Natural landscape features, human-related attractants, and conflict hotspots: a spatial analysis of human–grizzly bear conflicts

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Abstract: There is a long history of conflict in the western United States between humans and grizzly bears (*Ursus arctos*) involving agricultural attractants. However, little is known about the spatial dimensions of this conflict and the relative importance of different attractants. This study was undertaken to better understand the spatial and functional components of conflict between humans and grizzly bears on privately owned agricultural lands in Montana. Our investigations focused on spatial associations of rivers and creeks, livestock pastures, boneyards (livestock carcass dump sites), beehives, and grizzly bear habitat with reported human–grizzly bear conflicts during 1986–2001. We based our analysis on a survey of 61 of 64 livestock producers in our study in the Rocky Mountain East Front, Montana. With the assistance of livestock and honey producers, we mapped the locations of cattle and sheep pastures, boneyards, and beehives. We used density surface mapping to identify seasonal clusters of conflicts that we term conflict hotspots. Hotspots accounted for 75% of all conflicts and encompassed approximately 8% of the study area. We also differentiated chronic (4 or more years of conflicts) from non-chronic hotspots (fewer than 4 years of conflict). The 10 chronic hotpots accounted for 58% of all conflicts. Based on Monte Carlo simulations, we found that conflict locations were most strongly associated with rivers and creeks followed by sheep lambing areas and fall sheep pastures. Conflicts also were associated with cattle calving areas, spring cow–calf pastures, summer and fall cattle pastures, and boneyards. The Monte Carlo simulations indicated associations between conflict locations and unprotected beehives at specific analysis scales. Protected (fenced) beehives were less likely to experience conflicts than unprotected beehives. Conflicts occurred at a greater rate in riparian and wetland vegetation than would be expected. The majority of conflicts occurred in a small portion of the study area, where concentrations of attractants existed that overlapped with bear habitat. These hotspots should be the target of management and conservation efforts that focus on removing or protecting attractants using non-lethal techniques.

Key words: attractants, beehives, grizzly bear, livestock, management practices, Montana, private landowners, ranches, *Ursus arctos*

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Reduction of human-caused mortality is an important element of recovering threatened grizzly bear (*Ursus arctos*) populations in the contiguous United States (US Fish and Wildlife Service 1993), because most deaths of subadult and adult grizzly bears in this region are caused by humans (Mattson et al. 1996, McLellan et al. 1999). A disproportionate number of these deaths occur on private lands as a result of conflicts precipitated by attractants (Servheen 1989). In Montana, researchers and managers have called for a reduction in the availability of

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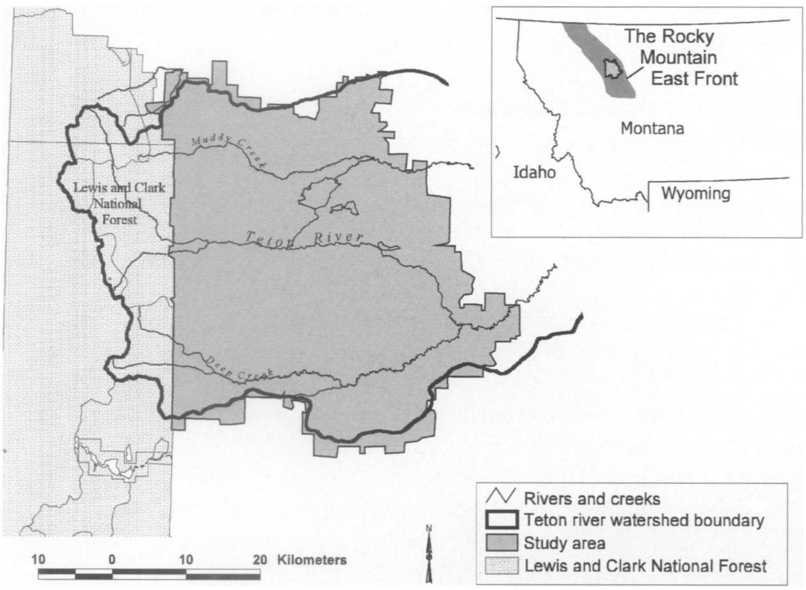

Fig. 1. Study area on the Rocky Mountain East Front, Montana, USA.

anthropogenic foods and other attractants on privately owned lands to reduce conflicts and mortalities, particularly of female grizzly bears (Madel 1996, Mace and Waller 1998). However, interactions between grizzly bears and humans on private agricultural lands and spatial associations with factors that predispose grizzly bears to risk of conflicts have not been thoroughly investigated.

Domestic livestock and beehives have long been attractants to grizzly bears in North America (Mattson 1990). Under certain conditions, grizzly bears can kill substantial numbers of cattle and sheep (Murie 1948, Johnson and Griffel 1982, Jorgensen 1983, Knight and Judd 1983, Brown 1985). Both grizzly and black bears (*U. americanus*) can also cause substantial damage to beehives (Jorgensen et al. 1978). Along Montana's Rocky Mountain East Front during the 1980s, 44% of conflicts were cattle depredations and 40% were property damage reports (Aune and Kasworm 1989). During 1991–1994, 82% of all human–grizzly bear conflicts were attractant related and approximately 55% of conflicts were associated with livestock operations (Madel 1996).

Data on reported human–grizzly bear conflicts contain information on different types of conflicts. Although the type of conflict is relevant to describe general categories of conflicts, understanding the spatial patterns, locations, and scales of conflicts are important for reducing future human–grizzly conflicts. For example, there are areas throughout Montana and Wyoming dominated by agricultural land uses where grizzly bears are reoccupying former habitats (Schwartz et al. 2002). A spatial analysis may help managers predict where conflicts will occur, particularly in places where bears are reoccupying former habitats.

