The impact of landscape disturbance on grizzly bear habitat use in the Foothills Model Forest, Alberta, Canada

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ABSTRACT

The Rocky Mountains in Alberta, Canada are subject to a growing number of human activities that cause landscape disturbances. This region is important for large carnivore species such as grizzly bears, whose population decline is a serious management concern. Understanding the impact of landscape disturbance on grizzly bear habitat use is necessary to effectively manage this region and beyond. The goal of this research is to explore the spatial–temporal pattern of habitat use and to characterize the impact of disturbance on use through time. Research was conducted using radio-telemetry location data of female grizzly bears from 1999 to 2003. Kernel home ranges were created annually for three foraging seasons: hypophagia, early hyperphagia, and late hyperphagia. For each season, locations (30 m × 30 m grid cells) were characterized by the temporal persistence or variability in annual use by grizzly bears. Spatial–temporal trends were then compared for disturbed and undisturbed landscapes. Results indicate that in some foraging seasons, particularly hypophagia, the grizzly bear population's use of disturbed areas was proportionally higher than use in undisturbed areas. In other foraging seasons the trends are less clear, but all show instances of preferential selection of disturbed areas. Given that grizzly bear mortality tends to rise when bears use disturbed areas, this preferential selection of disturbed areas is a management concern. To enhance conservation efforts it may be beneficial to control human use in high-quality habitats. This protection may be most important for high-quality habitats used in the spring, as bears appeared to use smaller areas during this period.

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1. Introduction

Activities that lead to habitat loss may threaten the persistence of wildlife. Conservation and management planning require not only an understanding of how wildlife use habitat in space and time, but how habitat use changes in response to landscape disturbances and modifications. The Rocky Mountains in Alberta, Canada are subject to the influences of human activities, such as mining, oil and gas exploration and extraction, logging, and recreation (Linke et al., 2005). As this area also provides vital habitat for grizzly bears (*Ursus arctos* L.) and other wildlife, it is an appropriate region for understanding the interaction between disturbance and wildlife habitat use (Nielsen et al., 2004; Linke et al., 2005).

The results of recent grizzly bear population surveys have suggested that population levels are a management concern (Boulander et al., 2006; Mattson and Merrill, 2002; Nielsen et al., 2006). Given the numerous human pressures on grizzly bear populations, they are a suitable focal species for assessing the impact of disturbance on wildlife habitat use. Several studies have been conducted on the relationship between grizzly bears and habitat use, including the influence of disturbed habitats (Banci et al., 1994; Clark et al., 1996; McLellan, 1998; Schwartz et al., 2003; Peek et al., 2003).

Two general findings relating disturbance and habitat use from these previous grizzly bear studies have emerged. First, when grizzly bears use areas disturbed by humans, bear mortality increases (Banci et al., 1994; Clark et al., 1996; McLellan, 1998). In disturbed areas mortality risk increases due to a higher likelihood of conflict between bears and humans (Schwartz et al., 2003). Hunting, management removals, and defence of life and property by citizens account for a high proportion of grizzly bear mortalities in North America (Schwartz et al., 2003). Anthropogenic habitat disturbances affect bears directly by increasing their vulnerability to legal, or illegal, hunting by humans; and indirectly by changing the availability of food, and impacting reproduction and mortality rates (Peek et al., 2003).

The second trend that previous studies have shown is the complicated relationship between grizzly bears and habitat use (Mace et al., 1996; Waller and Mace, 1997; McLellan and Hovey, 2001; Apps et al., 2004; Nams et al., 2006). Several studies have demonstrated avoidance of clearcuts (Zager et al., 1983; Waller, 1992); however, a more recent study conducted in the foothills of west-central Alberta found that grizzly bears preferentially selected clearcuts during certain foraging seasons (Nielsen et al., 2004). The explanation for the selection of clearcuts in the foothills was that, unlike habitat in mountainous terrain where natural openings are available to bears, the foothills lack natural openings, making clearcuts attractive for foraging by grizzly bears. Given the increased occurrence of bear mortality in disturbed areas, the tendency for bears to select for clearcuts may have negative implications for population sustainability in the foothills of Alberta. The impacts of disturbance on the spatial distribution of wildlife such as grizzly bears require further investigation (Linke et al., 2005).

To understand how habitat use varies between disturbed and undisturbed areas, it is useful to have a mechanism for characterizing spatial–temporal trends in habitat use. Spatial patterns in habitat use are often characterized by delineating home ranges, defined as the area traversed by an individual in its normal activities of food gathering, mating, and caring for young (Burt, 1943, p. 351; White and Garrott, 1990; Kernohan et al., 2001). There are several methods for home range delineation, but kernel density estimation is often selected over other methods, such as the minimum convex polygon (MCP) which have been found to over-estimate home range size (Seaman and Powell, 1996; Marzluff et al., 2004; Borger et al., 2006).

Temporal analysis of habitat use is typically conducted based on intra-annual seasonal trends, such as the foraging seasons of grizzly bears (Nielsen et al., 2004), or inter-annual trends (Mace and Waller, 1997). Although studies have compared the use of habitat through time in multiple areas (e.g., Mace and Waller, 1998; Mace et al., 1999), few studies have simultaneously considered both the spatial and temporal aspects of habitat use using fine spatial resolution data. This is due in part to the general dearth of spatial–temporal analysis methods (Rey and Janikas, 2006). However, the development of novel methods combined with new radio-telemetry data will enable research questions on the variability in habitat use over space and through time to be addressed.

