A Conservation Assessment of the Kenai Peninsula Brown Bear

a publication of the

Interagency Brown Bear Study Team

(Alaska Department of Fish and Game, Region II; U.S. Fish and Wildlife Service, Kenai National Wildlife Refuge; National Park Service, Kenai Fjords National Park; USDA Forest Service, Kenai National Forest)

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Abbreviations and Acronyms

ADF&G	Alaska Department of Fish and Game
ANILCA	Alaska National Interest Lands Conservation Act
CIRI	Cook Inlet Region, Inc.
COY.	cub(s) of the year
GMU	game management unit
GPS	Global Positioning System
IBBST	Interagency Brown Bear Study Team
KCCP	*Kenai National Wildlife Refuge Comprehensive Conservation Plan and Wilderness Review*
KNWR	Kenai National Wildlife Refuge
MR	mark-recapture
MtDNA	mitochondrial DNA
NPS	National Park Service
USDA	U.S. Department of Agriculture
USFS	U.S. Department of Agriculture, Forest Service
USFWS	U.S. Fish and Wildlife Service

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A Conservation Assessment of the Kenai Peninsula Brown Bear

1. Introduction

Alaska brown bears (*Ursus arctos*) are large omnivores that commonly live in coastal areas and require unfettered access to productive salmon streams. These bears may live for more than 20 yr in the wild, but the stability of brown bear populations can be threatened by human-caused mortality and from fragmentation of habitat. The Kenai Peninsula has a population of brown bears that may be insular and highly vulnerable to human impacts; thus, the State of Alaska has formally declared the population to be one of special concern and one whose management needs close investigation. The Interagency Brown Bear Study Team (IBBST)—which comprises biologists and researchers from the Alaska Department of Fish and Game (ADF&G), the National Park Service (NPS), the U.S. Fish and Wildlife Service (USFWS), and the USDA Forest Service (USFS)—was asked to draft this assessment of the state of the team's knowledge of the biology of Kenai Peninsula brown bears. Information contained in this document is intended to provide scientific guidance for developing a conservation strategy for the Kenai Peninsula brown bears.

2. Brown Bear Ecology

2.1 General Review

2.1.1 Distribution and Status

The historic range of North American brown bears extended from the Mississippi River to the Pacific Ocean and from Mexico to the Arctic (Figure 1). During the past 200 years, brown bears have been extirpated from much of their range, and the current North American distribution includes small, geographically distinct regions in the contiguous 48 states, larger sections of western Canada, and most of Alaska (Figure 1). Human-related threats to the bear populations found within the contiguous 48 states has precipitated the identification of these bears as threatened under criteria established by the 1975 Endangered Species Act (Servheen 1989). Although larger, more robust populations of brown bears do exist in Canada's British Columbia, there are 10 subpopulations that have been listed as threatened and in need of recovery (Hamilton 2001). Within Alaska, brown bears occur in select regions of southeastern Alaska, on Kodiak Island, on the Kenai Peninsula, along the Alaska Peninsula, and in coastal regions generally. Bears that occur deeper in the interior of Alaska are considered to be grizzly bears. No Alaska brown bear population has been considered in need of recovery actions within the last 35 years.

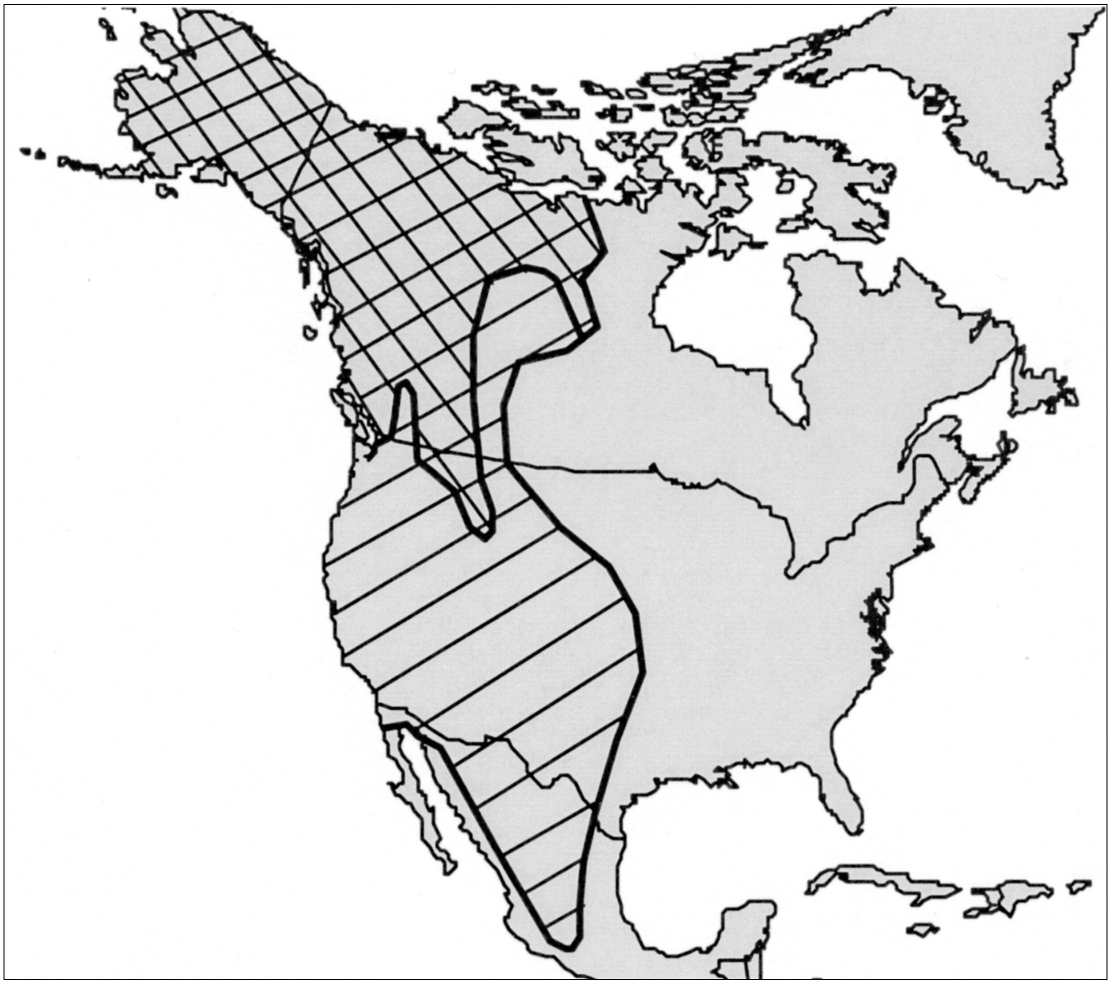

Figure 1. Current (cross-hatched lines) and historic (slashed lines) distribution of brown bears in North America (Servheen 1989)

2.1.2 Phylogeographic Conservation

Comparisons of mitochondrial DNA (mtDNA) from extant bear species indicate that the giant panda and the spectacled bear may be founding taxa and that today's bear species arose quickly during the early Pleistocene (Talbot and Shields 1996a). Further mtDNA work by Talbot and Shields (1996b) and Waits et al. (1997) identified differences in mtDNA sequences among some brown bear populations. Four genetically distinct groups, or clades, were identified by Talbot and Shields (1996b). These geographically disjunct populations may have evolved mtDNA differences if 1) populations of bears were separated during the Pleistocene, 2) multiple waves of brown bears migrated into North America from Asia, and 3) there exists a female-mediated effect on gene flow (maturing female brown bears tend to disperse shorter distances than do males).

Waits et al. (1998) proposed that population fragmentation during the Pleistocene and that limited female dispersal induced significant differences among mtDNA sequences of geographically distinct North American brown bear populations. These differences may be discrete enough for the bear populations identified by Waits et al. (1998) to be considered evolutionarily significant units, but

additional non-mtDNA work is required before this conclusion is accepted by biologists. Nevertheless, Waits et al. (1998) have concluded that three geographic locations (portions of southeastern Alaska, mainland Alaska-northern Canada, Kodiak Island, and sections of southern Canada and the western United States) could be considered as conservation refugia for North American brown bear populations.

2.1.3 Population Productivity

North American brown bear populations vary widely in life history traits and population productivity. There is no single physical characteristic that represents all populations. The diversity of values includes such measures as mean adult mass (expressed as two-fold variation across populations), litter size (ranging from 1.7 to 2.5 cubs), the age of first reproduction (from 4.4 to 8.1 yr), and the interval between litters (at 2.6–4.6 yr) (Blanchard 1987; Bunnell and Tait 1981; Hilderbrand et al. 1999c; McLellan 1994). Coastal regions can have bear population densities 100 times the size of those of interior populations (McLellan 1994; Miller et al. 1997). Researchers believe that a complex interplay among food resources, human impacts, and density-dependent population effects influence these variations.

2.1.4 Nutritional Constraints

Bears possess monogastric digestive tracts and do not have specialized physical attributes to enhance the digestion of vegetative food items. Other than metabolic adjustments present during hibernation (Barboza et al. 1997), bears do not display unique physiological traits enabling them to mobilize ingested food and metabolic stores any differently than do monogastric omnivores (Robbins 1993). Energetic and physical constraints act on bears to influence their dietary intake (Carbone et al. 1999; Rode et al. 2001; Welch et al. 1997); probably the most important physical effect is from animal body size. Digestive efficiency, handling time, and rate of food passage through a bear's gastrointestinal tract interact to determine the nutritive value to bears of particular food items, and larger bears are likely nutritionally constrained from utilizing foods that are low in energy or protein content (Figure 2). Thus, the biological value of specific habitats and food items to bears will vary with bear size and the total amount, distribution, and quality of available food items.

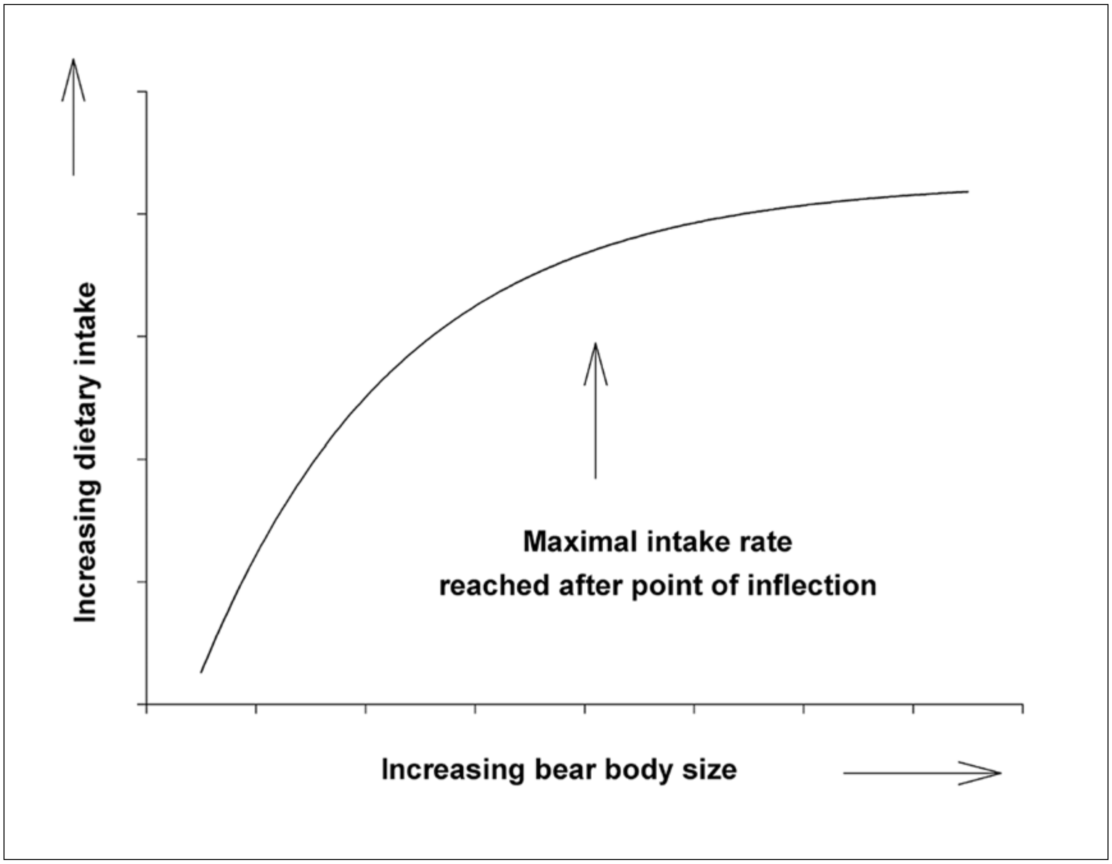

Figure 2. Theoretical limitation of dietary intake due to bear body size

Seasonally available meat is critical to maintaining population size when alternative food resources are predominately vegetation of low digestibility (Hilderbrand et al. 1999c; Jacoby et al. 1999). There is a strong, positive effect expressed on brown bear population productivity from abundant meat in the diet (e.g., salmon). Mean adult female body mass, mean litter size, and population density of North American brown bears all increase with increasing amount of meat in the diet (Figure 3; Hilderbrand et al. 1999c).

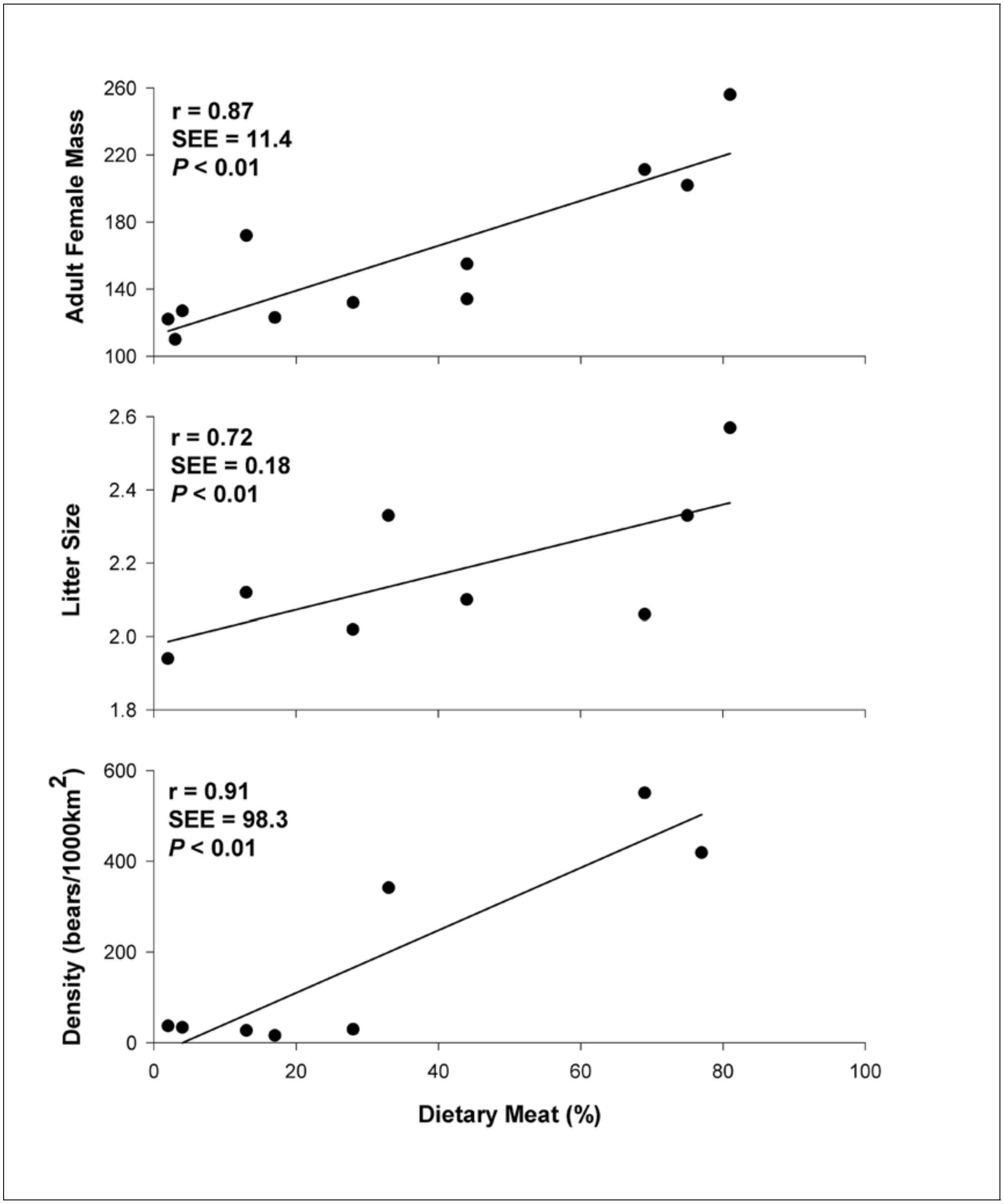

Figure 3. Relationship between dietary meat and population productivity in North American brown bear populations (Hilderbrand et al. 1999c)

