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Impact of human activities on grizzly bear habitat in Jasper National Park

Glynnis A. Hood and Katherine L. Parker

Abstract Grizzly bear (*Ursus arctos*) populations are subject to increasing human encroachment into their habitats. We gathered data on levels of human activity over 7 months (April–October 1997) to link with data on habitat suitability for grizzly bears in the Maligne Valley of Jasper National Park, Alberta, Canada. We used electronic trail counters, direct counting by observers, and self-counting methods to quantify and compare human use in linear (e.g., trails), point (e.g., campgrounds), and dispersed (e.g., water bodies) landscape features. We then combined the data with habitat data in a Geographic Information System to estimate habitat effectiveness to support bears (the capability of an area to support bears, as influenced by human activities, in relation to the area's inherent ability without human use) and availability of security areas (usable bear habitat that is >9 km^2 and >500 m from human activity). To minimize dilution of the effects of human activities on grizzly bear habitat due to large area size, we divided the Maligne Valley into 3 bear management units. Weekly averages of the amount of human use rose markedly during the first week of July and declined after the first weekend of September. Increasing recreational activity in habitats with high or very high value for grizzly bears resulted in a decrease in habitat effectiveness values. The 3 bear management units in July and August and one bear management unit in September did not meet Parks Canada's threshold for protected areas of having >80% habitat effectiveness levels. One bear management unit in August failed to meet the recommended >60% threshold value for the secure–usable category. Use of the grizzly bear habitat effectiveness model and security area analysis offers a predictive tool for more detailed planning of current and proposed developments in areas containing bear habitat.

Key words Geographic Information Systems, grizzly bear, habitat effectiveness, human activities, human use, Jasper National Park

Parks Canada's 1994 Guiding Principles and Operational Policies mandates that national park ecosystems be given the maximum degree of protection to ensure the perpetuation of natural environments essentially unaltered by human activity and that Parks Canada establish goals and strategies to ensure protection of ecosystems in and around national parks. As human use levels rise, park research is becoming increasingly focused on interactions of human influences on the ecosystem. Jasper National Park now receives approximately 3 million visitors annually (Wright et al. 1996); many are drawn up the Maligne Valley to the scenic attractions of Maligne Canyon and Medicine and Maligne Lakes. Current visitation estimates indicate a 50% increase in people coming to the park since the Jasper National Park Management Plan was written in 1988 (Environment Canada 1988). With

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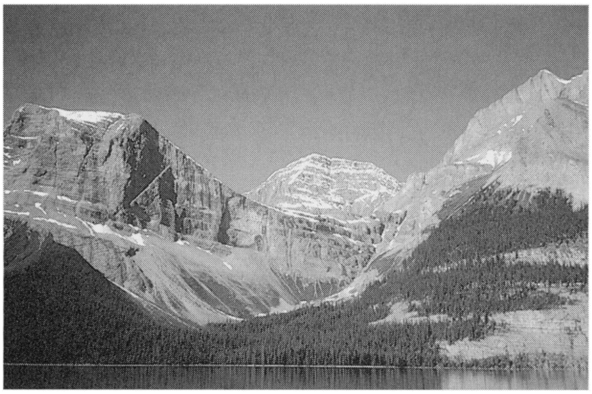

Spindly Creek on Maligne Lake in Jasper National Park.

this increase in visitation, park managers are looking for more refined approaches to ensure maintenance of the park's ecological integrity within their management plans (Parks Canada 1994). Ecosystem management initiatives (Nepstad and Nilsen 1993) and the Carnivore Conservation Strategy (Hummel and Pettigrew 1992, Weaver et al. 1996) have been the catalysts for addressing landscape ecology issues and concerns. One area of critical importance is the influence of human activities on natural systems and the wildlife within them (Page et al. 1996).

In Canada's 4 contiguous mountain national parks (Banff, Kootenay, Yoho, and Jasper), the grizzly bear (*Ursus arctos*) is regarded as an umbrella species (Page et al. 1996). Because of their large spatial requirements, maintenance of secure habitat for grizzly bears and other large carnivores in turn secures a high diversity of habitats for other wildlife species using the same area. One tool currently used to assess and manage grizzly bear habitat inside and outside of national parks is the grizzly bear habitat effectiveness model (Weaver et al. 1986, 1987; Gibeau et al. 1996).

The grizzly bear habitat effectiveness model combines measurements of habitat quality and human disturbance to quantify the ability of an area to support a viable population of grizzly bears (Weaver et al. 1986). The inherent habitat value of an area is termed "potential habitat," whereas habitat as influenced by human activities is defined as "realized habitat" (Gibeau et al. 1996). This model, therefore, can be used as a predictive tool using Geographic Information Systems (GIS) to provide an initial quantitative and qualitative assessment of the effects of current human use and proposed developments on grizzly bears. Kansas and Riddell (1995) developed habitat values for the grizzly bear habitat effectiveness model (i.e., habitat suitability index [HSI] values) for Jasper, Banff, Kootenay, and Yoho National Parks by rating ecological land classification polygons on a spatial and temporal basis. We based displacement values used in this model on measures and types of human activity and used them to reduce potential habitat to realized habitat.

In addition to using measurements of habitat effectiveness to assess the value of natural landscapes as grizzly bear habitat relative to human disturbance, security area analysis identifies areas that are usable at the scale of the individual foraging radius of an adult female grizzly (Mattson 1993). Security area analysis incorporates habitat quality, minimum area sizes, spacing, and connectivity between female home ranges (Gibeau 2000) to define habitat security that would foster wary behavior in bears (Mattson 1993). Both measurements assess effects of landscape fragmentation on grizzly bear habitat (Page et al. 1996).

Consequently, a reliable human-use data layer is an essential component in all aspects of habitat effectiveness mapping. Overall objectives of this study were to quantify human use within the Maligne Valley of Jasper National Park and to determine the habitat effectiveness in the valley. Specifically, we 1) compared levels of use among linear (e.g., trails), point (e.g., campgrounds), and dispersed (e.g., water bodies) landscape features; 2) determined effects of weather (maximum temperature and precipitation) and day of the week (weekends or weekday) on level of human use on 3 specific trails; and 3) assessed seasonal changes in habitat effectiveness and security areas for grizzly bears in the Maligne Valley as affected by changes in potential habitat and human use.

Maligne Tours Facility on Maligne Lake in Jasper National Park.