Therefore, we investigated ecological and social factors associated with human–grizzly bear conflicts on private agricultural lands. We focused on spatial associations among reported human–grizzly bear conflicts, natural landscape features, and attractants related to livestock and honey production for a portion of the Rocky Mountain East Front, Montana. Specifically, we examined the spatial patterns of areas with human–grizzly bear conflicts, and which natural landscape features and human-related attractants were associated with conflict areas.

Study area

Our 172,000-ha study area was located in north-central Montana, along the Rocky Mountain East Front at 47°50′ N latitude and 112°10′ W longitude (Fig. 1). We selected this study site because grizzly bears extensively use privately owned and managed agricultural land (Aune and Kasworm 1989). Because our research focused on private ranch lands, we bounded the study area on the west by the Lewis and Clark National Forest and on the east by the transition from cattle ranches to wheat farms. The north and south boundaries were defined by the Teton River watershed. Approximately 80% of grizzly bear spring habitat in this area is on private lands, primarily in fen and riparian habitats (Aune and Kasworm 1989). These riparian areas provide critical seasonal food, cover, and security for grizzly bears. The 61 livestock producers we surveyed owned, managed, or leased approximately 130,733 ha (≈97%) of the study area that was available for agriculture (≈134,000 ha). Ranch buildings and corral facilities mostly were located along creek and river bottoms. Beehives and newborn livestock, found in calving areas and lambing grounds, were readily available to grizzly bears.

Methods

Conflict, agricultural attractant, and natural landscape features

Human–grizzly bear conflicts ($n = 178$) were recorded during 1986–2001 and described by: calendar date, location (universal transverse Mercator [UTM] coordinates), type of conflict, and identity of grizzly bear, if known. We use the term "human–grizzly bear conflict" or "conflict" to refer to any incident reported to and verified by Montana Department of Fish, Wildlife and Parks (MFWP; Table 1). We considered the presence of a grizzly bear near a residence a conflict, although no damage to human property may have occurred. We felt that including these incidents in our analysis was important because bears that were in close proximity to humans, homes, or facilities may pose a risk of becoming food conditioned or habituated and therefore represent potential problems. It is also probable that residential conflicts were the result of grizzly bears attracted to the area because of boneyards, beehives, or calving areas.

Ranchers are often uncomfortable with grizzly bears that spend time near their homes, and the acceptability of grizzly bears depends on people's perceptions of bear behavior. Bears that spend time around homes and facilities are generally negatively perceived, whereas bears that travel through are more tolerated. Malicious killing of grizzly bears occurs in our study area and in the region. By using all types of conflicts from our dataset, we are better able to understand locations where regular interactions among humans and grizzly bears occur and where negative outcomes can be minimized.

All locations and conflicts were reviewed with MFWP for accuracy prior to analysis. The second author (M. Madel) responded to 91% of conflict calls from 1986–2001. He consistently recorded UTM locations of conflicts and had extensive knowledge of the study area (>20 years of field experience). Thus, errors due to observations by multiple individuals were limited. MFWP personnel identified and captured grizzly bears and marked bears with radiocollars, lip tattoos, and ear tags. Grizzly bears known to be associated with specific conflicts and hotspots were identified based on recapture or radiotracking and represented 9% of reported and verified conflicts.

During 1986–2001, 57% of the 178 conflicts were associated with either livestock or beehives and 80% of the 42 residential, close proximity conflicts occurred on ranches (Table 1). Slightly less than a third (30%) of all conflicts was associated with livestock depredations.

Table 1. Grizzly bear conflicts (n = 178) by type, Rocky Mountain East Front, Montana, USA, 1986–2001 from Montana Department of Fish, Wildlife and Parks Conflict Database for Rocky Mountain East Front, Choteau, Montana.

Conflict type	Number of conflicts	%
Livestock depredation	53	30
Residential conflict, close proximity	42	24
Beehive site damage	31	17
Grizzly bear feeding on livestock carcass (natural death)	13	7
Residential conflict, garbage/attractant related	12	7
Reported as grizzly, livestock depredation (unverified)	9	5
Livestock stressed by grizzly bear presence	5	3
Reported as grizzly, residential close proximity (unverified)	4	2
Reported as grizzly, beehive site damage (unverified)	3	2
Human–grizzly bear encounter	2	1
Residential/bird feeder	1	<1
Property damage	1	<1
Livestock injury	1	<1
Grizzly bear injury	1	<1
Total	178	100

We obtained information on agricultural attractants based on in-person interviews with 61 of 64 livestock producers in the study area (95% response rate). We tested all interview techniques on a sample of livestock producers outside the study area. We collected information on seasonal locations of cattle and sheep pastures, locations of boneyards (carcass dumps), and locations and protection status (fenced or unfenced) of beehives (Wilson 2003). We found that displaying high quality images of livestock producers' operations elicited detailed responses about locations of management practices and their experiences with grizzly bears. Wilson (2003) provided detailed information on participatory GIS mapping as a tool for incorporating local knowledge into wildlife management and research.

Rivers and creeks and associated riparian or wetland vegetation are important features of grizzly bear habitat in our study area (Aune and Kasworm 1989). We used a digital, 30-m Landsat Thematic Mapper (TM) image of the vegetation of western Montana to delineate riparian and other wetlands defined by Redmond (1996). Redmond (1996) did not directly assess accuracy of riparian and wetland cover class types, but these types corresponded well with riparian areas visible in digital orthophotos, and Redmond (1996) reported an overall prediction accuracy for cover types of 61.4%. We used a digital vector-based hydrography layer (1:100,000 scale) to represent rivers and perennial creeks (Natural Resource Information System 2001).