The goal of this paper is to quantify the impact of habitat disturbance on the spatial–temporal patterns in grizzly bear habitat use in the foothills of the Rocky Mountains in Alberta, Canada using telemetry data from 1999 to 2003. We characterize the annual seasonal spatial–temporal patterns of grizzly bear habitat use using home ranges, and temporal trends are characterized by creating unique time series that summarize the frequency of use across years. Maps quantifying spatial–temporal patterns of habitat use are then related to maps of annual landscape disturbance to assess the impact of disturbance on habitat use by grizzly bears. The spatial-analysis methods used in this paper are novel. The commonly used spatial method for home range delineation, kernel density estimation, is expanded to enable multi-temporal analysis of space time patterns. As such, the methods outlined here present a new approach to ecological analysis and may be applied to other data sets and application, where home ranges are defined categorically.

2. Study area

The study was carried out in the Rocky Mountains foothills portion of the Foothills Model Forest (FMF) Grizzly Bear Research Project (Linke et al., 2005; Stenhouse and Graham, 2005). Our study focuses on a 10,000 km² area in the Yellowhead Ecosystem, southwest of Hinton, Alberta where grizzly bear home ranges were observed in at least 1 year between 1999 and 2003 (Fig. 1). The elevation within the study area ranges from 770 m to 3522 m. This
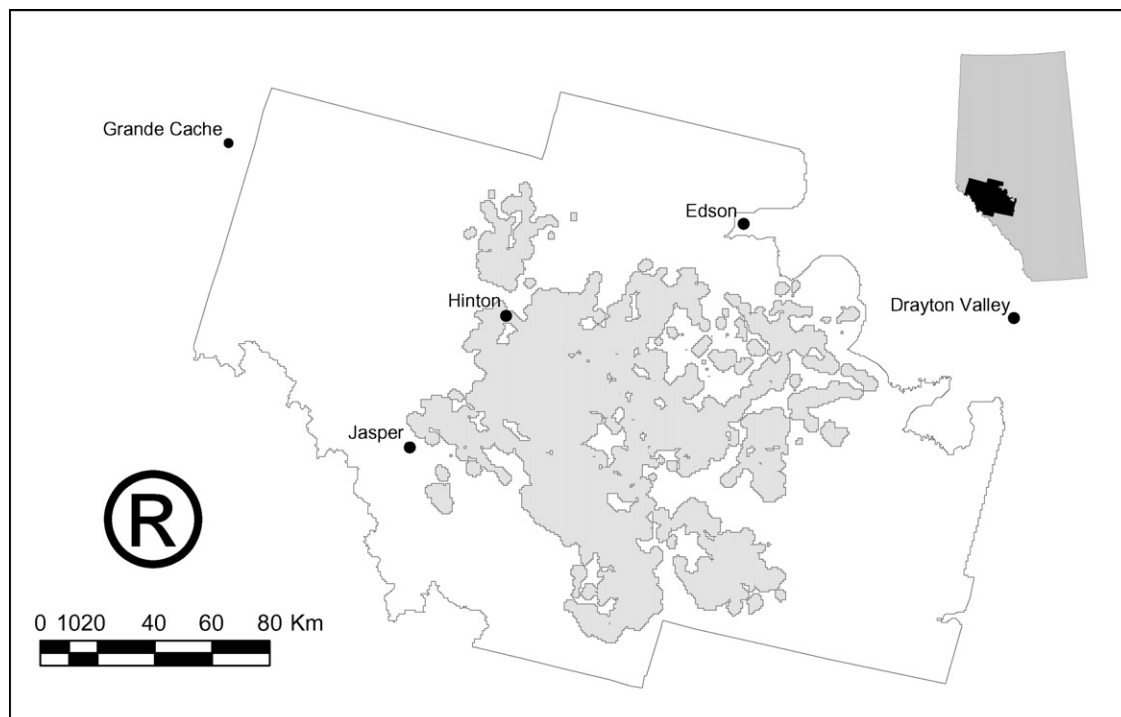

Fig. 1. The study area located in the foothills of the Rocky Mountains in west-central Alberta. The area shown in grey depicts the locations used by grizzly bears in at least 1 year between 1999 and 2003, and is the focus of this study.

elevation range encompasses a variety of habitat types, including glaciers, mountains, sub-alpine and alpine meadows, wet meadow complexes, and coniferous and mixed wood forests (Stenhouse et al., 2005). Jasper National Park contains the western portion of the FMF Grizzly Bear Project, and no anthropogenic activities related to resource extraction occur in this area. Outside of the protected areas, human disturbances of varying intensities exist throughout the study area (Linke et al., 2005). These activities include forestry, mining, oil and gas exploration and development, trapping, hunting and recreation (Stenhouse et al., 2005).

3. Data

From 1999 to 2003, data on adult and sub-adult grizzly bears were collected using radio-telemetry. Bears were captured using aerial darting and leg snaring, and collared using Televilt (Lindesburg, Sweden) or ATS (Advance Telemetry Systems, Isanti, Minnesota) GPS radio collars (Munro et al., 2006). Collars were programmed to collect six locations per day at 4-h intervals (Schwab, 2003). Only female bears were used for this analysis as the movement rates of male grizzly bears can vary substantially as compared to females (Schwab, 2003). There were between 8 and 16 collared female grizzly bears in each year. Only two of the bears were collared in every year, while the data generated from other individuals varied over time, due to collar drop off, malfunction or bear mortality.