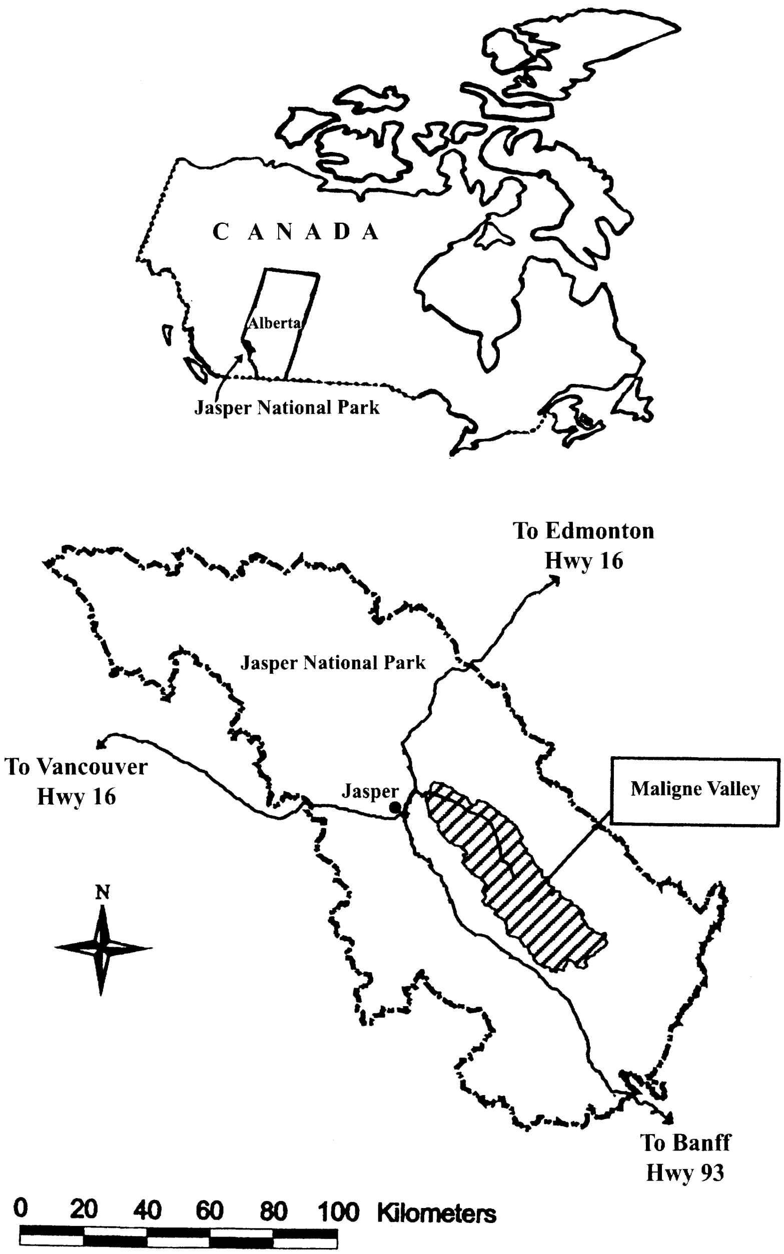

Figure 1. Study area in the Maligne Valley of Jasper National Park, Alberta, Canada. Solid lines represent roads from 1 April to 31 October 1997.

Study area

Jasper National Park is the largest (10,878 km^2) and most northerly of the 4 contiguous Canadian Rocky Mountain national parks (Jasper, Banff, Kootenay and Yoho). It comprises 3 ecoregions: the montane, the subalpine, and the alpine. The Maligne Valley is situated in the east-central section of the park. The valley is bisected by the Maligne River and is bounded to the west by the Maligne Range and to the east by the Queen Elizabeth Range (Figure 1). The latter is generally steep and rocky with little vegetation. Mid-slopes of the Maligne Range are characterized by open lodgepole pine (*Pinus contorta*)-spruce (*Picea glauca*, *Picea engelmanni*) and Engelmann spruce (*P. engelmanni*)-subalpine fir (*Abies lasiocarpa*) stands, whereas numerous subalpine (1,350-1,900 m) and alpine (>1,900 m) meadows dominate higher elevations (Holroyd and Van Tighem 1983). Two large lakes are part of the Maligne system, Maligne Lake in the southern section of the valley and Medicine Lake farther north. The Maligne River flows north through subalpine habitat from Maligne Pass and Maligne Lake, through Medicine Lake, and into the Athabasca River in montane habitat (1,000-1,350 m) of Douglas-fir (*Pseudotsuga meziesii*), white spruce (*P. glauca*), and aspen (*Populus tremuloides*).

The Maligne Valley is accessed by an all-season, paved road, which begins in the montane ecoregion near the confluence of the Maligne and Athabasca rivers. It ascends into the subalpine ecoregion and continues 44 km south to its terminus at Maligne Lake. Overnight accommodations available in the valley beyond the Maligne Youth Hostel include the Maligne Lake Warden Station, Beaver Warden Cabin, and 14 backcountry campsites.

The study area commenced immediately upstream of the Maligne Youth Hostel (Universal Transverse Mercator MJ 332 636) and continued up the Maligne Valley between the height of land of the Maligne and Queen Elizabeth Ranges to the southern extent of the Maligne River watershed. It encompasses 891 km^2 or 8.2% of Jasper National Park. We divided the Maligne Valley into 3 bear

