# THE INFLUENCE OF MINE RECLAMATION AND HIGHWAY RECONSTRUCTION ACTIVITIES ON GRIZZLY BEAR HABITAT SELECTION IN THE COOKE CITY BASIN, MONTANA

by

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# DEDICATION

To my wife, Andrea, who has been a source of encouragement, motivation, and inspiration.

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# ABSTRACT

The grizzly bear (*Ursus arctos*) population of the Greater Yellowstone Ecosystem is increasing in numbers and expanding its range. In this scenario, the number of conflicts between humans and grizzly bears is likely to increase. Understanding how grizzly bear habitat selection is affected by concentrated high human use, such as construction projects, plays a major role in management decisions for this species. In this research, we combined bear sign data collected in 27 permanent transects during 11 years (1990-91, 1996-97, 2003-04, and 2007-11) with food habits analysis to provide a description of grizzly bear habitat use in 91km$^2$ of the Cooke City Basin, Montana. Data were collected during years of mine reclamation (2003-04), highway reconstruction (2007-09), and years when no major human activities occurred (1990-91, 1996-97, and 2010-11). The main objectives of this study were to quantify grizzly bear spatial avoidance to mine reclamation and highway reconstruction activities and provide knowledge about environmental factors influencing grizzly bear habitat in the Basin. Resource selection functions were used to address these goals. Results showed that, in the Cooke City Basin, grizzly bears selected for mid-high elevation, forested, south-west facing slopes (areas where whitebark pine seeds are most abundant) and avoided areas of high tertiary road density. Mine reclamation occurred near whitebark pine forests. The estimated grizzly bear use of areas within 1 km and 2 km of reclamation epicenters decreased 83% and 52%, respectively, in years of mine reclamation. Grizzly bears did not avoid areas beyond 2 km of mine reclamation or areas within 4 km of highway reconstruction in years when these activities occurred. The lack of avoidance associated with highway reconstruction is likely explained by the fact that this occurred in the lowest elevation areas (below 2500 m) that are used less by grizzly bears. Grizzly bears use in the Cooke City Basin were mostly uninterrupted by two major construction projects. However, temporary and localized habitat loss occurred when construction was focused near whitebark forests with high bear use. Temporary habitat loss was not observed when construction occurred in areas distant from whitebark forests and used less by bears.

# LITERATURE REVIEW

## Grizzly Bear Distribution

Grizzly bears (*Ursus arctos*), also commonly referred to as brown bears, are widely distributed throughout Asia, Europe and North America. In North America, grizzly bears historical range extended eastward to Ontario, Ohio and Kentucky, southward to Mexico, and northeast to Labrador (Peterson 1965, Guilday 1968, Storer and Tevis 1996). Following European settlement, grizzly bear historical range was drastically reduced due to loss of habitat, reduction in availability of major food items, and human related mortality associated with market hunting, and defense of life or property. Currently, in the conterminous United States, there are five recognized populations, the population of Greater Yellowstone Ecosystem (GYE), of the Northern Continental Divide (NCDE), of the Selkirk (SE), of the Cabinet-Yaak (CYE), and the population of North Cascades (NCE). Recent demographic studies estimate that the GYE has ca.757 individuals, of which approximately 263 are females, 263 are males, and 230 are dependent young (Haroldson et al. 2014).

## Grizzly Bear Biology and Ecology

### Feeding Habits

Grizzly bears are opportunistic generalist omnivores. According to Schwartz et al. (2003) there are seven taxonomic groups of major consumed food items: (i) vegetative matter, including grasses and forbs, (ii) roots, corms, and bulbs, (iii) fruits, (iv) whitebark pine nuts, (v) insects, (vi) mammals and birds, and (vii) fish. The GYE grizzly bear forage mainly on neonate/carrion ungulates, overwintered whitebark seeds, and graminoids during spring; forbs, root crops, ungulates and graminoids during summer; and whitebark seeds and army cutworm moths (*Euxoa auxiliaris*) during fall, when these food items are most abundant (Mattson et al. 1991, French et al. 1994, Mattson and Reinhart 1997, Gunther et al. 2004). It is important to notice that the diet of GYE grizzly bear may change according to the availability of major food items within a bear's home range (Mattson et al. 1991, Gunther et al. 2014). For instance, grizzly bears with home ranges on the east side of the GYE may direct their feeding activity during fall toward army cutworm moths found in talus slopes, while bears with home ranges in other parts of the ecosystem, where army cutworm moths are not found, do not use this food item (Gunther et al. 2014). Some food items may be of significant importance for bears only during infrequent years of high consumption (Mattson et al. 1991). Yonge (2001) showed high consumption of an uncommon food source (berries) in the Cooke City Basin in 1990 during fall when whitebark pine seed availability was low.

