Bears and humans: How Canadian park managers are dealing with grizzly bear populations in a northern landscape

By Ramona Maraj

Abstract
This study investigated the effects of human land use on grizzly bear (*Ursus arctos* L.) habitat and populations in the Kluane region of southwestern Yukon, Canada. Previous studies in the region identify grizzlies as the species most at risk from cumulative impacts of human activity. The goals of this project were to identify the effects of cumulative human activities on grizzly habitat and populations, and to provide recommendations on human-use management with respect to the conservation of grizzlies and their habitat. To examine the influence habitat and mortality had on grizzly bear productivity and survival, I compared the explanatory power of empirical habitat models based on grizzly bear telemetry relocations or forage availability against expert-opinion models. Empirical habitat models were best for explaining reproductive and survival rates to predict population status for grizzly bears in Kluane. Survival and productivity of grizzly bears decreased on the periphery of the protected area adjacent to highways. While productivity in the areas adjacent to highways was relatively high, mortality was also high. These areas, therefore, were acting like attractive sinks. Reducing human-caused mortality on the park periphery and developing a transboundary management strategy will be necessary to conserve grizzly bears in Kluane.

Key words: cumulative impacts, expert opinion, grizzly bear, Kluane, park, resource selection, source-sink dynamics, transboundary management

The grizzly bear's perspective: No national park is an island

GRIZZLY BEARS (*URSUS ARCTOS* L.) HAVE AN ECOLOGICAL role that makes them useful focal species for evaluating the effectiveness of protected areas (Gibeau et al. 1996; Noss et al. 1996; Paquet et al. 1996). Landscapes that sustain viable populations of grizzly bears are often ones where natural vegetation predominates, where native species are still found, and where historical ecological processes still operate (Noss et al. 1996; Carroll et al. 2001). As an apex predator, grizzly bears are one of the first species to be lost from an area as a result of land development (Noss et al. 1996; Woodroffe 2000). Grizzly bears are particularly sensitive to the impacts of human activities because generally they have relatively few young, range over large areas, and occur at low population densities (Gibeau et al. 1996; Mattson et al. 1996b; Paquet et al. 1996; Russell et al. 1998; Purvis et al. 2000). Consequently, grizzly bears have been considered indicators of the health or integrity of an ecosystem. They are also prone to direct conflict with people. The combination of these biological traits interacting with people's affinity to develop and use grizzly bear habitat usually results in compromised bear populations and habitat (Banff Bow Valley Study 1996; Woodroffe 2000; Mattson and Merrill 2002).

In 1976, in an effort to protect grizzly bears and other wildlife species, the Canadian government designated a portion of southwestern Yukon Territory as a national park. This region, designated as Kluane National Park and Reserve (Kluane), adjoined Glacier Bay National Park in the Alaska panhandle, Wrangell–St. Elias National Park in Alaska, and later Tatshenshini-Alsek Park in British Columbia to form the world's largest international protected area and world heritage site (fig. 1)[1]. Since the designation of Kluane, the area has been described as one of the last remaining strongholds for grizzly bear populations in North America (Herrero et al. 1993). Kluane has also been described as an important grizzly bear "source" population for the surrounding area (Jingfors 1990). Grizzlies have shown regional movements south into Tatshenshini-Alsek Park, east into the Aishihik region, and north into the Kluane Wildlife Sanctuary. In the first two years of the most recent grizzly bear population study in Kluane (McCann 1998), 21% and 36%, respectively, of the tracked bears made out-of-park movements (McCann 1998). Hence Kluane plays an important ecological role for the surrounding area (Jingfors 1990; Hegmann 1995).