2.1.5 Mortality and Population Regulation

The best understanding of bear population trends rests upon knowledge of age-specific mortality rates. Intraspecific killing of all ages and both sexes does occur, and it may be that cubs are most susceptible (Dean et al. 1986; Hessing and Aumiller 1994; Mattson et al. 1992b; Olson 1993). The causes of intraspecific killing and its effects on bear populations are not fully understood. Various fitness-enhancing hypotheses have been invoked to account for adult bears killing younger bears

(Bunnell and Tait 1981; Mattson and Reinhart 1995; Tait 1980; Wielgus and Bunnell 1994b); however, information collected on known instances of intraspecific killing in brown bears is largely anecdotal. Bunnell and Tait (1981) postulated that bear populations are regulated by density-dependent factors at high population densities, whereas McLellan (1994) proposed that brown bear populations are ultimately regulated by food. McLellan (1994) also noted, however, that proximate social interactions near clumped food resources can result in intraspecific killing. Wielgus and Bunnell (1995) postulated that hunting pressure would reduce the number of mature adult males in a given population and thereby make it more likely that immature males could successfully move into the population. According to Wielgus and Bunnell (1995), these new resident males would kill young bears, and thus adult females with cubs would tend to avoid areas frequented by males. If the females were forced into lower quality habitat, overall population productivity could be reduced. However the sample sizes used by Wielgus and Bunnell (1995) in their analysis were small, and their conclusions are open to conjecture.

The recruitment of sub-adult females into a population of reproductive females and the subsequent survival of those females are the most critical variables influencing population productivity (Knight and Eberhardt 1985). Unfortunately, capturing and radio-collaring juvenile brown bears and determining mortality rates is very difficult. Thus, the extent and importance of intraspecific killing on populations is not well understood, and hypotheses on intraspecific killing are difficult to test.

2.1.6 Ecological Role of Brown Bears

Brown bears shape their habitats in a variety of ways and may be regarded as a keystone species (Noss et al. 1996), but see Paine (1966). Brown bears can have a regulatory influence on ungulate prey populations (Adams et al. 1995; Boertje et al. 1988; Young and McCabe 1997) and can influence plant distribution and abundance by depositing seeds in feces across the landscape (Traveset and Willson 1997). Brown bears may also have a vital role increasing primary productivity near salmon streams by transporting nutrients such as nitrogen and phosphorus from the marine environment into the terrestrial community (Hilderbrand et al. 1999a; Willson et al. 1998). Brown bears, however, are not keystone predators, as defined by Paine (1966), on salmonid populations.

2.1.7 Impacts of Human Activities on Brown Bears: Hunting, Habituation, Resource Extraction

Humans have extirpated brown bears from most of the contiguous United States, leaving only a few remnant populations in the western part of the country. Legal harvest of brown bears (largely adult males) continues as a management tool and as a recreational activity in much of Alaska and Canada; it is unclear, however, if a harvest of adult males leads to increased or decreased population recruitment (Miller 1990; Wielgus and Bunnell 1995). Wildlife managers attempt to monitor harvest rates and to model population responses to set seasons and bag limits. It is difficult, however, to quantify illegal harvest and other sources of mortality; thus, population models based solely on harvest regimes, without benefit of concurrent radio-telemetry studies, may be flawed and likely overestimate population productivity.

Occasionally brown bears become habituated to people, generally when bears exploit a human-related resource (e.g., garbage at dumpsites, pet food and garbage at individual residences, livestock). Invariably, such bears become classified as "problem" bears and are often subject to expensive relocation efforts or termination. Mattson et al. (1992a) reported that brown bears in the Yellowstone ecosystem that were habituated to people were killed 3.1 times more often than were nonhabituated bears. Minimizing conflicts between bears and humans is a problem throughout the bear's range and is an active management topic. Many resource-extraction activities (e.g., timber harvest, mining, oil and gas exploration) require the construction of roads, which increase human access to formerly remote areas and thereby increase the potential for bear-human encounters. McLellan and Shackleton (McLellan and Shackleton 1988) found that many bears tended to avoid habitats within 100 m of roads regardless of traffic volume, which effectively limited the amount of habitat available to bears. Yearlings and adult females with cubs used areas near roads more than did bears without cubs, perhaps as a means to avoid aggressive adult males (McLellan and Shackleton 1988). McLellan (1989b) determined that eight out of nine deaths of radio-collared bears were human-caused and occurred during a period of intense resource extraction. Mace and Waller (1998) also found that bears tended to avoid areas with roads, although Mace et al. (1999) reasoned that avoidance was not solely the result of human disturbance. Some seasonally attractive habitats (i.e., salmon streams, berry patches) may be used by bears regardless of road density.

Schoen et al. (1994) reported that brown bear telemetry locations were further from salmon streams in watersheds with roads and clearcuts than in nonroaded and uncut areas. Nevertheless, these bears still visited salmon streams in logged and roaded areas, which resulted in more frequent human-bear encounters. Titus and Beier (1991) demonstrated strong positive correlation between cumulative miles of road and bear mortality. Clearly, roads and increased human access can be deadly to bears.

In some habitats, humans compete directly with brown bears for resources (e.g., salmon, berries). Olson (1997) reported that nonhabituated adult brown bears reduced their activity at the Brooks River (Katmai National Park, Alaska) because of an extended tourist-lodge season. Similarly, Braaten and Gilbert (1991) found that use of the Brooks River by adult female bears with offspring was negatively correlated with peak human visitor use. The exclusion of some bears, especially reproductive females, from nutritional resources can adversely affect bear populations if nutritional resources are limited. The effect of commercial fisheries on brown bears has not been quantified, although a bear population could be negatively affected if commercial salmon harvests significantly reduce the amount of fish available to brown bears. However, the extent to which fish availability would need to be reduced to observe an effect on a bear population has not been quantitatively determined. The Rivers inlet–Owikeno Lake region of British Columbia, Canada, has recently (2000) experienced catastrophic decline in the sockeye salmon population. Early monitoring by biologists has documented the presence of starving adult females brown bears in early fall (Hamilton 2001).

3. Brown Bear Ecology

3.1 Kenai Peninsula Research Findings

Brown bears range across much of the Kenai Peninsula, generally avoiding only those areas heavily glaciated or populated by people. Research efforts have focused on the western half of the peninsula (Figure 4), and preliminary work is reported in Schwartz et al. (1999).

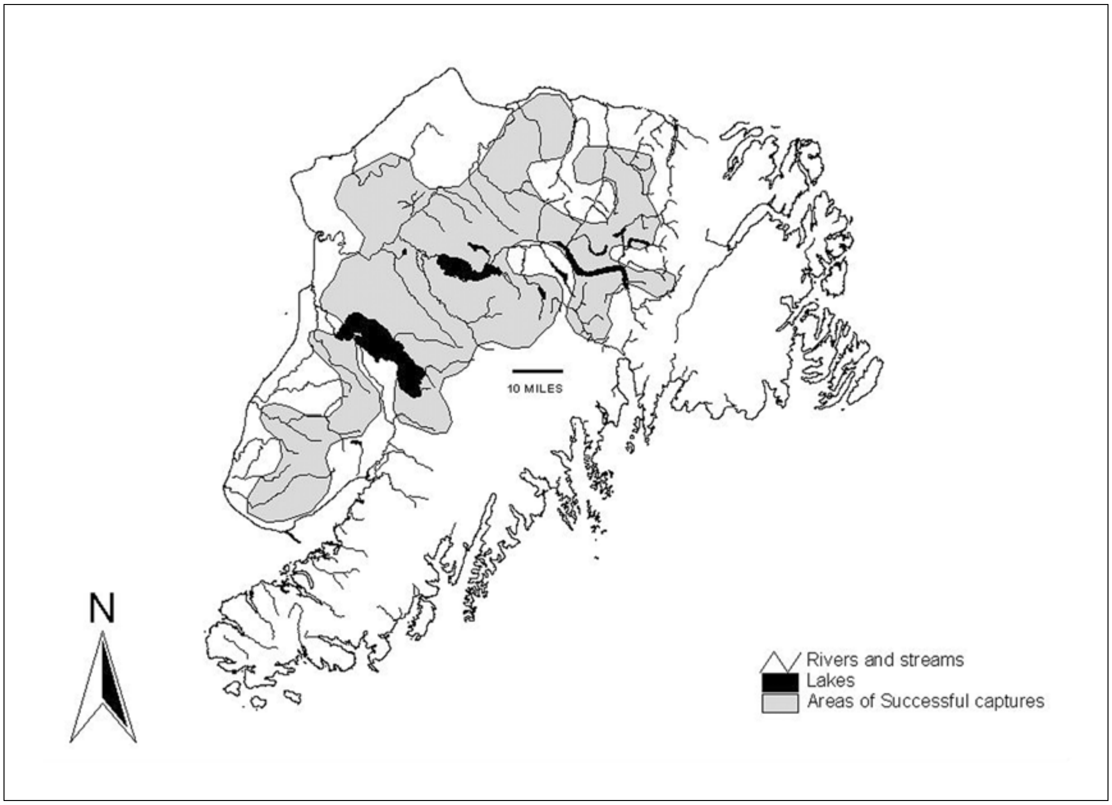

Figure 4. Regions of capture emphasis on the Kenai Peninsula (1995–1999; n = 114 captures)

3.1.1 Genetics Research

Shields (1998) proposed the following hypotheses for Kenai brown bears:

- The Kenai Peninsula brown bear population was founded with bears from the Katmai coast, Kodiak Island, or the mainland north of Portage.
- The genetic diversity, or regional heterozygosity, of Kenai Peninsula bears is likely low.
- The Kenai Peninsula brown bear population is most closely allied with mtDNA clade III (Talbot and Shields 1996b; see section 2.1.2).

Kenai Peninsula brown bears likely are not distinct from mainland Alaska bears when comparing mtDNA, but they may be genetically distinct when nuclear DNA frequencies and sequences are contrasted. Overall, the species *Ursus arctos* does not appear threatened with extirpation within Alaska. Although metapopulation dynamics such as extirpation and colonization of local bear populations undoubtedly occur

(Hastings and Harrison 1994), albeit on a millennial time scale, extirpation of local bear populations is not acceptable in today's conservation milieu. Thus, because the Kenai Peninsula brown bear population may be at risk from development and the relative geographic isolation of the peninsula, research is now underway to determine its genetic relationship with mainland bears. This research will estimate the regional heterozygosity displayed by Kenai Peninsula brown bears and is expected to be completed by the winter of 2002. A bear population that does not exhibit gene flow with other populations is at risk to inbreeding; the importance of gene flow to the conservation of Alaska bear populations, and particularly to Kenai Peninsula brown bears, is assumed to be important, although our understanding is still limited (Paetkau et al. 1998; Talbot and Shields 1996b).

3.1.2 Diet and Nutritional Constraints

The nutritional ecology of adult female brown bears was investigated on the Kenai Peninsula from 1996 through 1998. Researchers determined that the average body mass of adult Kenai female brown bears (both with and without young) increased from spring (time of den emergence) to fall. Mean values by season were spring—155.8 ± 23.6 kg, summer—184.6 ± 29.0 kg, and fall—240.7 ± 35.0 kg. The majority of the mass gained between spring (May) and summer (mid-July) was lean tissue (71.8 ± 28.2%), whereas the majority of the weight gained between summer (mid-July) and fall late-September to early-October) was lipid (81.0 (19.5%) (Figure 5; Hilderbrand et al. 1999b). Terrestrial meat (e.g., moose, caribou, rodents) accounted for 76.2 ± 26.0%, and vegetation accounted for 23.8 ± 26.0% of the spring-to-summer diet. In the fall, salmon (59.6 ± 35.3%) was the dominant food resource, with terrestrial meat (20.8 ± 34.5%) and vegetation (19.6 ± 22.2%) accounting for the remainder. Adult female brown bears consumed an estimated 541 ± 156 kg of moose in the spring and summer and 1003 ± 489 kg of salmon in the summer and fall (Hilderbrand et al. 1999b).

