ANALYSIS OF CUMULATIVE EFFECTS ON BROWN BEARS ON THE KENAI PENINSULA, SOUTHCENTRAL ALASKA

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Abstract: The approximately 280 brown bears (*Ursus arctos*) on the Kenai Peninsula, Alaska, are subjected to significant human impacts. A cumulative effects model was developed to evaluate the effects of several human actions on habitat capability for brown bear on the Chugach National Forest portion of the Kenai Peninsula. Changes in habitat quality for brown bears (habitat submodel) and reduced effectiveness of that habitat (human activities submodel) due to disturbance and mortality were evaluated. Habitat effectiveness was estimated to be reduced approximately 70% as a result of current human activities. Application of the model's results during land management planning will play a key role in avoiding future crisis management and in maintaining a viable population of brown bears on the Kenai Peninsula.

***Ursus* 10:107–117**

Key words: Alaska, brown bear, cumulative effects, Kenai Peninsula, *Ursus arctos.*

Brown bears range over most of Alaska and were estimated to number 25,000–39,100 in 1992 (Miller 1993). In some areas, bear populations and their habitat are declining due to direct human-caused mortality and human encroachment. The Kenai Peninsula (KP) has received some of the most significant human impacts in Alaska, to the detriment of some wildlife populations and habitat. The human population increased from 24,600 to 43,600 between 1977 to 1987 (E.E. Bangs et al., Conserving brown bear using limited data, U.S. Dep. Inter. Fish and Wildl. Serv., Soldotna, Alaska, 1990). Logging, mineral and energy development, and water impoundments occur on the KP and modify or destroy habitat for brown bears. Subdivision development, livestock grazing, recreational development, and sport hunting also occur on the KP. These activities lead to an increased likelihood of human–bear conflicts and bear mortality (Craighead et al. 1982, U.S. Fish and Wildl. Serv. 1993).

The brown bear population on the KP was recently estimated to be 140–420 (Miller 1993). The KP is 23,310 km^2, but only approximately 8,800 km^2 are regularly used by brown bears (Jacobs 1989). The KP brown bear population meets the criteria used to classify the grizzly bear in the lower 48 United States as threatened, although its isolation from other populations is uncertain. However, this population may be sufficiently isolated to meet this criterion. The KP is connected to the mainland by a 15-km-wide strip of land between Cook Inlet and Prince William Sound. Movements of brown bears through this strip may be sufficiently restricted by human development and physiographic features to isolate the KP population.

Habitat capability and cumulative effects models for brown bears have been created for other populations and are being used by land and wildlife management agencies (Christensen and Madel 1982, Christensen 1985, Weaver et al. 1986, Young 1986, U.S. Dep. Agric. For. Serv. et al. 1990, Schoen et al. 1994). We developed a cumulative effects model as an analytical tool to evaluate the effects of human actions on brown bear habitat capability on the KP. The interaction of habitat quality, as described by vegetation, food availability, and abiotic factors, and human activities determines the effectiveness of the habitat (Weaver et al. 1986). Our model evaluates changes in quality of habitat for brown bears as a result of habitat modification (habitat submodel) and the reduction in the effectiveness of that habitat as a result of disturbance and mortality (human activities submodel). A model of this type provides a relative index to the capability of habitat to support animals rather than an estimate of actual numbers present. Information used to develop this model was adapted from a similar model developed for Southeast Alaska (Schoen et al. 1994), taken from studies of brown bears in other parts of North America, or gathered during reconnaissance surveys on the KP (Bevins et al. 1985; Risdahl et al. 1986; Schloeder et al. 1987; Jacobs et al. 1988; Jacobs 1989; G.L. Risdahl, Review of brown bear food habits with inferences on the diet of Kenai Peninsula brown bears, U.S. Dep. Agric. For. Ser., Chugach Natl. For., Seward Ranger Dist., Seward, Alas., 1984).

S. Howell and A. Loranger participated in many of the discussions during the development of this model. D. Youkey assisted with the initial literature review for this manuscript. Constructive comments and editorial review were provided by L. Adams, V. Barnes, J. Schoen, N. Warren, and 2 anonymous reviewers.

HABITAT SUBMODEL

This model was designed to be applied on a single- or multiple-watershed (e.g., 10,000–500,000 ha) scale throughout the entire KP, with the exception of the Gulf of Alaska Prince William Sound coastal areas from Whittier to Seldovia. The vegetation in these coastal areas is considerably different from the remainder of the KP and is a different ecosystem. In addition, data are limited on brown bear use of these areas, although brown bear numbers in coastal areas south of Seward are suspected to be low.