Telemetry data on grizzly bears were partitioned into three foraging seasons: hypophagia, early hyperphagia, and late hyperphagia. The period of hypophagia occurred between 1 May and 15 June. During this season, grizzly bears fed on roots of Hedysarum spp., carrion, ungulate calves, and early herbaceous material (Nielsen and Boyce, 2005). During early hyperphagia, which occurred between 16 June and 15 August, bears fed on ants, green herbaceous material such as cow-parsnip (Heracleum lanatum), graminoids, sedges, and horsetail (Equisetum spp.), and ungulate calves. Late hyperphagia occurred from 16 August to 15 October. During this period, Canada buffaloberry (Shepherdia canadensis), blueberry and huckleberry Vaccinium spp., and late season digging for Hedydarum spp. made up the majority of the bears' diet (Nielsen, 2005; Nielsen and Boyce, 2005).

From 1999 to 2003, disturbance and anthropogenic features were identified using a Geographic Information System (GIS). We categorize the following features as landscape disturbance: clearcut, roads, pipeline, wellsites and powerlines, and railways. Clearcuts, roads, pipelines and wellsites were updated annually using procedures described below. No new powerlines or railways were built during the time period of study. Clearcuts were delineated using GIS data from the Alberta Vegetation Inventory and remote sensing imagery. The definition of clearcut is formalized by the Alberta Resource Inventory and includes areas where forest is less than 20 years old (www.srd.gov.ab.ca/lands, accessed 2008). Clearcut data were updated using 2005 forest regeneration layer created by the University of Calgary (McDermid et al., 2005) or were digitized using 2005 SPOT (2.5 m resolution) imagery. Often the year of construction for clearcuts and well sites were missing or unreliable from the datasets. Therefore we used 30 m Landsat imagery and other supplementary imagery, including Valtus color orthophotos (1 m resolution, 1999–2002), aerial orthophotos from West Fraser and Sundre Forest Products (70 cm resolution; 1995, 1999, 2001, and 2001, respectively), and IRS imagery (5 m resolution, 1999–2001) to determine year of construction for all features.

The road data were a compilation of several GIS road layers. The base layer was from Alberta Sustainable Resource Development (SRD, c 2004). Additional roads were included from various forestry companies or digitized manually based on SPOT imagery (2.5 m resolution, c 2005). The pipeline and well site data were also an assemblage of numerous GIS layers. The base layer was provided by Alberta SRD. Features from various sources, including the Alberta Energy and Utilities Board and digitizing from SPOT imagery (2.5 m resolution, c 2005), were added. Only pipeline right-of-ways that were wider than the 6 m seismic lines were retained. There were no new powerlines or railways constructed in the study area during the time period of our study. Base GIS layers for powerlines and railways were also from Alberta SRD.

Previous research identified that a 500 m zone of influence often existed around anthropogenic features (Mace et al., 1996, 1999; Hood and Parker, 2001). To assess the impact of anthropogenic features on the spatial–temporal habitat use of grizzly bears, we used a 500 m buffer around disturbance features. For each year (1999–2003), we combined all the anthropogenic features that existed up to that time period to create annual GIS layers.

4. Methods

4.1. Delineating the spatial pattern of habitat use as the home range

The annual seasonal home ranges for female grizzly bears were identified using a kernel density estimator. Kernel density estimators are widely used in habitat analyses (Worton, 1989; Mace et al., 1996; Seaman and Powell, 1996; Gitzen et al., 2006). This nonparametric approach results in a continuous intensity surface that is useful for visualization, and also enables maps of habitat use to be compared with continuous environmental data (Seaman and Powell, 1996). For home range delineation, kernel density estimation is increasingly selected over other methods such as the MCP (Seaman and Powell, 1996; Marzluff et al., 2004; Borger et al., 2006). MCPs have been found to over-estimate home range size as they include all the unused areas between the outermost locations, and generally increase in area with increasing sample size (Borger et al., 2006; Katajisto and Moilanen, 2006).

Theoretically, the intensity $\hat{\lambda}(\mathbf{z})$ of observations at each location $\mathbf{z}$ in a study area A is estimated using the kernel density estimator

$$\hat{\lambda}(\mathbf{z}) = \frac{\text{the number of events in a neighbourhood centered on } \mathbf{z}}{\text{area of the neighbourhood}}.$$

(1)

A more exact estimate, $\hat{\lambda}_\tau(\mathbf{z})$, can be calculated using

$$\hat{\lambda}_\tau(\mathbf{z}) = \left\{ \sum_{i=1}^{n} \frac{1}{\tau^2} k\left(\frac{\mathbf{z} - \mathbf{z}_i}{\tau}\right) \right\}, \quad \mathbf{z} \in A,$$

(2)

where $\mathbf{z}$ and A are defined as above, τ is the radius or bandwidth of a circular neighbourhood centered on $\mathbf{z}$, $k()$ is the probability density function that is symmetric about $\mathbf{z}$, and $\mathbf{z}_i$ ($i = 1, \ldots, n$), are the locations of n events.