## Habitat Selection

Habitat is a specific set of physical or environmental conditions that promotes occupancy by a species, allowing individuals to survive and reproduce (Morrison et al. 2006). Within their environment, individuals make disproportionate use of available resources. This disproportionate use is caused by a series of behavioral responses of the individual to its environment that aim to maximize fitness. This hierarchical process of behavioral responses is called habitat selection (Jones 2001). Grizzly bears occupy a variety of habitats, including Arctic tundra, boreal and coastal forests, and mountain forest/grassland ecotones (Schwartz et al. 2003). This wide habitat variation is often attributed to their omnivorous-carnivore nature (Schwartz et al. 2003). When selecting habitat, grizzly bears prioritize the need for meeting forage requirements, thus selecting the most seasonally productive habitats. Not surprisingly, their habitat selection patterns change according to the availability of seasonal food sources on the landscape (Schwartz et al. 2003). Availability of seasonal food sources greatly varies from one ecosystem to another and from one year to another (Schwartz et al. 2003).

The use of whitebark pine seeds by grizzly bears illustrates how food availability can influence habitat selection. Due to its high calorie content, whitebark pine seeds are an important food source for GYE grizzlies (Craighead and Craighead 1972, Mattson and Reinhart 1996, 1997). More than 90% of the whitebark seeds consumed by grizzly bears are obtained from red squirrel (*Tamiasciurus hudsonicus*) middens, areas where squirrels disaggregate cones and cache seeds. Because most of the seeds are harvested and cached during early August (Mattson and Reinhart 1996, 1997) seeds will be most abundant in the fall. However, annual whitebark cone production is variable (Haroldson and Podruzny 2011). In years of high cone production, bears will forage in higher elevations (above 2,360 m), where most whitebark trees are located (Mattson and Reinhart 1997). Conversely, during years of low cone production, GYE grizzly bears will forage on other food items, such as meat, located at lower elevations (bellow 2,360 m). Foraging at low elevation areas is problematic because that is where bear-human conflicts are more likely to occur. In fact, studies have shown a negative correlation between whitebark cone production and grizzly bear mortality (Mattson et al. 1992, Gunther et al. 2004). Availability of high quality food can also influence grizzly bear territoriality (Mcloughlin et al. 2000) and individual habitat use (Wielgus and Bunnell 1994). Female grizzly bears are known to alter habitat use in the presence of adult males, possibly moving to lower quality habitats to avoid intraspecific killing (Wielgus and Bunnell 1994).

To study habitat selection, scientists must define a spatial scale that is adequate to address specific ecological questions (Hobbs 2003). Habitat selection can be considered a hierarchical process with four different orders (Johnson 1980). The first order relates to the geographic range of the species; the second order relates to the selection of a home-range; the third order relates to the selection of resource patches within the home-range; and the fourth order relates to the selection of resource items within patches. Ciarniello et al. (2007*b*) showed that grizzly bear habitat selection is scale-dependent. This means that results obtained in different scales should be interpreted differently. In general, short term decisions made by an animal as a response to predation risk are usually addressed in finer scale studies (as those of third of fourth order). Because grizzly bears may respond to human-caused disturbances with anti-predator behavior (White et al. 1999, Frid and Dill 2002), the use of third and fourth order may be most appropriate to address grizzly bear responses to human activities. Therefore, the third order scale was used in this study.

## Effects of Human Disturbance on Grizzly Bear

When selecting habitat in areas of negligible human activity, grizzly bears prioritize the need for meeting forage requirements. However, in areas of high human use such as settlements, campgrounds, or hiking trails, human avoidance may become a priority (Gibeau et al. 2002, Frąckowiak et al. 2014). Bears usually avoid areas of high human use by up to 3 km during spring and fall, and up to 9 km during the summer when human use of their habitats is at its peak (Mattson et al. 1987). This avoidance pattern is not followed by habituated/food-conditioned bears that can occupy areas within 1 km of human developments.

Human avoidance patterns of bears are not homogeneous among cohorts and seasons (Mattson et al. 1987). Adult females for example may use habitats closer to human developed sites, where they forage on berries and other food sources (Gibeau et al. 2002). This female behavior is associated with three main factors: food availability, a flexible feeding routine (less time is spent foraging due to lower calorie requirement compared to males Schwartz et al. 2003), and displacement from higher elevation sites by dominant cohorts (McLellan and Shackleton 1988). Submissive cohorts may be displaced to areas of high human activity by dominant cohorts (Mattson et al. 1987, Wielgus and Bunnell 1994). During fall hyperphagia, when habitat selection of adult males is strongly influenced by availability of high quality food, the effects of the territorial dominance exerted over submissive cohorts is intensified (Mattson et al. 1987).

Grizzly bears generally avoid areas within 500 m of roads (Mattson et al. 1987, Mace et al. 1996, Waller and Servheen 2005), but may avoid roads by up to 2,000 m during summer when road use is at its peak (Mattson et al. 1987). Because roads are often constructed in riparian areas that could provide good forage opportunities for grizzly bears (McLellan and Shackleton 1988), male bears may use these areas, but they will do so at night and at sites where visibility is reduced by dense vegetation (Gibeau et al. 2002). Females generally use areas farther away from roads (Gibeau et al. 2002), but may also forage near roads when high quality food is available and dominant males are not present (Roever et al. 2008). Obviously, high quality habitat near roads can potentially attract all cohorts (Roever et al. 2008), but disturbance caused by highway configurations and vehicle density might counter this attraction (Gibeau et al. 2002). Mace et al. (1996) reported that grizzly bear use of areas near roads is reduced with high traffic levels (greater than 10 vehicles per day), high road density (greater than 6 km per $km^2$), and the existence of human settlement.

