SPATIAL ANALYSIS OF LOCATIONS OF BROWN BEARS KILLED IN DEFENSE OF LIFE OR PROPERTY ON THE KENAI PENINSULA, ALASKA, USA

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Abstract: The number of brown bears (*Ursus arctos*) killed in defense of life or property (DLP) on the Kenai Peninsula, Alaska, has been of increasing concern for natural resource managers. During the 1960s, 8 bear deaths were recorded (<1 bear/yr). From 1990 through 1999, 50 bear deaths were recorded (average of 5 bears/yr). This increase concerns natural resource managers because they have very little control over kills resulting from DLP, and the brown bear population may not be maintained if this increasing trend in mortality continues. In an effort to provide information to managers needed to reduce DLP related kills of brown bears, we quantified the relationships among DLP kills, human activities, and landscape characteristics. Most brown bears were killed at residences or by hunters. Brown bears were killed at residences to protect property (i.e., depredation of domestic animals) or because they were perceived to be a threat to humans. Landscape models of the probability of DLP kills of brown bears provided insights to relationships and interactions among kill locations, landscape features, and human developments. As the density of salmon (*Oncorhynchus* spp.) streams, trails, roads, and recreation sites increased, so did the probability of DLP kills of brown bears. Natural resource managers will be able to use this information to guide management of human use patterns and development activities on the Kenai Peninsula to minimize additional DLP kills of brown bears.

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Key words: Alaska, brown bear, defense of life or property, Kenai Peninsula, nonsport mortality, population sinks, *Ursus arctos*

Brown bears on the Kenai Peninsula move extensively throughout the Peninsula and utilize the full resources of the ecosystem to sustain the population (e.g., mountainside den sites, alpine foraging areas in the spring, riparian areas and fish streams in the summer, and upland berry patches in the fall). The Kenai Peninsula is also the site of some of the most significant human development in Alaska (e.g., Bangs et al. 1982), resulting in increasing numbers of encounters between brown bears and humans. The human population on the Kenai Peninsula has grown from just over 9,000 in 1960 to nearly 50,000 in 2000 (Fig. 1; Camp 2001). This has led to an associated increase in the number of brown bears killed in DLP (Fig. 1; Miller and Chihuly 1987, Miller and Tutterrow 1999, G. Del Frate, unpublished data). Annual sustainable harvests of brown bears are related to reproductive output and natural mortality rates on the Kenai Peninsula. Based on management assumptions and information from other areas in Alaska, the density of brown bears on the Kenai Peninsula was estimated to be 20 bears/1,000 km^2 with a population estimate of 250–300 brown bears (Del Frate 1993). The average allowable kill of brown bears on the Kenai Peninsula was estimated to be 5–6 females/year with total harvest not exceeding 14–18 bears (Del Frate

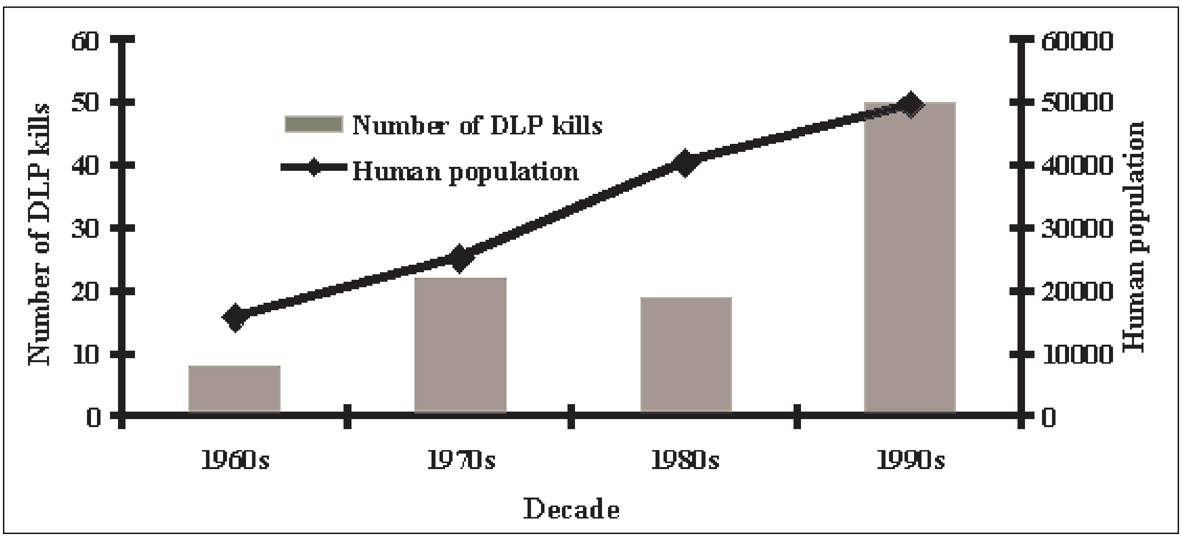

Fig. 1. The human population (Camp 2001) and number of brown bears killed in defense of life or property (DLP) by decade on the Kenai Peninsula, Alaska, USA.