In habitat analyses, each event is a radio-telemetry location, and the resulting density surface will have higher values in areas with many telemetry locations, and lower values in areas with few. The least-square cross-validation (LSCV) method has been demonstrated as an appropriate approach for selecting the kernel bandwidth when delineating wildlife home range (Silverman, 1986; Worton, 1989; Seaman and Powell, 1996; Katajisto and Moilanen, 2006).

Collectively, 15 home ranges were delineated, one for each of the three seasons in the 5 years of our study. This was done by pooling all the grizzly bear telemetry locations by season and year, to create annual seasonal home ranges for all the collared female grizzly bears combined. This also ensured home range delineation
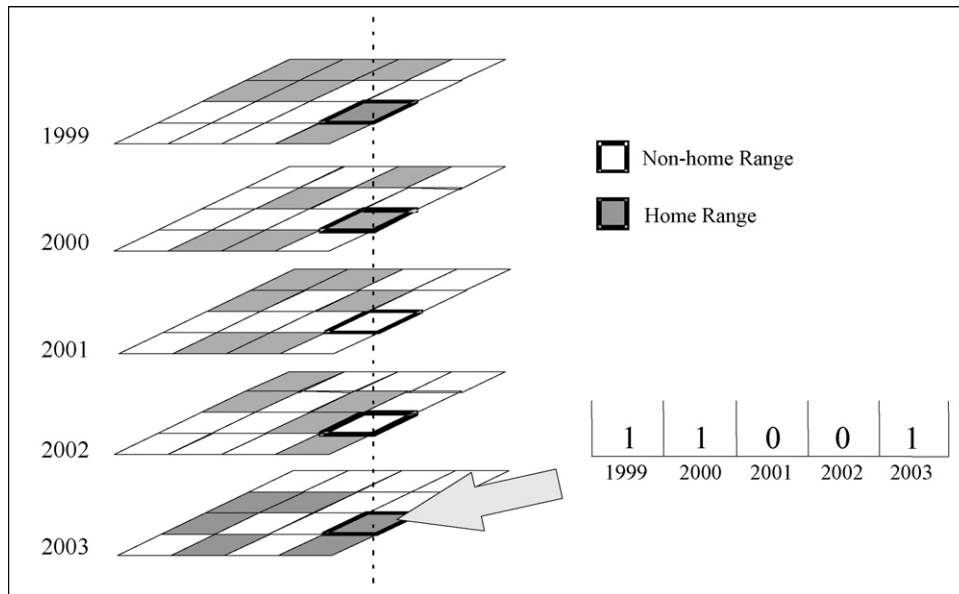
Fig. 2. Method for summarizing temporal trends in grizzly bear home ranges. When calculating the mode condition use (1) or non-use (0) in the year of and after disturbance, disturbances in 1999 would have a mode condition of use (1) and disturbances in 2001 would have a mode condition of non-use (0).

did not suffer from two few input locations (for further discussion see Arthur and Schwartz, 1999; Belant and Follmann, 2002; Girard et al., 2002). LSCV identified appropriate bandwidths that ranged from 644 m to 27,335 m. In order to have a uniform bandwidth for the analysis, the median value of 3074 m was selected to be used for all kernel estimations. This bandwidth value is supported by the daily movement distances observed for adult female grizzlies, which in these data ranged from 3 km to 6.4 km. The lower value is a conservative estimate of the area of association and corroborates the validity of the median bandwidth value. A 30 m × 30 m grid cell was used to estimate the kernel density surfaces, as this was the cell size of the disturbance data, and the spatial accuracy of the radio-telemetry locations is 10–20 m. The 95th percentile of the kernel density surface volume for each season in each year was used as has been the precedent in previous wildlife studies (e.g., Borger et al., 2006).

4.2. Quantifying temporal patterns in grizzly bear habitat use

Annually, a grid cell was assigned a value of 1 if it was part of a home range, while all other grid cells were assigned a value of 0. For each foraging season, temporal patterns of the collective home ranges were summarized over all years using a one-dimensional binary string to characterize the temporal sequence of habitat use (home range = 1) in each grid cell (see Fig. 2). As an example, the string 10110 signifies that the location was part of a grizzly bear's home range during 1999, 2001, and 2002. Properties of the binary string, such as the number of home range years, were used to summarize temporal trends. The string 10110 indicates a grid cell was part of a grizzly bear's home range for 3 years. Binary temporal strings were generated for each of the three foraging seasons. Recall that only grid cells used by grizzly bears in at least 1 year were considered in this study, and as such no temporal strings of 00000 were generated.

4.3. Relating spatial–temporal patterns in grizzly bear home ranges with disturbance

For each year of disturbance, we used the temporal binary strings to quantify whether cells were dominantly used or unused after disturbance had occurred. First, we made annual disturbance maps, which differentiated between grid cells with disturbance in a given year and grid cells without disturbance (Fig. 3A). Then, using the binary strings, the grid cells were assigned the mode condition, use (1) or non-use (0), in the year of disturbance and all following years. If the mode value was 1 then habitat use was considered to be dominant after disturbance had occurred; while a mode value 0 signalled habitat non-use was dominant. Fifteen maps of post-disturbance habitat use were generated; these represented post-disturbance trends in habitat use during three foraging seasons and over 5 years of disturbance.