Mapping conflict density

We defined conflict hotspots by identifying discrete clusters of human–grizzly bear conflicts. This process enabled us to display the seasonal locations of concentrated conflicts, identify hotspots characterized by recurring conflicts, determine the scale at which the majority of conflicts occurred, identify and characterize areas without chronic conflicts, and determine which hotspots were associated with (1) many bears as a potential function of landscape conditions, or (2) a few problem bears as a function of potentially idiosyncratic learned behavior. We recognize that a direct estimate of conflict probability is a possible approach, but for this analysis, such estimates would be confounded by the presence of several attractants being found together. Thus, a simple Monte Carlo approach was taken to quantify the association without assigning a conflict probability. However, our analysis is useful for understanding spatial relations between conflicts and individual human land uses.

We used density mapping as a tool to identify concentrations of conflicts. We normalized the conflict data by season to account for season length. Spring, summer, and fall were 4.5 months, 2 months, and 1.5 months long, respectively. We used the inverse of season duration (1/4.5, 1/2, and 1/1.5) to weight each seasonal density map for parameterizing conflicts as density per month. We used a moving window analysis to generate density surfaces with intervals that corresponded to >3 conflicts within the search radius serving as a threshold for hotspot identification. Mattson (1993) suggested that features encountered by bears during 24–48-hr foraging bouts have the greatest influence on likelihood of conflict with humans. Based on investigations of daily movements by female grizzly bears with cubs in southern Alberta (Gibeau 2000, Gibeau et al. 2002), we chose a search radius of 1.6 km. A 1.6-km search radius was represented by an 8-km^2 moving window area.

Delineating conflict hotspots

We delineated and described discrete areas that were characterized by concentrations of conflicts. These hotspots were a focus of conflict between humans and grizzly bears compared with other portions of the study area. We defined hotspots based on the number of conflicts ($\geq$3) and the number of years ($\geq$2) within which conflicts occurred. Thus, a hotspot was defined, in part, as a density surface area with $\geq$3 conflicts based on a moving window analysis. Locations with several conflicts over a short time (several months) probably do not constitute an enduring problem. Individual bear behavior, poor food conditions, or idiosyncratic responses of livestock producers likely explain the occurrence of these ephemeral hotspots more than landscape conditions. However, areas where conflicts occurred during at least 2 years suggest that specific landscape conditions may play a contributing role. The 2-year criterion is based on the assumption that repeated human–grizzly bear interactions and continuity of certain human activities lead to repeated conflicts.

Chronic and non-chronic hotspots

Chronic hotspots are logical focal areas for management and conservation efforts. Therefore, after we identified hotspots, we further refined our analysis to separate chronic hotspots from those that were non-chronic. We defined chronic hotspots as having $\geq$4 years of conflicts and non-chronic hotspots as having $<$4 years (total) of conflict.

We recognize the normative and subjective nature of these definitions. However, our primary intent was to develop transparent criteria that could be systematically used to identify problematic landscape contexts for targeting management and conservation efforts. We used a liberal definition of hotspots and a more restrictive definition for those that were chronic so that managers could use a definition of concentrated conflict that best suited their needs.

Monte Carlo methods for natural landscape features and agricultural attractants

We measured the linear distance of conflicts ($n = 178$) to the nearest river or creek, calving and lambing area centroid (center of polygon), cattle and sheep spring pasture centroid, cattle and sheep summer pasture centroid, cattle and sheep fall pasture centroid, aggregated calving and lambing area centroid, and boneyards. We recognize that distance measures to pasture centroids are not an ideal measure because there is variability in pasture size. Thus, summer and fall pastures, due to their larger sizes and their respective association with conflicts, may be slightly overstated as these pastures are well distributed throughout the study area.

In preliminary analysis we attempted to measure conflicts to the nearest pasture edge, but results became confusing due to pasture configurations and layout. MFWP has a carcass redistribution program where carrion from ranches that are placed in boneyards are collected in the spring and randomly redistributed to remote locations along the Rocky Mountain East Front. Livestock producers started participating in the program throughout 1986–2001, making it impractical to run Monte Carlo (MC) simulations for each time interval with a different sample size. Because grizzly bears may continue to investigate managed boneyards if they have found carrion in the past and because only 12–15 boneyards out of >50 boneyards were part of the MFWP program, we used all boneyards in the MC simulations.

For each feature and season, we compared the observed distribution of distances to a distribution based on 1,000 randomized locations equal to the number of conflicts (Manly 1997, McKenney et al. 2002). We calculated the number of means and medians from random distributions that were greater than the observed mean and median of observed distances for conflicts and computed the MC *P*-value and 95% confidence intervals. We produced histograms for all distributions and used median distance values in our results because all distributions were consistently right-skewed (certain features were located long distances from conflicts). The numbers of locations used in MC simulations varied by the number of seasonal conflicts.

We grouped conflicts into seasons based on timing of changes in grizzly bear diets (Craighead et al. 1982, Mace and Jonkel 1986): spring (den/den vicinity emergence–15 Jul), summer (16 Jul–15 Sep), and fall (16 Sep–denning). These intervals overlapped with changes in livestock pasture locations. Livestock producers identified areas traditionally used for spring, summer, and fall pastures during 1986–2001. For analysis purposes, we assumed that these pasture locations were generally stable, although some changes in pasture locations occurred. The Teton County Extension Agent (D. Clark, Choteau, Montana, USA, personal communication, 2003) indicated that calving areas, spring pastures for cow–calf pairs, lambing areas, and spring pastures for ewe–lamb pairs were the most spatially stable pasture locations. Those areas were located near ranching facilities to oversee the calving and lambing process during the early spring and were often annually planted with a forage crop.