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1993). Closely managing the mortality of brown bears, especially females, in small populations is a primary factor in ensuring their conservation (Mattson et al. 1996). The harvest of brown bears on the Kenai Peninsula recently exceeded estimates of sustained yield, and hunting seasons have been curtailed. In 1992, despite a season reduction in 1989, the total kill peaked at 27 bears from all human caused sources. The Alaska Board of Game (which sets seasons and harvest limits) shortened the season again in fall of 1995. Because harvest quotas continued to be exceeded, the Alaska Department of Fish and Game (ADF&G) closed fall brown bear seasons by emergency order in 1995–98 and the spring season in 1999. Also in 1999 the ADF&G recommended, and the Alaska Board of Game approved, a permanent closure of the spring season to maintain harvests at sustainable levels. Currently, a 17-day fall season remains and human-caused mortality has stabilized within objectives (Del Frate 1999).

Increasing land development and human activity on the Kenai Peninsula has resulted in increased DLP kills and has generated concern about the ability to maintain a viable population of brown bears (Schwartz and Arthur 1997). Recent projects on state and federal lands designed to manage forests infested with spruce bark beetles (*Dendroctonus rufipennis*) were litigated and eventually withdrawn after allegations were made that increased road access and activities associated with proposed timber harvest would result in increased DLP kills of brown bears. To respond to those and other management issues, the Interagency Brown Bear Study Team initiated this study and developed a habitat capability–cumulative effects model to assess ecosystem management options (Suring et al. 1998). Initial applications of the cumulative effects model indicated that large reductions in habitat effectiveness have occurred as a result of past land management activities. Current and planned development activities on the Kenai Peninsula have the potential for increased human encounters with brown bears and increased DLP kills (e.g., Martinka 1982). It has been hypothesized that this population of brown bears is isolated from other populations in the state. These and other factors may decrease population viability of brown bears on the Kenai Peninsula. For these reasons, the ADF&G listed brown bears on the Kenai Peninsula as a species of special concern (Del Frate 1999).

The objectives of this study were to (1) establish and describe relationships between DLP kills of brown bears, landscape features, human activities, and human developments; and (2) predict probability of DLP kills of brown bears based on human activity patterns and mapped variables. Identifying human activities and developments that compromise a viable brown bear population can help refine management standards to minimize that risk. Information resulting from this study will allow land managers to minimize impacts on the brown bear population on the Kenai Peninsula from activities associated with timber harvest, recreation, hard rock mining, energy development, and community expansion. This study complements and expands previous work reported by Miller and Chihuly (1987) and Miller and Tutterrow (1999).

STUDY AREA

The study was conducted within the known range of brown bears on the Kenai Peninsula, Alaska (Del Frate 1993). The 23,310-km^2 Kenai Peninsula is located in south central Alaska between 59°–61° N and 148°–152° W. It lies between Prince William Sound to the east, Cook Inlet to the west, and the Gulf of Alaska to the south (Fig. 2). The Peninsula is connected to the Alaska mainland by a narrow isthmus approximately 18 km wide (Spencer and Hakala 1964, Peterson et al. 1984, Schwartz and Franzmann 1991), which may effectively isolate brown bears on the Kenai Peninsula from other populations. The major physiographic landform on the eastern two-thirds of the peninsula is the rugged, heavily glaciated Kenai Mountain Range, which rises to 2,000 m. The Kenai low-

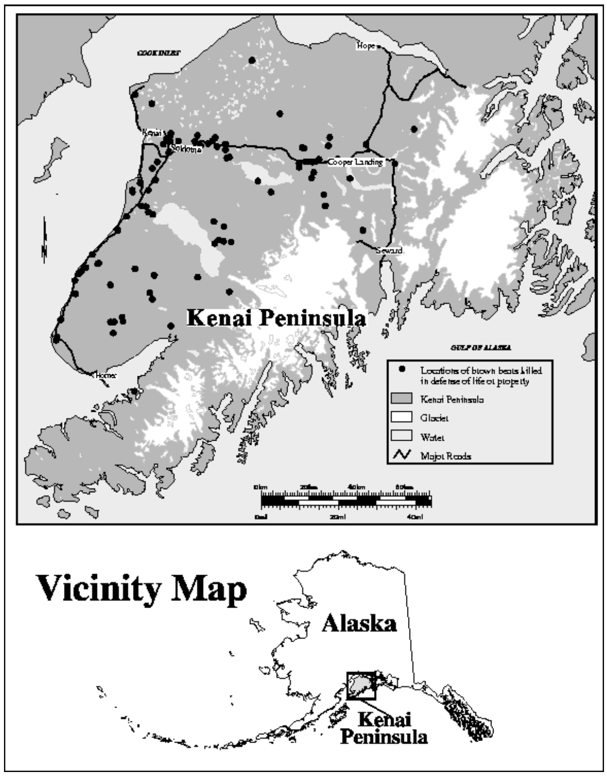

Fig. 2. Approximate locations of brown bears known killed in defense of life or property, 1961–99, on the Kenai Peninsula, Alaska, USA.

lands landform, a glaciated plain with limited relief interspersed with numerous lakes, dominates the western third (Spencer and Hakala 1964). Most stream systems on the Kenai Peninsula support wild runs of salmon (Alaska Department of Fish and Game 1998).