The post-disturbance habitat use maps were used to compare differences in the proportion of disturbed and undisturbed cells having a mode condition of post-disturbance habitat use or non-use. The hypothesis is that if the proportion of disturbed grid cells with use is significantly greater than the proportion of undisturbed grid cells with use, grizzly bears are preferentially utilizing disturbed grid cell locations. The statistical differences in proportions were tested using a Pearson's chi-squared statistic to assess whether two samples have the same proportion parameter ($\alpha \leq 0.05$).

We anticipated observing different trends for grid cells that had been used by bears prior to disturbance relative to those that were not used prior to disturbance. As such, for each of the 15 maps we categorized cells as being used or unused prior to disturbance and repeated the above analysis (e.g., Fig. 3B). In total, three comparisons were made: trends in post-disturbance habitat use for all disturbed and undisturbed locations, trends in post-disturbance habitat use for disturbed and undisturbed with prior use, and trends in post-disturbance habitat use for disturbed and undisturbed locations without prior use.

5. Results

5.1. The spatial–temporal pattern of habitat use

When seasonal home ranges are combined for all years, the total seasonal home ranges become 5418 km², 6937 km², and 5628 km² for hypophagia, early hyperphagia, and late hyperphagia, respectively. The early hyperphagia season has the largest area,
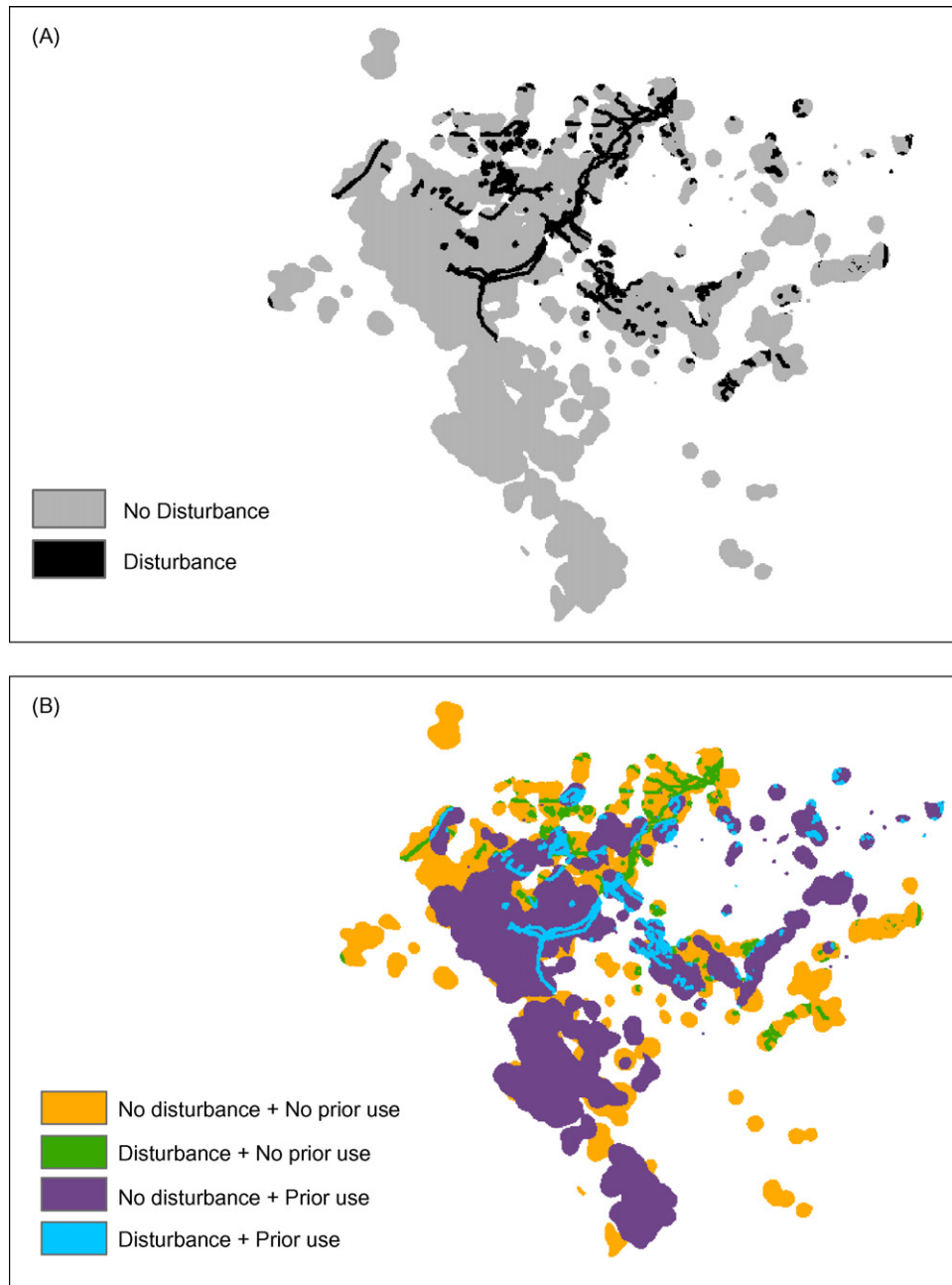
Fig. 3. An example, for 2001, of the study area partitions used for comparing post-disturbance habitat use. (A) Partitioned based on whether pixels are disturbed in 2001 and (B) further partitioned based on whether disturbed and undisturbed grid cells were used during hypophagia prior to 2001.

suggesting that the bears were most mobile during this season, which includes the mating period.