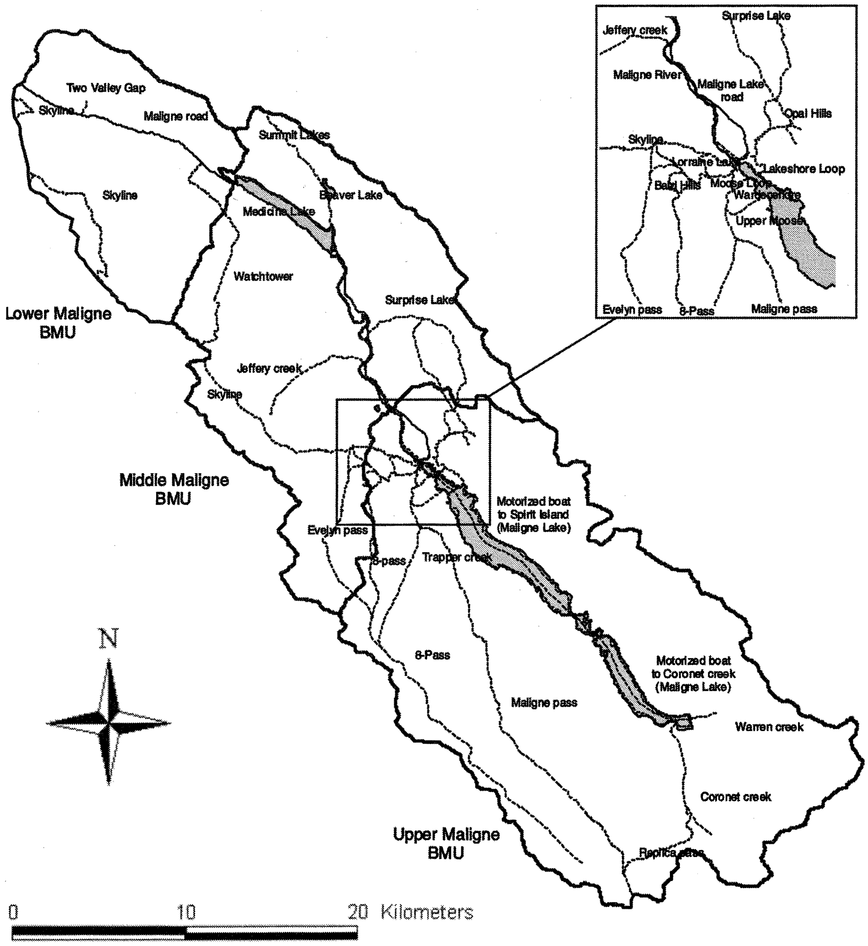

Figure 2. Linear (--- trails, — roads) and dispersed features (in gray), including 3 bear management units, in the Maligne Valley, Jasper National Park, Alberta, from 1 April to 31 October 1997.

management units (BMUs): the Lower Maligne (136 km^2), the Middle Maligne (275 km^2), and the Upper Maligne (408 km^2, which includes 21 km^2 encompassed by Maligne Lake). We used natural topographic features, such as height of land, shared biophysical and human activity qualities, and distinct differences in the hydrology of the watershed to define the BMUs. All 3 BMUs were larger than monthly home ranges reported for female grizzly bears radiocollared by Russell et al. (1979) in the Maligne Valley and surrounding areas.

Methods

Acquisition of data on human activity

We categorized human activities as linear, point, or dispersed in nature and then as either high or low use. Linear features ($n = 43$) included the Maligne Lake Road, the motorized boat routes on Maligne Lake, and trails, some of which we divided into several linear feature segments (Figure 2). Point features included 14 backcountry campgrounds, 3 cabins, and 6 picnic sites (Figure 3), and dispersed features included Maligne, Medicine, and Beaver Lakes; the Maligne River; 3 gravel pits; one backcountry ski area; the Maligne Lake Warden Station; and the Maligne Tours facility on Maligne Lake (Figure 2). Following Gibeau et al. (1996), we defined high use as >100 people or vehicles/month and low use as <100 people or vehicles/month.

We used indirect-counting, direct-counting, and self-counting methods to collect data on human use in Jasper National Park between 1 April and 31 October 1997. Human-use data sets were associated through a DBASE V for Windows format with an Arc/Info GIS human-use data layer containing human-use features in the study area (Figures 2, 3).

Indirect-counting techniques included using 10 electronic trail counters (TrailMaster®, Lenexa, Kans.) and 3 infrared video cameras (RM-680 Video Surveillance System, Compu-Tech, Inc., Bend, Ore.). Counters recorded a count with the time and date every time an infrared beam linking the receiver and transmitter was broken. We used an infrared pulsation rate of 3 pulses/0.15 seconds in an effort to ensure that most trail-user types would be detected by the equipment. To detect hikers, cyclists, and horse use while excluding dogs and smaller wildlife, we mounted counters 1.5 m above ground level. We also placed counters a minimum of 10 minutes walking time on the trail beyond trail junctions to avoid counting users who were diverting onto a different trail. In cases where trails extended beyond a specific destination point (e.g.,

Figure 3. Point features (▲ campgrounds, ● picnic sites, ■ cabins), including 3 bear management units, in the Maligne Valley, Jasper National Park, Alberta, from 1 April to 31 October 1997.

onds on hiker-only trails and for 30 seconds on trails with commercial horse use. The difference in timer settings allowed for long strings of horses to be fully recorded prior to the camera shutting off. We later reviewed all videotapes on a television monitor.

Direct-counting methods included use of park staff and 28 volunteers to record location, timing, and number of people at linear, dispersed, and point features within the study area. We used a stratified random sampling design to ensure coverage of specific locations relative to weekends, holidays, and peak times of day. In the design, high-use trails had twice as much likelihood of being sampled on weekends and holidays as trails suspected to have minimal use (<10 people/month). We divided sampling times for each trail into either an 0800- to 1200-hours time block or a 1200- to 1700-hours time block. Routine warden and volunteer patrols covered evenings and early mornings. We used direct counting for trails that had counters on them but no camera surveillance at that time, and on trails that we considered to have minimal use but were not equipped with trail counting equipment. Observers also surveyed water bodies for boating and fishing activity and point source locations such as picnic sites because these areas did not lend themselves to electronic surveillance. A subsurface road counter recorded traffic volumes, types, and timing of vehicle use along the Maligne Lake Road.

Self-registration counts included backcountry camping permits, summit registries, and commercial tour ticket sales information. Although backcountry camping permits were specific to individual campsites, it was possible to calculate number of people traveling on a specific trail segment on a

picnic site, lake), we placed a second counter on the next segment of the trail. The 10 trails selected to be monitored by trail counters are the only maintained hiking trails off the Maligne Lake Road and Maligne Lake. We downloaded all data via a handheld computer and then transferred them to a PC to convert to a Microsoft Excel® format for analysis.

We used camera data to validate counter data. To ensure comparable coverage of each counter, we randomly moved the cameras to a new counter location each week. An infrared trigger mounted on a nearby tree activated the cameras. We placed cameras as close to the counter locations as possible. We monitored all cameras and counters at least twice a week and camouflaged them to lessen chances of equipment detection by hikers. The cameras monitored 2-way traffic to mimic the counting abilities of the counters. As with the counter data, the time and date of each camera activation were recorded automatically on the videotape. After being triggered, cameras ran for 15 seccertain day from the itinerary associated with the required permit. Commercial tour operators in the study area provided commercial ticket sales information on number of people/tour and number of tours/day.

In general, we surveyed linear features using ≥1 counting technique (direct, indirect, and self-registration). We used cameras and counters to monitor the 10 major access trails and self-registration counts (i.e., campground permit itineraries, ticket sales) to monitor 28 backcountry trails. Observers recorded data for the remaining trails. We surveyed point features using self-registration counts for the 14 backcountry campgrounds and direct counts at picnic sites. We used direct-counting techniques to survey dispersed (polygon) features.

We gathered weather data daily at 0800 hours at a manual weather station at the Maligne Lake Warden Station. Data included maximum, minimum, and present temperatures; total 24-hour precipitation; cloud cover; wind direction; relative humidity, and barometric pressure.