We defined 3 scales of analysis for drawing random samples in our MC simulation of associations between beehives and conflicts. Our objective was to test whether protected (electrically fenced) beehives were more or less likely to be spatially associated with conflicts compared with unprotected (no electric fence) beehives. Unlike other attractants, beehives were only located in the eastern half of the study area and were not available at the scale of 24–48-hr movements to grizzly bears elsewhere. We were unsure of the scale of grizzly bear attraction to beehives, so we used different radii to define areas for analysis (Fig. 2). We used MC tests based on different analysis scales to determine the scale of attraction or influence that best explained patterns of conflict. The original 1.6-km radius produced an analysis area that was too small for MC simulations, so we created buffers that were 2, 3, and 4 times larger than the original (3.2 km, 4.8 km, and 6.4 km, respectively). We grouped beehives by protection status and by whether they were more than 4 years old.

We tested the hypothesis that the likelihood of conflicts at beehives ($n = 31$) was independent of whether the beehive was protected using a χ^2 test of association. We first identified beehives ($n = 12$) that had experienced conflicts and then buffered them by 3.2-km, 4.8-km, and 6.4-km to include nearby beehives ($n = 15$; 4.8- and 6.4-km buffers) that had not experienced conflicts. Our objective was to compare the likelihood of conflict at protected versus unprotected beehives only in parts of the study area that experienced consistent beehive conflicts. We accounted for change in beehive protection status in our analysis. For example, if an unfenced beehive experienced a conflict prior to being fenced, we classified it as an unprotected beehive and ascribed a conflict to it. Once fenced, the beehive was classified as protected.

Associations with riparian and wetland vegetation

We determined the number of conflicts inside and outside delineated riparian and wetland areas and calculated the associated contiguous area of riparian and wetland habitats. We used the one-sample proportion *z*-statistic to test for differences between proportional occurrence of conflicts and proportional availability of riparian and wetland habitat. We also used a *z*-test to determine the number of conflicts and total area defined by 3 buffers (200-m, 550-m, and 1,250-m intervals) around riparian and wetland areas containing approximately 50%, 75%, and 87.5% of all conflicts, respectively.

Results

We identified 19 seasonal conflict hotspots, including 6 spring hotspots (A–F) that contained 73% of all spring

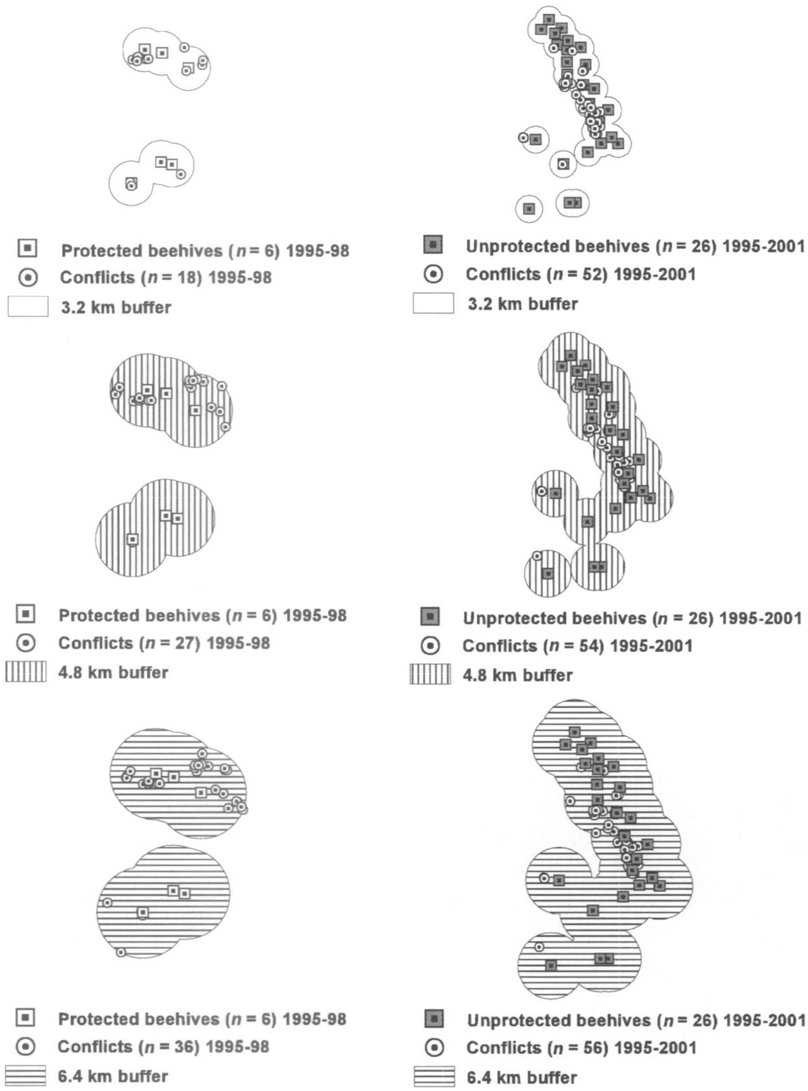

Fig. 2. Analysis Areas (3.2-, 4.8-, and 6.4-km distance buffers around beehive locations) used for MC analysis of protected and unprotected beehives in the eastern portion of the study area, Rocky Mountain East Front, Montana, USA, 1986–2001.

conflicts ($n = 93$), 9 summer hotspots (G–O) that contained 76% of all summer conflicts ($n = 50$), and 4 fall hotspots (P–S) that contained 77% of all fall conflicts ($n = 35$; Fig. 3). Combined, the 19 seasonal conflict hotspots accounted for 75% of all conflicts ($n = 178$) during 1986–2001.

We identified 10 chronic hotspots that contained more than half (58%) of all conflicts during 1986–2001 (Table 2; Fig. 4). More than a third (34%) of all conflicts occurred in spring chronic hotspots. Summer and fall chronic hotspots accounted for 10% and 14% of all conflicts, respectively (Table 2). Additionally, 8 out of 10 seasonal chronic hotpots overlapped spatially, suggesting that attractants were available across seasons (Fig. 4).