While the bear population in Kluane is thought to act like a source population, previous studies in the region singled out grizzly bears as the species most at risk of being affected by cumulative impacts (Hegmann 1995). Increasing town site development in communities neighboring the park; mining, hunting, forestry, and agriculture pressure outside of the park; landfills in nearby towns that attract bears; and air traffic are all potential threats to the ecological integrity of Kluane (Hegmann 1995; Danby and Slocombe 2005). Further, although the park area is more than 22,000 km^2 (8,492 mi^2), only 4,000 km^2 (1,544 mi^2) (18%) is vegetated (Environment Canada 1987). The remainder is rock and ice field. The vegetated portion of the park is a thin belt, confined on the west by the St. Elias Icefields, the largest nonpolar ice field in the world, and on the east by the Alaska and Haines highways. Four towns and several small, summer-use aboriginal villages are situated along the highways and consequently border Kluane (fig. 2). There are also numerous rural residential dwellings, summer homes, and other infrastructure along both highways. The distance between the highways and the ice field is approximately 55 km (34 mi) at its widest and averages 35 km (22 mi) (Environment Canada 1987). The dimensions of the greenbelt cannot easily contain the multiannual home range of a female grizzly (McCann 1998), so bears are highly reliant on the surrounding area to meet

[1] There are some differences among the parks in terms of the protection afforded to bears. For instance, hunting of bears is permitted in Tatshenshini-Alsek Park and under state sport and federal subsistence hunting regulations in different areas of Wrangell–St. Elias National Park and Preserve and in Glacier Bay National Preserve. Hunting of grizzlies is prohibited in Glacier Bay National Park and Kluane National Park.

Figure 1. Kluane National Park and Reserve, located in the southwestern corner of Yukon, Canada, is part of the world's largest protected area complex.

Figure 2. Haines Junction and the Alaska and Haines highways border Kluane National Park, as revealed in this satellite image. While Haines Junction is the main town bordering the park, it is only one of four towns and several summer-use villages along the park perimeter.

some of their life requisites. However, when bears have made out-of-park movements, they were subject to various sources of direct mortality, principally hunting and management kills (e.g., bears shot in defense of life and property). Rates of mortality have been high, exceeding the growth rate for the population (McCann 1998; Yukon Territorial Government 2003).

Building a model to represent Kluane's bear ecology

In light of the pressures on grizzly bears in and around Kluane, an essential approach to promoting effective conservation is identifying which landscape features are inherently attractive to the species and how that attraction is modified by the presence of humans (Clark et al. 1996; Nielsen 2005). Expert-opinion models, such as habitat effectiveness and security area models originally developed for grizzly bear management in Greater Yellowstone and Yellowstone National Park, are relatively inexpensive approaches identifying important habitat and estimating the impacts of human land use on grizzly bear habitat (USDA Forest Service 1990; Purves and Doering 1998; Gibeau 2000). However, these models have been criticized for not performing as well as empirical habitat models, and because of lack of statistical rigor they are viewed as unreliable (Nielsen et al. 2003; Stenhouse et al. 2003).

Resource selection function modeling (Manly et al. 2002) is a more statistically robust approach than expert-opinion methods for examining the distribution of wildlife in relation to landscape characteristics. The distribution of most organisms relates to the distribution of patches of habitat. Patches occur at different scales and are encompassed by a landscape matrix in which the species is absent or occurs at much lower densities (Paquet et al. 1996; Boyce et al. 2003). Disturbance by humans can displace organisms from preferred or frequently used habitat patches (Paquet et al. 1996; Woodroffe 2000). Disturbances may include concentrations of people in space and time, the physical alteration of an area, or some combination of these effects (Paquet et al. 1996).

For an empirical habitat model to be useful it is necessary to show how an animal's habitat selection might affect its survival or reproductive success (Boyce and McDonald 1999; Naves et al. 2003). Models based solely on habitat attributes cannot consistently and accurately estimate species' population responses (Mitchell and Powell 2003); however, if habitat models are specific to births and deaths, changes in the availability of resources