Habitat use by brown bears usually varies seasonally in response to food availability (Jacobs 1989, Schoen 1990, Risdahl 1984 unpubl. rep.). To describe these patterns, the habitat submodel contains 6 major land-cover designations: forest, alpine, subalpine, other nonforest, rock and ice, and urban. More specific forest or nonforest designations were not necessary to differentiate the availability or abundance of plant foods that influence distribution of brown bears on the KP. Rather, availability of important foods was influenced more by precipitation and other physiographic parameters.

Riparian areas were assumed to include all habitats influenced by adjacent streams or water bodies (Table 1). Valley bottom landtypes were used to define these riparian areas where they could be mapped from aerial photographs. These landtypes often included small, braided stream channels. Where mapped stream channels did not border these landtypes, a standard riparian width was delineated depending on the channel type (Table 1). Because riparian vegetation was less extensive adjacent to the steep gradient channel types, riparian area width varied with stream gradient. Riparian areas were so limited in subalpine habitats that a standard width criteria was not used in these habitats. The presence of small riparian areas was incorporated in evaluating the over-all importance of the subalpine designation to brown bears.

Because brown bear food habits and resulting patterns of habitat use vary seasonally (Bevins et al. 1985, Risdahl et al. 1986, Schloeder et al. 1987, Jacobs 1989, Risdahl 1984 unpubl. rep.), this submodel was designed to evaluate habitats separately for 2 seasons; spring (den emergence–14 Jun, Table 2) and summer (15 Jun–den entrance, Table 3). Summer is probably the most important of the 2 seasons to brown bears because this is when the most abundant and highest quality food is available (spawning salmon). Summer also is the season with the greatest potential for human–bear conflicts (Albert and Bowyer 1991, Jacobs and Schloeder 1992).

The major land-cover designations were subdivided based on factors influencing brown bear habitat selection during the 2 seasons used in the model to describe habitat units. A habitat capability index (HCI) was assigned to each habitat unit based on the estimated relative value to brown bears during each season in the absence of human activities. Only limited empirical data on habitat use were available for brown bears on the KP. Therefore, HCI values were based on information from field survey efforts, brown bear habitat use information from other areas, and professional judgment by the authors applied through a modified Delphi technique (Crance 1987).

Spring

Food habits of brown bears varied seasonally on the KP (Jacobs 1989). Horsetail (*Equisetum* spp.), skunk cabbage (*Lysichiton americanum*), grasses, and sedges were primary foods in spring and influenced brown bear distribution. These plants were widely distributed across the KP, and first became available in avalanche chutes on south aspects and wetlands (Bevins et al. 1985, Risdahl et al. 1986, Schloeder et al. 1987, Jacobs 1989, Risdahl 1984 unpubl. rep.). Similar spring food habits have been documented for most brown bear populations (Mace 1987). The spring habitat units used in this model mainly differed in the relative abundance of plant forage species preferred by brown bears. Horsetails were common in moist alpine meadows, alluvial fans, small wet meadows, riparian areas, and disturbed sites (Bevins et al. 1985, Risdahl et al. 1986, Schloeder et al. 1987, Jacobs 1989, Risdahl 1984 unpubl. rep.). Skunk cabbage was associated with wet Sitka spruce (*Picea sitchensis*) sites. Sedges were most common in open wet meadows. The majority of these wet sites were included in the following land-cover designations: forest riparian, subalpine, and other nonforest (Table 1). These designations were given high HCI values denoting the abundance of preferred forage species. It was not necessary to consider a nonforest riparian designation because most of the riparian areas on the KP were forested. Where nonforest areas existed near streams they were included in the nonforest other designation. While we recognized the importance of avalanche chutes to bears, it was impractical to map them (existing vegetation maps delineated only large avalanche chutes). The HCI value assigned to the subalpine habitat included

Table 1. Description of variables used in the cumulative effects model for brown bears, Kenai Peninsula Alaska, 1995. Variables within each category are mutually exclusive; 1 variable from each category was used to describe habitat units.