Forests on the Kenai Peninsula lowlands support typical northern boreal forest species, including white spruce (*Picea glauca*), black spruce (*Picea mariana*), black cottonwood (*Populus trichocarpa*), quaking aspen (*Populus tremuloides*), and paper birch (*Betula papyrifera*). Mature forest vegetation on dry upland sites includes white spruce, paper birch, quaking aspen, or some combination of these species; black spruce dominates poorly drained sites (Lutz 1956, Spencer and Hakala 1964); Sitka spruce (*Picea sitchensis*) occurs in wetter, coastal areas. Lutz spruce (*Picea lutzii*), a hybrid of Sitka and white spruce, occurs in forested areas throughout the Kenai Peninsula. Deciduous tree species typically occur in early to mid successional stages following fire. The Kenai Mountains also support coniferous and mixed hardwood forest up to approximately 500 m elevation (Peterson et al. 1984). Mountain hemlock (*Tsuga mertensiana*), mountain alder (*Alnus crispa*), willow (*Salix* spp.), and bluejoint reedgrass (*Calamagrostis canadensis*) occur in the transition zone between forest and alpine tundra. Alpine communities tend to be lichen tundra, dwarf shrub tundra, or a combination of both. Lichen tundra occurs on ridges and mountain tops; dwarf shrub tundra occurs below the lichen zone. Ice fields, glaciers, and snowfields with associated bare rock and scree slopes occur throughout the Kenai Mountains.

METHODS

Information concerning location and circumstances associated with brown bears killed in DLP on the Kenai Peninsula was collected from 1961 through 1999. This information came from questionnaires designed to document such kills by the ADF&G, Alaska Department of Public Safety (i.e., law enforcement) affidavits, and brown bear harvest reports. Information on brown bear harvest has been collected since 1961 when regulations were enacted that required all brown bears killed to be reported to the ADF&G. Prior to 1985, brown bears killed were reported as sport or nonsport kills. Nonsport kills included research kills, road kills, illegal harvests, and kills associated with DLP. During these years anyone who killed a bear in DLP was required to fill out an affidavit describing the circumstances that led to the killing. By comparing all kill reports with DLP affidavits, we were able to exclude all but DLP kills from the database. In 1985 the ADF&G began using a questionnaire to document brown bears killed in DLP. At the same time the Alaska Board of Game required that anyone who killed a brown bear in DLP complete the ADF&G questionnaire. Information concerning brown bear DLP kills from these sources was entered into a database for synthesis and analysis. It was difficult to fully quantify all information from historical records (i.e., prior to 1985) because many records were incomplete. Also, their purpose was to satisfy a regulatory responsibility by the affected parties. The data used in this study represent only verified reports of DLP kills where a brown bear was salvaged and turned over to the ADF&G. There may be non-reporting bias associated with these data. For example, people that had encounters with brown bears in rural areas that resulted in DLP kills may have been less likely to report them than people that killed brown bears in DLP at residences or in subdivisions. Caution on the further interpretation of these data is warranted.

The DLP questionnaire used as the basis for this analysis was the February 1990 version (Alaska Department of Fish and Game 1990). Questionnaires used before and after February 1990 had essentially the same questions but had some differences in question order and response options. Completed questionnaires were not available for most of the DLP kills prior to 1985, but some pertinent information was usually available in harvest records and affidavits. Location of the kill and the circumstances associated with the kill were the items of most interest to us for this analysis (Table 1).

Every effort was made to identify the exact location of the kill. Locations of kills were reported with varying specificity on either the DLP questionnaire or the harvest record. When possible, the person who shot the brown bear was interviewed by ADF&G personnel to determine specific location of the kill. ADF&G biologists and enforcement officers were also consulted for the best probable location based on their knowledge. In many instances agency personnel could recall the individual's residence or the exact location of the kill.

Locations of DLP kills were mapped on U.S. Geological Survey 1:250,000 quadrangles and digitized into a geographic information system (GIS) database using ArcInfo® software (Environmental Systems Research Institute, Inc., Redlands, California, USA). Each location was mapped to the best of our ability, using the information available to us. Accuracy of each mapped location was qualified by a numerical rating. Exact locations (i.e., at someone's residence) or locations that were known within 0.4 km were rated as class 1. General locations, usually within 0.4 km to 3.2 km, were rated as class 2. Usually these locations were described as a particular hunting camp, river mile, or housing subdivision. Less specific locations were assigned to class 3. These locations were assumed to lie within 3.2–8 km of the mapped

Table 1. Characteristics of defense of life or property (DLP) kills of brown bears, 1961–99, on the Kenai Peninsula, Alaska, USA.