Within the home range area, there are up to 32 unique binary strings describing the temporal trends of the presence or absence of a grizzly bear's home range for a grid cell. Over all seasons, the most common trend is for use to occur in only 1 year, with a single year of use observed in 53.5%, 57.1%, and 63.5% of all grid cells in hypophagia, early hyperphagia and late hyperphagia, respectively (Fig. 4). Four or five years of persistent habitat use in a particular grid cell area, was most common in early hyperphagia (12.7% of grid cells) and least common in late hyperphagia (6.9% of grid cells). In hypophagia this occurred in 10.2% of grid cells. The proportions of the study area used as habitat by the bears in a least 1 year were 14.0%, 17.9%, and 14.5% for hypophagia, early hyperphagia, and late hyperphagia, respectively.

5.2. Relating spatial–temporal patterns to disturbance

During the hypophagia season, in most years grizzly bear use was more frequent in disturbed grid cells than in undisturbed grid cells (Table 1). The exception is 2003, which is the last year of the study and trends in post-disturbance habitat use are not well represented since there are no data following the 2003 disturbances. During all years of hypophagia, the differences in the proportions of use for disturbed and undisturbed grid cells were statistically significant. In early hyperphagia, habitat use was more frequent in grid cells that were undisturbed in 1999, 2000 and 2003, as compared with grid cells overlapping disturbance (Table 1). In 2001, a higher proportion of disturbed grid cells were used by bears, and in 2002 the proportion of cells used by bears was not significantly different between disturbed and
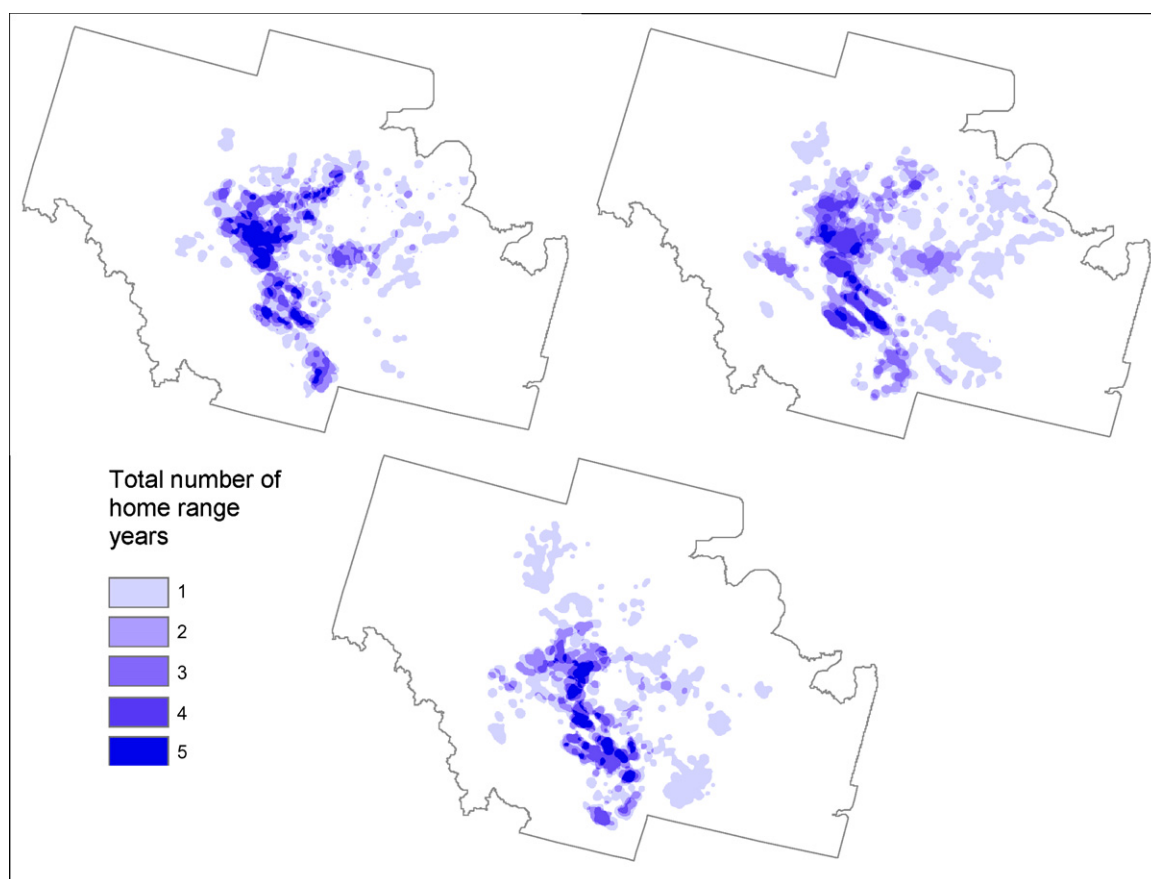
Fig. 4. The total number of home range years for, clockwise from top left, hypophagia, early hyperphagia, and late hyperphagia.