Variable	Description
Land-cover category	
Forest	Land at least 10% stocked with trees.
0–25 yrs of age	
Riparian	Areas ≤150 m of uncontained stream channels or lakes or ≤30 m of contained stream channels (U.S. Dep. Agric. For. Serv. 1992). Also includes valley bottom landforms beyond the 150 m or 30 m buffers (U.S. Dep. Agric. For. Serv. 1980). Not delineated above 450 m elevation.
Not riparian	
>25 yrs of age	
Riparian	Same as above.
Not riparian	
Nonforest	Lands that have never supported forests or lands managed for nonforest uses.
Alpine	Ecological alpine community (lichen tundra).
Subalpine	Shrublands, wet meadows, and grasslands above treeline and below alpine. Generally occurs > 450 m elevation.
Rock–Ice	Rock outcroppings and permanent snow fields.
Urban	Townsites, subdivisions.
Other	Muskegs, bogs, grasslands, and willow (*Salix* spp.) patches below subalpine.
Ungulate category	
Ungulates present	Known moose (*Alces alces*) winter range with densities ≥0.4 moose/km^2. Also includes known or suspected mountain goat (*Oreamnos americanus*), Dall sheep (*Ovis dalli*), and caribou (*Rangifer tarandus*) winter range.
Ungulates not present	Lands not suspected to be used as winter range by Dall sheep, mountain goats, caribou, or moose. Also includes known moose winter range with densities <0.4 moose/km^2.
Salmon spawning category	
High	Known bear fishing areas (Jacobs 1989), mouths of streams entering and leaving lakes used by spawning sockeye salmon (*Oncorhynchus nerka*), and stream channel types (U.S. Dep. Agric. For. Serv. 1992) that were classified as containing at least a moderate amount of spawning habitat for sockeye, coho (*O. kisutch*), king (*O. tshawytscha*), or pink salmon (*O. gorbuscha*) within Alaska Department of Fish and Game designated anadromous habitat.
Low	Alaska Department of Fish and Game designated anadromous habitat not included in the high designation.
None	Anadromous fish not present.
Aspect category	
North	Includes northeast, northwest and north aspects (i.e. 316°–360° and 0°–45°).
Other	Includes west, east, southeast, southwest, south (i.e., 46°–315°), and low elevation, flat (i.e., <5° slope) aspects.

the assumption that avalanche chutes were a major component of this designation.

Moose, caribou, Dall sheep, and mountain goat were also consumed by KP brown bears during the spring (Jacobs 1989). Several others have reported that ungulates were a major portion of the spring diet of bears (Craighead and Craighead 1971; Linderman 1974; Mace 1987; L. Glenn and L. Miller, Seasonal movements of an Alaska Peninsula brown bear population, Alaska Dep. Fish and Game, Anchorage, 1977); while several have reported ungulate use to be opportunistic (Mundy and Flook 1973, Pearson 1975, McCrory and Herrero 1983). The presence of ungulate carcasses can influence brown bear distribution in springtime (Craighead and Mitchell 1982, Servheen 1983). Brown bears readily consume carrion and likely gain weight faster and have higher productivity where this high protein source is available (Mealey 1975, Bunnell et al. 1978). The major land-cover designations in this submodel were further subdivided for the spring evaluation period into ungulate winter range and areas where ungulates were not present during winter to represent the availability of this food source (Table 2). Areas without wintering ungulates were assigned a HCI value that was 40% of the relative value of those areas with wintering ungulates, based on the professional judgment of the authors.

Areas with southern aspects had earlier growth of new vegetation and were more important to foraging brown bears in the spring than areas with northern aspects (Table

Table 2. Index of the capability of habitat units to support brown bears during spring (den emergence–14 Jun) on the Kenai Peninsula, Alaska, 1995.

	Habitat capability index			
	Ungulates present		Ungulates not present	
Land cover	North aspect	Other aspects	North aspects	Other aspects
Forest				
Riparian	0.5	0.9	0.2	0.4
Not riparian	0.5	0.8	0.1	0.3
Nonforest				
Alpine	0.5	0.8	0.1	0.3
Subalpine	0.6	1.0	0.2	0.4
Rock–Ice	0.0	0.0	0.0	0.0
Urban	0.0	0.0	0.0	0.0
Other	0.6	1.0	0.2	0.4

1). Moose, caribou, Dall sheep, and mountain goats also select areas with southern aspects for winter and spring foraging; thus, carcasses may be more abundant in these areas than on northern aspects. As a result, HCI values assigned to habitats with northern aspects were 60% of those with southern aspects, based on the professional judgment of the authors (Table 2).

Table 3. Index of the capability of habitat units to support brown bear during summer (15 Jun–den entrance) on the Kenai Peninsula, Alaska, 1995.

	Habitat capability index		
	Salmon spawning potential		
Land cover	High	Low	None
Forest			
Riparian		0.6[a]	0.4[b]
0–25 yrs	0.6	0.4	0.3
>25 yrs	1.0	0.5	0.3
Not riparian	0.6[c]	0.4[d]	0.3[e]
Nonforest			
Riparian	0.9 (0.6[a])	0.5 (0.4[d])	0.3
Alpine	0.6[c]	0.4[b]	0.3
Subalpine	0.6[c]	0.4[b]	0.3
Rock–Ice	0.1	0.1	0.1
Urban	0.0	0.0	0.0
Other	0.6[c]	0.4[b]	0.3

[a] Applies to riparian areas of low or no salmon spawning potential ≤1.6 km from a riparian area with high salmon spawning potential.
[b] Applies to riparian areas without salmon spawning potential ≤1.6 km from a riparian area with low salmon spawning potential.
[c] Applies to upland habitats ≤1.6 km from riparian areas with high salmon spawning potential.
[d] Applies to upland habitats ≤1.6 km from riparian areas with low salmon spawning potential.
[e] Applies to areas >1.6 km from riparian areas with salmon spawning potential.