	Brown bears[a]	
Characteristic of DLP kill	No.	(%)
Status of bear		
Alone	53	76
With another adult	4	6
With offspring	10	14
With mother	1	1
With litter mate	2	3
Total	70	100
Human injury		
None	70	99
Minor	1	1
Total	71	100
Why bear was killed		
Immediate threat	40	55
Thought to be dangerous	19	27
Protect property	13	18
Total	72	100
Where bear was killed		
Rural site	50	69
Developed site	22	31
Total	72	100
Person's activity		
Hunting	31	44
Sport fishing	2	3
Hiking	2	3
Timber harvest	1	1
Wildlife research	1	1
At home	26	37
Traveling on road	1	1
Ranching	3	4
Public safety response	3	4
Other	1	1
Total	71	99

[a] Totals vary because some kill records were incomplete.

location based on the information we used. Locations that could only be located within a specific watershed were rated as class 4. The ADF&G classified watersheds as uniform coding units (UCU; i.e., subdivisions of game management units associated with watersheds). That classification system was used in this analysis.

Spatial data files were created in ArcInfo® (Environmental Systems Research Institute, Redmond, California, USA) to represent locations of features of the landscape that may have influenced the distribution of brown bears killed in DLP (Table 2). Separate spatial data files were created for each decade for features with large changes in number or density (e.g., residences, recreation sites) over the time analyzed (i.e., 1961–99). A program was written in ArcMacro Language® to determine the density of landscape features and to create a grid (34.5-m cell size) containing that information. Density of linear features (e.g., streams, roads) was calculated in m/km^2. Density of point features (e.g., residences, recreation sites) was calculated as number/km^2. Digitized points representing locations of DLP kills were buffered at 400, 3,000, and 8,000 m to represent the area of potential error associated with class 1, 2, and 3 locations, respectively. Class 4 locations were analyzed at the watershed level (i.e., UCU). The ZONALMEAN function in ArcInfo® GRID was used to calculate a mean density of the features of interest within each buffer associated with a DLP kill location and in watersheds across the study area. Approximately 1,000 random points were selected across the study area for comparison. Mean densities of features of interest were calculated within 400, 3,000, and 8,000 m buffers around these points to represent the availability of these features across the study area.

Methods similar to those used in resource selection function analysis were used to identify landscape attributes associated with locations of brown bears killed in DLP. These methods statistically compare characteristics of a site and the landscape and measure the likelihood of an event occurring in the presence (or absence) of landscape characteristics (Manly et al. 1993). Discrete choice models were used to estimate these functions for the DLP kill sites because values for 2 explanatory variables (density

Table 2. Sources of spatial data for data files describing landscape characteristics on the Kenai Peninsula, Alaska, USA.

Spatial data file	Source
Roads	USDA[a] Forest Service 1996; Environmental Systems Research Institute 1983; small additional segments were digitized.
Trails	USDA Forest Service 1996; Environmental Systems Research Institute 1983; additional segments were digitized from Alaska Road and Recreation Map (1980, 1991).
Recreation sites	USDA Forest Service 1996; Environmental Systems Research Institute 1983; additional locations were digitized from Alaska Road and Recreation Map (1980, 1991).
Buildings	Kenai Peninsula Borough tax assessment records; global positioning system locations of trespass cabins on the southwest Kenai Peninsula.
All streams with probability for spawning salmon	USDA Forest Service 1996, Environmental Systems Research Institute 1983.
Streams with high probability for spawning salmon	USDA Forest Service 1996, Environmental Systems Research Institute 1983.

[a] U.S. Department of Agriculture

of human structures and recreation sites) changed throughout the study period (McCracken et al. 1998). The resulting models estimated the relative probability that a DLP kill will occur in a resource unit with certain attributes. Models were created for each of 4 scales: 400 m, 3,000 m, 8,000 m, and UCU. The analysis at each scale incorporated DLP kill records with locational accuracy known to be within the distance named in the scale (e.g., analysis of kill locations at the 3,000 m scale included locations used in the 400 m scale analysis).

To model these functions, >1,000 random points in the study area were used to describe characteristics of the landscape. Attributes associated with these data were contrasted to the attributes associated with the locations at which DLP kills took place. The likelihood analysis contained a term for every DLP kill (e.g., 93 for the 8,000 m scale), and for every term the likelihood contained information about the kill point in the numerator and the information about the kill point and all the landscape points in the denominator. The numerator is referred to as the choice and denominator is referred to as the choice set in discrete choice terminology (SAS Institute 2000). The decade in which the DLP kill occurred was incorporated by using the values of the density of human structures and recreation sites from the decade of the DLP kill. We fit the discrete choice model using the multinomial logit distribution. All possible models based on combinations of the 6 covariates were fit for each scale. The Akaike's information criterion (AIC) value was calculated for each of the 63 models and the coefficients for each model for each scale were recorded (Burnham and Anderson 1998). The Akaike weight was calculated for each of the 63 models. The model with the lowest AIC value was assigned the highest weight; other model weights decreased as the AIC value increased. Within each scale, the model with the lowest Akaike weight was selected as the best representation of the relationship of landscape characteristics to location of DLP kills. Importance values were calculated for model variables by summing the weights of every model containing the variable. Weights for all models summed to 1, so the largest possible importance value was 1. Importance values were determined for each covariate to display the relative contribution each variable made to describe the distribution of DLP kills (Burnham and Anderson 1998:141).