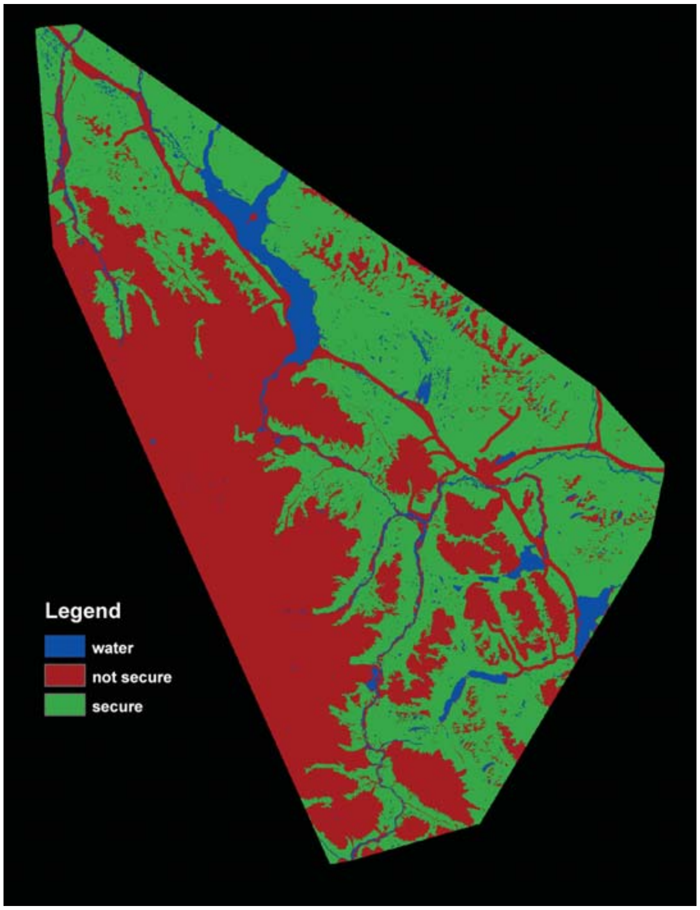

Figure 3. Expert-opinion maps, such as this security area map, were created using vegetation cover data. This study revealed that expert-opinion maps did not perform as well as occupancy and mortality risk maps.

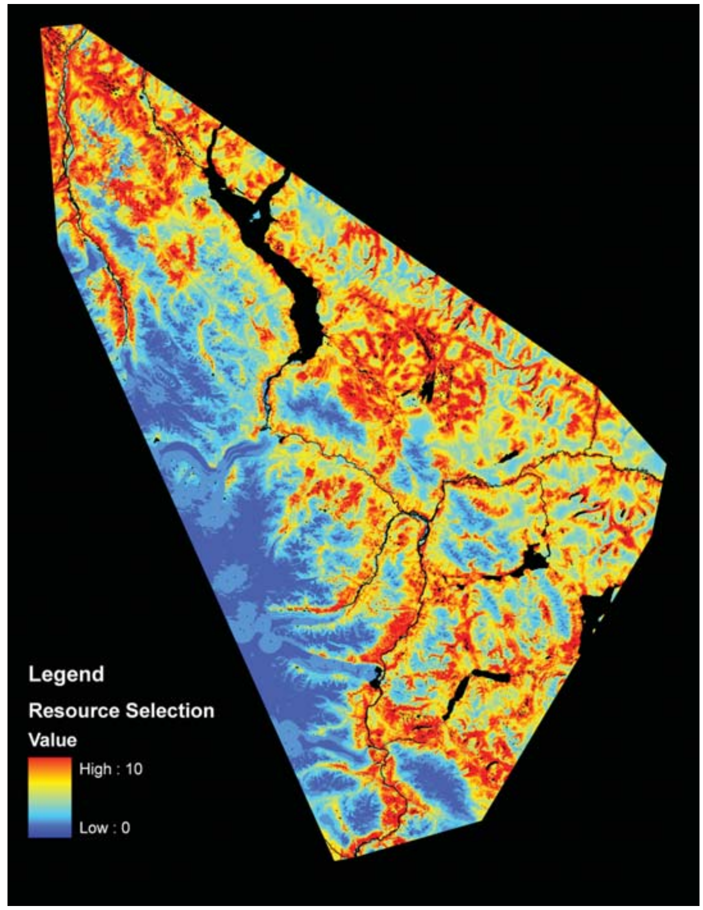

Figure 4. Telemetry relocations were used in a resource selection function to calculate the relative probability of occupancy for a grizzly bear in a given area.

that affect these processes may correlate with population responses (Naves et al. 2003). That is, as factors that increase the number of cubs that are born or live become prevalent, reproductive and survival rates for bears should concurrently increase (McLellan 1994). I evaluated this concept by assessing the effectiveness of occupancy (i.e., where bears use habitat) and mortality risk (i.e., where bears die) models for explaining productivity and survival rates, respectively. I appraised empirical habitat models, forage distribution models, and expert-opinion models with respect to reproductive and annual adult survival rates. Empirical habitat models described the relative probability distributions for family groups, adult females including family groups, adult males, and mortality locations. Expert-opinion models included habitat effectiveness and security models (fig. 3) and used the model parameters originally developed by experts researching bears in Yellowstone National Park. Habitat effectiveness describes the area's ability to support bears given the quality of the habitat and the extent of human disturbance. Security models describe the amount of area available to a female grizzly where she will be relatively secure from encounters with humans but can still meet her energy requirements. (See Maraj [2007] for full details of methods.)