Sixteen known grizzly bears were associated with the seasonal conflict hotspots, including 11 associated with spring hotspots, 2 with summer hotspots, and 3 with fall hotspots. These known bears accounted for 92 of the 178 total conflicts, including 24 during spring, 8 during summer, and 7 during fall. Fifteen known bears were associated with the 10 chronic hotspots. Four individuals were found at multiple seasonal hotspots. No yearlings or cubs were included in counts of known grizzly bears.

A majority of seasonal hotspots had riparian or wetland vegetation, or were associated with a river or creek, boneyard, or beehives (Table 3). Sixty-two percent of all conflicts were in hotspots that overlapped among seasons and contained both boneyards and beehives (Table 3).

Conflicts that occurred during 1986–2001 were concentrated near rivers and creeks. The mean distance of all conflicts to the nearest river or creek was 1.8 km; the median distance was 0.9 km. The mean and median distances for the 1,000 iterations of randomly distributed locations were 2.9 km and 2.5 km, respectively. The observed distance of conflicts from rivers and creeks was highly unlikely to have occurred by chance, considering both mean and median values ($P < 0.001$).

Spring and fall conflicts were strongly associated with sheep lambing areas and sheep fall pastures, respectively ($P < 0.001$; Table 4). Spring conflicts also were strongly associated with calving areas and spring cattle pastures, and fall conflicts were associated with fall cattle pastures ($P < 0.001$). Spring conflicts ($n = 93$) and all conflicts ($n = 178$) were strongly associated with calving or lambing areas combined ($n = 105$; $P < 0 .001$) and boneyards ($P < 0.001$). Year-round conflicts also were strongly associated with boneyards ($n = 53$) ($P < 0.001$).

Conflict locations were positively associated with unprotected beehives in the 3.2- and 4.8-km areas, 1995–2001 ($P < 0.042$; $P < 0.001$). Protected beehives were only associated with conflict locations at the 3.2-km scale ($P < 0.016$) during 1995–1998 (Table 5). Protected beehives were less likely to be associated with conflicts than were unprotected beehives within the 3.2-km area ($\chi^2 = 7.29$, 2 df, $P = 0.026$), but were only moderately less likely within the 4.8-km area ($\chi^2 = 5.69$, 2 df, $P = 0.058$) and 6.4-km area ($\chi^2 = 5.07$, 2 df, $P = 0.079$).

The proportion of conflicts within riparian and wetland vegetation was much greater than expected given the availability of this habitat within the study area. Additionally, disproportionately more conflicts occurred within the 200-m, 750-m, and 2,000-m buffers of the riparian and wetland associated vegetation than expected by the relative size of these buffers in the study area ($P < 0.001$). Nearly half of the cumulative proportion of conflicts ($n = 88$) occurred within 200 m of riparian and wetland vegetation ($P < 0.001$).

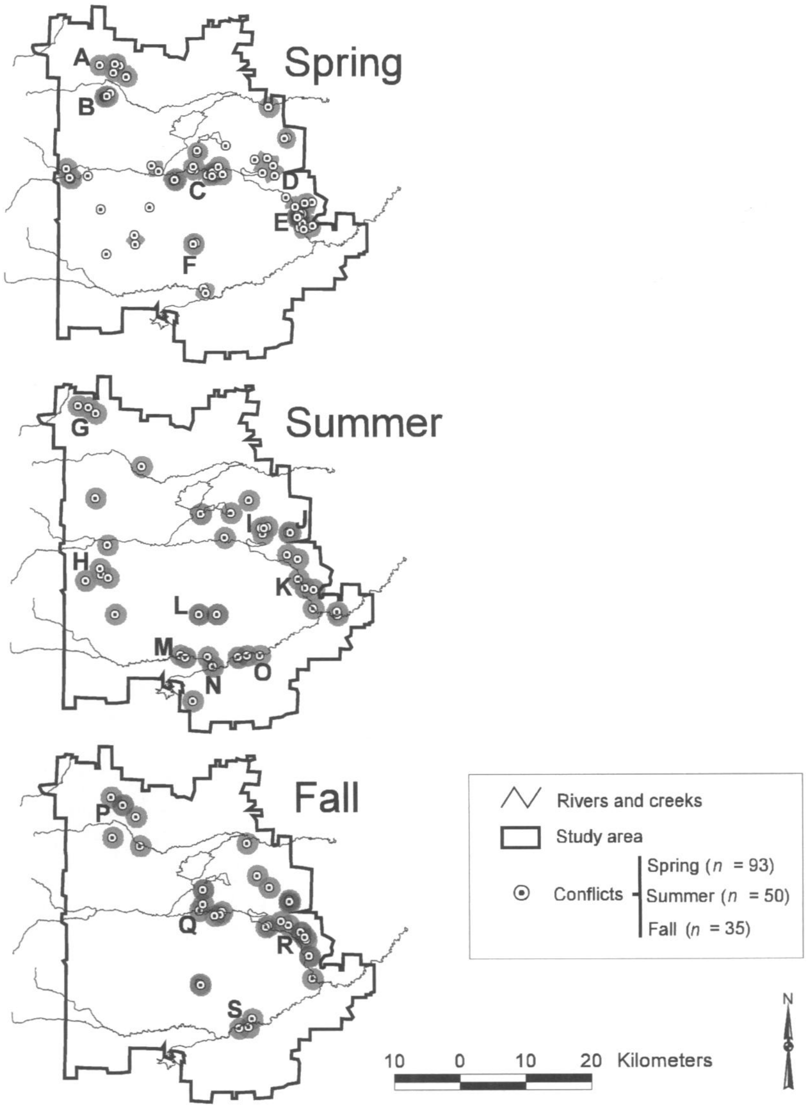

Fig. 3. Spring, summer, and fall conflict densities for hotspots A–F, G–O, and P–S (n/km^2/month; $n = 93$; $n = 50$; $n = 35$), Rocky Mountain East Front, Montana, USA, 1986–2001.