RESULTS

The harvest reports, questionnaires, other records, and interviews provided sufficient information to describe the location and circumstances associated with 96 brown bears killed in DLP (Fig. 2). Of the 96 DLP kill locations, 31 were known within 400 m, 77 were known within 3,000 m, 93 were known within 8,000 m, and the UCU was known for all (96) kill locations.

Of the brown bears killed on the Kenai Peninsula in DLP with adequate records, most were alone (76%), while 14% were with their cubs (Table 1). Although 82% of brown bears were killed because they were an immediate threat or thought to be dangerous, only 1 encounter (1.4%) resulted in a minor human injury. In 18% of the cases, brown bears were not considered a threat to humans but were killed to protect property. Nearly 70% were killed in rural sites (i.e., not near a community or developed site). Forty-four percent were killed while the person was hunting; 37% were killed at a primary residence.

Models representing the relationship of landscape characteristics to location of DLP kills included variables describing density of all salmon streams, density of streams with a high potential for spawning salmon, recreation trails, roads, recreation sites, and human residences (Table 3). The sign of the coefficients for each of the variables included in the models indicates the effect of the variable on the probability of a DLP kill occurring. Negative coefficients indicate a decrease in the density of the variable was associated with an increase in the probability of a DLP kill. Likewise, positive coefficients indicate an increase in the density of the variable was associated with an increase in the probability of a DLP kill.

The estimated coefficients for the density of all salmon streams were negative at the 400 m scale (smallest buffer for the most accurate locations of kills) and at the 3,000 m scale (Table 3). At the 8,000 m and UCU scales, the estimated coefficients were positive. Importance values for this variable were moderate to low for the 400, 3,000, and 8,000 m scales and high for the UCU scale (Fig. 3). The estimated coefficients for the density of high potential salmon streams indicated a positive association at all scales except the UCU scale. At the UCU scale, this variable did not have a strong association with the probability of a DLP kill. Importance values increased from the 400 to the 8,000 m scales but decreased at the UCU scale.

The estimated coefficients for the density of trails indicated a positive association between the density and the probability of a kill for all scales (Table 3). This variable was in the best models for the 400, 3,000, and 8,000 m scales. Importance values for density of trails were very high at the 400, 3,000, and 8,000 m scales and moderate at the UCU scale (Fig. 3). The estimated coefficients for the density of roads indicate a positive association between the density and the probability of a kill. This variable was in the top 3 models for all scales and the importance values were very high at all scales.

The estimated coefficients for the density of recreation sites indicate a positive association at all scales except the UCU scale (Table 3). At the UCU scale this variable did

Table 3. Akaike's information criterion (AIC) delta values, Akaike weights, and estimated regression coefficients for the best models for each scale for defense of life or property (DLP) kills of brown bears on the Kenai Peninsula, Alaska, USA, 1961–99. Positive coefficients indicate an increase in the density of the variable was associated with an increase in the probability of a brown bear killed in DLP. Negative coefficients indicate a decrease in the density of the variable was associated with an increase in the probability of a DLP kill.

			Estimated regression coefficients (SE)					
Model scale and rank	AIC value delta	Akaike weight	Density of all salmon streams	Density of high potential salmon streams	Density of trails	Density of roads	Density of recreation sites	Density of human structures
400 m scale models								
1	0.00	0.16	-0.0189	0.0197	0.0052	0.0026	2.9305	
			(0.0172)	(0.0172)	(0.0014)	(0.0005)	(1.6273)	
2	0.60	0.12	-0.0185	0.0197	0.0053	0.0021		0.0990
			(0.0165)	(0.0164)	(0.0014)	(0.0007)		(0.0689)
3	0.63	0.12	-0.0191	0.0206	0.0053	0.0028		
			(0.0166)	(0.0166)	(0.0014)	(0.0004)		
3000 m scale models								
1	0.00	0.32		0.0079	0.0152	0.0046	14.3487	
				(0.0031)	(0.0032)	(0.0006)	(6.9494)	
2	1.77	0.13		0.0098	0.0159	0.0050		
				(0.0029)	(0.0031)	(0.0006)		
3	1.98	0.12	-0.0006	0.0084	0.0153	0.0046	14.1004	
			(0.0037)	(0.0046)	(0.0033)	(0.0006)	(7.1371)	
4	2.00	0.12		0.0079	0.0152	0.0047	14.4498	-0.0070
				(0.0031)	(0.0032)	(0.0010)	(7.2360)	(0.1400)
8000 m scale models								
1	0.00	0.35		0.0305	0.0284	0.0080	42.2526	-0.4258
				(0.0057)	(0.0062)	(0.0016)	(17.8581)	(0.2331)
2	1.39	0.17		0.0296	0.0285	0.0056	25.8709	
				(0.0057)	(0.0060)	(0.0009)	(15.3210)	
3	1.87	0.14	0.0016	0.0288	0.0280	0.0080	45.8443	-0.4365
			(0.0044)	(0.0074)	(0.0062)	(0.0016)	(20.5466)	(0.2343)
4	2.12	0.12		0.0308	0.0297	0.0060		
				(0.0056)	(0.0058)	(0.0008)		
UCU scale models								
1	0.00	0.16	0.0159		0.0081	0.0095		-0.6330
			(0.0032)		(0.0046)	(0.0018)		(0.3799)
2	0.74	0.11	0.0183			0.0091		-0.5769
			(0.0029)			(0.0018)		(0.3830)
3	0.97	0.10	0.0170		0.0072	0.0067		
			(0.0032)		(0.0046)	(0.0009)		