Use of areas near roads increases the vulnerability of bears to vehicle-caused mortality. Roads built for resource extraction often increase human access to other activities (i.e. hiking, climbing, hunting, and poaching) that commonly lead to bear-human conflicts, which might result in the death of the bear (Benn and Herrero 2002, Johnson et al. 2004, Berland et al. 2008). In addition to direct mortality, encounters often result in high energy costs to bears that are displaced (McLellan and Shackleton 1988). Displaced bears will move to different areas, which may intensify intraspecific competition in these areas (McLellan 1990).

Constructions and resource extraction can also cause disturbance in grizzly bear habitat. These activities can disrupt forage, increase vigilant behavior, displace bears to other sites, and temporarily or permanently alter bear habitat(McLellan 1990). The distance from which grizzly bears are displaced from construction sites varies according to the intensity of the activity, the availability of high quality food at its surroundings, topography, cover type, and the degree of which bears are habituated to humans (McLellan and Shackleton 1989, McLellan 1990). Archibald et al. (1987) reported the displacement of two female grizzly bears from a 200 m buffer surrounding a resource extraction site, where hauling activity occurred along a logging road. It is uncertain whether or not bears were displaced from an even larger buffer surrounding the construction epicenter because Archibald et al. (1987) did not conduct investigations in areas outside the 200 m buffer. Harding and Nagy (1980) found that 16 of 17 monitored grizzly bears avoided hydrocarbon exploration drilling camps by 1 km. Nevertheless, intense human activity involving heavy machinery can produce little displacement on habituated bears (McLellan and Shackleton 1989).

Construction activities are particularly harmful to grizzly bears if mitigation guidelines are not strictly enforced. In a study conducted by Follmann and Hechtel (1990) while the Trans-Alaskan Pipeline was under construction, 85 nuisance problems associated with property damage and threats to human safety were registered as being caused by grizzly bears. Most of these nuisances (80%) were related to bear habituation to anthropogenic food sources resulting from of improper food disposal in camps and intentional feeding. As a consequence of these conflicts, 12 grizzly bears were relocated and 13 grizzly bears were killed. Follmann and Hechtel (1990) advised that construction planing in bear habitat should always use ecological knowledge to mitigate bear attraction and conflicts, and should include educational programs, proper food handling, garbage disposal and fencing. The high percentage of bear-human conflicts caused by food attractance highlights the importance of reinforcing guidelines associated with food handling/disposal during construction and suggests that monitoring food habits may provide insightful information about the efficacy of these guidelines.

Although it is known that high levels of human activity can negatively affect habitat selection by grizzly bears, there are still uncertainties on which levels of activity can be tolerated without avoidance/displacement. Where human and grizzly bear populations are increasing, bear habitat managed with the multiple use concept and with high human use should be considered a management priority because of the potential for bear-human conflicts (Gunther et al. 2004, Schwartz et al. 2010). Studying grizzly bear habitat selection in these areas is, therefore, fundamental for sustaining a healthy grizzly bear population while accommodating human needs.

# INTRODUCTION

Once widely distributed across North America, grizzly bear populations were extirpated from nearly all of their former range during the era of western settlement (Waller and Servheen 2005, Kendall et al. 2009). In 1975, in an attempt to preserve this species, the U.S. Fish and Wildlife Service listed the grizzly bear in the lower 48 states as "threatened" under the Endangered Species Act. Nearly 40 years later, the GYE grizzly bear population has expanded substantially and is likely near or at carrying capacity in proportions of the ecosystem (Bjornlie et al. 2014, van Manen et al. 2016), with a population size of about 757 individuals in 2014 (Haroldson et al. 2014). Given these data, the U.S. Fish and Wildlife Service indicated that the prescribed standards for a recovered population, as defined in the Grizzly Bear Recovery Plan (U.S. Fish and Wildlife Service 1993) and Conservation Strategy (U.S. Fish and Wildlife Service 2003), have been met. Thus, government agencies are taking administrative steps to remove the Yellowstone grizzly bear population from its current listed status. Long-term monitoring trends indicate that the GYE grizzly bear population has not only reached the highest numbers of individuals, but also its widest distribution, since it was listed as threatened in 1975 (Bjornlie et al. 2014).