Table 1
The proportion of grid cells, partitioned by whether the location was disturbed or undisturbed in a given year, where seasonal habitat use by grizzly bears was the mode condition

Hypophagia	Disturbed	Undisturbed	p-value
1999	0.30	0.26	0.00
2000	0.23	0.18	0.00
2001	0.31	0.25	0.00
2002	0.22	0.14	0.00
2003	0.11	0.27	0.00

Early Hypophagia	Disturbed	Undisturbed	
1999	0.22	0.26	0.00
2000	0.19	0.20	0.00
2001	0.34	0.31	0.00
2002	0.15	0.15	0.88
2003	0.46	0.50	0.00

Late Hypophagia	Disturbed	Undisturbed	
1999	0.21	0.19	0.00
2000	0.14	0.13	0.25
2001	0.28	0.32	0.00
2002	0.10	0.17	0.00
2003	0.37	0.50	0.00

The grey background indicates the difference in proportions was significant ($\alpha = 0.05$).

undisturbed grid cells. During late hyperphagia, results were also mixed (Table 1). In 1999, a greater proportion of disturbed grid cells were used by bears, while 2001–2003 bear use was proportionally greater in undisturbed grid cells. Differences in proportions are significant for 2001–2003. Although disturbed grid cells were used more often in 2000, the difference is not statistically significant.

When only grid cells that are part of a home range in, or before, the year of disturbance were considered, results were similar to those presented for all disturbed and undisturbed grid cells (Table 2). During hypophagia, in the proportion of disturbed grid cells used by bears was greater for all years except 2003 and in all cases differences in proportions were statistically significant. During early hyperphagia, disturbed grid cells had proportionally greater use by bears than undisturbed grid cells in 1999 and 2000, use was similar in 2001, and greater in disturbed grid cells in 2002 and 2003. Statistical significance in the difference of proportions was only observed in 1999, 2000, and 2003. In early hyperphagia, trends change with time and proportionally there is greater use of undisturbed grid cells relative to disturbed grid cells. This temporal variability may result from the longer time period over which we considered post-disturbance habitat use when disturbance occurred during the early years of the study (i.e., 1999 and 2002). During late hyperphagia, only in 2000 and 2001 was habitat use dominant in previously used disturbed areas. In other years, habitat use was dominant in previously used undisturbed grid cells. Statistical significance in the difference of proportions is observed from 2001 to 2003.

When only grid cells with no previous grizzly bear use are considered, the proportions of habitat use in disturbed and

Table 2
For grid cells where grizzly bear habitat use had been previously used and unused, the proportion of locations, partitioned by whether the location was disturbed or undisturbed in a given year, where seasonal habitat use by grizzly bears was the mode condition

Hypophagia	Previously used & disturbed	Previously used & undisturbed	p-value	Previously unused & disturbed	Previously unused & undisturbed	p-value
1999	0.85	0.43	0.00	0.25	0.20	0.00
2000	0.38	0.30	0.00	0.06	0.02	0.00
2001	0.40	0.32	0.00	0.14	0.07	0.00
2002	0.29	0.17	0.00	NA	NA	NA
2003	0.11	0.27	0.00	NA	NA	NA

Early Hypophagia	Previously used & disturbed	Previously used & undisturbed		Previously unused & disturbed	Previously unused & undisturbed	
1999	0.73	0.59	0.00	0.17	0.13	0.00
2000	0.40	0.33	0.00	0.02	0.05	0.00
2001	0.38	0.38	0.69	0.27	0.16	0.00
2002	0.20	0.21	0.68	NA	NA	NA
2003	0.46	0.50	0.00	NA	NA	NA

Late Hypophagia	Previously used & disturbed	Previously used & undisturbed		Previously unused & disturbed	Previously unused & undisturbed	
1999	0.42	0.50	0.06	0.20	0.11	0.00
2000	0.29	0.28	0.39	0.06	0.02	0.00
2001	0.24	0.22	0.04	0.36	0.41	0.00
2002	0.14	0.23	0.00	NA	NA	NA
2003	0.37	0.50	0.00	NA	NA	NA

Statistical comparisons were conducted between previously used and disturbed vs. undisturbed and previously unused disturbed vs. undisturbed. The grey background indicates the difference in proportions was significant ($\alpha = 0.05$).

undisturbed cells are more consistent (Table 2). Given our definition of the home range areas there are no grid cells unused by 2003, but also there are no grid cells where habitat use was dominant that are not used by 2002. During hypophagia, all disturbed grid cells have proportionally greater use than undisturbed cells, and the differences are statistically significant. During early hyperphagia, the proportion of grid cells used by bears is greater in unused disturbed grid cells than in unused undisturbed grid cells in 1999 and 2001. In 2000, the proportions of grid cells used by bears are low, 2% and 5% in disturbed and undisturbed cells, respectively; however, use was greater in undisturbed grid cells. All differences in proportion are significant in early hyperphagia. In the late hyperphagia season, habitat use is dominant in previously unused disturbed grid cells in 1999 and 2000. The opposite trend is seen in 2001, and all differences in proportion are statistically significant.