not have a strong association with the probability of a DLP kill. Importance values for density of recreation sites were moderate to high for the 400, 3,000, and 8,000 m scales and low for the UCU scale (Fig. 3). The estimated coefficients for the density of human structures were positive at the 400 m scale and were negative at the 8,000 m and UCU unit scales; importance values were moderate at these scales.

DISCUSSION

The majority of brown bears killed in DLP on the Kenai Peninsula during the last 40 years were in rural areas (i.e., outside incorporated community boundaries) where the person involved was likely to be hunting or at their residence. This implies that as people who possess firearms (for hunting, protection, or both) enter and live in brown bear habitat, the likelihood of brown bears being killed in DLP increases. The spatial analysis of the relationship of DLP kills to landscape characteristics supports that conclusion.

The relationships of the density of all salmon streams and the density of streams with high potential for spawning salmon were evaluated to determine the effect of habitat quality on the likelihood that brown bears would be killed in DLP. Brown bears on the Kenai Peninsula show a high affinity for salmon-bearing streams, particularly during summer and fall (Hilderbrand et al. 1999, L.H. Suring, unpublished data). The density of salmon streams is a key indicator of habitat quality for brown bears. At fine and mid scales (i.e., 400 m and 3,000 m), density of all salmon streams had a negative association with probability of DLP kills, while at larger scales (i.e., 8000 m and UCU) the association switched to positive. Density of streams with a high potential for spawning salmon was included in models at all scales except the largest. At finer scales, brown bears select high potential salmon bearing streams over all salmon streams and are therefore more

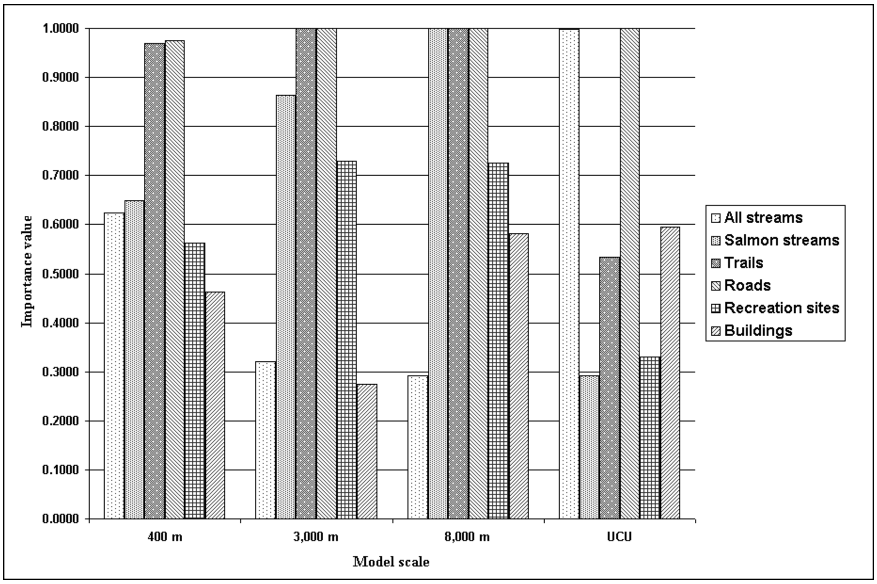

Fig. 3. Importance values for each variable at each model scale for defense of life and property kills of brown bears on the Kenai Peninsula in Alaska, USA, 1961–99. Values are calculated as the sum of the Akaike information criterion weights for each model in which the variable appears.

likely to be present at these locations. At the watershed scale, density of all salmon streams may better define high quality brown bear habitat (i.e., riparian vs. upland areas) rather than high potential salmon streams alone. The presence or absence of salmon streams alone may not predict the relative probability of brown bears being killed in DLP. However, when human activities or developments (e.g., recreation sites) near salmon-bearing streams bring brown bears and humans together, the relative probability of DLP kills increases.