Analysis of data on human activity

We created graphs of data from all counters to represent hourly blocks in the original TrailMaster® format and then analyzed them in a minute by minute text display. Occasionally, we observed spikes (uncharacteristically high counts) in the data. Generally, we considered spikes to be counts that greatly exceeded the normal number of users present on a particular trail within a specific time span. We identified spikes by visual examination and subjective evaluation of all count data. For spikes that appeared to have ambiguous starts, we left 2 counts at the beginning and 2 counts at the end of the spike in the data set to provide a conservative average number of counts/minute for that particular trail. In some cases, camera and observational data assisted in the recognition of spikes; early morning-late evening spikes were often triggered by animals. Daytime spikes often followed extreme wind events and heavy snowfall. All spike data were set to 0. We tabulated seasonal counts and monthly counts (used in the habitat effectiveness model) for all features.

We calculated the average number of people/day during each week of the study for each trail monitored by counter, campsite, and commercial boat tour operation. Then we determined the weekly average for number of people/day based only on number of days in that week when data were available, compensating for missing data due to equipment failure or tampering. We also calculated percentage changes in use on a weekly basis ($[\text{week}_x - \text{week}_{x+1}]/\text{week}_x$) to determine whether changes in human activity during the season were similar between point (campground) and linear (trails) features. We used accumulated percentage change over the season, calculated as the $\sum$(% change/week), to determine the seasonal pattern and timing of the greatest change in human activity for all features, regardless of absolute numbers of people using them.

We used linear regressions to compare counter data and camera data and counter and direct-counting information. Camera data were used to assess accuracy of the counters. After establishing validity of counter data, we used a regression to determine accuracy of observer data. We used multiple regression to determine whether number of people/day varied significantly with temperature, precipitation, and day of the week (dichotomous variable for weekdays and weekends) on 3 trails (Bald Hills, Beaver Lake, and Lakeshore). Each trail represented a different location and degree of hiking difficulty. The Lakeshore trail (Lakeshore Loop) is a popular, easily accessible, short (1-km) loop; Beaver Lake is a slightly longer (2.4-km), more moderate walk; and Bald Hills is a long (8-km) hike to alpine habitat. We used a relative Pratt index (d_j) to determine the relative importance of each explanatory variable by attributing a proportion of the overall R^2 to each one (Thomas and Zumbo 1997); a variable was considered "important" if $d_j > 1/(2\times[\#\text{ of explanatory variables}])$. In our analyses, we used counter data in cases when we also used other data-collection methods on the same trail. The level of significance for all analyses was $\alpha=0.05$.

Analysis of habitat effectiveness and security areas for grizzly bears

All analyses of habitat effectiveness were done on an Arc/Info GIS at a scale of 1:50,000 to coincide with the habitat data. We based the habitat component of the habitat effectiveness model on research by Kansas and Riddell (1995), which classified the original ecosites from the Ecological Land Classification for Jasper National Park (Holland and Coen 1983) into functional units with broad similarities in vegetation cover and land form. Habitat suitability values ranged from 0 to 10, with 0 indicating no suitable habitat for grizzly bears and 10 signifying habitats of greatest value. Kansas and

Riddell (1995) categorized habitat suitability into very high (>7), high (5.0-6.9), moderate (3.0-4.9), and low (<2.9). The original 0-10 scale was then converted to a percentage (i.e., a habitat suitability of "7" became 700%) and was divided by 10 for use in the GIS model (Purves and Doering 1998). This value was termed "potential habitat."

We categorized human activities into 3 dichotomous groups as in Gibeau et al (1996): motorized or nonmotorized, low use (<100 people or vehicles/month) or high use (>100 people or vehicles/month), and location in vegetative cover or noncover. We then assigned each point, linear, and dispersed feature (i.e., trail, campground, water body) associated with a human activity a disturbance coefficient (DC), developed by bear biologists to quantify effects of human disturbance on habitat use by nonhabituated grizzly bears (Weaver et al. 1987). Disturbance coefficients ranged between 0 and 1, with 0 indicating total displacement and 1 implying no displacement of the bears. For example, a nonmotorized, linear, low-use feature with cover had a DC of 0.88, whereas a motorized, linear, high-use feature without cover had a DC of 0.16. We also assigned a zone of influence (ZOI) to each feature type. This zone of influence, developed for the Yellowstone ecosystem and subsequently adopted by Banff, Kootenay, and Yoho National Parks (Gibeau et al. 1996), was applied as a region buffer in the GIS to indicate the physical area where grizzly bears would be disturbed by human activity (Purves and Doering 1998). We assigned all motorized features a buffer (or ZOI) of 805 m (based on 0.5 mi used in the Yellowstone system) and nonmotorized features a buffer of 402.5 m. All assumptions for the disturbance coefficients and zones of influence are outlined in Weaver et al. (1986).

We then applied a cumulative disturbance coefficient (CD) to the potential habitat value for each BMU (Purves and Doering 1998). We calculated the CD as the product of the overlapping disturbances using the following formula:

$$CD_p = DC_{pai} \times DC_{paj} \times DC_{pak} \ldots DC_{pax},$$

where CD_p is the cumulative disturbance for the polygon and $DC_{pai} \ldots DC_{pax}$ are the disturbance coefficients for each region with a different zone of influence in which the polygon exists. Realized habitat, as the habitat value after human activities have been accounted for, was calculated as:

$$RH_p = PH_p \times CD_p,$$

where RH_p is the realized habitat for a polygon and PH_p is the potential habitat for a polygon. Finally, we derived habitat effectiveness for the BMUs from the area of the polygon ($area_p$) and the potential and realized habitats:

$$HE_{bmu} = \frac{\left[\Sigma(RH_p \times area_p) / \Sigma area_p\right]}{\left[\Sigma(PH_p \times area_p) / \Sigma area_p\right]}.$$

A habitat effectiveness value of 0 indicates that the habitat is effectively unavailable to bears because of the high level of human activity; a value of 1 would indicate that 100% of the habitat is available (with no human use) to bears. A threshold habitat effectiveness value adopted for Jasper National Park is >0.8 (80%), which implies that the area, encompassing habitats ranging from no human use to very high levels of human use, should average >80% habitat effectiveness (Parks Canada 1997, Gibeau 1998).

We ran the habitat effectiveness model using data for each month between April and October 1997 for each BMU. We used multiple regression to determine amount of variability in the habitat effectiveness value that could be explained by the variation in the disturbance value and the habitat suitability index. We also calculated a relative Pratt index (Thomas and Zumbo 1997).

We also ran the model to determine which features decreased the habitat effectiveness values within a BMU below the selected threshold of >80%. We edited human-use data within the GIS in different scenarios (e.g., removing use on specific trails) relative to their proximity to high or very high habitat polygons, current Jasper National Park Management Plan objectives (Environment Canada 1988), and the overall feasibility of closing down specific features. Additionally, we ran the model with all point features set to zero use, then with the linear features set to zero use, and finally with all polygon (dispersed) features set to zero use to determine which feature types had the greatest influence on the model outcome.