Discussion

The pattern and nature of conflict between humans and grizzly bears in our study area were consistent with what we know about grizzly bear dietary preferences and foraging behavior. Grizzly bears eat meat wherever it is available, and meat provides the majority of energy for some bears and some populations (Mattson 1997, Jacoby et al. 1999). Meat is highly digestible to bears and contains high concentrations of energy (Pritchard and Robbins 1990). Grizzly bears rely on predation to obtain meat from smaller-bodied ungulates (Mattson 1990, 1997), but will assiduously seek out and exploit carrion from larger-bodied ungulates that die of other causes (Green et al. 1997). Grizzlies also seem to prefer ambush predation and the advantages offered by cover when preying on large animals such as adult moose (*Alces alces*), elk (*Cervus elaphus*), and domestic cattle (Murie 1948, Mattson 1997). Given these tendencies, it is not surprising that cattle and sheep were the focus of much conflict between humans and grizzly bears in our study area; that much of the depredation occurred near cover provided by woody riparian vegetation in an otherwise open environment; that boneyards were a focus of scavenging activity by bears; and that small-bodied calves and lambs were an apparent focus of attention for bears during the calving and lambing seasons. The availability of calving afterbirth and concentrated odors

Table 2. Annual frequency of grizzly bear conflicts for seasonal chronic hotspots, Rocky Mountain East Front, Montana, USA, 1986–2001.

	Spring				Summer			Fall			
Year	A[a]	B	C	E	K	L	O	P	Q	R	Totals
1986	1		2		1						4
1987										1	1
1988									1		1
1989									2	1	3
1990			1	2	1						4
1991	3	3	2	2		3		1		3	17
1992			1				2				3
1993						1	1	1			3
1994		1					1	1	2		5
1995	3		10	2							15
1996			5	1	2				2	2	12
1997	1		2	6	1						10
1998	2	2			2			1		5	12
1999		1	1	1		1	1				5
2000				5						1	6
2001				1		1					2
Totals	10	7	24	20	7	6	5	4	7	13	103
Years of conflict	5	4	8	8	5	4	4	4	4	6	

[a]Letters represent chronic seasonal hotspots (≥3 conflicts and ≥4 years with conflict).

of sheep lambing and bedding grounds also contribute to the attractiveness of calving and lambing areas to grizzly bears foraging and traveling along riparian corridors. Thus, patterns of depredation along the Rocky Mountain East Front seem to be deeply rooted in the natural foraging behavior of grizzly bears.

Human–grizzly bear conflicts were concentrated in a small portion of our study area. About 75% of all conflicts occurred in only 8% of the study area, in locales that we defined as seasonal hotspots. More than half (58%) of all conflicts occurred in hotspots that we defined as chronic. The extent of association between conflicts and hotspots is partly an artifact of how we defined hotspots. However, when we considered a hotspot definition based on a threshold of 2 rather than 3 conflicts, we added only 12 conflicts (out of 178). From this we conclude that our hotspot definition was relatively robust. Even prior to analysis, the extent of conflict concentration in our study area suggested that conflict was not independent of landscape of features.

We acknowledge that our use of close proximity conflicts in our analysis may overstate the extent of our delineation of conflict hotspots. However, such conflicts have serious impacts on how people perceive grizzly bears even though no property damage may have occurred. By including those data in our analysis, we attempted to direct management and conservation attention to locations where bears consistently encounter people. This approach is precautionary in that knowing more about potential problem sites provides an opportunity to proactively ameliorate more serious conflicts before they start.

Conflict hotspots were not the result of a few problem bears. We identified 16 individual bears associated with seasonal conflict hotspots during our 16-year study. Fifteen bears were identified with 10 chronic hotspots. Moreover, as evident in our hotspot definition, many conflicts occurred in specific locales during >1 year, including non-consecutive years. Of course, not all bears are equally prone to cause conflict. Certain bear classes, especially adult males in the case of livestock depredation, are more likely than others to cause conflicts (Mattson 1990, Anderson et al. 2002). Yet, 10 of the 16 grizzly bears associated with conflict hotspots were either adult or subadult females. Given these observations, we conclude that behaviors of individual bears alone can not adequately explain the observed patterns of conflict and that most conflicts were more likely the result of problematic contexts. There was substantial overlap among hotspots from all seasons, suggesting the effects of enduring multi-seasonal human-related attractants and potentially a multi-seasonal lag effect of attractants available during one season. This was especially true for chronic hotspots. Most seasonal and particularly chronic hotspots shared riparian or other wetland vegetation, proximity to a watercourse, presence of boneyards, and presence of beehives. Overlapping hotspots with these features accounted for 62% of all conflicts. Spring and fall hotspots, in particular, tended to be clustered along watercourses. This is consistent with documented use of riparian areas by grizzly bears in our area for travel, foraging, and cover during spring and fall (Aune and Kasworm 1989). Riparian vegetation communities along the Rocky Mountain East Front provide some of the highest quality grizzly bear habitat in the area (Waller 1999). Grizzly bears actively forage on natural herbaceous plant foods during spring and high-energy fruiting shrubs in the fall despite the availability of attractants. The abundance and density of these natural foods combined with high security vegetation draws bears near to ranch facilities and concentrated livestock pastures and likely contributes to conflict hotspot formation.