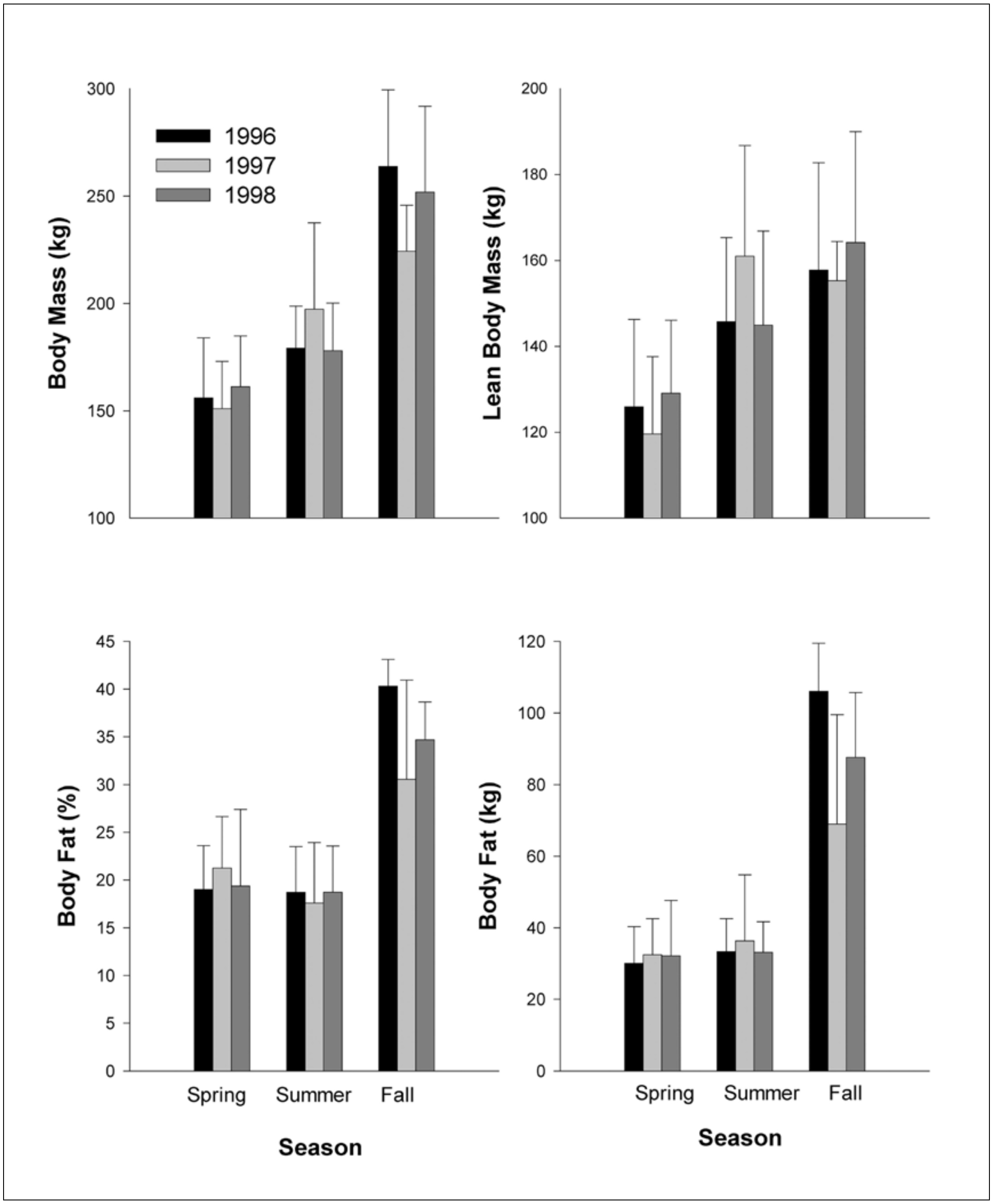

Figure 5. Seasonal body composition of adult female brown bears on the Kenai Peninsula, Alaska (Hilderbrand et al. 1999b)

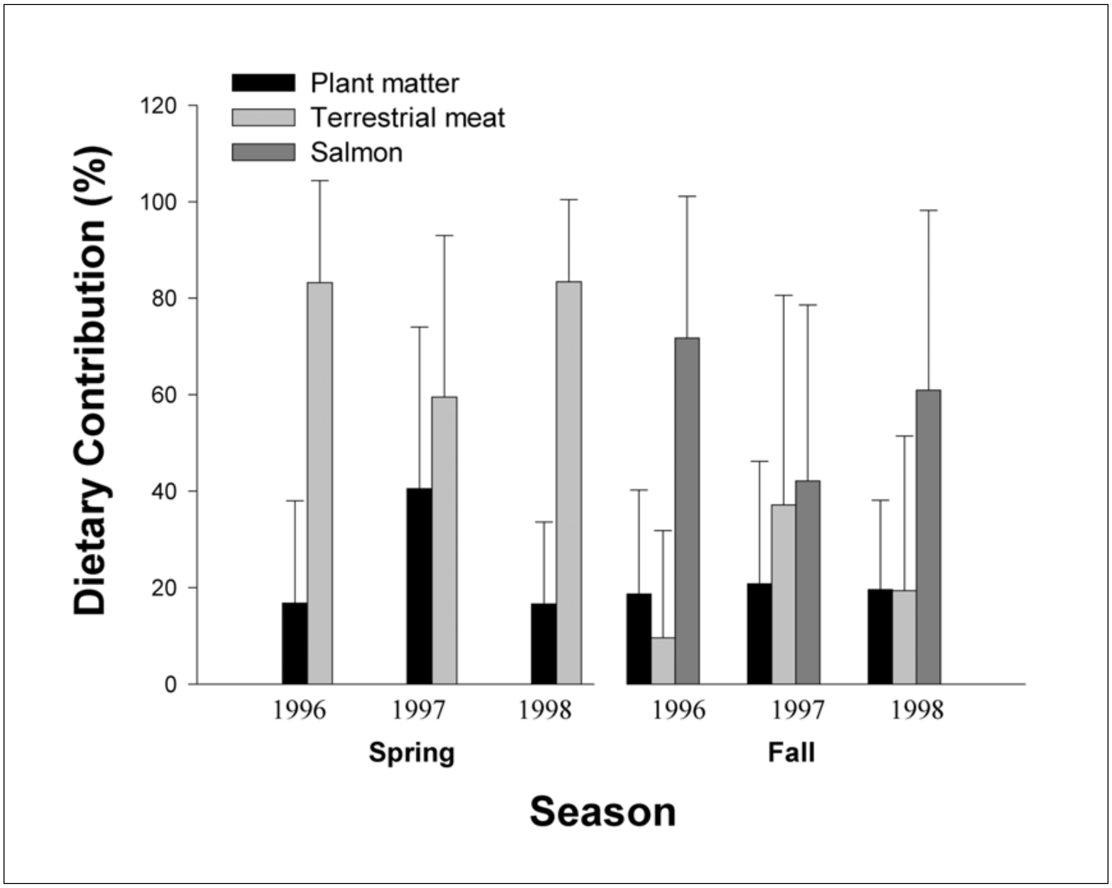

Figure 6. Seasonal diet of adult female brown bears on the Kenai Peninsula, Alaska (from Hilderbrand et al. 1999b)

During hibernation, adult female brown bears lost an average of 73 ± 22 kg (32 ± 10%) body mass. These losses were from both lean tissue (44 ± 22%) and lipid stores (56 ± 22%) (Hilderbrand et al. 2000). Lone females had higher body mass, higher lean body mass, and more body fat content than did females with cubs of the year or females with yearlings. Most likely, this difference was due to the increased energetic demands on mothers rearing young (Table 1; Hilderbrand et al. 2000).

Table 1. Body composition ($\bar{x}$ ± 1 SD [n]) of adult female brown bears by season and reproductive class

		Body Mass (kg)	Fat Mass (kg)	Lean Mass (kg)
Spring				
	Alone	176.9 ± 6.2 (5)[a]	40.0 ± 9.8 (5)[a]	136.9 ± 18.5 (5)[a]
	COY	152.6 ± 16.3 (12)[b]	35.7 ± 8.5 (12)[a]	116.8 ± 12.0 (12)[b]
	1 yr	152.0 ± 22.1 (23)[b]	28.8 ± 11.6 (23)[a]	124.1 ± 19.9 (23)[ab]
	2 yr	169.0 ± 28.8 (5)[ab]	33.1 ± 18.3 (5)[a]	135.9 ± 13.4 (5)[a]
Fall				
	Alone	248.0 ± 29.7 (16)[a]	90.7 ± 18.7 (16)[a]	157.2 ± 18.9 (16)[a]
	COY	230.3 ± 28.8 (7)[a]	71.8 ± 15.0 (7)[b]	[1]58.5 ± 21.2 (7)[a]
	1 yr	225.3 ± 29.5 (10)[a]	70.9 ± 20.7 (10)[b]	154.4 ± 18.8 (10)[a]

[a,b] Means within the same column and season having the same superscript are not significantly different (ANOVA and Fisher's LSD analysis)

The availability and abundance of salmon on the Kenai Peninsula enable brown bears to accumulate the energy reserves required to meet the costs of hibernation and reproduction. Moose become an important food resource in the spring when bears may be in a negative energy or protein balance incurred from the spring costs of growth, lactation, and replenishing lean mass lost while hibernating (Hilderbrand et al. 1999a). Thus, any plan to manage Kenai Peninsula brown bears must also incorporate effective management of the Kenai Peninsula's salmon and moose.

3.1.3 Distribution and Movements

The relationships among bear movements, landscape characteristics, and seasonal distribution of food items was investigated by use of radio and Global Positioning System (GPS) collars. Beginning in 1996, bears were captured and outfitted with GPS store-on-board collars and GPS Argos collars, which recorded locations every 5.75 or 11.5 hours with 100–250 m accuracy, respectively (Argos collars do not store the data, but transmit it to a base station via satellite uplink). The straight-line distance between each bear's location and the nearest body of freshwater was determined, and the mean distances were calculated by month for each bear. These individual means were used to calculate overall monthly means for the entire adult female population (Figure 7). The data show a clear trend, with the proportion of locations within 1 km of freshwater increasing from May through October. This increase appears to be correlated with the presence and abundance of salmon.

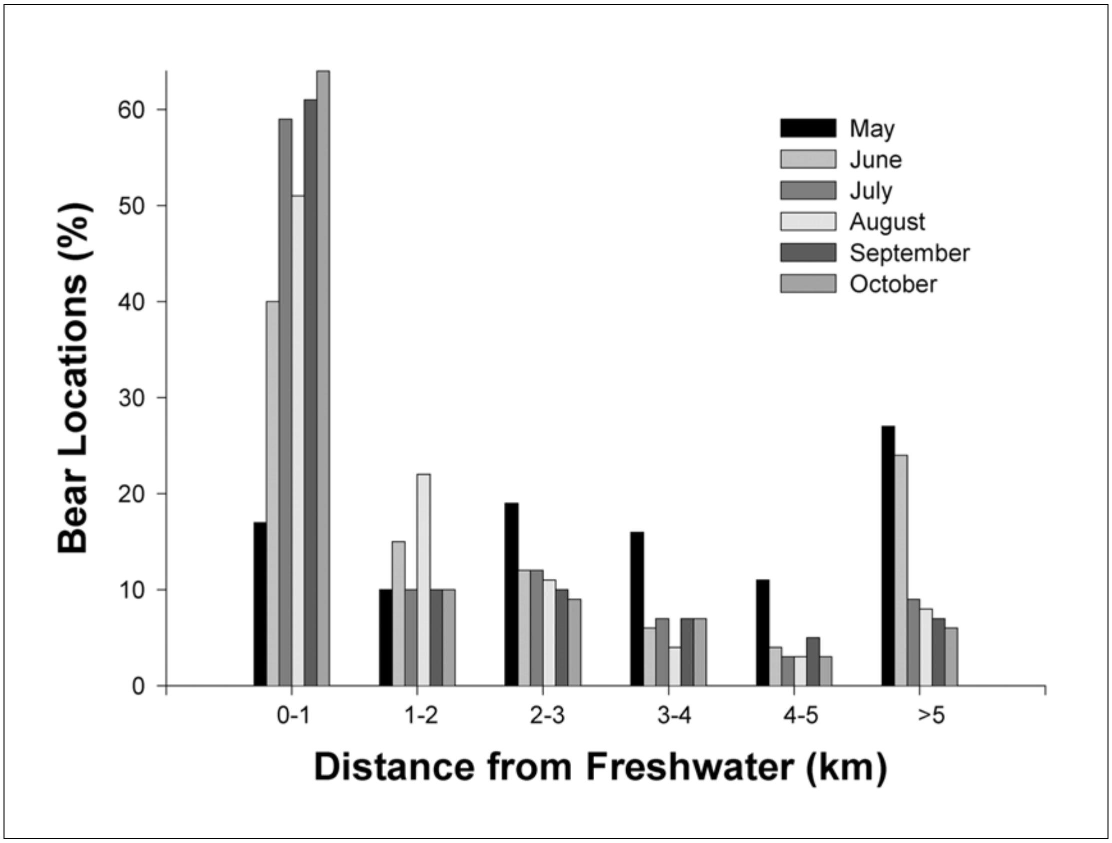

Figure 7. Spatial distribution of adult female brown bears on the Kenai Peninsula, Alaska (1996–1998)

The geographic distribution of adult female brown bears relative to salmon streams is related to reproductive class (Figure 8). Lone adult females and females with 2-yr–olds (“other adult females” in Figure 8) tended to move to streams before females with yearlings or cubs of the year (COY). The use of presumed salmon streams by other adult females peaked in July and decreased thereafter. Females with yearlings were found more often near salmon streams from July through September and less so in October. Females with COY arrived at salmon streams much later than did females of any other reproductive class and continued to use these areas well into October.

It is presumed that females with COY decreased the risk of intraspecific predation to their cubs by limiting the use of salmon streams until other bears had moved away. The temporal niche partitioning of salmon use by adult females (Figure 8) demonstrates that the Kenai Peninsula brown bear population utilizes this resource from spring through late fall. Thus, even though individual bears feeding on salmon are capable of achieving the large body mass and fat gains needed for hibernation in only a short time period (days to weeks), the health of the bear population is maintained by continuous access to salmon. Data on the spatial distribution of male bears relative to presumed salmon streams has not been collected. The behavior of males likely will provide further insight into spatial distribution patterns of adult females.

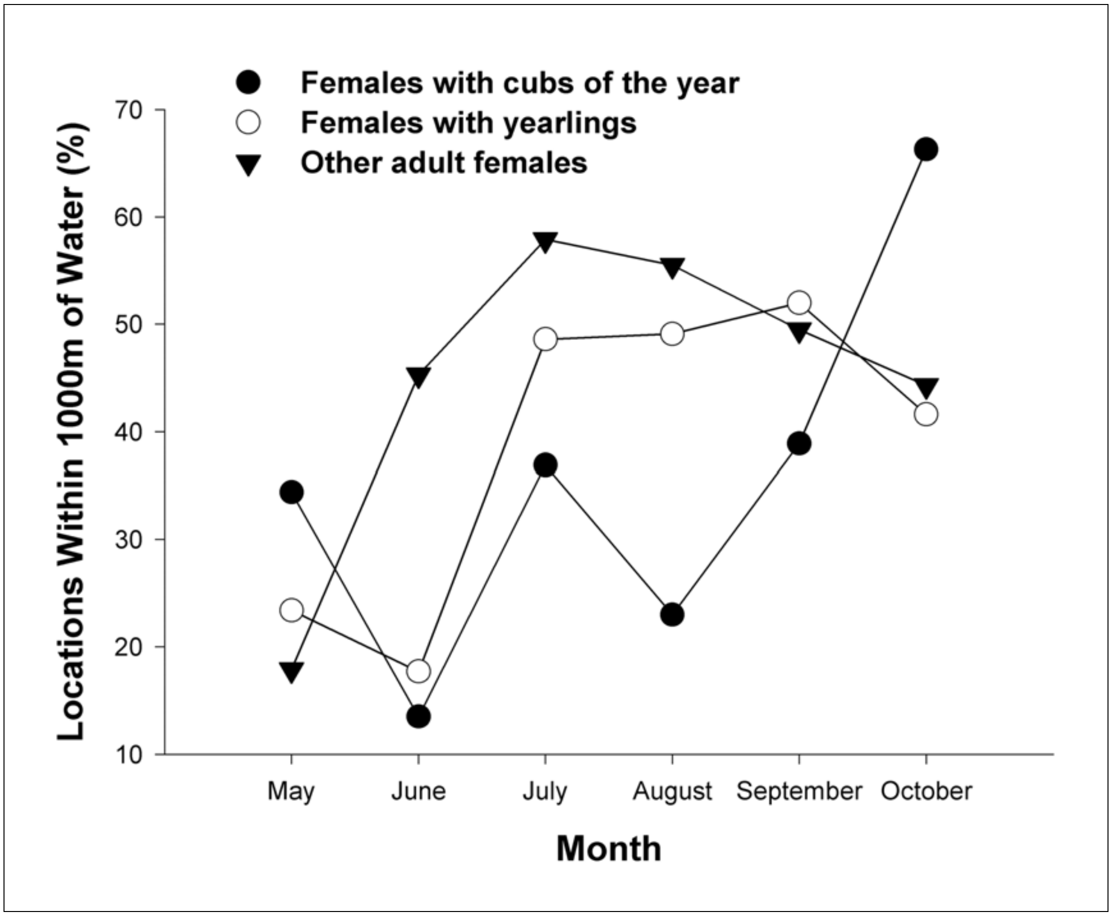

Figure 8. Relationship between female reproductive class and distance from presumed salmon streams on the Kenai Peninsula, Alaska, 1996–1998 (sample sizes ranges from 5 through 10)

3.1.4 Buffer Zones Along Anadromous Streams

It is recognized that buffer zones along streams protect riparian habitat from nearby disturbances such as logging, mining, or road construction and vehicle use (Titus and Beier 1998). The *Kenai Area Plan* (a Kenai Peninsula Borough planning document) and the proposed USFS standards and guidelines for the Chugach National Forest recommend that buffers be established for the benefit of brown bears foraging along riparian (usually anadromous) streams of the Kenai Peninsula. The borough plan stipulates that buffers be 115 m wide, while USFS has proposed a buffer width of 230 m. Both recommendations are based on professional judgment because, until quite recently, appropriate data on the movements and landscape use by bears did not exist. Previously, Titus and Beier (1998) discussed the efforts involved in determining the width of no-cut buffers on the Tongass National Forest in southeastern Alaska. For the Tongass National Forest, a panel of bear biologists had the option of choosing one of only two predetermined widths as an a appropriate buffer. After reviewing data from Titus and Beier (1998), the panel selected the wider buffer (153 m). It is important to note that until the advent of GPS collars it was very difficult to collect information on bear use of riparian areas.