The HCI values should be considered to represent the relationships among the various habitats. The highest values were given to habitat units with the largest amount of preferred plant forage, earliest growth of new vegetation, and the greatest abundance of ungulate carcasses. In general, this included areas with southern aspects and wet habitats within defined ungulate winter range (Table 1). The availability of ungulates was considered slightly more important than availability of green forage in assigning the HCI values because of the nutritional advantages of carrion (Schwartz and Franzmann 1991).

Summer

Salmon become an important food source for brown bears during spawning in mid-June. During July through October, 73% (n = 100) of the locations for radiotagged brown bear occurred near salmon streams (Jacobs 1989). Salmon were also consumed during fall on the KP but were augmented with many species of berries: American devil's club (*Oplopanax horridus*), crowberry (*Empetrum nigrum*), salmonberry (*Rubus spectabilis*), highbush cranberry (*Viburnum edule*), blueberries (*Vaccinium* spp.), and lowbush cranberry (*Vaccinium vitis-idaea*). Brown bears continued to congregate near salmon streams later in the season but often moved between the salmon streams and berry patches (Jacobs 1989, Risdahl 1984 unpubl. rep.). Mace (1987) noted that berries, where present, were an important summer and fall food item for brown bears throughout their range.

Habitat selection by brown bears on the KP in the summer was closely related to the presence and abundance of spawning salmon. The major land-cover designations for

summer were used to differentiate riparian areas adjacent to salmon streams. Thus, a riparian designation was included for the nonforest land cover and all nonforest upland land covers were considered as having equal value. Major land-cover designations were subdivided into areas with high, low, or no potential for spawning salmon (Tables 1 and 3). While berries were also important to bears during this period (Schwartz and Franzmann 1991), we were unable to differentiate which habitats provided the greatest foraging opportunities.

Stand age, as it related to the availability of cover, was assumed to be a factor influencing brown bear use of riparian forests, especially in avoiding contact with other bears and humans. Blanchard (1983) documented a majority of bear observations (i.e., 79%) in cover >3 m tall. The availability of cover is most important near salmon spawning areas. Forested riparian areas were subdivided by stand age to represent availability of cover (Table 1). Stands >25 years old were assumed to provide adequate cover for brown bears. Stand age was not considered to be a factor influencing brown bear use of nonriparian forest stands.

Similar to the spring HCI, the numbers assigned to each habitat unit indicate their estimated relative value, rather than a specific value calculated from empirical data. In general, highest HCI values were given to riparian areas with high numbers of spawning salmon and lowest values were given to nonriparian habitats and riparian areas without anadromous fish (Table 3). Areas ≤1.6 km from riparian areas with spawning salmon were considered to be more important to brown bears than areas further away. During salmon runs, brown bears tend to remain near this food source (Schoen and Beier 1987). Forested riparian areas >25 years of age were given a greater value than younger stands because of the security cover associated with the older stands.

Application

Digitized maps of each of the variable categories (Table 1) were combined through geographic information system (GIS) techniques to spatially identify habitat units as defined in Tables 2 and 3. HCI values were assigned to each habitat unit for spring and summer seasons and calculated for the total area of interest as follows:

$$HCI_{mean} = \Sigma HCI_i A_i / \Sigma A_i$$

where HCI_{mean} is the mean habitat capability index for the total area, HCI_i is the habitat capability index for habitat unit *i*, and A_i is the area of habitat unit *i*.

HUMAN ACTIVITIES SUBMODEL

Human impacts on brown bear populations can be either indirect (habitat modification and disturbance), or direct (mortality). Logging, mining, dams, recreational activities, and expansion of communities and road systems usually reduce the quantity and quality of brown bear habitat and brown bear populations (LeFranc et al. 1987). The human activities submodel evaluates the effects of such activities on the effectiveness of brown bear habitat. Although habitat capability may be maintained in proximity to human developments, that habitat may not be used by brown bears because of human activity; thus, its relative effectiveness is low. The habitat reduction factors used in this model indicate a relative magnitude of effects from various human activities and were based on best professional judgment (Table 4). The reduction in habitat effectiveness was evaluated in terms of both disturbance and mortality. Disturbance reduces the time brown bears use an area by displacing brown bears from the area or forcing a change in diurnal use patterns. Intense human activities may displace some brown bears from an area. However, these areas also will have concentrations of garbage, remains of hunting kills, and carcasses of domestic animals that may attract brown bears and increase encounters.