Security area analysis also used Arc/Info GIS at a scale of 1:50,000 and the same human-use data layer as the habitat effectiveness modeling for April through October 1997. We buffered areas of high human use (>100 people or vehicles/month) at 500 m. By preset criteria, we considered security areas to be areas less than 2,300 m (unless vegetated), >500 m from high human use, and >9 km^2 (Gibeau et al. 1996, Purves and Doering 1998). In addition, we considered all water, rock, and ice unsuitable habitat for grizzly bears and did not use these features in area calculations.

Security area analysis classified the land base into 4 groupings: "unusable" (areas of rock, ice, and water; and nonvegetated sites above 2,300 m), "not secure due to human disturbance" (areas that fall within the 500-m buffer around high-human-activity features), "not secure due to size" (suitable areas that did not meet the required area of 9 km^2 but met all other criteria and included areas of low human use), and "secure" (all remaining areas). We calculated the overall percentage of available secure areas within each BMU as the proportion of secure areas to the amount of usable habitat. Because Jasper National Park states that >60% of a BMU should be in secure status for grizzly bears (Parks Canada 1997), we reran model outcomes with a BMU less than 60% secure-usable under different scenarios by varying human use levels to determine which features affected security areas within the BMU.

Results

Trends in human activity

All trails in the study area experienced days of no human use; however, the maximum number of people/day on a seasonal basis using specific Maligne Valley trails (Figure 2) monitored by electronic trail counters ranged from 2 to 577 between 1 April and 31 October 1997. Lakeshore trail, at the northern end of the Maligne Lake Road, received the most use, and Coronet Creek trail, at the southern end of Maligne Lake, received the least use. All trails except Lakeshore trail had an average level of use <200 people/day, and only the Lakeshore and Opal Hills trails had maximum use levels >200 people/day. The greatest number of people recorded on the 10 electronically monitored trails was 1,191 on 2 August. The greatest total number of people occurred between 0800 and 2030 hours, with the greatest use being between 1000 and 1730 hours.

Similarly, all Maligne Valley campgrounds (Figure 3) experienced days of no use, and hence, seasonal averages were all <6 people/day. Parks Canada applied a quota system to all Maligne Valley backcountry campgrounds to ensure ≤30 people/night in the campgrounds at all times. On many days, campgrounds on the Skyline Trail (Evelyn Creek, Little Shovel, Snowbowl, Tekarra, and Signal) and on Maligne Lake (Fisherman's Bay and Coronet Creek) met their quota allowances throughout summer (June, July, August). The maximum total number of people overnighting in the 14 monitored campgrounds was 119 on 30 August.

The maximum number of outbound vehicles/day, as registered on the Maligne Lake road counter near the Jasper Park Lodge turnoff, was 1,720 ($\bar{x}$±SD=979 ±421). The maximum number of motorized commercial boats/day on Maligne Lake was 29 ($\bar{x}$=19±6).

There was a weekly temporal variation within the 1997 season. Averaged per week, trail use on 70% of trails (n=10) monitored by electronic counters typically remained ≤100 people/day, with a marked decline in use after the long 6 September weekend. Use on the remaining 30% of trails (n=3) monitored by electronic counters exceeded 100 people/day, averaged on a weekly basis. Campground use remained <30 people/day because of the present quota system for all backcountry campgrounds. Eight of the 13 campgrounds (62%) averaged <10 people/night weekly. Three of the remaining greater-use campgrounds (>10 people/night) were on the Skyline Trail, whereas the 2 other greater-use campgrounds were on Maligne Lake.

Of the 25 use features for which we had continuous data (10 trails monitored by counters, 13 campgrounds, the Maligne Lake Road, and motorized commercial boat use), 14 (56%) showed the greatest increase in human activity during the week ending 5 July. At that time, maximum percentage changes in trail use increased 1.4 to 10.5 times from the previous week. Several other trails in the study area were at high elevation and remained snow covered and impassible until later in the season. Maximum changes in backcountry campground use increased 1.7 to 21.2 times. As with trails, many of the popular campgrounds were at high elevations and received a rapid increase in use once the access trails were free of snow. The maximum change in use for the Maligne Road increased 1.3 times during the week of 5 July, whereas motorized commercial boat use on Maligne Lake stayed relatively consistent once the operational season commenced on 5 June.

Infrared video camera data obtained from 7,200 hours of surveillance explained 79% of the variation in trail counter data, with a slope of the equation very close to 1.0 (Figure 4A). Direct-counting data from over 860 hours of observations by

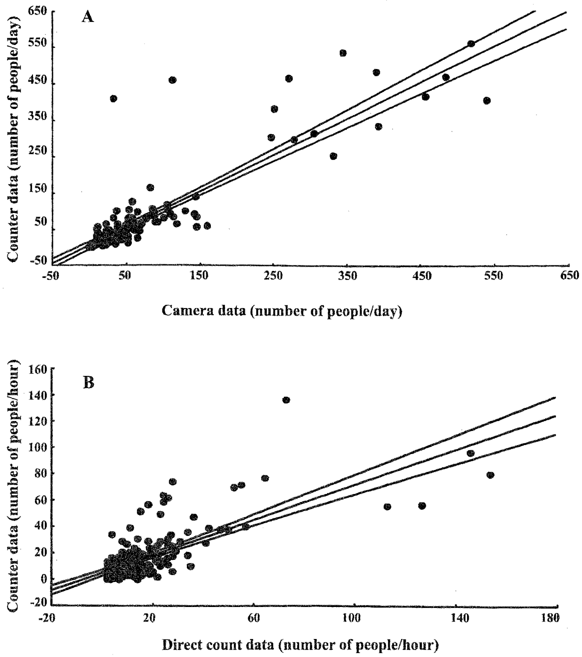

Figure 4. Relationships (A) between daily trail counter data (Y) and daily video camera data (X), where $Y=6.13 + 0.99X$ ($n=156$); and (B) between trail counter data (Y) and direct-counting data (X) (B), where $Y=4.87 + 0.67X$ ($n=194$) on Maligne Valley trails from 1 April to 31 October 1997. Outer lines represent 95% confidence limits.

volunteers and Jasper National Park personnel explained 53% of the variation in counter data with a slope of 0.67 (Figure 4B). No cameras recorded any observations of bears.

The influence of maximum temperature and day of week (weekends or weekday) on level of human use varied among 3 trails analyzed. Precipitation did not significantly influence use of these trails. Only maximum temperature significantly affected numbers of users (relative Pratt index $d_j=0.7322$) for the Bald Hills trail going to alpine areas, though predictability of the model was very low ($R^2=20, P=0.03$). On the Beaver Lake trail midway up the Maligne Valley and accessing the Jacques Lake campground, day of the week (weekends or weekdays) significantly affected numbers of users (relative Pratt index $d_j=0.7265, R^2=0.20, P=0.03$). On the Lakeshore trail, maximum temperature, precipitation, and day type did not significantly influence human use ($R^2=0.13, P=0.14$).