Members of the IBBST deployed GPS collars on Kenai Peninsula brown bears to characterize patterns of their uses of riparian habitat. Data were collected from 28 female adult brown bears during 1996 through 2000 and included more than 28,000 locations. The data clearly showed that bears made extensive use of habitat spanning from stream's edge to well over 2000 m away (Figure 9). During the months when salmon were an important component of the Kenai Peninsula brown bear diet, the average distance from an anadromous stream for an adult female Kenai brown bear was about 2000 m. Importantly, bears used the habitat extending *from* streamside to well over 2000 m distant. Presumably they gorged on salmon and then moved away from the stream to digest and assimilate their gut loads.

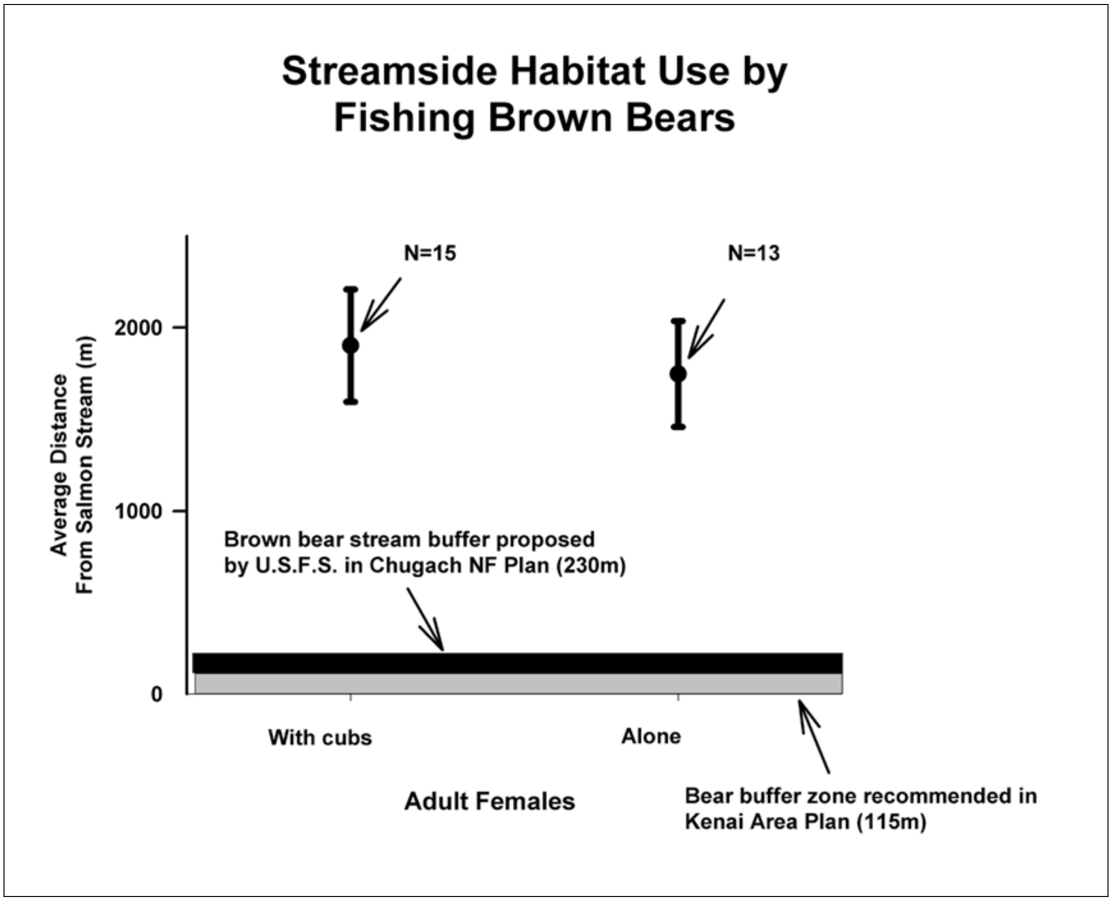

Figure 9. Brown bear use of streamside habitat (mean and standard error calculated across females using GPS location data, 1996–2000; total number of locations = 28,178)

These location data do not identify a specific width necessary for a riparian buffer for bears. They clearly show, however, that buffers only a few hundred meters wide will encompass just a fraction of the habitat actually used by salmon-feeding bears. Unfortunately, determining any appropriate buffer width is not a trivial undertaking. If the only habitat protected in a watershed or drainage is a narrow riparian strip, bears can be at risk from extraction or development activities outside that strip. Also, when good bear habitat is constrained to narrow riparian strips, bear activities that normally occur across entire watersheds (e.g., foraging, resting, nursing) may be restricted to whatever riparian strip remains, making more likely

bear-to-bear interactions, some of them detrimental. For example, restricted riparian buffers may prevent females with COY from finding adequate security cover, or they may greatly increase the probability of encounters dangerous to bears and humans. Emergent vegetation within clear-cut areas will likely provide some security cover over time. The individual and population level effect(s) of restricting riparian buffer zones are unknown.

3.1.5 Movements by Bears

Mean daily movements of individual bears were measured across month and reproductive class. The number of locations recorded each day strongly influences the estimated daily distance traveled (Figure 10); thus, only the multiple locations collected via GPS store-on-board collars were included in daily movement analyses. Daily movements of individual adult female brown bears were calculated with Arc-View. Mean daily distance traveled was calculated for each bear by month. The daily movement was expressed as a slowly decreasing distance from May through the fall (Figure 11). Relatively large daily movements in the spring may have reflected movement from the den site to spring habitats as well as travel necessary to forage for vegetation, move to winter kill carcasses, and stalk and kill live prey. The decrease in daily movement beginning in July corresponded with the return of salmon (a concentrated resource) to Kenai Peninsula rivers. The continued decrease in daily movement through October likely reflected reduced travel occurring at the onset of hibernation.

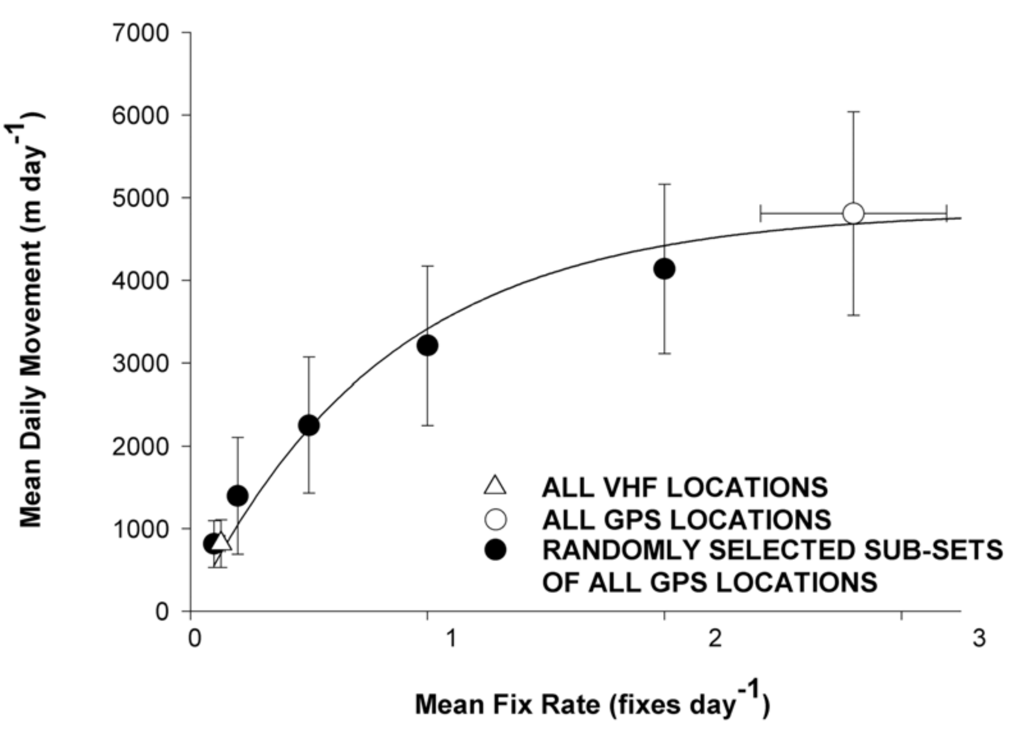

Figure 10. Effect of fix rates on estimates of daily movement by adult female brown bears on the Kenai Peninsula, Alaska (1996–1998)

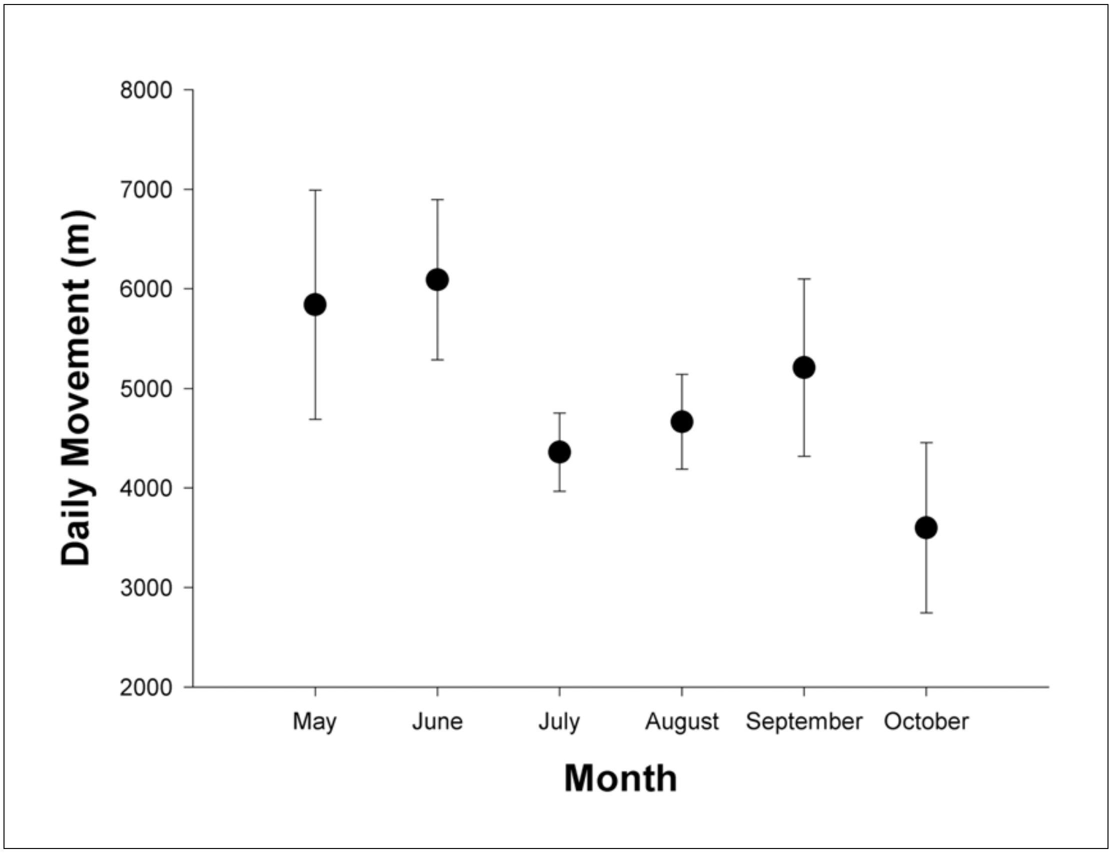

Figure 11. Seasonal daily movement (mean ± SE) by adult female brown bears on the Kenai Peninsula, Alaska, 1996–1998 (sample sizes range from 7 through 10)

Movements by individuals were pooled by reproductive class (Figure 12). Daily movements of lone females and females with 2-yr–old cubs ("other adult females" in Figure 12) decreased throughout the active period. The reduced movement of these bears from July onward likely reflects their use of salmon and thus a shift from terrestrial foods (vegetation, terrestrial meat). Daily movements by females with yearlings were relatively constant throughout the active period. Daily movements by females with COY were shorter than those of other reproductive classes throughout much of the year. This may reflect the reduced mobility of the young cubs in the early part of the active period and the use of salmon later in the summer and fall.

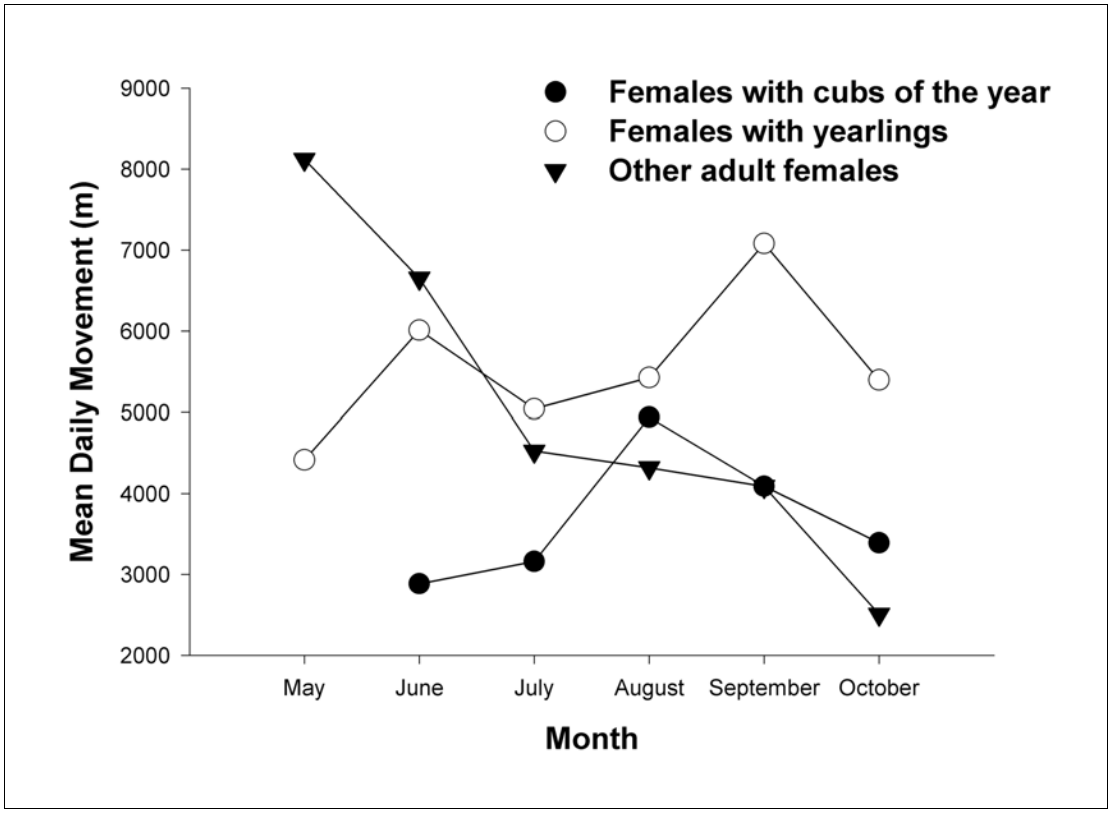

Figure 12. Effect of reproductive class on daily movement distance of adult female brown bears on the Kenai Peninsula (1996–1998)