Road construction substantially reduces habitat effectiveness for brown bears. Grizzly bears in Yellowstone National Park avoided areas ≤500 m from roads; foraging also was disrupted ≤2 km from roads (Mattson et al. 1987). Kasworm and Manley (1990) reported an 80% reduction in habitat use by grizzly bears ≤1,000 m from roads open to motorized vehicles in Montana. These investigators also found that mean distance from grizzly bear radiolocations to a road nearly doubled after a closed road was opened to vehicle traffic. Some habitat value may be maintained near roads if traffic and firearms are restricted during resource extraction and roads are closed to all use (including all-terrain vehicles) after resource extraction has been completed. Roads that are closed are considered a non-motorized linear use in this model; associated habitat effectiveness is increased by up to 100% over motorized linear use (Table 4).

The availability of security cover is considered important in how brown bears are influenced by human activities (Archibald 1983, LeFranc et al. 1987). Grizzly bears in Yellowstone National Park used areas ≥500 m from cover significantly more when areas were closed or had restricted human use compared to areas that were open to human use (Gunther 1990). Responses of brown bears in British Columbia to people on foot and to moving ve-

hicles were greater when bears were in the open than in cover (McLellan and Shackleton 1989). Security cover for this model was considered to be all areas with either a forest or shrub overstory. Brown bears were assumed to be at least twice as likely to be displaced from an area where they can see or be seen (Schoen and Beier 1990; Table 4). In addition, human activities were considered to affect brown bears and brown bear use of habitats twice as far from the source of activity in habitats without cover as in habitats with cover.

The reduction factors were applied to 2 zones of influence for each activity in habitats with and without cover (Table 4). The zones of influence and associated reduction factors developed for this model were based on those used in a similar model for Southeast Alaska (Schoen et al. 1994). In this model, the impact associated with the source of the activity (e.g., vehicles on a road, hikers on a trail, people in a campsite) was applied to the first zone of influence. The less severe impact resulting from dispersed activities radiating from the mapped activity source (e.g., hiking or hunting away from a road, off a trail, or from a campground) was applied to the second zone of influence.

Application

The following relationship was used to calculate habitat effectiveness:

$$E_i = (HCI_i\, R_i)\, (R_{i+1})\, R_{i+2} \ldots$$

where E_i is the habitat effectiveness of habitat unit i, HCI_i is the habitat capability index of habitat unit i, and R_{i+n} are the habitat effectiveness reduction factors influencing habitat unit i.

The reduction in habitat effectiveness within overlapping zones of influence is cumulative. For example, a habitat with a HCI of 0.5 (e.g., northern aspect, upland forest, in ungulate winter range, Table 2) would be reduced to 0.2 (0.5 x 0.4) because of a high use road (motorized linear high use, Table 4) within 1.6 km. This would be further reduced to 0.12 (0.2 x 0.6) if a campground was present 3.2 km away (motorized point, Table 4). Human use activities which occur only during the denning period (i.e., Dec, Jan, Feb) did not diminish the effectiveness of habitat because brown bears were not directly subjected to disturbance or mortality factors. Activities of short duration had less effect on habitat effectiveness than activities that occur year round. We represented the relationship between duration of activity and the modification of the habitat effectiveness reduction factor by the following formula:

$$R' = R^P$$

where R and R' are the original and modified habitat effectiveness reduction factors, respectively, and P is the proportion of the activity period. Habitat effectiveness for the total area of interest (E_{mean}) was calculated as follows:

Table 4. Brown bear habitat effectiveness reduction factors within zones of human activity for cover and non-cover areas on the Kenai Peninsula, Alaska, excluding denning period (Dec–Feb), 1995.

	Habitat effectiveness index			
	Cover		Non-cover	
	Zone of influence		Zone of influence	
Activity group	0–1.6 km	1.6–3.2 km	0–3.2 km	3.2–6.4 km
Urban areas, towns	0.1	0.2	0.0	0.2
Motorized				
Linear high use	0.4	0.8	0.2	0.3
Linear low use	0.6	1.0	0.3	0.5
Point	0.3	0.6	0.1	0.2
Non-motorized				
Linear high use	0.8	1.0	0.4	0.6
Linear low use	0.9	1.0	0.5	0.7
Point	0.7	0.6	0.1	0.2
Hunting camp	0.3	0.6	0.1	0.2
Grazing (domestic)	0.9	1.0	0.5	0.7

$$E_{mean} = \Sigma E_i A_i / \Sigma A_i$$

where E_i and A_i are the effectiveness value and area, respectively, of habitat unit *i*.

SENSITIVITY ANALYSIS

We conducted a sensitivity analysis to assess the responsiveness of the model to changes in the values of the habitat variables. Each of the variables in the model was modified during separate runs of the model on a pilot test area while all other variables were held constant. Values associated with lowest and highest habitat capability were used as the modifications for each variable. The resulting estimates of habitat capability from each run of the model were recorded and the percent change was determined (Table 5). During spring, without considering human disturbance, ungulate winter range was the dominant variable, followed by aspect, and then cover type (Table 5). These results represented the importance of carrion availability and forage in areas where new growth appeared first in the spring. Riparian habitat made a minor contribution to the definition of habitat capability. Riparian buffers did not affect definition of spring habitat. When human disturbance was considered, cover type made a significant contribution to habitat capability

During summer, without considering human disturbance, riparian habitat and riparian buffers were the only significant attributes. This indicated the importance of anadromous fish on the summer distribution of brown bear. When human disturbance was considered, cover type again provided a significant influence on habitat capability. For both seasons, these results indicate the magnitude of difference in habitat capability assigned to each variable.

