges in search of salmon or other foods. Such activity would provide animals an opportunity to exploit seasonal or annual fluctuations in food abundance. Regardless of what clues bears used to locate salmon and other foods, behavior of individual animals was an obvious influence on movement and range; differences among individuals using the same habitats appeared to mask the effects of annual variation in food abundance and distribution on bear movement.

MANAGEMENT IMPLICATIONS

The strong link between salmon and brown bears in southwest Kodiak Island deserves the attention of resource managers. Key elements that should be considered are salmon escapement into streams and protection of anadromous stream habitat from excessive human disturbance. Recently the Alaska Department of Fish and Game and the Kodiak National Wildlife Refuge cooperatively established an escapement level of sockeye salmon into the Frazer Lake system that incorporated a mortality estimate due to bear predation (T. Chatto, Kodiak National Wildlife Refuge, pers. commun.). This concept of allocating fish to brown bears should be extended to other salmon species and in other watersheds important to bears.

Improved data on timing and numbers of some anadromous fish runs would enhance the ability of managers to detect significant declines in salmon escapements before they cause important economic and biological impacts. For example, the increasing commercial fishery for coho salmon, if continued, could seriously reduce an important late season food supply for bears in many local areas. Unfortunately, escapement data for coho salmon are incomplete or absent for many streams.

Managers should also recognize that projects to introduce or increase the abundance of salmon can markedly affect bears. It is unknown whether or not establishment of a sockeye run in the Frazer Lake system increased bear density in that watershed, but it clearly influenced the seasonal distribution of bears. Feeding congregations of bears on lower Dog Salmon and Pinnell Creeks are a direct result of that salmon enhancement project. Future plans to establish or rehabilitate depleted salmon populations in brown bear habitat should recognize that bear movement patterns could be altered and new areas of concentration might develop. The extent that bears and bear/human interactions are affected will depend on specific characteristics of each project.

Reliable evaluation of bear habitat needs on Kodiak Island will require current information on bear utilization of salmon stream habitat. Thus, I recommend that aerial surveys of bear concentrations on selected streams be continued as a means of documenting trends in bear use, relating bear use to salmon escapement data, and detecting potential sources of disturbance to bears.

Protection of bear feeding sites on the Kodiak National Wildlife Refuge may require regulations to exclude or limit recreational use. The current trend of expanding human activity on Kodiak Island (Smith et al. 1989) can be expected to focus recreational use in areas such as Karluk Lake, Red Lake and the lower Ayakulik

River that offer good floatplane access. The stress of avoiding humans will probably have an adverse affect on some bears (Mattson et al. 1987). Alternatively, some animals can be expected to habituate to humans and reduce probability for their survival (Herrero 1985, Archibald et al. 1987). Restrictions on recreational use, if necessary, should be directed at specific tributaries or segments of shoreline, and limited to those time periods when bear densities are highest and most susceptible to disturbance.

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