Because most grizzly bear mortalities in the GYE are human-caused (Schwartz et al. 2006), remote areas with fewer bear-human encounters provide more secure grizzly bear habitat. The GYE is composed mostly of designated or proposed Wilderness, with low human density, but it also contains areas with comparatively high levels of human activities, including National Park Service visitor facilities, Forest Service areas managed for resource extraction, or private land in-holdings. In the early 1990s, areas of high human activity like the Cooke City Basin were considered either marginal habitat avoided by bears or mortality sinks where food-conditioning of bears led to conflicts (Knight et al. 1988). Research has showed that grizzly bear habitat declined with the presence of, or increase in, the extraction of natural resources, recreation use, and development on public and private lands in the GYE (Knight et al. 1988, Mattson and Reid 1991). Roads facilitate access by humans, and increase availability of anthropogenic foods commonly associated with bear-human conflicts and bear mortalities.

Because of the known negative effect of roads on grizzly bears, the GYE Grizzly Bear Conservation Strategy (2003) limited motorized access to improve bear habitat, and to reduce conflicts and bear mortality. Supporting research indicated that secure habitat, defined as areas ≥4.05 ha that are >500 m from open or gated motorized access routes during the non-denning period, are especially important to the survival of female grizzly bears (Mattson et al. 1987, Gibeau et al. 2002, Schwartz et al. 2010). Consequently, a Conservation Strategy Habitat Standard for management requires that a percent of secure habitat, defined as those areas more than 500 meters from a motorized access route during the non-denning period, must be maintained at or above levels that existed in 1998. Managers of each grizzly bear unit are required estimate and report the annual amount of secure habitat, all areas with open motorized access route density greater than one mile/ square mile, and total motorized access route density greater than two miles/square miles.

The Cooke City Basin, located in the Eastern GYE, is an example of an area with relatively high human use in a larger wilderness landscape. It has been the focus of management attention and has played a significant role in the GYE grizzly bear recovery effort. Cooke City Basin is characterized by  extensive whitebark pine forests, along with a network of roads facilitating recreation use and resource extraction, many private inholdings, and 3 small year-round communities (Yonge 2001, D. Tyers, U.S.F.S., personal communication). Given these landscape conditions, the Basin presents a higher potential for human-bear conflicts than the extensive wilderness areas surrounding it. In fact, in 1988, the Interagency Grizzly Bear Study Team (IGBST) identified the Cooke City Basin as a population sink because of the high annual proportion of GYE grizzly bear mortalities during the 1970s and 1980s. It was advised that, unless the current rate of mortalities was reduced in the Cooke City Basin, efforts to recover the GYE grizzly bear population would be negated (Knight et al. 1988). Moreover, as this project began in 1990, the IGBST and the U.S. Fish and Wildlife Service advised the U.S. Forest Service that the Cooke City Basin was comparatively not important bear habitat because of the density or roads and associated level of human activity (D. Tyers U.S. Forest Service, personal communication). It was considered to be nominally used by grizzly bears, except for individuals that had been food conditioned and were of management concern because of the potential for conflict.

Since the Yellowstone grizzly bear was listed in 1975, a primary management challenge in developed areas like the Cooke City Basin has been reducing anthropogenic food attractants to prevent conflicts. This management challenge has increased with the number and distribution of GYE grizzly bears. Areas in the GYE once considered marginal habitat because of high human use levels must now be managed as occupied by grizzly bears. If the GYE grizzly bear population is at carrying capacity in portions of the ecosystem, in addition to bears seeking attractants, these areas may now be used by an important population segment seeking space. Because bear-human conflicts can be lethal for bears, wildlife managers seek effective ways to mitigate conflicts. Therefore, understanding how grizzly bears select habitat in areas with high human use levels is an important topic for grizzly bear managers in the GYE.

Cooke City Basin provides a unique opportunity to investigate the effects of human activities on grizzly bear habitat use. Although surrounded by established Wilderness area and Yellowstone National Park, the Cooke City Basin is designated in the Gallatin National Forest Plan (U.S. Dept. of Agriculture Forest Service 1987) as available for resource extraction and many areas are accessible by road. Historically, human activity in the Basin has been dynamic and involves greater environmental changes than other portions of the GYE. Because of extensive whitebark pine forests, the Basin is also a high quality foraging area for grizzly bears (Craighead and Craighead 1972, Mattson and Reinhart 1996, 1997, Yonge 2001).

High levels of human activity in the Cooke City Basin dates back to the 1860s when gold was discovered in the Basin, which initiated an era of mineral exploration and extraction that lasted until the 1950s. The consequences were the establishment of Cooke City, the construction of a network of roads, and a variety of substantial mining operations. After the initial gold rush, the human population declined and Cooke City developed a tourist industry as a gateway community to Yellowstone National Park.

In the 1980s, Noranda Inc. began mineral exploration in the Cooke City Basin and, with technologically advanced equipment, located a valuable deposit of precious metals that had not been found during the earlier mining era. Noranda Inc. applied for a permit in 1990 to conduct mineral extraction in the Cooke City Basin, which required the Forest Service to prepare an Environmental Impact Statement (EIS). Because of the listed status of the GYE grizzly bear, impacts of the proposed mine on this population were of special concern. At the request of the U.S. Fish and Wildlife Service, a monitoring plan was drafted by the IGBST and the Forest Service to assess current grizzly bear use and distribution in the Basin with the intent to establish a baseline before mine development began and to identify potential mitigation. Monitoring began in 1990 and used methods that could be repeated over the long-term to allow comparisons of pre-mining conditions with the mine operational period and post-mining.