Effects of human activity on habitat effectiveness for grizzly bears

During the 7 months of the study, an average of 40% of the Maligne Valley had a habitat suitability for grizzly bears of 0 ("nil", Table 1), indicating areas which were unsuitable bear habitat and which were excluded from analyses of habitat effectiveness. The percentage of the valley classified as "very high" habitat suitability never exceeded 18% and "high"-valued habitat ranged from 15% to 25%, depending on the month. August was the month with the habitat most suited for grizzly bears and June was the least.

Habitat effectiveness values in all 3 bear management units during July and August (Table 2) were less than the >80% threshold value set by Parks Canada (1997). The September value for the Lower Maligne BMU also was below the 80% threshold value. Potential and realized habitat qualities were greatest for all 3 BMUs in August, except for the Upper Maligne BMU, which had its greatest realized habitat value in April. Months of greatest human disturbance were July and August, whereas the least amount of disturbance occurred in April and May. Habitat effectiveness values declined in months when human activity was at greatest levels, with the decline in effectiveness being greatest for the Upper Maligne area. Habitat potential and the cumulative disturbance coefficient explained 92% of the variation in the calculated habitat effectiveness value. Disturbance was the most important variable (Relative Pratt Index $d_j = 1.069$) in the model.

Several scenarios for which we ran the habitat effectiveness model with curtailed levels of human activity resulted in defining actions that would increase habitat effectiveness values above the 80% threshold and allowed us to assess the relative impact of different landscape features. The elimination of all point features (i.e., campgrounds) had no effect on overall habitat effectiveness values,

Table 1. Variation in habitat suitability for grizzly bears in the Maligne Valley from 1 April to 31 October 1997, as rated from nil (0) to very high (>7), using groupings derived from Kansas and Riddell (1995).

	Habitat suitability ratings (% of study area)				
Month	Nil	Low	Moderate	High	Very high
April	40	11	18	15	17
May	40	5	26	23	7
June	40	7	36	16	1
July	41	8	10	25	16
August	40	8	10	24	18
September	41	6	12	23	18
October	40	12	10	22	16

Table 2. Monthly habitat effectiveness values for each bear management unit in the Maligne Valley, Jasper National Park, using empirically gathered human use data from 1 April to 31 October 1997. Potential and realized (including effects of human disturbance) habitats are categorized as very high (>70), high (50–69), moderate (30–49), and low (<29). Cumulative disturbance coefficients represent the overall effect of human activity on bear habitat, where a value of zero implies total displacement of grizzly bears and a value of one implies no displacement. The habitat effectiveness values ≤80% represent areas that are considered very threatened (Parks Canada 1997).

Month	BMU	Potential habitat	Realized habitat	Cumulative disturbance	Habitat effectiveness
April	Lower Maligne	43.95	36.03	0.89	82%
	Middle Maligne	35.01	29.19	0.90	83%
	Upper Maligne	25.28	23.39	0.96	93%
May	Lower Maligne	41.08	34.09	0.88	83%
	Middle Maligne	34.74	29.82	0.91	86%
	Upper Maligne	24.32	23.05	0.97	95%
June	Lower Maligne	35.19	29.26	0.88	83%
	Middle Maligne	30.45	25.51	0.89	84%
	Upper Maligne	20.96	16.89	0.87	81%
July	Lower Maligne	48.25	37.81	0.85	78%
	Middle Maligne	37.93	30.27	0.87	80%
	Upper Maligne	25.77	20.20	0.88	78%
August	Lower Maligne	51.20	40.20	0.85	79%
	Middle Maligne	39.99	32.01	0.87	80%
	Upper Maligne	27.37	21.54	0.88	79%
September	Lower Maligne	48.41	38.15	0.85	79%
	Middle Maligne	38.01	30.95	0.88	81%
	Upper Maligne	26.32	22.43	0.91	85%
October	Lower Maligne	46.00	37.45	0.88	81%
	Middle Maligne	36.18	30.34	0.90	84%
	Upper Maligne	25.40	22.05	0.92	87%

whereas the elimination of either linear or dispersed features contributed to varying degrees depending on the bear management unit and month. The Maligne Lake Road accounted for the greatest decrease in habitat effectiveness in the Lower Maligne BMU (up to 17% in August), whereas overall motorized boat use (both commercial and warden-service use) decreased habitat effectiveness in the Upper Maligne BMU by a maximum of 2%.

Relative to security areas for grizzly bears, the ratios for secure habitat to usable habitat for grizzly bears exceeded the 60% threshold value set by Parks Canada (1997) for all bear management units, except for the Upper Maligne BMU in August (56.0%, Table 3). Ratios of secure-usable habitat reached the lowest levels in July and August because of increased human activity. Throughout the 3 BMUs, areas considered not secure for grizzly bears because of human use were concentrated along the Maligne Lake Road, along greater-use trails, and on both sides of Maligne Lake, as mapped for August (Figure 5). Areas rated as not secure because of physical size requirements usually occurred between areas with human use and the unusable areas of high-elevation rock and ice.

Discussion

Collection of data on the distribution of recreational activities, trends in seasonal use, total visitation, and types of human use in the Maligne Valley followed guidelines described in Hollenhorst et al. (1992). The sampling strategy allowed coverage of a large area within a short field season using limited resources. It also accommodated the varied nature of human use within the study area in which some trails experienced extremely high levels of use whereas others, especially winter routes, were used rarely from April to October. By using direct and indirect counting, and self-registration counts, we were able to monitor the variety of point, linear, and dispersed features within the study area.

Electronic video cameras were an efficient method to validate data from electronic trail counters. Observers also provided reliable data to validate trail counters, but without a large number of volunteers, data collection would have been more difficult. Observers were extremely useful in areas that did not lend themselves to electronic surveillance, such as Maligne Lake. Complete reliance on observers, however, limited our ability to obtain census-level data because these areas received coverage only during set time periods. Therefore, it is likely that we underestimated human use for features that relied entirely on observational data (i.e., lakeshore picnic sites). In addition, using a number of observers reflected varying levels of diligence in

Table 3. Security areas (area size and percentage of each bear management unit [BMU]), for grizzly bears in the Maligne Valley, Jasper National Park from 1 April to 31 October 1997. Areas are considered "not secure" if they do not meet the usable habitat size requirement of >9 km^2 because of physically small areas or because areas have been reduced in size by human use and its associated buffering within the security area model. Usable habitat includes all areas that would normally be considered grizzly bear habitat (i.e., not rock and ice, or non-vegetated areas above 2,300 m) and is represented as a percentage of the entire BMU. The secure–usable ratio is the percentage of secure area within the BMU relative to usable habitat.