CUMULATIVE EFFECTS ANALYSIS

This cumulative effects model was applied to an area of nearly 500,000 ha managed by the Chugach National Forest on the northeast portion of the KP. The topography of this area consisted of rounded to jagged mountains separated by valleys shaped by alpine glaciers. Elevations ranged from 30–1800 m. The climate was wet and transitional between marine and arctic-continental with mild to cool summers and cool winters. Conifer forests in the area included white spruce (*Picea glauca*), Lutz spruce (*P. glauca* x *P. sitchensis*), mountain hemlock (*Tsuga mertensiana*), and black spruce (*P. mariana*). Mountain hemlock occured primarily on sideslopes at low to mid elevations while the spruces dominated on both valley bottoms and side slopes. Paper birch (*Betula papyrifera*) was a major component of mixed conifer-deciduous forests. Deciduous forests of black cottonwood (*Populus trichocarpa*) and willow were normally found in the valley bottoms. Understory species common within the forests included bluejoint reedgrass (*Calamagrostis canadensis*), rusty menziesai (*Menziesia ferruginea*), early blueberry (*Vaccinium ovalifolium*), devil's club, lowbush cranberry, and crowberry. Alpine vegetation was dominated by species such as crowberry, bog blueberry (*V. uliginosum*), bluejoint reedgrass, and rough fescue (*Festuca altaica*). Application of the habitat portion of the cumulative effects model on this area produced an overall HCI of 0.38 for the spring season and 0.43 for the summer season (Table 6).

Human activities and facilities evaluated in the disturbance portion of the cumulative effects model included 25 active mining operations, 26 recreation sites accessible by motorized vehicles, 88 recreation sites accessible by trails, 519 km of recreation trails, 443 km of open roads, and 230 ha occupied by 44 residential areas or townsites. The effects of these types of disturbance were analyzed separately to demonstrate how they individually influenced habitat effectiveness. Individual reductions of habitat effectiveness ranged from 16–39% during spring and from 12–40% during summer (Fig. 1). Simultaneous analysis of all known human activities resulted in a total cumulative reduction in habitat effectiveness of 71% for spring and 72% for summer. In both seasons, the area of habitat classified as high or very high habitat effectiveness was reduced to minimal amounts as a result of disturbance factors (Fig. 2). The largest reduction in habitat effectiveness in both spring and summer resulted from the reclassification of habitat effectiveness from moderate to low (Fig. 2).

MANAGEMENT IMPLICATIONS

This application of the cumulative effects model indicated that past management activities appeared to have significantly reduced habitat effectiveness for brown bears on the KP. The model indicates that habitat effectiveness for brown bears on a large portion of the KP has been reduced by more than 70% as a result of disturbance and mortality associated with human facilities and activities. Developments often were concentrated in high-quality brown bear habitats without consideration of their individual or cumulative effects on brown bears.

To our knowledge, the application of this model represents the first comprehensive assessment of cumulative effects on brown bears in Alaska. The magnitude of the

Table 5. Analysis of the sensitivity of habitat variables included in the cumulative effects models for brown bears on the Kenai Peninsula, Alaska, 1995.

	Mean habitat capability and effectiveness indices											
	Spring						Summer					
	No disturbance			Disturbance			No disturbance			Disturbance		
Variable[a]	High	Low	Change (%)	High	Low	Change (%)	High	Low	Change (%)	High	Low	Change (%)
Riparian habitat	0.43	0.40	7	0.12	0.11	8	0.81	0.32	60	0.24	0.09	63
Riparian buffer	0.41	0.41	0	0.11	0.11	0	0.55	0.30	45	0.16	0.09	44
Cover type	0.53	0.40	25	0.24	0.01	96	0.38	0.38	0	0.18	0.01	94
Aspect	0.49	0.26	47	0.14	0.07	50	0.34	0.34	0	0.10	0.10	0
Ungulate winter range	0.66	0.24	64	0.20	0.07	65	0.34	0.34	0	0.10	0.10	0

[a] Riparian habitat (high = riparian habitat adjacent to streams with high anadromous fish values, low = not riparian habitat).
Riparian buffer (high = buffer adjacent to streams with high anadromous fish values, low = not a riparian habitat buffer).
Cover type (spring: high = subalpine, low = alpine habitats; summer: high = forest >25 yrs, low = forest 0–25 yrs).
Aspect (high = other aspects, low = north aspect).
Ungulate winter range (high = ungulate winter range, low = not ungulate winter range).

estimated loss in habitat effectiveness indicates the high level of risk faced by this population of brown bears. When new developments are planned, they should be located outside habitats important for brown bears to minimize creation of additional risk for these bears. In the absence of complete knowledge of the seasonal distribution of brown bears on the KP, this model may assist in identifying potential brown bear habitats. In cases where

Table 6. Amount and habitat capability index of habitats available to brown bears on the Chugach National Forest, Kenai Peninsula, Alaska, 1995.