Boneyards may provide multi-seasonal opportunities for scavenging. However, boneyards were more likely to have carrion during the spring compared with summer or fall. Interviews with ranchers indicated that dead livestock were occasionally placed in boneyards during the summer and fall seasons. Our MC results suggested that boneyards were strongly associated with conflicts in the study area. However, this finding should be interpreted with caution because we did not account for changes in management status of boneyards that were unmanaged for some time and became managed under the MFWP Carcass Redistribution Program. Multi-variable analysis is warranted to explicitly account for changes in management practices in boneyards.

Bears exploit beehives wherever they have the opportunity (Mattson 1990), presumably because beehives provide a rich source of simple carbohydrates, much like fleshy fruits. Electric fences, used to protect beehives in our study area, are well-proven deterrents of many species of large carnivores, including bears (Kruuk 1980, Follman and Hechtel 1990, Madel 1996, Kacznesky 1999, Sillero-Zubiri and Laurenson 2001, Jonkel 2002). Unprotected beehives were clearly associated with conflicts at the 3.2- and 4.8-km scales during 1995–2001. However, protected beehives were also associated with conflicts at the 3.2-km scale for the same period. Overall, evidence suggested that protected beehives were less likely to be spatially associated with conflicts. Although we do not have a conclusive explanation why protected hives were associated with conflicts at the 3.2-km scale, we suspect that some conflicts associated with beehives may have been attributable to other nearby features, such as riparian or calving areas. In some instances, previous rewards from exploiting a beehive when it was unprotected may also draw bears back to a beehive. Beehive depredation along the Rocky Mountain East Front generally is a learned behavior among certain grizzly bears (Madel 1996). Because results based on univariate analyses did not explicitly control for effects of multiple spatially correlated features, it is difficult to separate the effects of riparian areas from those of anthropogenic features such as boneyards and beehives. However, our analysis qualitatively and quantitatively assesses specific landscape conditions that may contribute to conflict hotspots. Many ranch facilities and operations were concentrated near riparian areas because they offered shelter and water for livestock. Shelter is especially critical for late winter and early spring calving and lambing. Further analysis based on multi-variable techniques (multiple logistic regression) may isolate the effects of the different factors considered in this analysis. Even so, our analysis presents strong evidence for functional relations between human–grizzly bear conflicts and riparian areas, watercourses, and a suite of agricultural-based attractants that can be managed to reduce conflict.

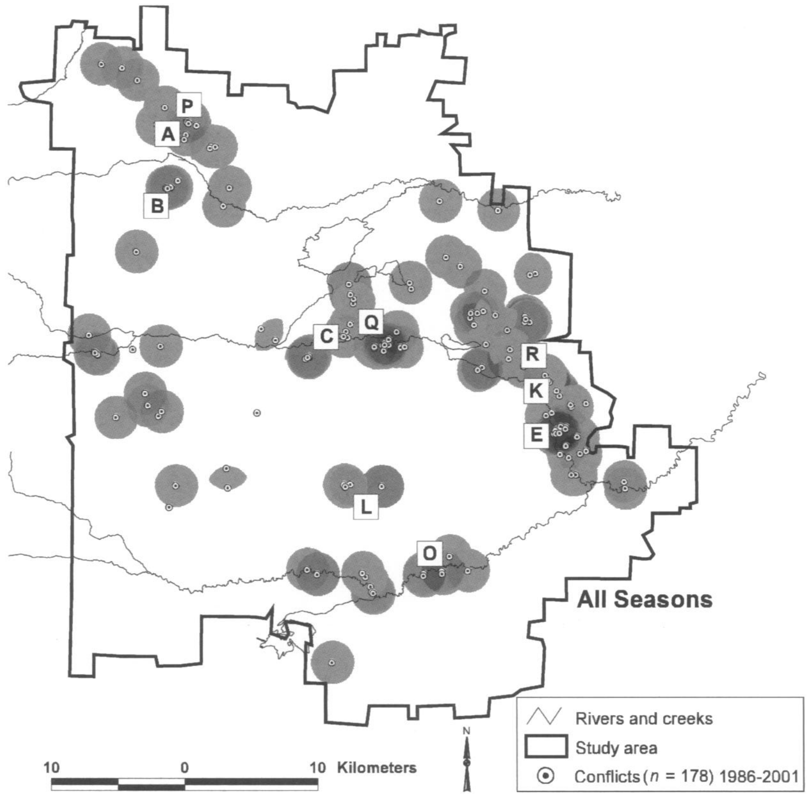

Fig. 4. Chronic conflict hotspots for all seasons based on normalized seasonal density maps, Rocky Mountain East Front, Montana, USA, 1986–2001.

Management implications

To reduce conflicts associated with calving and lambing areas, ranchers could move calving and lambing operations out of riparian areas, protect calving and lambing operations with electrified fencing, move calving and lambing operations out of grizzly bear range, and increase traditional fencing along riparian areas to

Table 3. Seasonal hotspots with spatial overlap, frequency of conflicts, and types of year-round attractants, Rocky Mountain East Front, Montana, USA, 1986–2001.

Overlapping seasonal hotspots[a]	Total number of conflicts[b]	Year-round attractants found in overlapping hotspots
Spring–summer overlap		
Spring-D + Summer-I, J	12	Boneyards, beehives
Spring-E + Summer-K	27	Boneyards, beehives
Spring-F + Summer-L	6	Boneyards, beehives
Summer–fall overlap		
Summer-G + Fall-P	7	Boneyards
Summer-K + Fall-R	13	Boneyards, beehives
Summer-O + Fall-S	8	Boneyards, beehives
Fall–spring overlap		
Fall-P + Spring-A	14	Boneyards
Fall-Q + Spring-C	31	Boneyards, beehives
Fall-R + Spring-D, E	13	Boneyards, beehives
Total	131	

[a]Letters are the hotspot we delineated for each season to account for overlap among hotspots. For example, Spring-D + Summer-I, J describes conflicts in both spring and summer, that boneyards and beehives were found in the hotspots, and that hotspots D, I, and J overlapped.