3.1.6 Population Parameters

A population census has not yet been conducted for Kenai Peninsula brown bears, although a rigorous DNA-based census is scheduled to begin under IBBST supervision in 2002. In the early 1990s, management biologists with ADF&G used the following procedure to estimate population size (Del Frate 1999):

> Cost-effective survey techniques to determine brown bear population size over large forested areas have not been developed and tested. We derived a population estimate for the Kenai by combining results from a habitat-based model and a density estimate using expert interpretation. Suitable brown bear habitat was estimated by mapping (1:250,000 topographic map) harvest locations of brown bears killed 1961 through 1993. We approximated the area used by brown bears by including similar habitat surrounding the harvest location and calculated the area within the polygon for each game management unit. We included all land above mean high tide, roads, waterbodies (except Skilak and Tustumena lakes), and municipalities. We assumed that all bears were harvested within their normal home ranges and that similar adjacent land was also suitable habitat.
>
> By comparing estimates of bear density to other parts of Alaska, we could approximate the density on the Kenai by assessing expert impressions. At least 16 density estimates have been completed in Alaska, from low densities in the northern interior Alaska to very high

> densities in coastal areas (Miller 1997, Miller *et al.* 1997). Miller (pers commun) suggested that the density of brown bears on the Kenai was probably lower than the 27.1 bears per 1000 km^2 (7.0 bears per 100 mi^2) that he reported for his middle Susitna Study Area (1987). Consequently, we estimated the bear density on the Kenai to be 20 bears per 1000 km^2 (5.2 bears per 100 mi^2), and we calculated the suitable habitat to be 13,848 km^2 (5347 mi^2). We derived a brown bear population estimate for [Game Management] Units 7 and 15 by multiplying the suitable habitat by the density estimate.
>
> . . . . .
>
> Assuming that the brown bear density was 20 bears per 1000 km^2 (5.2 bears per 100 mi^2) and the suitable habitat was 13,848 km^2 (5347 mi^2), we estimated the brown bear population for [Game Management]Units 7 and 15 at 277 (range = 250–300). We believe the population is stable or may be slightly increasing.

A population estimate based on census methodology does not exist for the Kenai Peninsula brown bear population. Although absolute population size has not been determined, IBBST members collect data useful for estimating population characteristics each time we handle an animal or observe it during radio-tracking. Team members count cubs and determine the ages of bears handled in order to estimate litter size, age-specific survival, and population age distribution.

Litter size can provide useful insight to bear population health. The IBBST defined litter size as the largest number of offspring seen with an individual adult female bear in any given year. Using this definition, observations from aerial tracking indicated the following average litter sizes (± 1 SD): COY 2.36 ± 0.67 (n = 56 litters) individuals; yearlings 2.06 ± 0.65 (n = 51 litters); 2-yr–olds 2.04 ± 0.68 individuals (n = 25 litters). Mean interval between litters is 3.5 ± 0.6 yr (n = 13). Compared to other brown bear populations, Kenai Peninsula brown bears tend to have large litters, which may be a reflection of the excellent food resource provided by anadromous fish.

Survivorship was calculated by the Kaplan-Meier method according to Pollock et al. (1989). The IBBST considered each bear-year to begin April 1 and to end March 31. The team assumed that offspring less than 2 yr did not survive without their mothers. Survival rates of adult females and offspring are reported in Tables 2 and 3, respectively. We did not determine survivorship for adult males because of small sample size. The survival rates for Kenai yearlings (0.3– 0.7) are lower than those reported in other studies (0.78–0.96;(Ballard et al. 1993; Craighead et al. 1974; Knight and Eberhardt 1985; McLellan 1989b; Reynolds and Hechtel 1984; Sellers 1994). Although orphaned yearlings in some populations may survive to adulthood (Swenson et al. 1998), it is not known if this is true for Kenai Peninsula brown bears. Low yearling survival would result in low recruitment into the population.

Table 2. Survivorship of adult female brown bears on the Kenai Peninsula, Alaska

Year	Number of Adult Females	95% Confidence Intervals
1995	0.9286 (14)[a]	0.7937-1.0635
1996	0.9355 (31)	0.8490-1.0220
1997	0.9048 (42)	0.8160-0.9935
1998	0.8750 (40)	0.7725-0.9775
1999	0.9032 (31)	0.7991-1.0073

[a] Number of individuals at start of year.

Table 3. Survivorship of brown bear offspring on the Kenai Peninsula, Alaska

Year	COY	95% Confidence Interval	Yearlings	95% Confidence Interval
1995	1.0000 (3)[a]	1.0000-1.0000	0.4000 (10)	0.0964-0.7036
1996	0.7500 (36)	0.6085-0.8915	0.3333 (9)	0.0253-0.6413
1997	0.7317 (41)	0.5961-0.8673	0.7000 (30)	0.5360-0.8640
1998	0.7917 (24)	0.6292-0.9541	0.5313 (32)	0.3583-0.7042
1999	0.6000 (15)	0.3521-0.8479	0.6667 (15)	0.4281-0.9052

[a] Number of individuals at start of year

The age distribution of female Kenai Peninsula brown bears is summarized in Figure 13. The sex of all bears greater than or equal to 3 yr of age was determined from visual inspection of captured bears. However bears less than 3 yr old are not captured, and the number of females in this age class was estimated by assuming a 50:50 ratio of female cubs to male cubs in all observed family groups. Thus, the sum of female bears 0, 1, and 2 yr old shown in is one-half the total number of bears observed in these age classes. The overall age distribution from 1995 through Fall 1999 shows that few bears 3–6 yr old have been observed or captured. This is troubling because, in other brown bear studies, weaned sub-adult bears usually account for >20% of a population size (Ballard et al. 1993; Craighead et al. 1974; Knight and Eberhardt 1985; McLellan 1989a; Reynolds and Hechtel 1984; Sellers 1994; Wielgus and Bunnell 1994a; Wielgus et al. 1994).

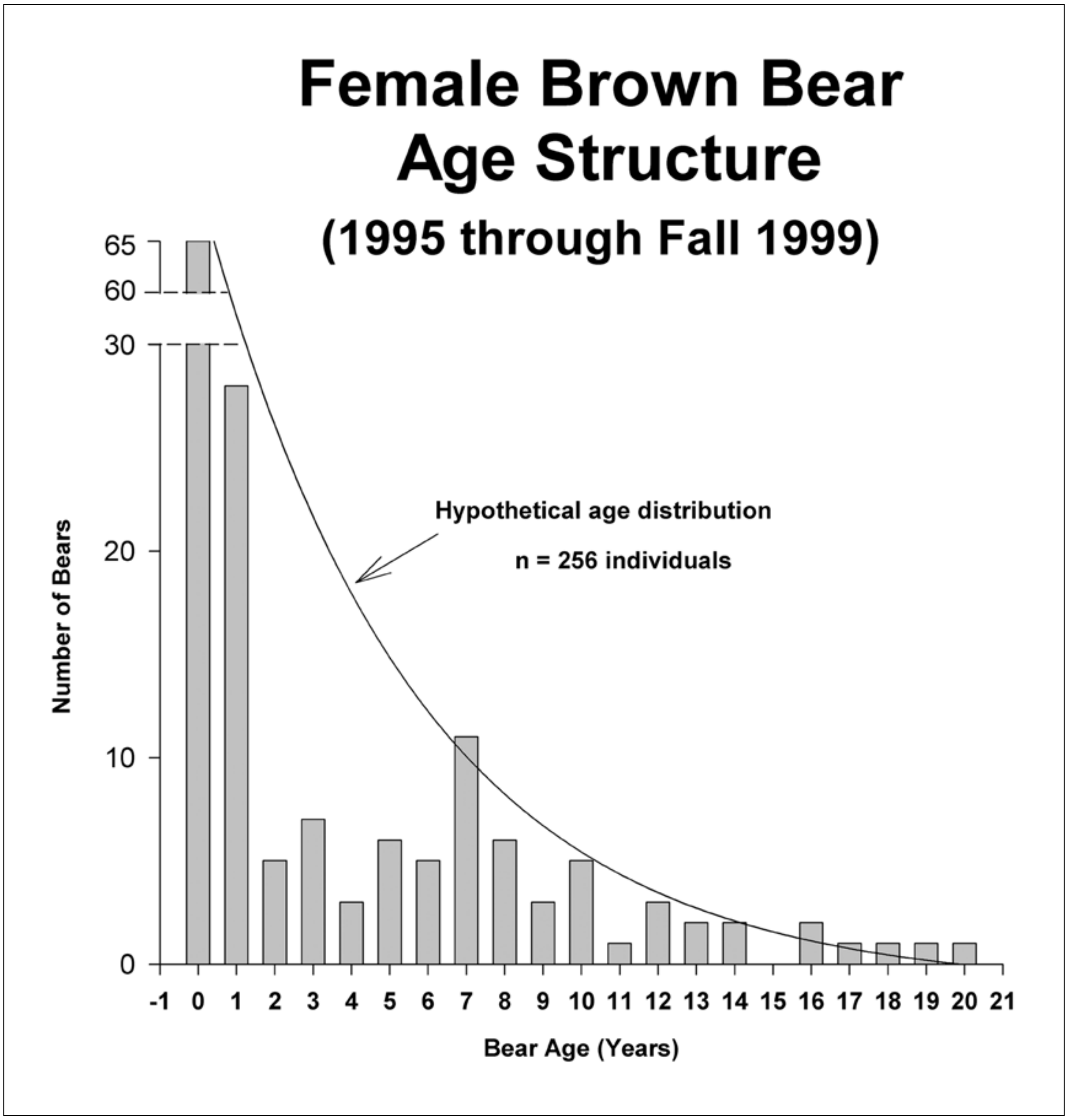

Figure 13. Age of female brown bears at time of first capture (≥ 3 yr) or first observation (< 3 yr); a ratio of 50% males:50% females was assumed for all observed bears < 3 yr old; the graph shows one-half of all observed bears < 3 yr old

The hypothetical age distribution for the Kenai Peninsula brown bear population is indicated by the curve in Figure 13. The observed data closely follow the hypothesized age distribution for bears 7 yr and older; however, the observed age distribution for 2- to 6-yr–old bears is depressed below the hypothesized level. If real, this effect could result from a weak cohort or a marked decline in survivability for young Kenai Peninsula brown bears. The former is not uncommon in wildlife populations and has a transitory effect on the population; the latter could induce population collapse. Sampling bias against 3- to 6-yr–old Kenai brown bears could account for the lack of animals in this age class. The IBBST does not believe this bias exists because few regions of the Kenai Peninsula have not been actively searched, and young female bears are strikingly blond and quite visible from the air.

Fortunately, if data collection is continued on the reproduction and survival of collared animals, we will be able to determine if this trend is real or an artifact. Another analysis of age distribution should be conducted by fall 2003.

The finite rate of increase (λ) of the population was calculated according to Testa's (1997) ADF&G memorandum based on Eberhardt and Siniff (1977) and Eberhardt (1985) as follows:

$$1 = \lambda^{-a} * P^0 * P^1 * P^{a-2} * F * (1-P/\lambda)^{-1}$$

where P is adult female survival, P^0 is survival from birth to age 1, P^1 is survival from age 1 yr to age 2 yr, F is mean birth rate (female cubs/adult female/year), and a is age of first parturition. Confidence limits were determined from a frequency distribution of λs derived from bootstrapping samples of each variable according to Eberhardt et al. (1994). It was determined that 2000 bootstrap samples were sufficient, because the change in overall mean with each additional λ value became asymptotic after 250–500 values.

The Kenai Peninsula brown bear population has an λ of 1.0128 with 95% confidence limits of 0.9364-1.0588 (data from 1995 through 1999). Bear populations with λ values greater than 1.0 are considered to be stable; those populations with values less than 0.995 are considered to be decreasing (Mace and Waller 1998). The Kenai Peninsula population brackets this range with its 95% confidence intervals; thus, it is not clear if the Kenai Peninsula brown bear population is increasing or decreasing. Data specific to the Kenai Peninsula brown bear population are limited, and estimates of λ should be interpreted with caution. Models of λ assume a stable age distribution, which, as mentioned, has not been verified for the Kenai Peninsula brown bear population. Additionally, no data have been collected on the survival of sub-adult females on the Kenai Peninsula. If survival of sub-adult females is greater than that of adult female brown bears (an unlikely assumption), λ is underestimated; if sub-adult survival is less than that of adult female brown bears, λ is overestimated. Finally, still too little data exist for the age of first parturition for Kenai Peninsula brown bears.

It is difficult to characterize the health of the Kenai Peninsula brown bear population at this time. The calculated finite rate of population increase indicates neither an increase nor a decrease, whereas demographic information (survivorship data and the female age distribution) indicates the possibility that reproductive females have a low recruitment into the Kenai brown bear population. This is an area that warrants continued research and monitoring.

3.1.7 Bear-Human Interactions on the Kenai Peninsula: Cumulative Effects Model

The Kenai Peninsula has seen a dramatic increase in resident human population (Figure 14) and human visitors (Figure 15) and a dramatic acceleration of logging (Figure 16). These pose risks to Kenai bears from improved human access to bear habitat and an increased number of people traveling in bear habitat, which can lead to an increase in the number of bear mortalities due to defense of life or property (DLP). Suring et al. (1998) developed a cumulative effects model evaluating the effect(s) of human actions on Kenai Peninsula brown bear habitat quality and effectiveness. The model was applied to the Kenai portion of the Chugach National Forest, and it was found that human activities had reduced habitat effectiveness (defined as the

interaction of habitat quality [vegetation type, food availability, other abiotic factors] and human activities; as in Weaver et al. 1986 by 70% in some areas [Suring et al. 1998]). However, the model still requires validation and testing. Currently, bear movement and habitat use data collected on Kenai brown bears with GPS collars are being processed for testing and refining model components.