To build empirical occupancy or habitat models, I used 3,941 aerial VHF telemetry relocations for 69 bears collared in the period 1989 to 2004. I used a resource selection function to model habitat selection by grizzly bears (Manly et al. 2002; fig. 4). This method employed telemetry locations for family groups and adult females, and a number of random coordinates, representing available habitat, to model the chance of a grizzly bear being at a given location as a function of a set of variables. Variables related to forage productivity, security from humans, terrain, and distribution of other bears. I recategorized the values produced by the resource selection function into two classes. The top 50% of the values represented habitat that had a high chance of being occupied by a grizzly bear, or high-quality habitat. The remainder of the values represented low-quality habitat.

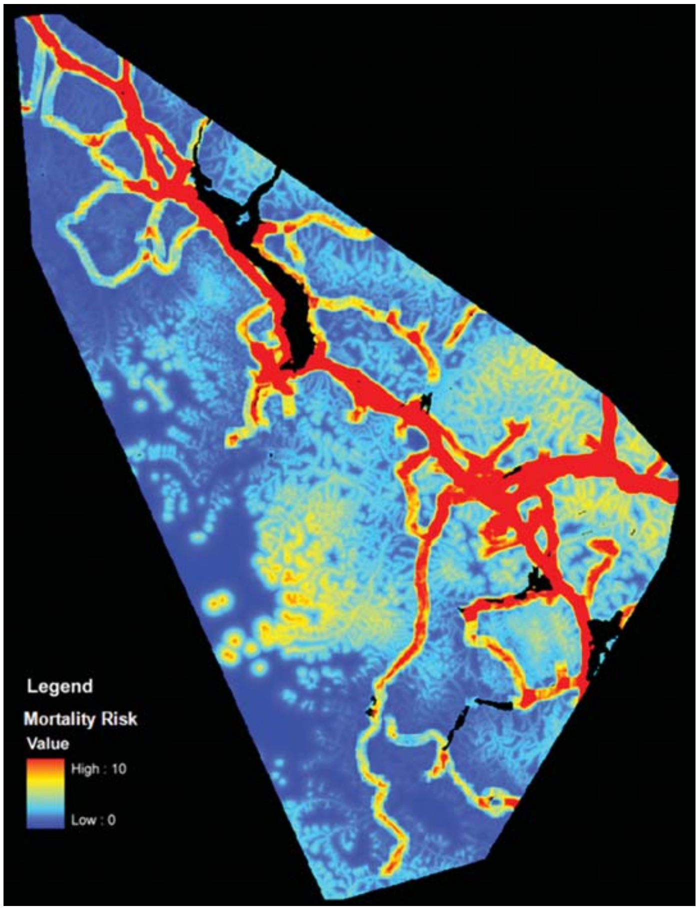

Figure 5. Kill locations were used in a resource selection function to calculate the relative probability of human-caused mortality for a grizzly bear in a given area.

I built the mortality risk models using reported kill site data (fig. 5). From 1983 to 2004 the Yukon Territorial Government and Kluane tracked mortalities (hunting and nonhunting) and translocations through wildlife-in-conflict and year-end reports, by way of the Yukon Biological Submission process. Mortalities included dead bears and bears translocated so far that they could be considered removed from the population. Legal hunter kills were also included in the mortality data set. Nonhunt mortalities included management-related kills (translocations were considered management-related kills), defense kills, accidental kills, and poaching. Natural mortalities were not considered. I used a resource selection function model to explore the relationship between grizzly bear mortalities and possible variables. Variables, in this case, were elevation, distance to water, infrastructure density, distance to primary roads, distance to other linear features, and distance to landfills. As with the occupancy model, I recategorized the values produced by the resource selection function for mortality risk into two classes: the top 50% of the values represented high-mortality-risk areas and the remainder of the values represented low-mortality-risk areas.