[b]Conflict counts were not duplicated for hotspots across seasons.

Table 4. Median distances of spring (n = 93), summer (n = 50), and fall (n = 35) conflicts to centroids of lambing areas (n = 16), spring sheep pastures (n = 13), summer sheep pastures (n = 17), fall sheep pastures (n = 10), cattle calving areas (n = 89), spring cattle pastures (n = 86), summer cattle pastures (n = 121), and fall cattle pastures (n = 93), with MC simulation medians, P-values, and 95% CI using 1,000 iterations, Rocky Mountain East Front, Montana, USA, 1986–2001.

Median distance to feature	Conflict distance (km)	MC simulation distance (km)	95% C.I. (km)	P
Sheep pastures				
Nearest lambing area.	3.8	8.7	7.0–11.1	<0.001
Nearest spring pasture	3.5	3.2	2.7–3.8	0.858
Nearest summer pasture	5.1	6.6	5.1–8.5	0.028
Nearest fall pasture	0.9	2.4	1.8–3.1	<0.001
Cattle pastures				
Nearest spring calving area	0.7	3.2	2.6–3.8	<0.001
Nearest spring pasture	1.3	2.4	2.0–3.0	<0.001
Nearest summer pasture	1.7	2.2	1.7–2.6	<0.001
Nearest fall cattle pasture	0.9	2.4	1.8–3.2	<0.001

keep livestock out. Moving operations out of riparian areas is an obvious remedial measure, but confronts ranchers with the problem of providing shelter for newborn calves and lambs. Moving calving and lambing operations out of grizzly bear range could be very effective but is only an option for livestock producers with extensive land holdings or options on leases. Electrified and traditional fencing would be an important strategy for ranchers keeping calving and lambing operations in riparian areas. The average size of fenced lambing and calving pastures was 94 ha (range = 0.34–950 ha). Fencing costs would need to be carefully weighed against the risk of depredation and size of fence needed. Predation of livestock in general could be reduced by limiting grazing in riparian areas to late fall and winter, when seasonal overlap between livestock and bears would be minimized (Ehrhart and Hansen 1997). The Nature Conservancy's Pine Butte Swamp Preserve has used this grazing strategy in some of the most productive grizzly bear habitat in our study area and has had no grizzly bear–livestock conflicts. In all cases, financial assistance from government agencies and non-governmental conservation organizations could facilitate implementing these measures.

Boneyards were associated with conflicts in our study area. Heavy exploitation of boneyards by bears was probably a function of their static location and nearness to riparian areas or other attractants. Such circumstances are likely to attract and retain bears and are often viewed as a threat to human safety because boneyards typically are located near ranch residences and calving areas. The carcass redistribution program by MFWP offers a promising solution to the problem of boneyards. Under this program, livestock carcasses are distributed according to a non-repetitive pattern in areas that are far from human residences or other areas of human activity. By moving carcasses away from people, bears are not conditioned to return to predictable locales. Many livestock producers in our study area participated in the MFWP carcass redistribution program; however, many traditional boneyards remain and could be included in the carcass redistribution program.

Our results suggest that fenced beehives were less likely to be associated with conflict areas than unfenced beehives. There is ample evidence from other studies for the efficacy of electrified fences in preventing conflict between humans and bears (Follman and Hechtel 1990, Madel 1996, Jonkel 2002). MFWP and the conservation group Defenders of Wildlife offer a program that defrays the cost of installing solar-powered electric fences around beehives. Many electric fences protecting beehives in our study area were installed under this program. We recommend that priority be given to fencing remaining unprotected beehives in the study area, particularly beehives near conflict hotspots or ones that have experienced depredation.

Our study provides managers with key information, such as trends in numbers and types of attractants that may, in turn, explain trends in human–grizzly bear conflicts. Temporally explicit maps of attractants also offer managers and researchers the opportunity to analyze locations of radiomarked bears in relation to availability of attractants. This, in turn, provides a basis for determining the relative importance of different types or combinations of attractants and for strategically targeting management efforts. General models also provide tools to assess the risk of conflict for proposed reintroduction areas or in areas such as the eastern and southern portions of the Yellowstone ecosystem where grizzly bears seem to be expanding into areas under private land ownership (Schwartz et al. 2002, Pyare et al. 2004).

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Table 5. Median distances of grizzly bear conflicts and MC simulations to nearest protected and unprotected beehives within areas defined by 3.2-km, 4.8-km, and 6.4-km analysis areas around beehives that experienced depredation by grizzly bears, Rocky Mountain East Front, Montana, USA, 1986–2001.

Analysis areas, protection status, conflicts, and time periods	Conflict distance (km)	MC simulation distance (km)	95% CI (km)	*P*
3.2-km buffer				
protected beehives ($n = 6$) and conflicts ($n = 18$), 1995–1998	1.5	2.1	1.5–2.5	0.016
unprotected beehives ($n = 26$) and conflicts ($n = 52$), 1995–2001	1.6	1.9	1.5–2.2	0.042
4.8-km buffer				
protected beehives ($n = 6$) and conflicts ($n = 27$), 1995–1998	3.1	3.1	2.3–3.7	0.513
unprotected beehives ($n = 26$) and conflicts ($n = 54$), 1995–2001	1.6	2.7	2.2–3.3	<0.001
6.4-km buffer				
protected beehives ($n = 6$) and conflicts ($n = 36$), 1995–1998	3.5	4.1	3.3–4.9	0.090
unprotected beehives ($n = 26$) and conflicts ($n = 56$), 1995–2001	1.6	3.5	2.8–4.3	0.463

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