6. Discussion

In the foothills of Alberta, grizzly bears are not avoiding disturbed areas. Particularly during hypophagia, the phase following den emergence, bears are consistent in the use of disturbed grid cells relative to undisturbed cells. Reasons for the use of disturbed habitat may be related to general trends observed in the use of space, during this time period. Feeding on roots, carrion and sprouting grasses, forbs and horsetails during hypophagia, the grizzly bears inhabited a smaller area as compared with other foraging seasons. The dominant spatial–temporal pattern in habitat use during all foraging seasons is for use to occur within a 30 m by 30 m grid cell for only 1 year. However during the hypophagia season, this trend is weakest and the tendency to repeatedly use grid cell areas in 4 or 5 years is relatively moderate. These results indicate that post-den emer-

gence the bear population is less likely to use an area within their home range for only 1 year and, relative to other seasons, have a moderate likelihood of reusing a habitat location in 4 or 5 years over the 5-year period of study. It is possible that during this phase, energy stores are low and bears are feeding to maximize the efficacy of feeding. Shortly after den emergence, feeding on foods that are high in nutrients and easy to attain may be important foods for grizzly bears at this time. Recently disturbed sites such as cutblocks, wellsites and roads tend to have large areas of emerging grasses and forbs high in nutrients that may be highly attractive to grizzly bears (Nielsen et al., 2004; Roever, 2006). Mate selection, and conspecific avoidance factors may also be influencing habitat use choices during this period (Stenhouse et al., 2005; Wielgus and Bunnell, 1994, 1995). The reduced extent of the bear population's home range during this time period may in part explain why they do not seem to be avoiding areas within their home range that have been disturbed.

During the early hyperphagia season, typically the use of habitat is proportionally greater in undisturbed grid cells. With few exceptions, use of disturbed grid cells is dominant regardless of whether comparisons are made for previously used, previously unused, or all cells. During this season, grizzly bears also use the largest areas of habitat and are likely the most mobile, while feeding on ants (myrmecophagy), ungulate calves, and green herbaceous material. During early hyperphagia the tendency to use grid cells only once in 5 years is relatively moderate and use of the same grid cells in 4 or 5 years is more common than in other seasons. There are a couple of possible explanations for the different pattern of disturbed habitat use in the early hyperphagia season, compared to the hypophagia season. First, given that the presence of food has been shown to be a good predictor of grizzly occurrence (Nielsen et al., 2003), it follows that the spatial pattern of bears is an indicator of the spatial pattern of available food.

Available, or preferred, foods may be more dispersed in the early hyperphagia season. However, food-foraging models, which work well during most months, have been shown to be problematic in July (Kansas and Riddell, 1995; Nielsen et al., 2003). Alternatively, a second hypothesis relies upon the characteristics of early hyperphagia, such that foods become more available and a bear's energy stores are returning. Therefore, bears may have extra energy to expend in seeking out the best foods, or a greater amount of searching may be required to obtain food and more energy is expended in travel. In addition, Stenhouse et al. (2005) found that associations between bears may significantly affect the movement and location of grizzly bears at this time of year as a result of the breeding season.

The results we obtained for the early hyperphagia season contrast Nielsen et al. (2004), which demonstrated that grizzly bears preferentially selected clearcuts during the early hyperphagia. While our results are unexpected, they may highlight the different impact habitat disturbances. Here we consider disturbances from pipelines, wellsites, roads, and clearcuts, which may account for the difference in results.

In the final foraging season, late hyperphagia, the use of disturbed areas is found to be proportionally greater during the first years of the study, but as the study progresses through time, the trend switches and use of undisturbed areas dominates. This may be an artefact of the data used for the study and perhaps the plant phenology associated with this foraging season. When disturbance occurs near the end of the study (i.e., 2002 or 2003), there are few years over which to consider post-disturbance habitat use. Berries (and ungulate carcasses) are the primary food of interest during this time, and sufficient berry populations generally take longer than 1 or 2 years to establish and attract bears after disturbances. In particular, Hamer (1996) found that after fire, buffaloberry (S. canadensis) takes 5 years to resume fruit production.

The total area of habitat used during this season is less than in the early hyperphagia, but greater than in hypophagia. The proportion of grid cells used in only 1 year is the highest of all seasons and the proportion of grid cells used in 4 or 5 years is the lowest. The temporal switching of trends in habitat use, combined with high use in only 1 year, and a low tendency for use in 4–5 years, may indicate that studying patterns in the late hyperphagia stage could benefit from a longer period of study. However, these results corroborate the findings of Nielsen et al. (2004) which suggest that avoidance of clearcuts during this stage could not be conclusively demonstrated. Preferential selection of non-clearcut areas was also inconclusive.

7. Conclusion

In the foothills of Alberta, grizzly bears preferentially use previously disturbed areas during some foraging seasons. Given the tendency for bear mortality in disturbed regions, preferential use of disturbed areas presents a concern for the conservation of grizzly bears. Land managers are tasked with the challenge of managing multiple users and interests over the same landscape. This research seems to add to the evidence that there may be benefits to limiting human uses in the areas that are of highest quality for grizzly bears (Benn and Herrero, 2002; Nielsen et al., 2004) especially in areas used during hypophagia.

This analysis was conducted at a subpopulation level using all female grizzly bears sampled, and clearly shows variability between years and seasons. To investigate this further we suggest future analysis should investigate spatial–temporal trends in grizzly bear use at the individual level. This would also enable changes in habitat use, or preferences to use or avoid disturbed areas, to be directly linked to mortality.

The spatial–temporal analysis methods used in this study are novel, in that they extend commonly used home range delineation methods to include multiple time period. As such, our approach has application to other data sets where home ranges are defined in multiple time periods. A limitation of this spatial–temproal approach is that it requires home ranges be defined categorically, with each cell of the study area being included (1) or excluded (0) from the home range. Future research should expand this approach to include home ranges defined with continuous values that reflect spatial variability within the home range.

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