Increasing densities of roads and trails were associated with an increased likelihood that brown bears would be killed in DLP. Importance values for these variables were high across scales. Roads and trails are the primary means for hunters and rural residents to reach their destinations. Roads and trails also facilitate the use of adjacent lands. These landscape features are often located in high quality habitat for brown bears (e.g., near riparian areas; Jacobs and Schloeder 1992). Recreation sites (e.g., campgrounds, cabins) can concentrate use by hunters and other recreationists and allow land managers to direct such use away from high quality brown bear habitats. However, most current recreation sites on the Kenai Peninsula were constructed before killing of brown bears in DLP was a management concern. Consequently, these sites were often located in areas adjacent to streams and lakes that are also heavily used by brown bears. This concentrated use by brown bears and humans, in turn, tends to increase human–bear encounters, which often lead to brown bears killed in DLP (McLellan et al. 1999).

Density of human structures (i.e., buildings) did not enter into models at the finer scales (i.e., 400 and 3,000 m) and was negatively associated with probability of DLP kills at the larger scales (i.e., 8,000 m and UCU). High quality habitats that are near high human densities (i.e., towns and villages) tend to have low levels of use by brown bears (L.H. Suring, unpublished data). The fine-scale analyses were unlikely to include high densities of human structures because brown bears avoided such areas and were less likely to be killed in DLP in these areas. As the scale of the analysis increased, areas with higher densities of buildings were more likely to be included. Again, because brown bears generally avoid areas with high density of human structures, they were not killed in DLP near human structures, resulting in a negative relationship with density of buildings.

MANAGEMENT IMPLICATIONS

The message provided by this analysis is clear. Brown bears tend to be killed in DLP in rural areas by people who have firearms immediately available (i.e., at residences and while hunting). As access to rural areas increases, as indicated by density of roads and trails, the probability that brown bears will be killed in DLP will also increase (Herrero 1985). As the tenuous condition of this population of brown bears increases, it becomes increasingly important to manage mortality within the population. Mortality from hunting can be closely monitored and regulated by the ADF&G; DLP mortalities cannot be directly controlled. The best way to manage DLP kills is to decrease the probability of their occurrence, or at least ensure that the probability does not increase. This can be accomplished by carefully evaluating the risk to brown bears of constructing or upgrading roads, trails, and recreation sites (e.g., Velquist 1989). If development of roads, trails, or recreation sites is planned, their locations should be carefully selected to ensure they do not encroach on areas likely to be used by brown bears (Herrero 1985, Peek et al. 1987, McLellan 1990, Mattson et al. 1996, McLellan et al. 1999). This approach has been successful in reducing brown bear–human encounters in other areas (Mace and Waller 1996). On the Kenai Peninsula, roads, trails, and recreation sites should be constructed as far as possible from salmon streams (Jacobs 1989). Probability of the occurrence of DLP kills may be decreased by closing areas to recreation activity that have a high potential for conflict during the times that brown bears are using these areas. In some cases, relocation of trails may be advantageous. Programs to educate rural residents, hunters, and other recreationists about preventing conflicts with brown bears may also reduce the potential of DLP kills.

Our models may be combined with GIS (geographic information system) technology to map the relative probability of brown bear DLP kills across the landscape. Such maps may be used to identify areas that have the potential to be sinks for this brown bear population with the intent to more closely manage human access in these areas. The models may also be applied to evaluate proposed construction of roads or trails and to graphically represent the potential effects of the increased access on probabilities of DLP kills occuring.

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LITERATURE CITED

ALASKA DEPARTMENT OF FISH AND GAME. 1990. Defense of life or property/non-hunting bear kill reporting form. Form 11-077, Alaska Department of Fish and Game, Anchorage, Alaska, USA.

———. 1998. Catalog of waters important for spawning, rearing or migration of anadromous fishes. Alaska Department of Fish and Game, Juneau, Alaska, USA.

ALASKA ROAD AND RECREATION MAP. 1980. Kenai Peninsula. Southcentral Alaska. Alaska Road and Recreation Maps, Anchorage, Alaska, USA.

———. 1991. Kachemak Bay. Kenai Peninsula, Alaska. Alaska Road and Recreation Maps, Anchorage, Alaska, USA.

BANGS, E.E., T.H. SPRAKER, T.N. BAILEY, AND V.D. BERNS. 1982. Effects of increased human populations on wildlife resources of the Kenai Peninsula, Alaska. Transactions of the North American Wildlife and Natural Resources Conference 47:605–616.

BURNHAM, K.P., AND D.R. ANDERSON. 1998. Model selection and inference: a practical information-theoretic approach. Springer-Verlag, New York, New York, USA.

CAMP, J. 2001. 2000 situations and prospects of the Kenai Peninsula Borough. Kenai Peninsula Borough, Community Economic Development Division, Soldotna, Alaska, USA.

DEL FRATE, G.G. 1993. Units 7 and 15 brown bear. Pages 49–57 *in* S. Abbott, editor. Management report of survey and inventory activities 1 July 1992–30 June 1994. Federal Aid in Wildlife Restoration Project W-23-4 and W-23-5, Study 4.0. Alaska Department of Fish and Game, Juneau, Alaska, USA.