Month	BMU	Secure	Not-secure (due to size)	Not-secure (due to use)	Usable	Secure/usable
April	Lower Maligne	93 km^2 (68.7%)	0.0%	10.1%	78.8%	87.2%
	Middle Maligne	153.8 km^2 (56.0%)	0.2%	8.6%	64.8%	86.4%
	Upper Maligne	210.8 km^2 (43.9)	0.2%	3.9%	48.1%	91.4%
May	Lower Maligne	93.4 km^2 (68.7%)	0.0%	10.1%	78.8%	87.2%
	Middle Maligne	156.4 km^2 (56.9%)	0.2%	7.7%	64.8%	87.8%
	Upper Maligne	218.5 km^2 (45.6%)	0.2%	2.3%	48.1%	94.8%
June	Lower Maligne	92.9 km^2 (68.2%)	0.0%	10.5%	78.8%	86.6%
	Middle Maligne	148.3 km^2 (54.0%)	0.3%	10.6%	64.8%	83.3%
	Upper Maligne	171.9 km^2 (35.8%)	3.0%	9.2%	48.1%	74.6%
July	Lower Maligne	78.2 km^2 (57.5%)	1.1%	20.1%	78.8%	73.0%
	Middle Maligne	122.9 km^2 (44.7%)	4.2%	15.9%	64.8%	69.0%
	Upper Maligne	156.2 km^2 (32.6%)	4.2%	11.3%	48.1%	67.8%
August	Lower Maligne	78.2 km^2 (57.5%)	1.1%	20.1%	78.8%	73.0%
	Middle Maligne	122.9 km^2 (44.7%)	4.1%	16.0%	64.8%	69.0%
	Upper Maligne	129.0 km^2 (26.9%)	4.8%	16.3%	48.1%	56.0%
September	Lower Maligne	78.2 km^2 (57.5%	1.1%	20.1%	78.8%	73.0%
	Middle Maligne	124.4 km^2 (45.3%)	4.2%	15.4%	64.8%	69.9%
	Upper Maligne	207.8 km^2 (43.3%)	0.3%	4.5%	48.1%	90.2%
October	Lower Maligne	93.4 km^2 (68.7)	0.0%	10.1%	78.8%	87.2%
	Middle Maligne	152.2 km^2 (55.4%)	0.8%	8.6%	64.8%	85.5%
	Upper Maligne	212.1 km^2 (44.2%)	0.2%	3.6%	48.1%	92.0%

data collection and could potentially lack the consistency found with the trail-monitoring equipment. Presence of spikes in the data sets resulted in the loss of data for that time period. Even though equipment tampering was rare, when it did occur, as much as a week of data was lost for a particular trail and trail counts would be set to 0 for that time period. In these situations, trail counters also potentially could have underestimated human activity.

Multiple regression of trail-selection patterns in relation to effects of weather and day of the week (weekend or weekday) revealed that different trails could possibly be grouped by different user types. Colder days had a greater effect on human use on the trail with the greatest change in elevation, Bald Hills trail, than the Lakeshore trail, which has easy access and no elevation gain. Weekend use had a greater effect on the Beaver Lake trail, which accesses the Jacques Lake campground and Beaver Lake (a popular fishing location). Schueck and Marzluff (1995) also stressed the importance of accounting for weather prior to making conclusions about effects of human activities in ecological research.

One field season of data collection was useful to compare human use of different feature types, but did not allow for yearly climatic variations. The "ice-off" date for Maligne Lake in 1997 was 5 June, whereas in 1998 it was 14 May (one of the earliest on record). Winter snow packs can vary dramatically annually in Jasper National Park and often determine timing and amount of access to trails and backcountry campgrounds. These variations could affect grizzly bear habitat effectiveness and security area values on a yearly basis. For example, amount of area considered "not secure" was greatest in July and August (Table 3) because of the reduction in the habitat available to the bears, resulting from improved trail access following snow melt. Because 1997 was a year of high snow pack, levels of human use should be considered conservative for April, May, and June, and habitat effectiveness values may have been greater than in other more typical years.

A decrease in habitat effectiveness values with

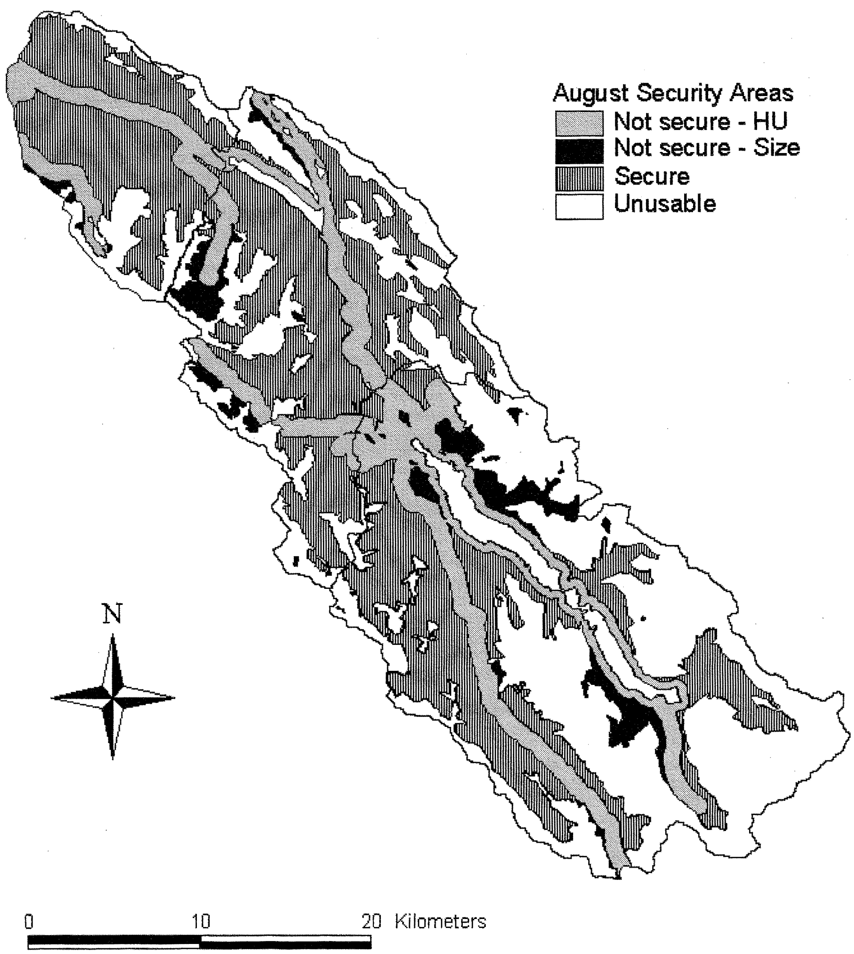

Figure 5. Security-area ratings for grizzly bears inhabiting 3 bear management units in the Maligne Valley in August, 1997. Areas not considered secure were separated based on insufficient size or effects of human use (HU).

increased human use in this study occurred even with an increase in habitat suitability values (Table 2). This relationship exists due to the multiplicative nature of the habitat effectiveness model because areas of greater habitat value are influenced more strongly by human use (as represented by the disturbance coefficient, DC). For example, an area with a habitat value of 10 and a DC of 0.45 is reduced to a value of 4.5 (a decrease from very high habitat suitability to moderate habitat suitability). An area with a habitat value of 1 and a DC of 0.45 is reduced to a value of 0.45, but in the latter case there is no change in the original low habitat suitability rating.