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I also developed an expert-opinion model. I calculated the proportion of each bear's home range that was scored as secure habitat and that had 80% or greater habitat effectiveness (Gibeau 1998; Purves and Doering 1998; Gibeau et al. 2001). For habitat effectiveness analysis I created a map of habitat values based on rankings of forage availability within land cover classes without human activity, then overlaid this map with a human disturbance layer. Habitat values up to given distances from a human disturbance feature were multiplied by values specified by expert opinion. The output map reflected the ability of the landscape to support grizzly bears in light of human disturbance (habitat effectiveness). For the security area analysis, I used the realized habitat map to identify suitable patches for foraging. All habitat patches that were large enough to meet the minimum average daily foraging radius for a female grizzly bear (Gibeau et al. 2001) were deemed secure.

I mapped the home range for each female bear and calculated the proportion of each bear's home range that was classified as high-quality habitat, high mortality risk, effective habitat, and secure habitat. I could then model the number of cubs and cub survival, and adult survival rates with the amount of high-quality and high-risk-mortality habitat in each female's home range. The number of cubs accompanying an adult female was recorded each year. If the cubs-of-year (those less than a year old) or yearlings were not seen with the adult female on two subsequent and consecutive flights, they were presumed dead. Yearlings were presumed dead if they did not emerge from the den with their mother. If the cubs were two years or older but were not accompanying the adult female, they were presumed dead or dispersed.[2]

These explanatory models for habitat-related productivity and survival rates were then used to predict productivity and survival

[2] Generally, grizzlies in Kluane do not disperse until two years of age, so cubs-of-year and yearlings that were not relocated were always assumed dead. While most two-year-olds dispersed from their mother, in some cases they died. The uncertainty as to whether a two-year-old had dispersed or died did not affect my survival estimates, as animals whose fates were unknown were coded the same way.

In light of the pressures on grizzly bears in and around Kluane, an essential approach to promoting effective conservation is identifying which landscape features are inherently attractive to the species and how that attraction is modified by the presence of humans.

rates in bear management units (BMUs) throughout the study area. BMUs aerially encompassed enough area of a watershed to support the multiannual home range of a female grizzly bear (fig. 6). Population status for each BMU, or the index for impact of human activities on the bear population, was classified as source-like, refuge-like, attractive sink-like, and sink-like (Naves et al. 2003).[3] Habitats where local reproductive success is greater than local mortality support source-like populations, characterized by an excess of individuals, who must disperse outside their natal patch to find a place to settle and breed. Areas that have scarce food resources but low risk of human-caused mortality are refuge-like, allowing for population persistence. The finite growth rate in refuge-type habitat would be close to one. Habitats where reproductive success and human-caused mortality are high, and result in a finite growth rate of less than one, are attractive sink-like. Poor habitats, where local reproductive success is lower than local mortality, are sink-like. Populations in sink habitats inevitably spiral to extinction without immigration from other areas.

The impacts of human activity on bears

Though habitat-based methods for assessing impacts of human activities on grizzly bears are relatively inexpensive, their utility is limited if they do not express the relationship of habitat to demographic processes (Van Horne 1983; O'Neil and Carey 1984; Hobbs and Hanley 1990; Garshelis 2000; Tyre et al. 2001). I appraised empirical habitat models and expert-opinion models with respect to reproductive and annual adult survival rates.

[3] *Like* is used at the end of each habitat condition to represent the hypothetical state of the area without explicit consideration of demographic features.