	Area		Habitat capability index	
Land cover	ha	%	Spring	Summer
Forest				
0–25 yrs	8,333	1.7	0.59	0.49
>25 yrs	82,859	17.7	0.45	0.54
Nonforest				
Alpine	125,066	25.2	0.24	0.36
Subalpine	56,900	11.4	0.38	0.38
Avalanche chutes	1,822	0.4	0.46	0.49
Grass	22,371	4.5	0.43	0.42
Muskeg	1,560	0.3	0.63	0.54
Other	38,279	7.7	0.51	0.52
Nonhabitat				
Rock–ice	146,001	29.4	0.00	0.00
Water	13,672	2.7	0.00	0.00
Total	496,863	100.0		
Weighted mean			0.38	0.43
Riparian	52,161	10.5		
Nonriparian	444,702	89.5		

development must be located within high-quality habitat, adequate mitigation measures should be implemented (e.g., remove roads) to minimize the effects on brown bears.

This cumulative effects model provides a tool that may assist in making management decisions that will either maintain or improve habitat effectiveness for brown bears on the KP. Other cumulative effects models developed for brown bears tend to require complex data files that are often difficult to develop and maintain (e.g., Yellowstone ecosystem model). The model presented here incorporates the variables thought to be most critical to the welfare of brown bears. This was done to simplify initial mapping and database development to produce a reliable model that could be applied in an area that has had limited resource mapping completed. GIS technology made possible the simultaneous consideration of habitat and disturbance factors in a spatial context. A GIS database that will allow implementation of this model over the entire KP should be assembled so that range-wide effects may be analyzed. This would facilitate coordination of multi-agency management actions that affect brown bears.

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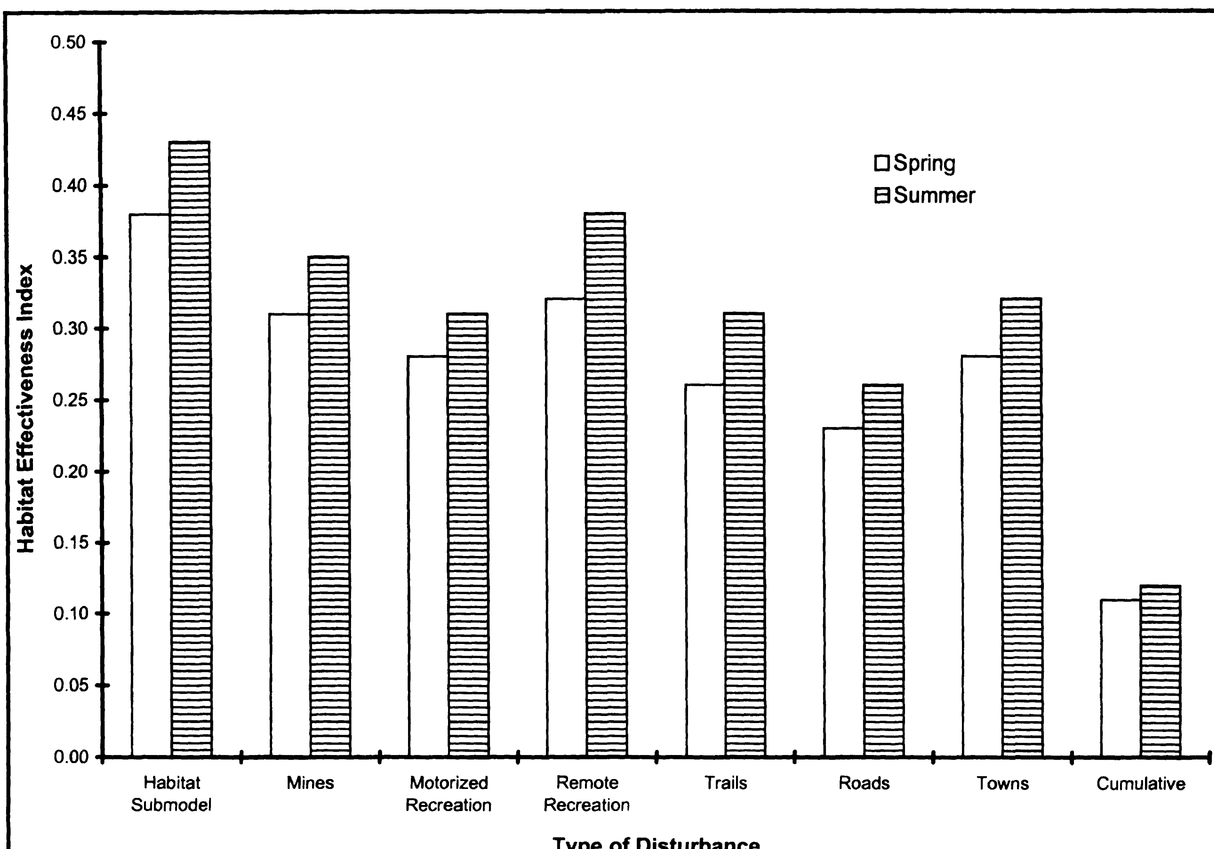