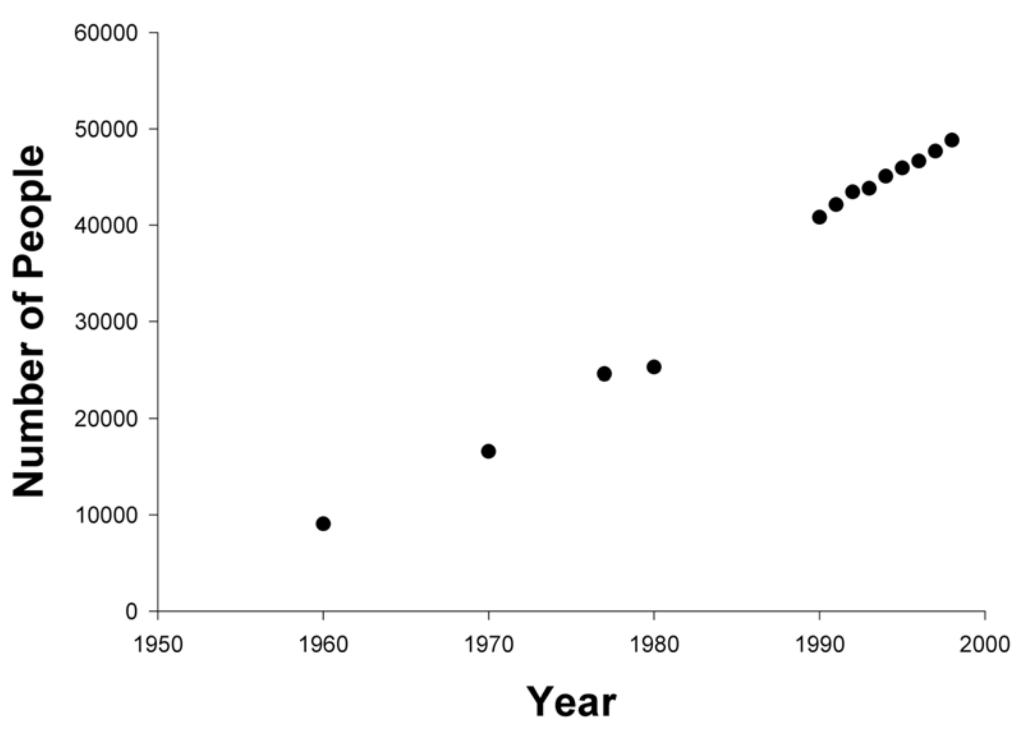

Figure 14. Growth of human population on the Kenai Peninsula

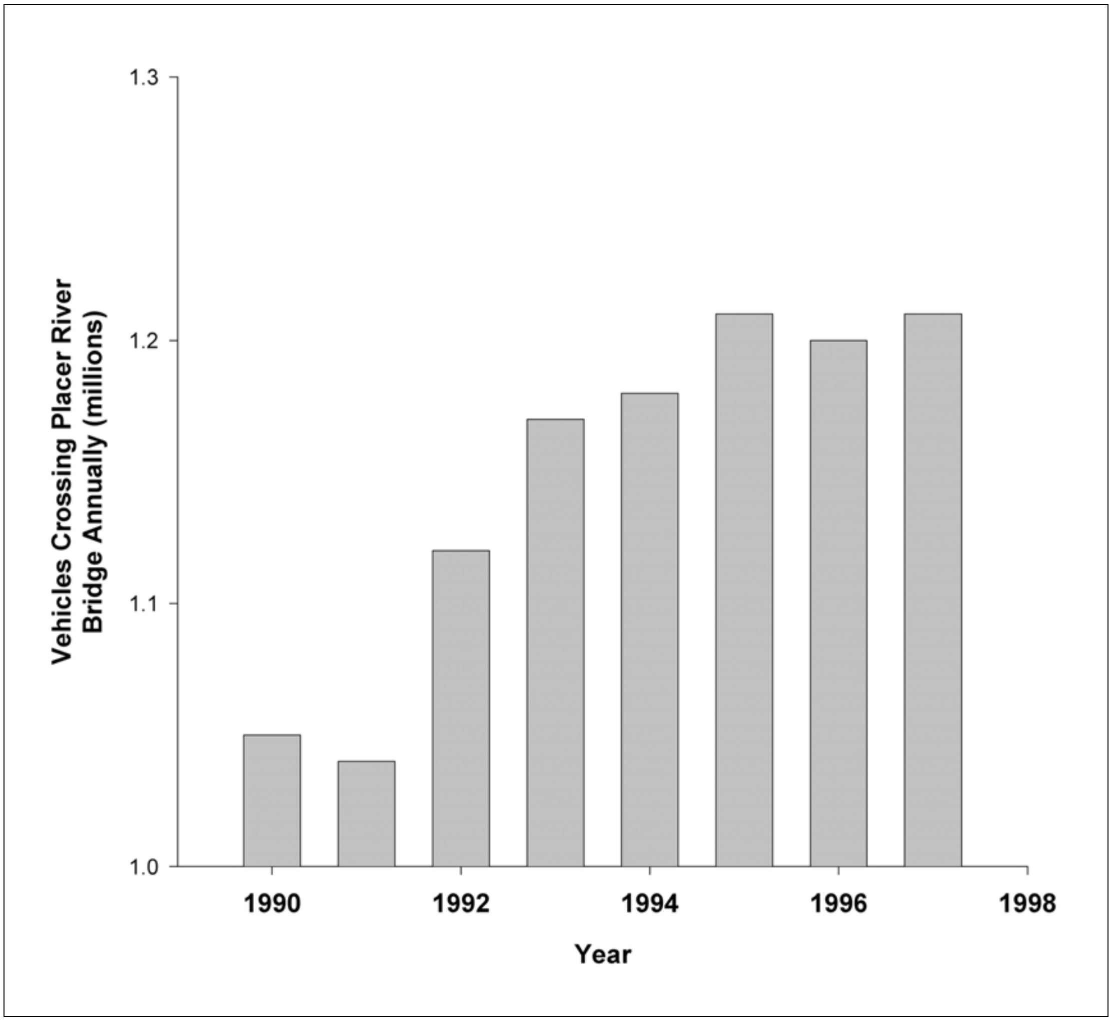

Figure 15. Increase in road vehicle traffic to the Kenai Peninsula

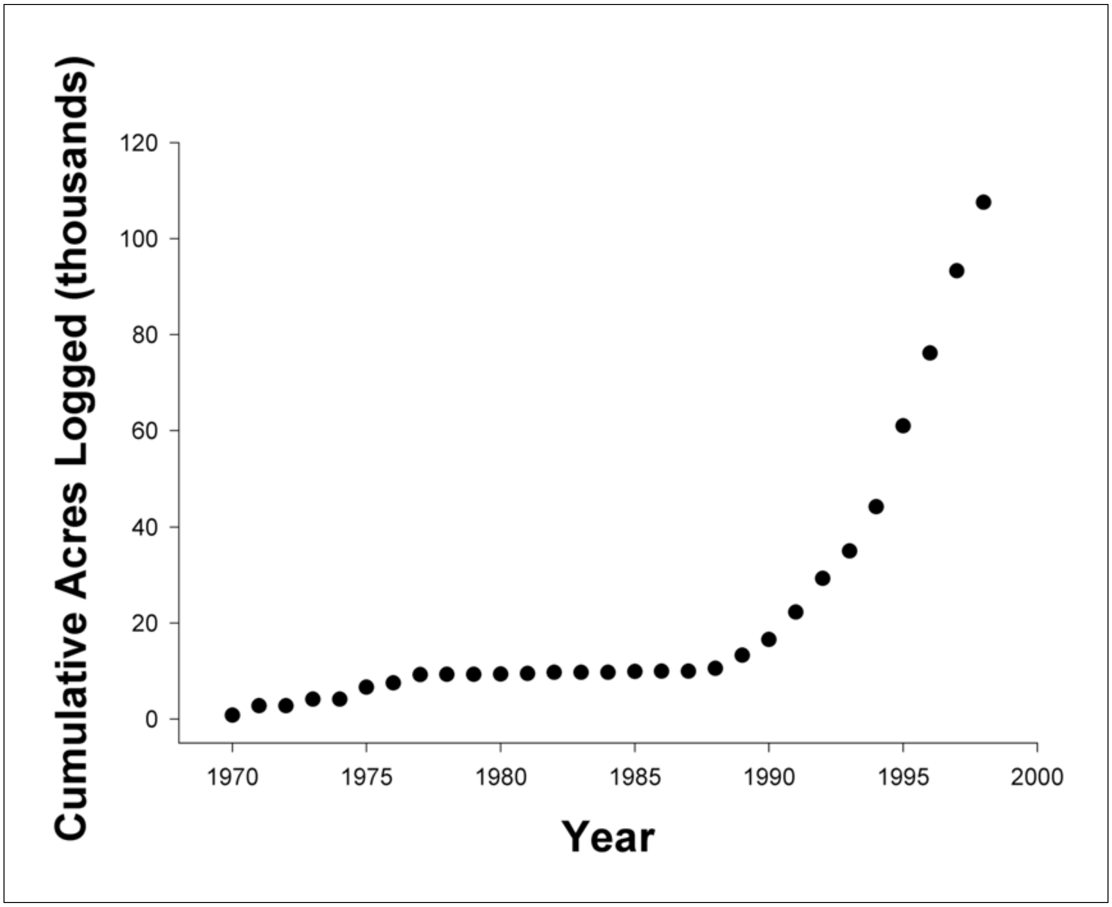

Figure 16. Logging activity on the Kenai Peninsula

3.1.8 Bear-Human Interactions on the Kenai Peninsula: Defense of Life or Property Mortality

A person is legally entitled to use lethal force in self-defense or to protect other people and some types of property from injury or damage from wild animals (AS 5AAC 92.410). If an animal is killed, the action is referred to as a DLP kill, and ADF&G must be notified and an affidavit filed describing the incident. If a bear has been killed, the skull and hide are forfeited to ADF&G. Data on Kenai Peninsula brown bear DLP actions have been collected since 1962.

Figure 17 shows locations at which Kenai Peninsula brown bears have been killed in DLP actions. There have been 100 brown bear DLP kills reported since 1964, of which 84% occurred in Game Management Unit (GMU) 15, 15% in GMU 7, and 1% in unknown locations. GMU subunit 15C had the most (37%), followed by GMU 15B and 15A (25% and 20%, respectively). The subunit location for 3% of the DLP kills was unknown.

The age of a bear is strongly related to its chance of being killed in a DLP action. Bears 0 to 3 yr old accounted for 39% of all mortalities;, animals 5 to 10 yr old (there were no 4-yr olds) were 16% of deaths, and the remainder (older than 11 yr) were 17%. Age was not known for 28% of all DLP mortalities. If all ages are combined, males and females were killed in equal numbers (45% and 46%,

respectively; however, sex was not identified for 9% of the bears). There is a strong sex-age correlation, however, in the types of bears killed in DLP actions. Young (≤3 yr) males made up 21% of all DLP actions; females of similar age class constituted 15% (3% of bears ≤ 3 yr old were of unknown sex). This relationship was reversed for bears older than 4 yr, because more females were killed than males of similar age range (20% vs. 13%, respectively). Again, 28% of all bear DLP mortalities were not identified by age.

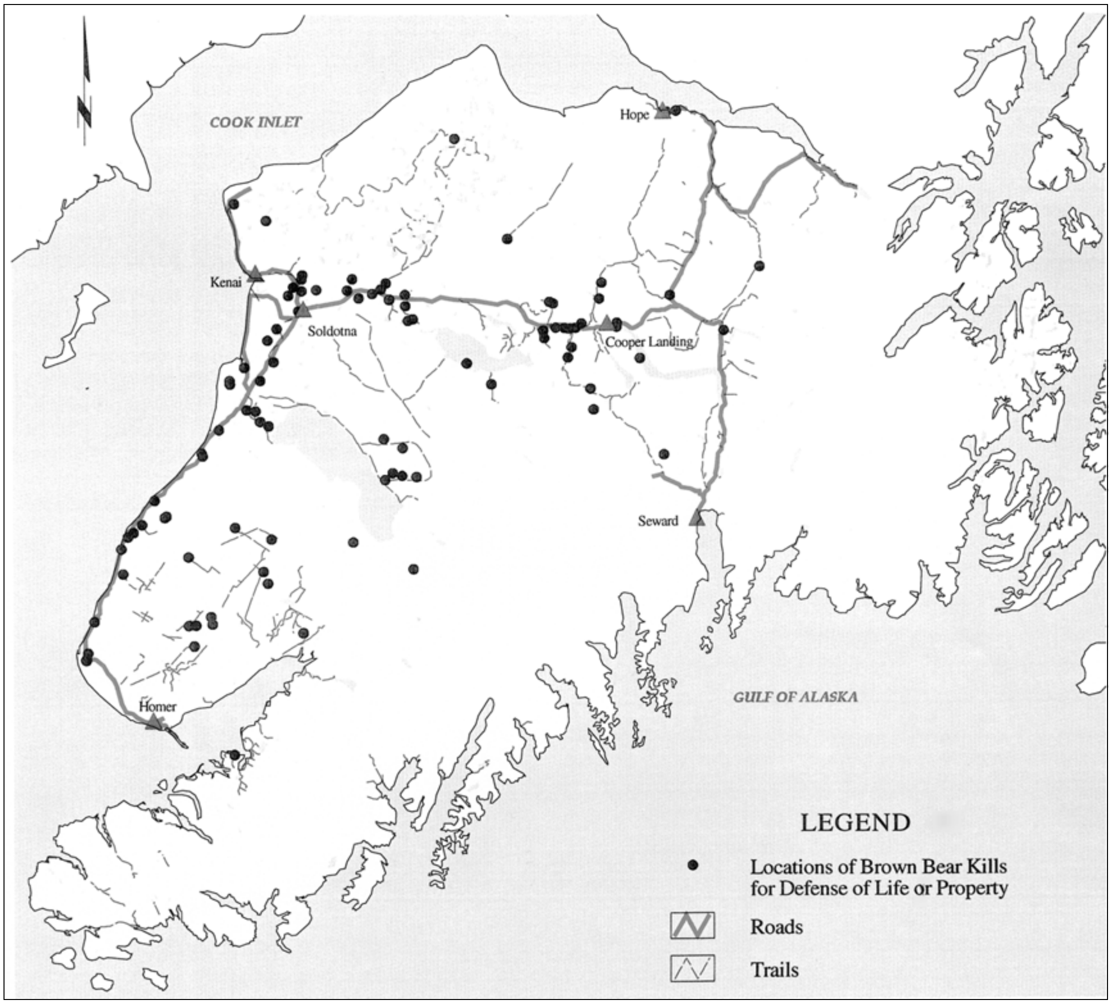

Figure 17. Locations where brown bears have been killed in defense of life or property

Reducing bear-human interactions and DLP kills is a vital component of brown bear management on the Kenai Peninsula. One can clearly see in Figure 17 that Kenai bears near the road system and near trails are at a high risk of being killed by humans, and it is clear that more bears are being killed in GMU subunit 15C than in other areas of the peninsula. Females with offspring may be at greater risk of being killed in a DLP action than are lone bears because the public perception of a dangerous bear is greatest for a mother with cubs. Any loss of female bears has a negative effect on the sustainability of the Kenai brown bear population and is a critical concern for wildlife managers.

3.1.9 Patterns of Landscape Use by Brown Bears on the Kenai Peninsula

Wildlife biologists are keenly interested in the location, type, and amount of habitat needed to support wildlife populations. The identification of important or critical habitat has classically been accomplished by combining professional judgment with data describing the organisms' general ecology (e.g., home range, food habits). Those areas not identified as important habitat are considered, by default, to be of lesser value to the species, even though the identification procedure (professional judgment) is based on opinion and experience, and not on scientific data. Those areas not considered important habitat generally will be the first made available for consumptive human use (housing developments, logging, mining, etc.), which can irrevocably alter their value to wildlife. The correct identification of habitat and resources important to Kenai Peninsula brown bears is critical to successful peninsula brown bear management, lest incorrect decisions result in the loss of important resources.

The traditional method for identifying and ranking bear habitat relies on accumulating location fixes of the animals (usually via radio-telemetry) and enumerating physical characteristics describing the habitat types in which the bears are found. The intensity with which bears use certain habitat types is measured by the amount of time and the number of visits to those habitat types, and it is assumed that the time spent in a habitat is a direct reflection of the value of that habitat to the animal. However, the length of time an animal spends in a habitat type is not necessarily the best descriptor of that habitat's value to the animal. The geographic landscape of an animal's range is best represented as an integration of habitat characteristics (vegetation type, slope, etc.) and the animal's nutritional and behavioral state. These values combine to produce, for the individual animal, a mosaic of values across the animal's range of use, which will shift with changes in the animal's metabolic requirements and with season. Furthermore, the scale of habitat selection can range from multiple hectares (total summation of area used over time) to daily use microsite that may be less than one hectare in size.