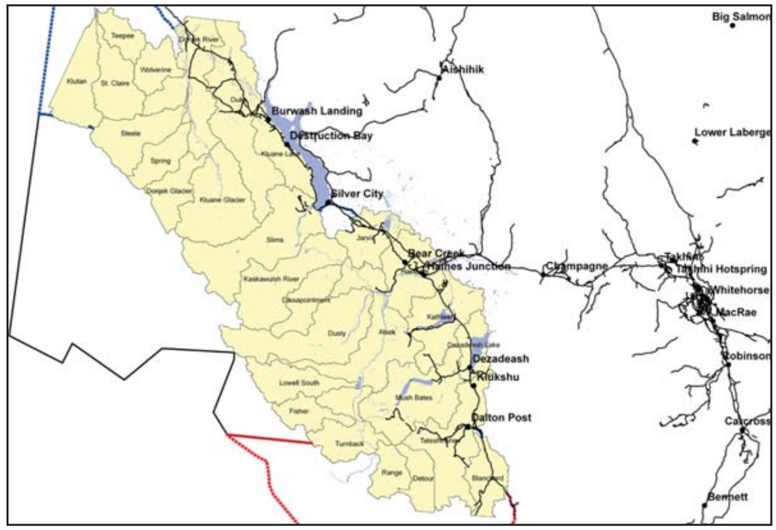

Figure 6. Shown here, bear management units (BMUs) for Kluane encompass watershed in which female grizzlies can have a multiannual home range.

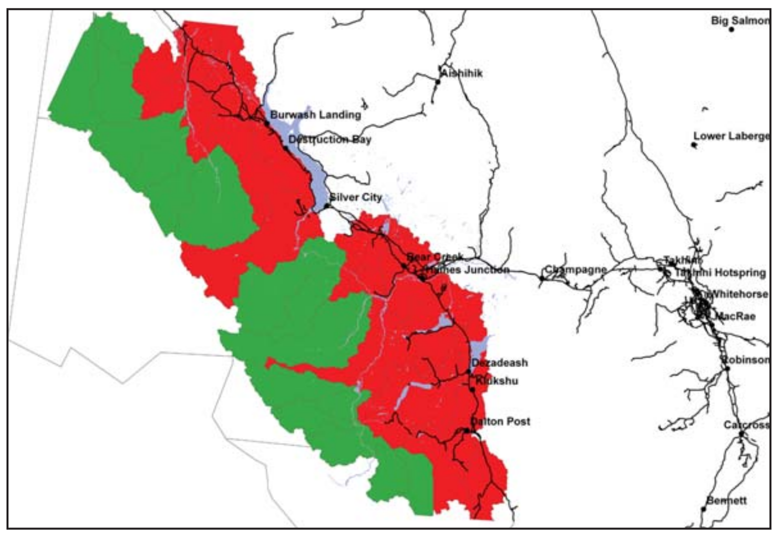

Figure 7. By considering the habitat-based mortality rates and productivity rates in each bear management unit, the ability of a BMU to retain a female can be assessed. Eleven BMUs (red) in the Kluane region area act like attractive sinks. The remaining BMUs are source-like habitat (green).

I found that empirical habitat models were substantially better than expert-opinion models for explaining the observations of cub productivity and adult survival rates. In the case of Kluane, expert-opinion models indicated that only two BMUs had reduced potential for bears to survive as a result of human activities, whereas empirical habitat models showed that 11 BMUs had lost this potential (fig. 7). Notably, this expert-opinion model has been employed throughout North America in places such as Yellowstone National Park (USDA Forest Service 1990), Jasper National

Table 1. Potential landscape- and watershed-level recommendations

Area/Type of BMU	Recommendations	Options to Achieve Recommendations
Landscape		
	• Develop linkage zones between watersheds and protected areas	• Designate corridors between watersheds as places where low-impact or no activity can occur
Attractive sink-like (watershed)		
	• Reduce access, particularly in high-quality bear habitat • Reduce the availability of bear attractants • Reduce human-caused mortality through excessive harvest	• Limit development of new trails and roads • Close trails and roads • Reroute trails and roads into low-impact areas • Use seasonal road closures • Use guided access only • Prohibit activities that produce bear attractants (e.g., backcountry camping) • Allow activities but regulate attractants (e.g., mandatory storage of bear attractants in bear-proof receptacles) • Develop education programs about attractants • Implement quotas on resident harvest
Source-like (watershed)		
	• Protect these watersheds by limiting human activities	• Limit development of trails and roads • Designate as off-limits to human activity • Allow some low-impact activities and use seasonal closures when there is high potential for bear-human conflict • Allow some low-impact activities and implement human use quotas • Regulate activities to reduce bear attractants and chances of encountering bears (e.g., location of camping, management of garbage and food)

Note: This table outlines some of the management options available to reduce human-caused bear mortality. Options are generally listed in order of intensity, and are not exclusive. Options may be used in combination, or one option may be applied in one watershed while another option may be applied in another watershed. Options for attractive sink-like watersheds recognize that development has already occurred in these watersheds. Options for source-like watersheds recognize that development in these areas is currently very limited.