Fig. 1. Habitat effectiveness for brown bears resulting from various types of disturbance on the Kenai Peninsula, Alaska, 1995.

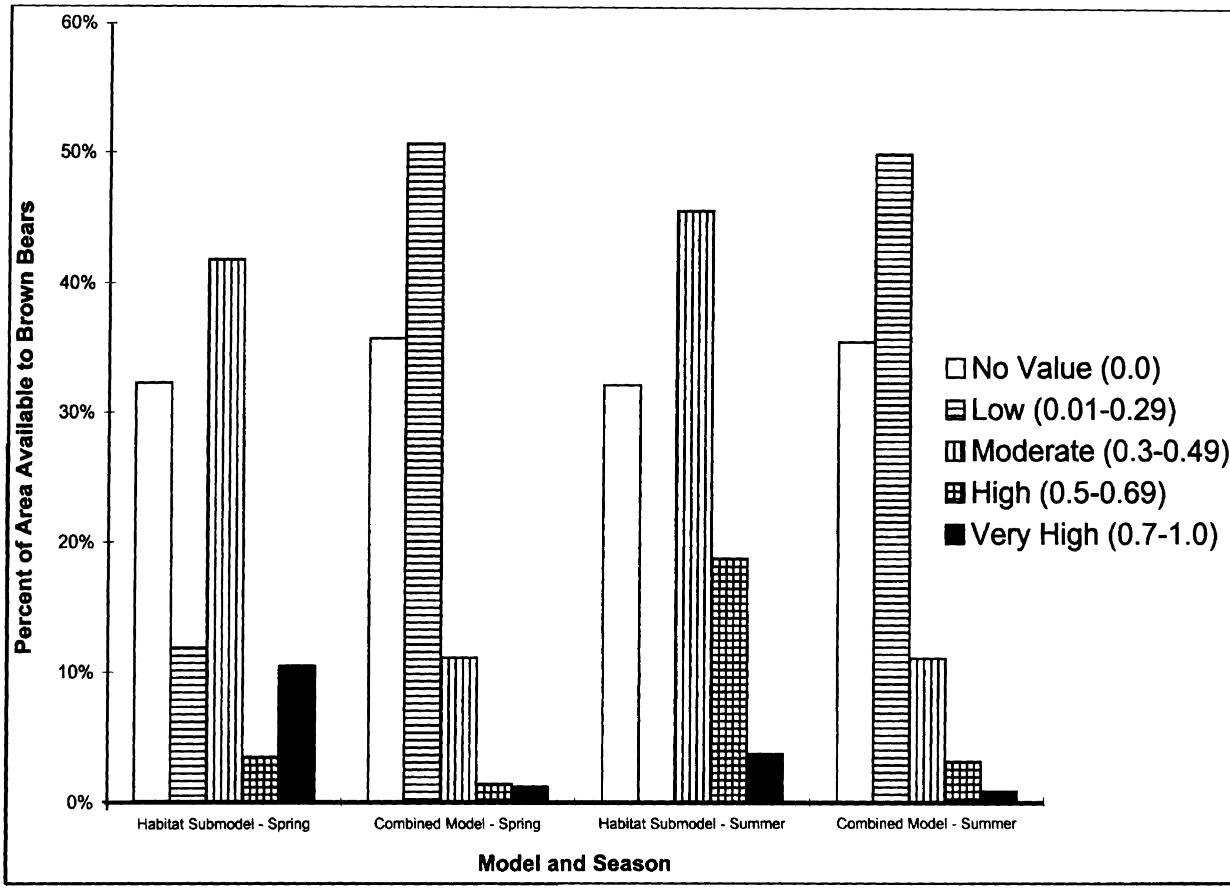

Fig. 2. Percent of area classified by potential habitat effectiveness for brown bears on the Kenai Peninsula, Alaska, according to models with (combined models) and without (habitat models) human disturbance, 1995.

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