Jasper National Park used the DCs and ZOIs for the Yellowstone ecosystem, with minor modifications for Banff National Park, because both areas are considered protected areas surrounded by multiple-use lands (Gibeau et al. 1996) and were therefore expected to exhibit similar parallels between human influences on grizzly bear habitat use. We reduced the elevational cut-off separating suitable from unsuitable nonvegetated habitat from 2,400 m, as used in Banff, to 2,300 m in Jasper to accommodate the difference in latitude between Jasper and Banff (Purves and Doering 1998, Gibeau et al. 1996).

Using Parks Canada's current threshold of >80% for habitat effectiveness (Parks Canada 1997), the Maligne Valley did not meet these standards for July, August, or September (for the Lower Maligne BMU only). The least habitat effectiveness value was 78% (Table 2), and we assume that any increase in human activity on low-use features, or any additional development in the valley, would continue to compromise the estimated amount of habitat available to grizzly bears. As mentioned, measures of human use in this study may have been conservative in cases where we removed suspect counts from electronic trail counter data and where observers were unable to obtain census-level data. Additionally, the values derived from this study did not incorporate effects of trails and other human-use features adjacent to the study area boundary. Buffering of these features would add to the reduction of habitat effectiveness in the Maligne Valley. In contrast, assumptions of the model, which would increase habitat effectiveness if they were not met, include those times when backcountry users did not stay at the permitted campground because of inclement weather and when people using the trails did not travel the entire segment for which the use and its associated buffer were assigned.

In manipulating the habitat effectiveness model to increase values to >80%, we needed to remove a feature of significant size or several features in combination to cause any change in the overall value. Consequently, we observed greater effects for linear and dispersed features than for point features because of their size and associated zones of influence. Proximity of the feature to high or very high value habitat was a primary factor in model responsiveness. Deficits in security-area size were easier to "correct" because areas of usable habitat that we could reconnect by removing a feature (i.e., trail, campground) were simple to identify on map output. Such modifications might not prove realistic in practice, however, because of the unlikelihood of closing the main access road to the valley or the difficulty of enforcing the closure of remote trails.

Another strong influence on model responsiveness is how and where BMUs were established. Because the model is based on various assumptions and landscape divisions, only full validation of the model (i.e., collaring and tracking bears to determine habitat use and displacement behaviors) would ensure that the BMUs, displacement coefficients, zones of influence, and study-area boundaries were applicable. Model validation is critical for accurate predictions of species presence and behavioral response because failure to do so could allow Type I and Type II errors in the model to go undetected (Morrison et. al. 1998). Management actions resulting from Type I and Type II errors could result in incorrect mitigation actions or false predictions of impacts on vulnerable species respectively (Morrison et al. 1998). We have assumed that Gibeau's data on habitat use by bears in response to disturbance (Gibeau 2000), gathered in Banff National Park, can be used to refine Jasper National Park's model, because both parks use the same ecological land classification (Holland and Coen 1983, Holroyd and VanTighem 1983) and grizzly bear habitat model (Kansas and Riddell 1995). Major limitations to this assumption are that habitat value is accurately predicted by availability of vegetative habitat and that the vegetation classification systems used for mapping are accurate predictors of food and cover value for grizzly bears. There was no accommodation in the model for bears using insects in high scree or talus areas, as observed in Glacier and Yellowstone National Parks (e.g., Mattson et al. 1991, White et al. 1998). Jasper and Banff National Parks have nonhunted grizzly bear populations and similar visitor-use patterns (within the park boundaries). The effect of the latter on habitat effectiveness may be most limited in the model by logarithmic groupings of people (encompassing a wide range of visitor use within a single category) over a monthly time step (which may not be the appropriate temporal scale eliciting response by bears). Behavioral differences also are likely between habituated and nonhabituated bears that encounter motorized or nonmotorized activities by humans. Therefore, in addition to tracking bears in different habitats with different levels of human use to validate the model and its assumptions, further research should implement a sensitivity analysis of the habitat effectiveness model to determine which component is most sensitive to or has the greatest impact on the outcome.

Management implications

Many studies indicate that human activities can adversely affect grizzly bear movements, behaviors, and habitat use (Elgmork 1978, Jope 1985, McLellan and Shackleton 1989, Mace and Waller 1996). The grizzly bear habitat effectiveness model is being explored as a management tool by agencies responsible for grizzly bear management (e.g., Weaver et al. 1986, Weaver et al. 1987, Apps 1993). This model and security-area analysis allow human activities to be included in habitat evaluation modeling for grizzly bears (Gibeau et al. 1996, Page et al. 1996). The ability to predict bear-human conflict areas and habitat fragmentation for grizzly bears is a strong tool in times when grizzly bear habitat is declining and visitation to our natural areas is increasing rapidly (Hummel and Pettigrew 1992, Page et al.1996). Our results suggested that when human activities increased in areas of high habitat suitability for grizzly bears, habitat effectiveness values decreased. With the increase in human activities, there also was an increase in buffer distances and consequently an additional reduction in usable security areas. Including a sensitivity analysis into habitat effectiveness models would provide a more succinct indication of the types of human activities and habitats that influence the model's output. Further research to set priorities and alternatives should be implemented to determine whether there are some types of human activity (e.g., vehicular traffic versus horse use versus hiking versus canoeing) that might be more compatible with bear behavior than others.

Within our study, an increase in human use corresponded with the end of the school year and the beginning of the long July weekend. This rise in human activity coincided with an increase in grizzly bear habitat suitability resulting from snowmelt and changes in plant phenology. Planning and regulation of trails and other features such as picnic sites, roads, and campgrounds to ensure avoidance of high and very high value habitats for grizzly bears would help to maintain greater levels of habitat effectiveness and security areas. We recommend that any new facilities in the Maligne Valley be placed only in areas with low habitat suitability and that efforts be made to determine whether rerouting some trails could provide secure corridors for movement by bears. By using the predictive nature of the habitat effectiveness model and the modeling options presented by GIS, managers are able to build scenarios that allow for an overall assessment of present and proposed developments on the landscape.

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