Park (Purves and Doering 1998), and Banff National Park (Gibeau 2000), and the results in these regions may also underrepresent the conservation concern.

Using the results of the empirical habitat models, I looked at how well each BMU in Kluane sustained adult female grizzly bears (see fig. 7). While productivity in the BMUs adjacent to the highways was relatively high, so was mortality. These areas, therefore, acted as attractive sinks. The attractive sink-like areas were effectively regions that could support viable populations of bears but, because of human activity, were unable to. Rather, bears came into these areas, attracted by the high-quality forage, and subsequently were killed by people. The primary reason for the high mortality rates was the high amount of access, either by foot or by motorized vehicle, penetrating important grizzly bear habitat. These areas probably relied on the adjacent source areas to sustain a population. Source-like areas were found in the northern and southern interior of Kluane and abutted the St. Elias Icefields.

These findings were corroborated by information from management agencies on mortality rates (Yukon Territorial Government 2003). McCann (1998) found that the resident Kluane population was declining at approximately 3% per year, and most attractive sink-like BMUs bordered or partially contained Yukon Territorial Government game management subunits where the management threshold rate for bear mortality (2% for females and 6% for males) was exceeded (Yukon Territorial Government 2003). Human-caused mortality in these regions was split equally between hunting and management kills (McCann 1998). For these areas, conservation of a grizzly bear population will require management actions to reduce mortality rates, including a combination of reduced harvest, reduced access, reduced bear attractants, and limiting or otherwise mitigating the effects of development in high-occupancy bear habitats (table 1). Many recommendations to reduce bear mortality were implemented in the national park over the course of the study, so the key area for management will be the regions bordering Kluane.

Source-like areas have high productivity and high survival. Attractive sinks may rely on source-like BMUs to sustain bear populations (Doak 1995). The dual role of source-like BMUs in producing individuals for recruitment within and supplying emigrants to other BMUs substantiates a priority need for protecting these areas (Knight et al. 1988; Doak 1995). Furthermore, with the high prevalence of attractive sink-like BMUs, management actions should be taken to reduce potential degradation of source-like BMUs. Management actions for preventing impacts on these BMUs would be similar to those for attractive sinks, though the current distance of these areas from human habitation offers de facto protection to bears (table 1).

Large carnivores ... are generally not specialized, and pristine conditions are not needed for their continued survival.... the principal factor affecting their abundance is security from human conflict.

In addition to protecting source-like BMUs, the connectivity between source and attractive sink-like BMUs should be a key management concern (Noss 1991). Breaks in connectivity would impede repopulating sink-like BMUs. Kluane's terrain is rugged, and valley bottoms, used by people for recreation, are also likely the primary travel routes for wildlife. This highlights the need for a land-use planning process in the region.

The outlook for Kluane grizzly bears

For this study I examined the cumulative impacts of human activity on grizzly bear habitat and populations in a northern ecosystem containing a protected-area complex. Cumulative impacts are disturbances where the combined effect of more than one human activity on the landscape often has a greater (multiplicative) negative impact than the additive impacts of each activity alone. Global conservation priorities primarily emphasize areas with the highest species richness or areas with species in imminent risk of extinction (Myers et al. 2000). Areas such as Kluane are usually of low concern to conservationists because the public and agencies commonly associate northern terrestrial environments with pristine wilderness (e.g., Ricketts et al. 1999). Though the footprint for human land use is smaller in the north than in southern environments, the latent global extinction risk for places like Kluane is high—some argue as high as that of severely disturbed wildlife habitats in Southeast Asia (Cardillo et al. 2006). With the increasing prevalence of tourism quotas and outright moratoriums on human use in southern parks (e.g., areas closed to public use in Yellowstone National Park), increased demand for a remote wilderness experience, and increased economic development in the north, northern terrestrial ecosystems—including protected areas—are increasingly prone to human-wildlife land use conflicts. Unfortunately, northern ecosystems have less capacity than southern ecosystems to withstand impacts from human land use (Rohde 1992; Cardillo et al. 2006). The paucity of biodiversity and biomass compared with ecosystems south of the 60th parallel means that Yukon ecosystems have poor ecological resilience (Rapoport 1982; Stevens 1989; Peterson et al. 1998). Given the current and emerging human land-use pressures in the north, without proactive attention wildlife populations of species such as grizzly bears will likely experience unsustainable rates of human-caused mortality and habitat loss.