Researchers have developed statistical methods to quantify some of these relationships (Manly et al. 1993), and we can now model the value of animal locations relative to physical characteristics such as land cover, hydrography, human developments, vegetative cover, and other factors. These statistical techniques are referred to as resource-selection procedures, and they enable researchers to make predictions about the potential use of *all* habitats present in the animal's landscape. The procedure does not identify optimum or critical habitat; it only identifies habitats that are used disproportionate to their availability. Critical habitat designation is still very much an indeterminate and shaky science.

Kenai bears use certain habitats more than others, but resource-selection procedures may not indicate if the used habitats are the most productive or the best for the animals. Other factors such as nutritional constraints, reproductive status, and age class must be considered prior to attempting to identify any particular location(s) as "critical" or "important" habitat. Such designation can not be made lightly. The maps (Figure 18 on the fold-out following page 27) presented describe areas with high probability of use, but they may not necessarily define optimal habitat.

Kenai Peninsula female brown bears were equipped with radio telemetry and GPS collars. The latter collected thousands of coordinates identifying locations visited by the bears from den emergence until late fall. Discrete characteristics of the specific location (e.g., land cover type, derived slope, and aspect) and continuous variables (e.g., proximity to anadromous streams and roads) were also collected for each location. The values of the variables describing sites used by bears were compared to values for the same variables at randomly selected sites in the same geographic area. If the values were the same, the bear did not select for any specific habitat characteristics. However, if the values differed significantly, the bears were not randomly choosing which habitats to use. The pattern of selection identified for each bear was pooled by reproductive class and converted to a probability of use for the entire potential habitat on the Kenai Peninsula (Figure 18).

Female bears with COY tended to avoid mountaintops and areas near roads during the early part of the summer (Figure 18C, light shading). They sometimes moved to streams; but, unlike lone females, they also used the landscape between streams extensively (Figure 18C vs. 18A). After salmon arrived, females with COY were less likely to be found at the extreme northern and southern edges of the peninsula (Figure 18D). Lone females during the same period were likely to be closely following salmon along streams (Figure 18B).

These model results closely parallel trends suggested by radio-tracking data. Females with COY can be found on salmon streams, but appear to also heavily use the surrounding landscape. Lone females seem to patrol streams until satiated with fish.

4. Management of Kenai Peninsula Brown bears

4.1 Historical Review

4.1.1 USFWS Wildlife and Habitat Management on the Kenai Peninsula

The Kenai National Wildlife Refuge (KNWR) was established for "the purpose of protecting the natural breeding and feeding range of the giant Kenai moose on the Kenai Peninsula" (Executive Order 9879 by President F.D. Roosevelt, 1941). Its boundaries encompassed 2,058,000 acres, but allowed for human settlement and other public land uses. In May 1964, the refuge size was reduced to 1,730,000 acres as per public land order (PLO # 3400); in 1981, the refuge size was expanded to 2,007,262 acres as a result of the December Alaska National Interest Lands Conservation Act (ANILCA). Currently, the refuge has designated 1,350,000 acres as wilderness and has additional acres under varying status.

The boundaries and land status of the current KNWR have changed numerous times since 1941. At least 18 public land orders, amendments to public land orders, a Secretary (of Interior) Order, and the original 1941 executive order defined and redefined refuge boundaries, withdrew lands for various reasons, and classified lands within the refuge for oil and gas leasing. After December 1980, approximately 67,902 surface acres of the refuge were patented or conveyed to four Alaska Native organizations; within the refuge, 1,507 surface acres were identified as either Native allotments or as private and State of Alaska inholdings. These actions removed from the refuge system forested lowlands having high wildlife value. Today, the refuge no

longer has wildlife-management authority over the surface activities of 48% (33,307 acres) of these conveyed lands and undetermined (ANILCA, Sect. 22g) wildlife management authority over the remaining 52% (36,102 acres).

ANILCA awarded to Cook Inlet Region, Inc.(CIRI), subsurface exploration and development rights to 200,294 acres of KNWR for oil, gas, and coal extraction. If CIRI exercises these rights within the refuge but not on inholdings and conveyed lands, the refuge can establish wildlife protection guidelines for those activities. However, the refuge cannot do so if the exploration and development occur on inholdings and conveyed lands, because the refuge has relinquished its management authority over those parcels. Three federally owned oil lease areas (Swanson River, Beaver Creek, and Birch Hill) are also open to future gas and oil exploration and development (approximately 14,000 subsurface acres of the refuge).

Bears are specifically mentioned in the December 2, 1980, ANILCA legislation that redefined the KNWR. In this legislation, Congress mandated that refuge management goals include . . .

> *(i) to conserve fish and wildlife populations and habitats in their natural diversity including, but not limited to, moose, bears, mountain goats, Dall sheep, wolves and other furbearers, salmonoids [sic] and other fish, waterfowl and other migratory and nonmigratory birds;*

In 1986, USFWS approved the *Kenai National Wildlife Refuge Comprehensive Conservation Plan and Wilderness Review* (KCCP). This document estimated the refuge had a population of 130 brown bears (KCCP 161: Table 28) and stated that most fish and wildlife populations [on the refuge] would be managed to preserve naturally determined genetic traits, social structure, and species diversity (KCCP 128). During the early 1980s, refuge staff voiced concerns regarding the future of brown bears on the refuge and was instrumental in the formation of the Interagency Brown Bear Study Team in 1984. The refuge participated in the first research investigation of brown bear ecology on the KNWR and Kenai Peninsula (Jacobs 1989). Since 1994, USFWS and the KNWR have been significant collaborators on additional research and have provided funds for helicopter and fixed-wing aircraft, for the purchase of radio telemetry and other equipment, and to support a graduate student. In addition, the KNWR has provided wildlife biologists, pilots, aircraft, and computer facilities to obtain and analyze biological data on Kenai Peninsula brown bears.

Refuge boundaries encompass a significant fraction of Kenai Peninsula brown bear habitat, which means that the population health of peninsula brown bears will always be a critical refuge management issue. Public use is a mandated purpose of the refuge, and staff are directed to provide opportunities for fish- and wildlife-oriented recreation. Inevitably, conflicts arise between an increasing number of refuge users and brown bears. People camp in areas traditionally used by resting, feeding, and traveling bears, and sometimes compete with brown bears for fishing sites and streamside trails. Human displacement of brown bears from previously undisturbed areas and the number of human-bear encounters increase as the human population on the Kenai Peninsula increases and develops urban environments on lands adjacent to the refuge.

When warranted, the refuge will alter or eliminate expansion of refuge recreational opportunities to reduce human-bear conflicts. In the near future, recreational activities such as sport fishing, camping, hiking, and black-bear baiting may need to be reviewed and regulated in ways that reduce human-bear interactions on the refuge. These actions may be necessary to reduce the number of DLP kills of brown bears, which can be a significant portion of human-caused mortality of Kenai brown bears.

Gas and oil development and future exploration on a significant portion of the refuge lowlands are other important brown bear management issues facing the refuge. Winter exploration can displace brown bears from dens. The gas and oil industry on the refuge needs to build drill pads and construct roads and pipeline corridors. Powerline and utility corridors, unrelated to the gas and oil industry, are proposed for other areas of the refuge. Development increases human access to brown bear habitat can displace brown bears, fragment and decrease the quality of brown bear habitat, and lead to higher numbers of human-brown bear conflicts. The cumulative impacts of habitat loss (i.e., from roads, from other human infrastructures), habitat fragmentation, habitat degradation, and increased human access are threats to managing for a stable, viable population of brown bears on the refuge.

The KNWR is mandated to maintain and enhance a healthy brown bear population. The refuge provides the largest continuous, homogenous block of brown bear habitat on the Kenai Peninsula and is the only Kenai Peninsula land unit specifically mandated by Congress to conserve bear populations and habitat in their natural diversity. In the future, as development and urbanization outside the refuge boundaries continue to eliminate and decrease the quality of brown bear habitat elsewhere on the peninsula, refuge management decisions will become even more important and critical to conservation of Kenai Peninsula brown bears.

4.1.2 USFS Wildlife and Habitat Management on the Kenai Peninsula

The Chugach National Forest encompasses 5.45 million acres of southcentral Alaska, which makes it second largest in the National Forest System. Its boundaries include mountains, wetlands, the Copper River delta, and more than 1.6 million acres of rock and ice. The Chugach National Forest extends into Prince William Sound and south of Anchorage onto the Kenai Peninsula, where brown bear conservation is of paramount importance in USFS management policies.

An extensive array of legal opinions and orders direct USFS’s management actions (e.g., Organic Administration Act, Multiple-Use/Sustained-Yield Act, Forest Land Management Act, Sikes Act, ANILCA, and general USDA policy). The Chugach National Forest acknowledges state jurisdiction over issues related to fish and wildlife, although it is clear that forest habitat management actions affect fish and wildlife populations, and forest planning decisions will be critical to maintaining healthy wildlife populations. This is especially true for Kenai Peninsula brown bears. USFS directives require the Chugach National Forest to manage fish and wildlife habitat to maintain viable populations of existing native and desired non-native vertebrate species (viable population has been defined as one with sufficient numbers and distribution of reproductive individuals to prevent its extirpation in the planning area). Current (2000) forest plans on the Chugach National Forest call for population viability analysis to be conducted on a 100-yr time period.

The Chugach National Forest has selected Kenai Peninsula brown bear as a Management Indicator Species for the next planning cycle (estimated to be 2001–2010). Although brown bears may be found in forest habitats ranging from sea level to alpine, the Kenai Peninsula brown bear population may be a small, isolated population subject to significant human impacts (Suring et al. 1998). The USFS officially considers this population to be stable, but no studies have tested this assumption, and, as mentioned previously, the population estimate is based only on professional judgment. The Chugach National Forest staff recognizes that the Kenai Peninsula brown bear population fits the criteria of "threatened," as applied in the lower 48 states, largely because of the small estimated population size and possible geographic isolation because only a narrow strip of land connects the peninsula to the mainland. If movements of brown bears through this strip become restricted, it may be sufficient to isolate the Kenai Peninsula population.

The Chugach National Forest is completing a management plan that will provide guidance for the next 10 to 15 yr. Highlights that will affect Kenai Peninsula brown bears are synthesized as follows. The Chugach National Forest will

- provide areas of cover that are approximately 750 ft from both sides of select anadromous streams for brown bear use; within this 750-ft management zone, new roads and trails will not be allowed unless they are crossing the zone at right angles
- require prompt removal of garbage from all facilities, camps, or sites to prevent habituation of bears, and will mandate the use of bear-proof <most biologists say there are no such thing; they prefer "bear-resistant">containers or other methods to make food unavailable to bears
- recommend a minimum one-mile separation between areas of high bear density and locations of concentrated human activities
- institute management actions to minimize bear-human interactions <or conflicts?>
- institute visitor education programs emphasizing methods to minimize human-bear conflicts
- provide training and signage where needed to emphasize bear awareness and bear safety

4.1.3 Alaska Department of Fish & Game Wildlife and Habitat Management on the Kenai Peninsula

Brown bears first became a regulated game animal in Alaska in 1902 (Del Frate 1995) and harvest and bag limits have fluctuated over the years. By 1956, the allowable personal harvest on the Kenai Peninsula was one bear per year, with cubs and sows with cubs protected. Hunting seasons have ranged from 20 to 45 days and have been held in both spring and fall. Currently (2000–2001), the hunting season is held in the fall (October 15–31), and the allowable harvest is one bear every four years. Cubs and sows with cubs are protected.

ADF&G management personnel have set a population objective of maintaining 250 brown bears on the Kenai Peninsula. This population should be capable of sustaining a total annual harvest of 15 bears, of which no more than six may be

female (Del Frate 1995). A mandatory program requires hunters to present all bears killed for data collection, which enables biologists to determine distribution and sex-age composition of harvested bears.

ADF&G biologists have expressed concern that increasing trends in nonhunting-related brown bear mortality will continue as road construction to support proposed logging sales proceeds. This increased access may jeopardize the long-term health of Kenai Peninsula brown bears through increased number of bears killed in bear-human interactions and in increased habitat fragmentation (Del Frate 1995).

4.1.4 Kenai Fjords National Park Wildlife and Habitat Management on the Kenai Peninsula

Brown bears are known to inhabit only a small portion of what is now Kenai Fjords National Park, although unvalidated sightings have been reported in several other areas. Historical records indicate that brown bears have been long-time residents of the Resurrection River valley and the northern tip of the park, but there is no mention of brown bears along the coast. The earliest documentation of brown bears on the coast of the park was in 1987, when a pilot reported a sighting near Addison Lake in the Aialik Bay area (no other sightings have been reported in that area). Brown bears have begun appearing in the Beauty Bay area near the mouth of the Nuka River since 1996, with several confirmed sightings; in 1998 a positive sighting occurred at the head of James Lagoon on McCarty Fjord. Some recreational boaters have reported sightings in Black and Thunder bays on the outer coast of the park, but these sightings have never been confirmed, and no sightings have been reported on nearby Delight and Desire creeks (which support commercial salmon runs of sockeye salmon).

Because of the small amount of brown bear habitat that exists within the park, NPS management regarding brown bears has been limited to documenting casual observations. Brown bears are a growing concern regarding people management in the increasingly visited Exit Glacier area. In addition, brown bears appear to be slowly expanding their range along the coast from Beauty Bay, making them susceptible to subsistence and sport hunting on recently conveyed Native village corporation lands in that area.

5. Management Concerns and Research Directions for Kenai Peninsula Brown Bears

5.1 Population Parameters

5.1.1 Bear Movements and Landscape Use; Bears, Salmon, and Human Disturbances

Threats exist to the Kenai Peninsula brown bear population; continuing research will be needed to determine if a stable, viable population currently exists on the peninsula and, if so, what measures will be needed to ensure its survival. If the population is determined to not be viable, it may be candidate for federal protection. Research is needed to determine the current size and status of the population and to identify measures necessary to maintain viability in the presence of all types of human use.

Not all the threats arise directly from human causes; in all instances, however, human influence is a large measure of the problem. The IBBST has a deep concern for the health of the brown bear population, including its stability and size and effects from human-caused mortality. The bear's use of the landscape and of peninsula resources will be affected by the landscape change brought about by spruce bark beetle kill, and intensive logging activity and alteration of habitat productivity post-logging may precipitate an increase in DLP-related bear deaths. Conflicts over allocations for commercial and sport fisheries and for bears and wildlife will arise in the future, as will issues regarding possible disturbance effect(s) from nonconsumptive uses of wildlife, such as bear viewing. The research directions summarized in the following sections of this assessment encapsulate the most critical issues related to Kenai Peninsula brown bears. Improving our understanding in these areas is a critical step toward developing sound, scientifically based management of Kenai Peninsula brown bears.

5.1.2 Size

The current population estimate is no longer adequate for today's conservation needs for the Kenai Peninsula brown bear. Assessment of population status now requires a statistically rigorous population count. Aerial-based counting methods have been the standard for censusing bear populations for many years; unfortunately, the topography and vegetation of the Kenai Peninsula prevent the use these techniques for Kenai brown bears.

Newer methodologies, however, are being tested, and the IBBST has been adapting a technique using DNA-based identification methodologies for deriving an estimate of the Kenai brown bear population. The first phase of this project began in Spring 2000 and will enable the IBBST to calculate a preliminary estimate of the effective population size (N_e) of the Kenai brown bear population (USFWS 1986) using blood samples collected from Kenai bears over the years. The completion date for an N_e estimate is the winter of 2002. Although the N_e estimate can be conducted at this time, sound management will eventually require a population estimate based on count data. Depending on funding, the IBBST will begin determining a population estimate based on mark-recapture (MR) protocols utilizing a stratified sampling design. The IBBST has contracted statistical consulting to develop a sampling protocol for modifying traditional MR designs. Field work for the second phase will begin in the summer of 2002 (pending funding) and continue for two years (ending in the fall of 2004, with possible extension to 2005). The goal of the MR project is to provide an accurate and precise estimate of the size of the Kenai Peninsula brown bear population and to produce an estimate that is scientifically credible and held to the highest statistical standards (Boulanger et al. 2001; Mowat and Strobeck 2000).