Monitoring associated with obtaining baseline information for the EIS was conducted in 1990–1991 and 1996–1997. The findings from these monitoring efforts were reported in Yonge (2001). Yonge (2001) found bear sign to be abundant contrary to the conventional presupposition by managers at that time that bear activity was minimal in the Basin due to high levels of human activity. Yonge (2001) concluded that road density was not a critical factor for bear habitat utilization in the Basin. He found that bear activity was equally distributed among areas that are more than 500m away from roads and human developments, and areas that are within 500m of these features. The tendency of bears to avoid open areas more than roaded forested areas suggested that forested cover played a greater role in bear habitat utilization in the Cooke City Basin at that time than road density.

Whitebark pine availability is known to influence bear movements in the Basin (Yonge 2001). Comparatively high concentrations of grizzly activity occurred in areas with high intensity human use during years of good cone production during the 1990-91 and 1996-97 monitoring. Bears were apparently willing to occupy habitat near human activity when high quality food source were available. Whereas variables that influence bear habitat use typically include density of roads, human activity, and food availability, cover may be an important component associated with use of human occupied landscapes (McLellan 1990, Yonge 2001, Gibeau et al. 2002, Martin et al. 2010). Vegetative and topographic cover can screen bears from most human observations, which was an important component of Yonge's (2001) findings regarding bear use in the Cooke City Basin. The intent was that these findings on grizzly bear habitat use would be used to develop mitigation strategies for pending mine development.

As the EIS for Noranda's proposed New World Mine was being completed in 1997, President Clinton intervened, expressing concern for the potential impacts to the adjacent designated Wilderness areas and Yellowstone Park and the special features they contain. Using Executive Order, he discontinued Federal involvement in the mine permitting process and directed a $22.5-million investment in the reclamation of historic mining and tailing sites.

Mine reclamation work occurred during 2003–2004 and was conducted under CERCLA or “Super Fund” authority (Comprehensive Environmental Response, Compensation, and Liability Act, 1980). The US Fish and Wildlife Service stipulated that the effects of the mine reclamation work would be monitored to determine impacts to grizzly bears and to identify potential mitigation, which could be applied progressively during the reclamation work. Consequently, the same methodology used for the New World Mine EIS to monitor bear habitat use was also used during 2003 and 2004. Mine reclamation activities included preparing repository sites that received waste material, removing toxic tailings, re-contouring and revegetating disturbed slopes, erosion control, and establishing watertight cement plugs to close mine tunnels. The heavy machinery used to reclaim the mines included 20 cubic yard haul trucks, bulldozers, excavators, loaders, graders, and scrapers.

Concurrent with these activities, the Federal Highway Administration proposed reconstructing Highway 212, which bisects the Cooke City Basin. In response, as with the mine reclamation work, the U.S. Fish and Wildlife Service requested a monitoring plan to track effects to grizzly bears. The protocol used in response to the New World Mine EIS was repeated in 2007–2009 during the road project and 2010–2011 after the project was concluded. The major activities and respective years when data were collected are shown in Table 1. During both periods, of mine reclamation and highway reconstruction, constructors had to follow guidelines designed to mitigate impacts of human activity on bears. To develop the guidelines it was assumed that predictable disturbance has less effect on habituated bears (McLellan and Shackleton 1988, Olson et al. 1997), and that every source of attraction should be eliminated. Therefore, the guidelines consisted of the following rules: i) construction activities were restricted to the reclamation/highway reconstruction sites; ii) vehicles associated with construction had to use designated routes; iii) construction stopped if any bear was seen; iv) workers were not allowed to carry guns, to have dogs or to camp within the Basin; v) project work was restricted to daylight hours, and vi) all attractants, as food and trash, should be unavailable to bears. Following these restrictions, contractors would reduce the potential of human-bear conflicts and allow bears access to the area during night time.

Table 1. Description of major activities in the Cooke City Basin, Montana in years when data were collected, from 1990 to 2011.

| **Years** | **Activities** | **Description** |
|---|---|---|
| 1990, 1991, 1996 and 1997 | Normal Activities | No major activities happened during these years. |
| 2003 and 2004 | Mine Reclamation | Mines were reclaimed in 5 of the 7 sites within the Cooke City Basin. |
| 2007, 2008 and 2009 | Highway Reconstruction | Highway 212 was reconstructed. |
| 2010 and 2011 | Normal Activities | No major activities happened during these years. |