———. 1999. Units 7 and 15 brown bear. Pages 55–65 *in* M. Hicks, editor. Management report of survey and inventory activities 1 July 1996–30 June 1998. Federal Aid in Wildlife Restoration Project W-24-5 and W-27-1, Study 4.0. Alaska Department of Fish and Game, Juneau, Alaska, USA.

ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE, INC. 1983. Alaska land and resource mapping program final report. Volume 2. Data base user's guide. Alaska Department of Natural Resources, Anchorage, Alaska, USA.

HERRERO, S. 1985. Bear attacks—their causes and avoidance. Winchester Press, Piscataway, New Jersey, USA.

HILDERBRAND, G.V., C.C. SCHWARTZ, C.T. ROBBINS, M.E. JACOBY, T.A. HANLEY, S.M. ARTHUR, AND C. SERVHEEN. 1999. The importance of meat, particularly salmon, to body size, population productivity, and conservation of North American brown bears. Canadian Journal of Zoology 77:132–138.

JACOBS, M.J. 1989. An initial population analysis and management strategy for Kenai Peninsula brown bears. Thesis, West Virginia University, Morgantown, West Virginia, USA.

———, AND C.A. SCHLOEDER. 1992. Managing brown bears and wilderness recreation on the Kenai Peninsula, Alaska, USA. Environmental Management 16:249–254.

LUTZ, H.J. 1956. Ecological effects of forest fires in the interior

Alaska. U.S. Department of Agriculture Technical Bulletin 1133.

Mace, R.D., and J.S. Waller. 1996. Grizzly bear distribution and human conflicts in Jewel Basin Hiking Area, Swan Mountains, Montana. Wildlife Society Bulletin 24:461–467.

Manly, B.J.F., L. McDonald, and D. Thomas. 1993. Resource selection by animals: statistical design and analysis for field studies. Chapman and Hall, London, U.K.

Martinka, C.J. 1982. Rationale and options for management of grizzly bears in sanctuaries. Transactions of the North American Wildlife and Natural Resources Conference 47:470–475.

Mattson, D.J., S. Herrero, R.G. Wright, and C.M. Pease. 1996. Science and management of Rocky Mountain grizzly bears. Conservation Biology 10:1013–1025.

McCracken, M.L., B.F.J. Manley, and M. Vander Heyden. 1998. The use of discrete-choice models for evaluating resource selection. Journal of Agricultural, Biological, and Environmental Statistics 3:268–279.

McLellan, B.N. 1990. Relationships between human industrial activity and grizzly bears. International Conference on Bear Research and Management 8:57–64.

———, F.W. Hovey, R.D. Mace, J.G. Woods, D.W. Carney, M.L. Gibeau, W.L. Wakkinen, W.F. Kasworm. 1999. Rates and causes of grizzly bear mortality in the interior mountains of British Columbia, Alberta, Montana, Washington, and Idaho. Journal of Wildlife Management 63:911–920.

Miller, S.D., and M.A. Chihuly. 1987. Characteristics of nonsport brown bear deaths in Alaska. International Conference on Bear Research and Management 7:51–58.

———, and V.L. Tutterrow. 1999. Characteristics of nonsport mortalities to brown and black bears and human injuries from bears in Alaska. Ursus 11:239–252.

Peek, J.M., M.R. Pelton, H.D. Picton, J.W. Schoen, and P. Zager. 1987. Grizzly bear conservation and management: a review. Wildlife Society Bulletin 15:160–169.

Peterson, R.O., J.D. Woolington, and T.N. Bailey. 1984. Wolves of the Kenai Peninsula. Wildlife Monographs 88.

SAS Institute, Inc. 2000. Multinomial logit, discrete choice modeling: an introduction to designing choice experiments, and collecting, processing, and analyzing choice data with the SAS system. SAS Technical Report TS-621.

Schwartz, C.C., and S.A. Arthur. 1997. Cumulative effects model verification, sustained yield estimation, and population viability management of the Kenai Peninsula, Alaska brown bear. Federal Aid in Wildlife Restoration Study 4.27. Alaska Department of Fish and Game, Juneau, Alaska, USA.

———, and A.W. Franzmann. 1991. Interrelationship of black bears to moose and forest succession in the northern coniferous forest. Wildlife Monographs 113.

Spencer, D.L., and J.L. Hakala. 1964. Moose and fire on the Kenai. Tall Timbers Fire Ecology Conference 3:11–33.

Suring, L.H., K.R. Barber, C.C. Schwartz, T.N. Bailey, W.C. Shuster, and M.D. Tetreau. 1998. Analysis of cumulative effects on brown bears on the Kenai Peninsula, southcentral Alaska. Ursus 10:107–117.

U.S. Department of Agriculture Forest Service. 1996. Resource information management data dictionary. U.S. Department of Agriculture Forest Service, Chugach National Forest. Anchorage, Alaska, USA.

Velquist, G.W. 1989. Management of beach camping to reduce human–bear conflicts in Glacier Bay, Alaska. Pages 129–231 *in* M. Bromley, editor. Bear–people conflicts: proceedings of a symposium on management strategies. Northwest Territories Department of Renewable Resources, Yellowknife, Northwest Territories, Canada.

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