5.1.3 Genetics

A key question is the degree of genetic similarity among Kenai Peninsula brown bears and the degree of genetic similarity between peninsula bears and mainland brown bears. There may be barriers to gene flow on the peninsula (e.g., Tustumena and Skilak lakes, the Harding Icefield) as well as from the mainland to the peninsula that could result in localized inbred populations of brown bears. The IBBST is

exploring these questions of regional heterozygosity as part of the laboratory work associated with determining effective population size (N_e; see section 5.1.2), and initial results are expected by winter of 2002.

5.1.4 Demographics

Data collected from handling animals over the last four years suggest the population has experienced a decline in the number of bears between 3 yr and 6 yr (Figure 13). This effect could be an artifact of data collection or it might be a temporary reduction in bear numbers that is self-correcting given time (i.e., a weak cohort). Alternatively, the lack of 3- to 6-yr-old bears in the observed population could be demonstrating a real decline in bear numbers resulting from either unknown or cumulative stress on the population and a decline not likely to recover until the stressors are removed. The IBBST shall collect data on litter size, cub production, and survivorship for the bear population through ongoing collaring and radio telemetry work (projected end, 2005). These additional data will provide critical information for managers to determine the appropriate response. Given the dynamic state of the understanding of Kenai Peninsula brown bear population demographics, it would not be prudent to ignore the decline without verifying its cause.

5.1.5 Recruitment and Calculating Sustained Yield

A foundation of wildlife biology is that management practices are applied to populations of animals and not to individual animals in populations. Virtually all management is geared to the population level. However, initial results from IBBST radio-telemetry studies indicate that a small subset of Kenai Peninsula female brown bears is responsible for the majority of recruitment into the brown bear population and that some females have disproportionately high or low effect on population stability. The most effective management approach for the Kenai Peninsula brown bear population might be to focus on a select group of females within the population.

The IBSST is combining information on regional heterozygosity (see section 5.1.3) with tracking studies to develop a map of the peninsula that displays areas from which brown bear population recruitment arises. Preliminary work indicates that there are some regions containing the home ranges of individual bears responsible for the population's recruitment, whereas other areas have bears that generally do not successfully reproduce. It is not clear if the high recruitment from these areas is due to the habitat they contain or to the individual attributes of the bears living there. Until the IBBST analysis of regional heterozygosity and recruitment is complete and has undergone peer-review, we recommend that classical measures of overall population robustness and management, such as sustained yield calculations, be used by managers.

The IBBST recommends that sustained yield be calculated according to Testa's Alaska Department of Fish and Game memorandum (1997). To calculate sustained yield, λ (rate of finite increase) is calculated as described previously except that reported, human-caused mortalities are censored from the calculation of P. Reported, human-caused mortalities include bear deaths due to DLPs, legal harvest, vehicle accidents, and known poachings. Sustained yield is then calculated as

$$\text{Sustained yield} = (\lambda - 1) * N$$

where N is the estimated number of females in the population. Using the current management estimate of population size (277) and assuming a 50:50 sex ratio, annual sustained yield for the Kenai Peninsula brown bear population is 5.4 female bears of any age killed by reported, human-caused mortality. Males are not considered in this method of sustained yield estimation.

This method assumes, however, an equal probability of reproductive success for females of a given age. Demographic data collected on Kenai Peninsula brown bears indicate that recruitment of 2-yr-old bears into the population is not equal among all females. Based on a sample of 43 adult collared females with at least three years' known reproductive history, approximately 90% of the total recruitment into the population has been accomplished by only 51% of the adult females. Fully 37% of the adult females contributed nothing to population recruitment (Figure 19). The geographic distribution of all females, scaled by recruitment into the population, shows that the probability of successfully rearing cubs could be due to either specific areas or specific female bears (Figure 20). The ongoing DNA-based investigations into N_e, genetic heterozygosity, and degree of relatedness among Kenai brown bears will be used to determine if differential recruitment is based on bears or habitats. If individual bears are most important, the current management practice for determining sustained yield is likely inaccurate.

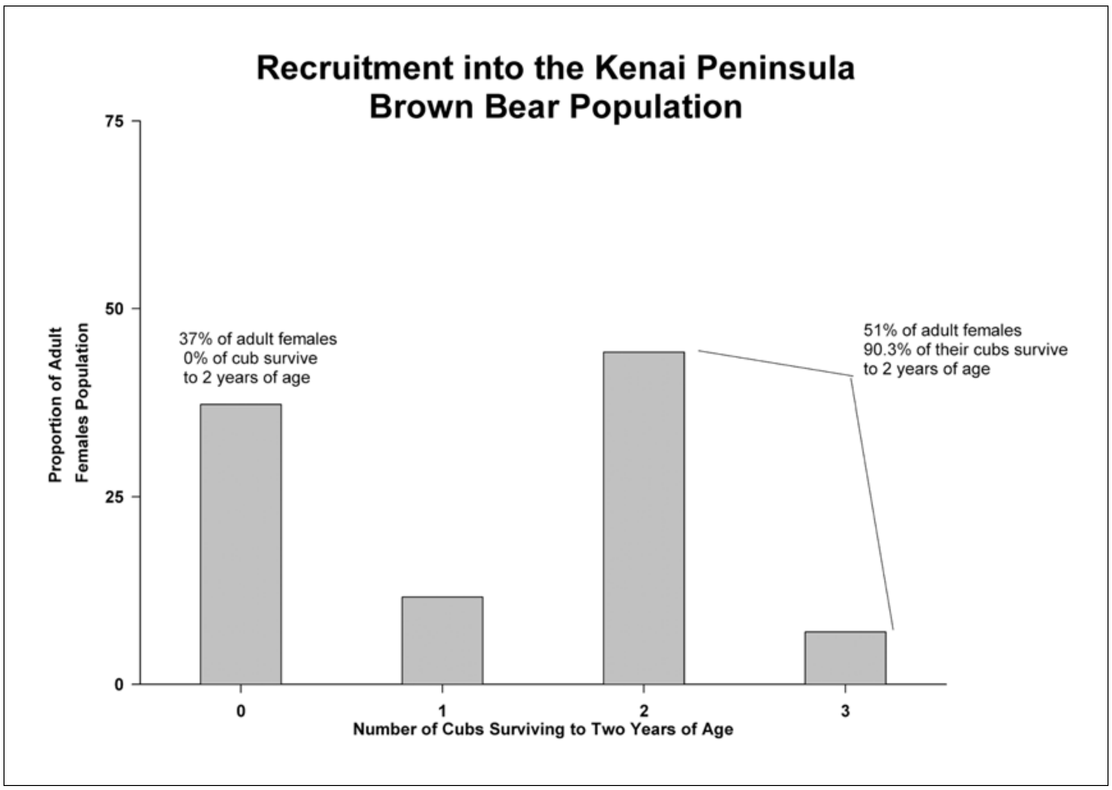

Figure 19. Differential reproductive output by female brown bears

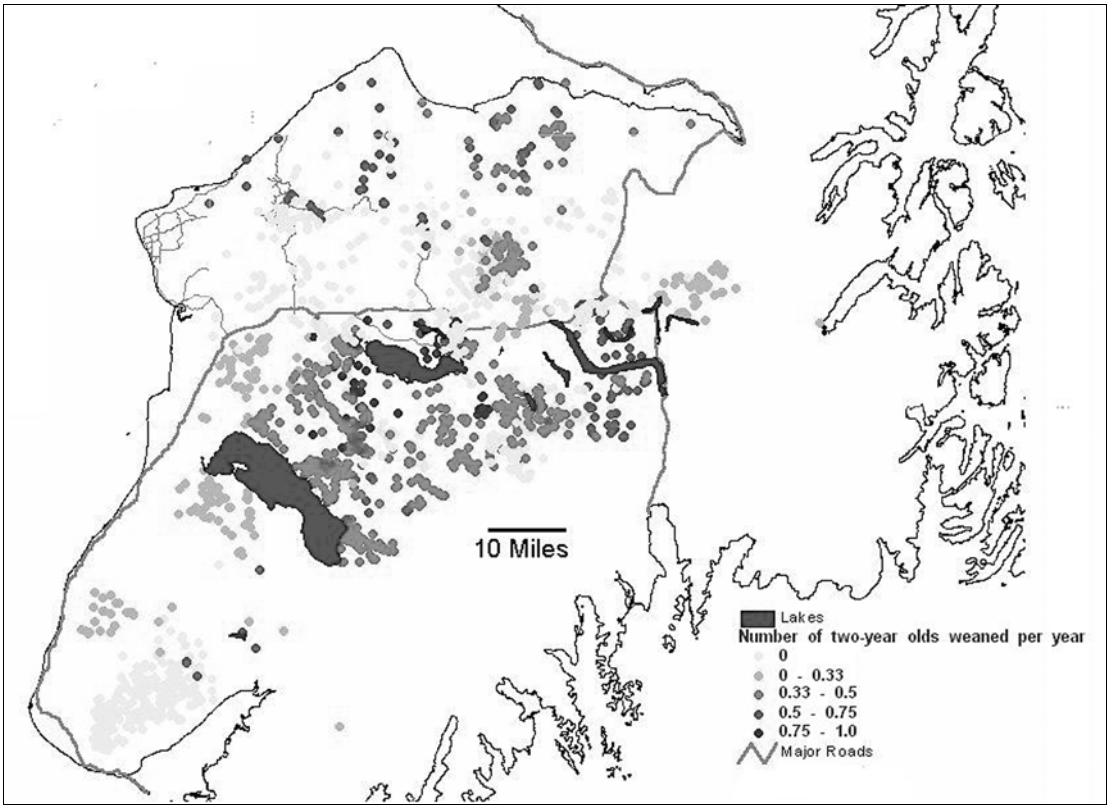

Figure 20. Geographic distribution of reproductive output by brown bears

5.1.6 Defense of Life or Property Mortality

Human-caused mortality of brown bears, through DLP actions, poses a significant hazard to the Kenai Peninsula brown bear population. There is a strong positive correlation between human access to bear country (via roads and trails) and the number of DLP kills (Suring and Del Frate). As logging effort increases across the peninsula, and as trails for hunting opportunities are expanded, it is likely that DLP rates will increase. Some of this increase can be offset by improved bear safety and awareness among peninsula residents, but it must be recognized that some DLP actions will be unavoidable because of bear actions.

5.2 Bear Movements and Landscape Use: Beetle Kill and Riparian Buffers

The kill rate of Kenai Peninsula white spruce from the spruce bark beetle may be as great as 95%, and an ecosystem-scale shift of species guilds is now underway in response to the landscape changes. The effects of this on brown bears are not clear; the tree die-off, however, has brought accelerated logging activity and concomitant increased human access to the back country. While the IBBST would not be surprised if DLP actions rise as a result of increased human access, it is not clear how bear use of the landscape will change. There is no evidence that physical barriers to animal movement exist from downed timber (i.e., jackstrawing).

The standards and guidelines recommended for riparian buffers are *not* based on data of Kenai Peninsula brown bear movements. The IBBST has collected information on bear movements for several years and has most recently radio-collared several bears with GPS collars that report the animal's location every 40 minutes for

several months. It is clear from these data that bears make extensive use of areas as far as several kilometers from stream edge (Figure 8). The effect of narrow riparian buffers on bear conservation efforts is not clear. Additional GPS collars will be placed on bears in future research to expand the dataset of bear landscape use in watersheds, and it may be necessary to increase the width of riparian buffers if their intent is to provide cover and habitat to bears utilizing salmon streams.

5.3 Bears, Salmon, and Human Disturbances

Salmon are a critical food item for Kenai Peninsula brown bears (Hilderbrand et al. 1999b), which makes it imperative that we improve our understanding of the interactions between fish availability, human disturbance, and bears. There are strong correlations between the fall condition of adult females, their reproductive success, and the stability of bear populations (Bunnell and Tait 1981; Craighead et al. 1974; Elowe and Dodge 1989; Rogers 1976; Schwartz and Franzmann 1991; Stringham 1989; Young and Ruff 1982), thus any disturbance that interferes with Kenai bears eating fish will have negative impacts on the population.

Virtually all studies of human disturbance on bears have monitored overt behavioral responses of the animals but have not included experimental manipulations to test hypotheses. Hence, most studies have produced information that is largely anecdotal, and causal relationships between human disturbance and free-ranging bears can only be inferred. This limits the ability to apply study results across various management situations. Although documenting overt behavioral changes is an important first step in disturbance research, more direct measures of individual and population effects can be gathered by determining nutritional and physiological impacts from human disturbance (Hanks 1981). A study that combines behavioral monitoring and the measurement of physiological effects with experimental manipulation has the greatest potential to produce clear, unambiguous information that would be useful in a variety of management scenarios. Such a study conducted on the Kenai Peninsula would be vitally important for effective management of the Kenai brown bear population, as well as for brown bear populations in general.

The absolute need that Kenai brown bears have for salmon dictates that management should consider allocating salmon escapement for brown bears as well as for humans. A critical element of the allocation will be to factor in potential effects of human disturbance on the ability of bears to utilize the salmon. If bear-viewing and sportfishing reduce the effectiveness of fishing bears, more fish will be needed to offset the loss. Thus, it is critical for effective management of the Kenai brown bear population that we learn as much as possible about the relationship among salmon availability, human disturbance, and brown bears.

The KNWR has several locations ideally suited for conducting experimental controlled research on the effects of human activities (i.e., bear-viewing and sportfishing) on brown bears. Pending funding and approval, the IBBST will initiate a study designed to address the following questions:

- What is normal bear behavior at a salmon stream under undisturbed conditions?
- When salmon are available, how do brown bears move through the landscape around salmon streams?
- How many salmon does an individual brown bear need to consume to meet its nutritional demands?
- How does the availability of salmon affect brown bear behavior?
- How does the presence of human visitors affect the behavior, patterns of stream use, and physiological ecology of brown bears feeding on salmon?

This research will include experimental manipulations of human disturbance to areas in which bears feed on salmon. This project will greatly enhance our understanding of the basic biological relationships between brown bears and salmon and will provide needed insight to the potential impacts of human visitation and bear-viewing operations on bear populations.

5.4 Summary

Future research can be directed in a multitude of directions, however, financial and manpower constraints are considerable for bear research. This assessment has highlighted several key areas that lack information critical for effective management of the Kenai Peninsula brown bear population. The IBBST will meet these management needs by focusing its research efforts of the next five years in these areas:

- Determine the effects of fish availability and human disturbance on brown bear ecology
- Conduct a rigorous, scientifically defensible estimate of the size of the Kenai Peninsula brown bear population
- Continue collaring, monitoring, and data analysis activities that identify the cumulative effects of human activities on the bear population
- Continue monitoring activities to determine population recruitment and survivorship and to provide an annual update of all measures of population demographics

No matter how well intended, advocacy and management in the absence of data build a weak foundation for successful bear conservation. Land and resource agencies routinely make decisions with profound implications for the Kenai Peninsula brown bear population; a thorough understanding of the bear's ecology is needed, however, to guarantee those are sound management choices. This conservation assessment presents a review of the research that has improved our ability to wisely manage the population of Kenai brown bears. The assessment also highlights significant knowledge gaps that need to be addressed through additional research. The data presented here, and the proposed IBBST research, will be critical to the long-term successful conservation of the Kenai Peninsula brown bear population.

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