Previous studies have described a negative effect of human activities on grizzly bear habitat selection (McLellan 1990, Mace et al. 1996, Gibeau et al. 2002). However, the literature provides little understanding of the impact of major construction actives, such as mine reclamation and highway reconstruction, on grizzly bear habitat selection and food habits. Cristescu et al. (2016) compared grizzly bear movement patterns before and after reclamation of active mines, but they did not study grizzly bear response to reclamation activity when it was occurring. Cristescu et al. (2015) studied how grizzly bears shifted their diet to consume more vegetation following mine reclamation activities, but they also did not study the effects of ongoing reclamation on grizzly bear diet. McLellan and Shackleton (1989) documented that one female grizzly bear with cubs remained within 1 km of a road during maintenance activities. The literature provides no information on the effects of highway reconstruction activities on grizzly bear habitat selection and diet at the population level. Therefore, the objectives of this study were to:

1) Provide knowledge about what anthropogenic and environmental factors are important for grizzly bear habitat selection in the Cooke City Basin,

2) Assess whether grizzly bears avoided areas surrounding mine reclamation and highway reconstruction activities, and if avoidance is present, quantify the extent of spatial avoidance associated with these activities,

3) Assess whether the relative consumption of main food sources changed during years of mine reclamation and highway reconstruction,

4) Estimate minimum number of grizzly bears using the Basin between 2007 and 2011

# STUDY AREA

The study was conducted at Cooke City Basin, MT (45.02° N, 109.94° W), located near the northeast entrance of Yellowstone National Park (Figure 1). With a total area of 91 $km^2$, the Cooke City Basin is located within the Yellowstone Grizzly Bear Recovery Zone (U.S. Fish and Wildlife Service 1993) where conservation of grizzly bear habitat is a management priority. Cooke City Basin climate is classified as high-elevation temperate, with mean lowest temperature of -15º C in January, and mean maximum temperature of 23º C in July. The average snow fall per year is 527 cm and 207 cm falls between December and January. The highest average snow depth is 239 cm and occurs in March (Western U.S. climate historical summaries, data from 1980 to 2010). Slopes above the Basin are characteristically steep with high gradients near stream channels. The elevation of the Basin ranges from 2,280 m to 3,103 m, and adjacent peaks exceed 3,477 m (Reinhart and Mattson 1992). The road density within the study area is 0.88 $km/km^2$ and 53% of the study area is within 500m of motorized routes. The study area was divided in subunits delineated by drainages determined by mountain configuration and hydrologic divides (Reinhart and Mattson 1992, Yonge 2001). The eight drainages were: Fisher Creek, Miller Creek, Mud Lake, Sheep Creek, Still Water, Republic Creek, Woody Creek, and Cooke Face (see Methods, Figure 3).

The vegetation in the study area was a mosaic of forested community types interspersed by talus, avalanche chutes, non-forested openings, and alpine meadows (Reinhart and Mattson 1992). Forested areas generally contained Engelmann spruce (*Picea engelmannii*), whitebark pine (*Pinus albicaulis*), lodgepole pine (*Pinus contorta*), or subalpine fir (*Abies lasiocarpa*). Large carnivores common in the Cooke City Basin are grizzly bear, American black bear (*Ursus americanus*), red fox (*Vulpes vulpes*), and coyote (*Canis latrans*). Less common carnivores the Basin are wolverines (*Gulo gulo*), wolves (*Canis lupus*), mountain lions (*Felis concolor*), bobcat (*Lynx rufus*) and lynx (*Lynx canadensis*) (Craighead et al. 1995, Ulvund 2007).