Conservation of large carnivores and conservation of other elements of biodiversity are linked (Linnell et al. 2000; Carroll et al. 2001). In many ecosystems, protecting large carnivores facilitates preservation of other organisms (Noss et al. 1996; Linnell et al. 2000; Carroll et al. 2001). However, the causes of decline for each are not necessarily the same (Woodroffe 2000; Treves and Karanth 2003). Most terrestrial species have experienced population declines because of human-caused habitat change (Brooks et al. 2002). Large carnivores, however, are generally not specialized, and pristine conditions are not needed for their continued survival (Woodroffe 2001). While habitat loss has been cited as a fundamental concern for preserving some bear populations (Mattson and Merrill 2002; Ross 2002), the principal factor affecting their abundance is security from human conflict (Woodroffe 2001; Treves and Karanth 2003). Direct mortality appears to be the primary force driving grizzly bear populations to the brink of extirpation (Mattson et al. 1996b; Linnell et al. 2000; Woodroffe 2001; Benn and Herrero 2002). Roads and other linear access features are often a factor for high rates of human-caused bear mortality because they provide access for hunters, poachers, and others into regions where bears reside (McLellan and Shackleton 1988; Nielsen et al. 2004). Societal tolerance for property damage is often low (Sillero-Zubiri and Laurenson 2001), and fear of human injury or mortality is often high (Kellert et al. 1996; Bath 1998; Røskaft et al. 2003). As such, coexistence may require that there are tracts of land with little to no human access and limited human activity. Valley closures to human activity have become a common tool for grizzly bear conservation in many regions, including Yellowstone and Banff national parks, and restrictions on human access and activity have been successfully applied in places such as Denali National Park.

The Canadian and U.S. national park systems are a primary means of protecting large carnivores in North America; however, most of the protected areas that comprise the systems have not been designed to sustain populations of wide-ranging species (Newmark 1985; Mattson et al. 1996a). Many protected areas, particularly in mountainous regions, do not encompass enough area to provide for the lifetime home range requirements of a minimum viable population of grizzly bears (Weaver et al. 1996; Woodroffe and Ginsberg 1998). Most mountainous national parks are overwhelmingly composed of uninhabitable rock and ice (Banff Bow Valley Study 1996). Protected areas are often designed without linkages to other wildlife populations (Noss et al. 1996). Population status, particularly where bears experience high rates of human-caused mortality, becomes highly precarious with increasing geographical isolation from surrounding populations (Doak 1995). Kluane is unlike most mountain parks: it is contiguous to three other parks, forming the world's largest protected area complex. The approximately 4,000 km^2 (1,544 mi^2) of green-belt in Kluane, which appears inadequate for maintaining a viable bear population, may rely heavily on influxes of bears from these adjacent areas (e.g., Glacier Bay National Park, Alaska). If high mortality rates continue unabated and there is no means to increase the land base for protection of bears, the key may be to focus on corridors and the surrounding source populations. Consequently, interagency dialogue will be a prominent part of grizzly bear conservation for protected areas in this region.

Although the concepts of limiting or reducing human activity in important grizzly bear habitat and keeping corridors traversable for bears appear logical and straightforward, perhaps the most challenging steps will be implementation of new management prescriptions to achieve security for grizzly bears. Humans are not generally accepting of land-use policies that restrict individual liberties (Rutherford and Clark 2005), particularly when economic gains are sacrificed. In the end, grizzly bears may prove to be the ultimate challenge for whether humans can coexist with nature (Kellert et al. 1996). The difficulty of coexisting with large carnivores is less about the carnivores than about societal values and perceptions (Primm and Clark 1996). Grizzly bears are relatively easy to manage; managing people in cooperative ways that give grizzly bear populations reprieve is much more challenging.

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