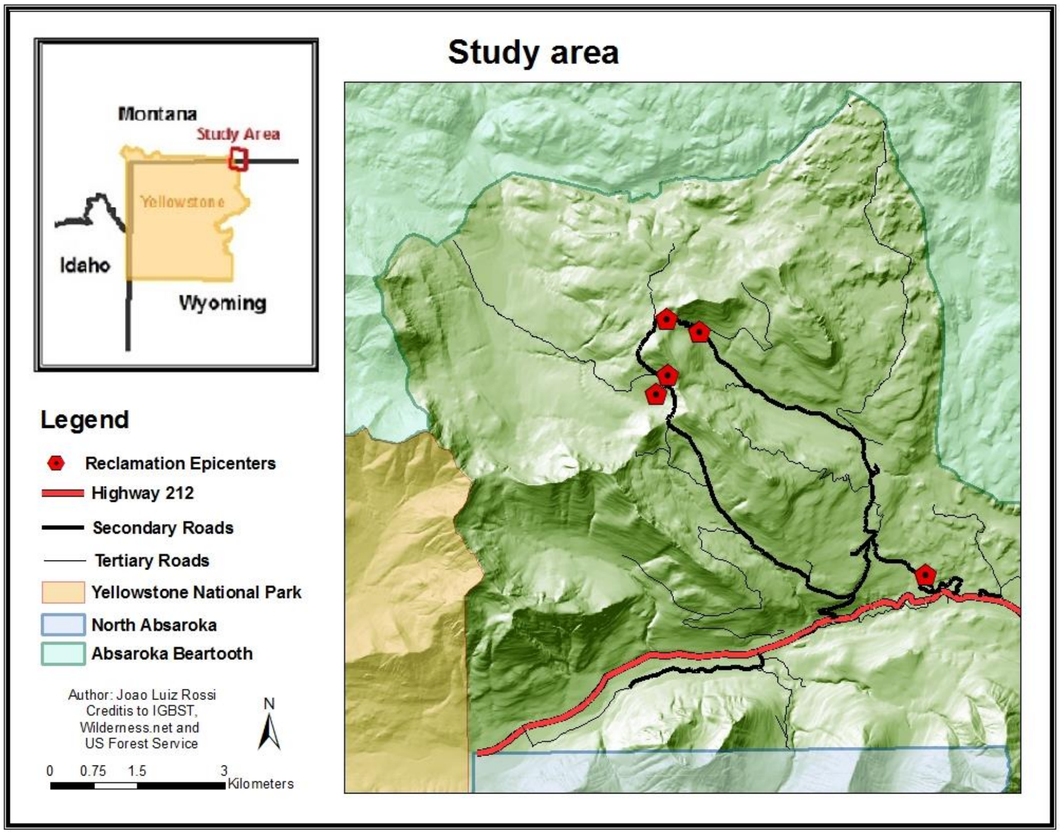


Figure 1. Study area within the Cooke City Basin, containing reclamation epicenters, primary roads (highway 212), secondary roads, tertiary roads, and the borders of Yellowstone National Park, Absaroka Beartooth and North Absaroka Wilderness, Montana, 1990-2011.

# METHODS

## Grizzly Bear Sign on Transects

In 1990, IGBST established 36 belt transects distributed among the eight drainages of the Cooke City Basin (Reinhart and Mattson 1992; unpublished report to Gallatin National Forest, Bozeman, Montana). Transects were strategically oriented perpendicular to topographic contours of each drainage to cover elevation gradients (Figure 2). Transects were not stratified by vegetation cover types. The length of transects varied from 715 m to 5,904 m and the width of all transects was 500 m. The summed length of transects was 65.3 km. Data collection was performed from1990 to 2011. The number of transects was reduced from 36 to 27 during 1996–2011 because nine transects were considered redundant or too dangerous for data collection. Thus in this study, I report information from the 27 transects from which data were collected during all years (Figure 2). Members of the data collection crew changed during the long-term study. However, all crew members were trained by the same person (D. B. Tyers, U.S. Forest Service, personal communication) for the duration of the study to reduce variation in detection of sign among years and crew members. Crew members were trained for one week prior to data collection. The training included information about grizzly bear sign identification and collection. Moreover, only four different crew leaders were in charge of transect sampling during 2003–2011.

A team of three members collected bear sign data as follows: one member walked the center line of each transect oriented by a compass (between 1990 and 1997) or a handheld Global Positioning System (GPS) unit (between 2003 and 2011), while the other two members walked in a zigzag pattern, covering either side of the transect center line. The crew looked for scats, tracks, sightings, and evidence of foraging. Once sign was found, the species of bear that produced the sign was tentatively identified *in locus* (Mealy 1975). Fecal samples were collected and sent to laboratory facilities for identification, except for those collected in 1990. Thin layer chromatography (TLC) of species-specific bile acid patterns (Fernández et al. 1997) was used to differentiate scats from grizzly and black bears collected during 1991, 1996, and 1997. The TLC analysis was performed at Montana State University by H. D. Picton (Picton 1991). This technique is known to be moderately reliable because it can correctly identify a carnivore species in ~80% of the cases (Fernández et al. 1997). Samples collected after 2003 were sent to the Wildlife Genetics International (Nelson, British Columbia, Canada) for fecal DNA analysis (Waits and Paetkau 2005, Boulanger et al. 2006). Signs of the same age found within 5 m of grizzly bear scats were also considered grizzly bear signs. The month that the scat was produced was estimated *in situ* based on the state of decay and desiccation, vegetation growth under and around the scat, and the stage of maturity of insects/larvae when these were present (Mealy 1975). Data were collected along the transects 2-4 times from June to October in 1990–1991, 3-4 times from June to October in 1996-1997 and once a month between July and October in 2003–2004, and 2007–2011. Data collected between 1990 and 2009 were used in other studies (Reinhart and Mattson 1992, Yonge 2001, Karterud 2009, Haaverstad 2011). The 65.3 km of transects were surveyed in each of the above mentioned months/years, producing a total length of approximately 2,677 km of surveyed transects in all years.

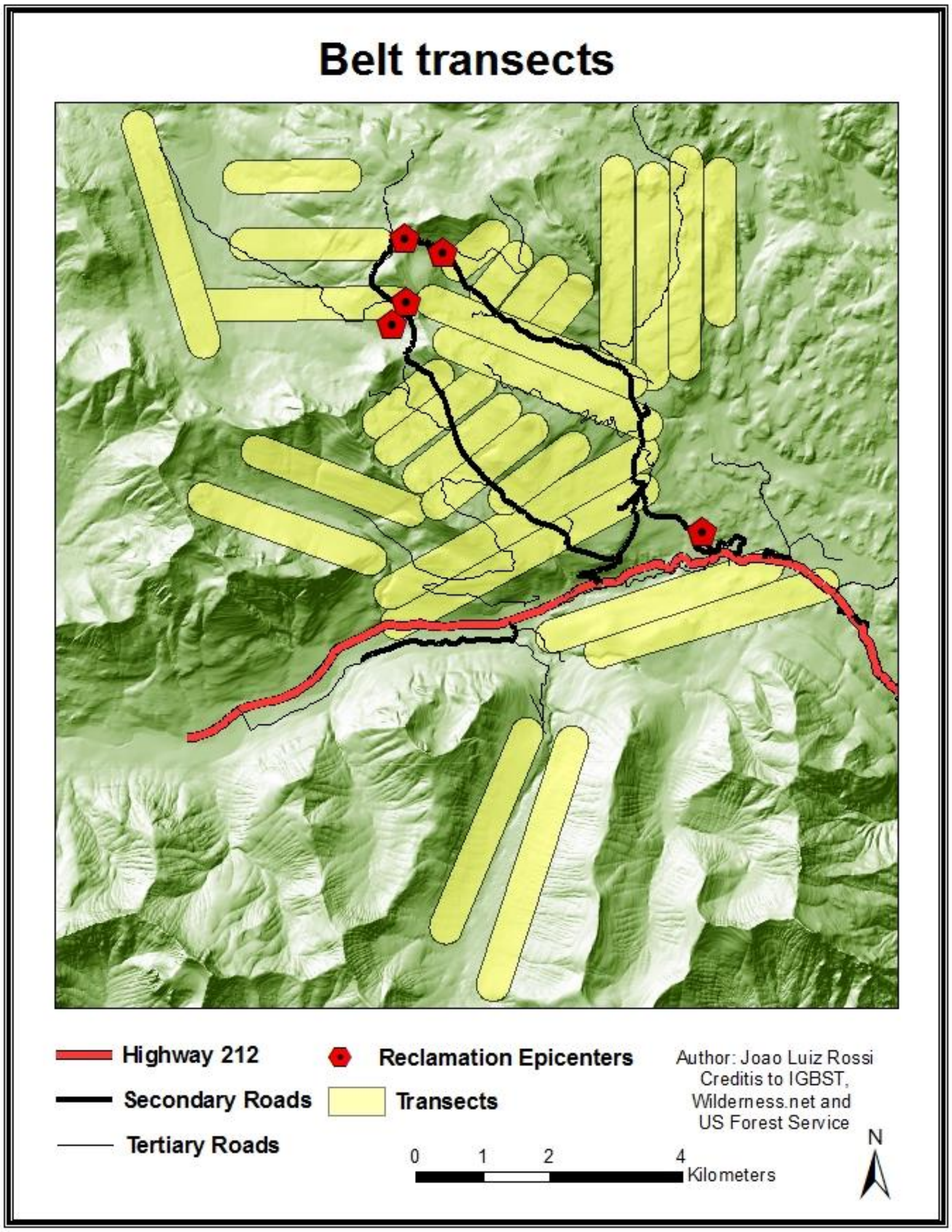


Figure 2. Transects placed within the Cooke City Basin, Montana, 1990-2011. The map also contains reclamation epicenters, primary road (highway 212), secondary roads, and tertiary roads.

## Habitat Selection

There are many statistical analyses designed to quantify habitat selection. Among the main tools are MaxEnt (Elith et al. 2011), MaxLike (Fitzpatrick et al. 2013), Resource selection function (RSF; Manly et al. 1993) and occupancy models (MacKenzie et al. 2002). I used resource selection function (RSF) to quantify habitat selection and test hypotheses associated with objectives one and two. Resource selection functions were used because they allow the use of random effects (Zuur et al. 2009) to account for spatial and temporal dependence among observations. I assumed constant probability of detection of grizzly bear signs in all cover types in our study area. Even though detection may differ according to environmental conditions (MacKenzie et al. 2002), the majority of signs used in this study were scats, signs from which detection is the least influenced by environmental characteristics (Posillico et al. 2004).

I used RSF to evaluate grizzly bear habitat use by comparing population use with population availability (Manly et al. 1993). Locations of bear sign were considered used by grizzly bears. Five available locations were generated randomly within all belt transects in the study area for each used location. Available locations were assigned to months when data were collected with equal probability. Generalized linear mixed effects models with binomial response (GLMM; Zuur et al. 2009) were used to estimate the coefficients of the RSF. The GLMMs were fitted to the data using the R package “lme4” (R Core Team 2014, Bates et al. 2015).

The models were designed as (Zuur et al. 2009, Li et al. 2011):

$$y_i \sim \text{Binomial}(1, \mu_i) = \begin{cases} \mu_i & if \quad y_i = 1; \\ 1 - \mu_i & if \quad y_i = 0. \end{cases}$$

Where:

$$logit(\mu_{ijl}) = ln\left(\frac{\mu_{ijl}}{1 - \mu_{ijl}}\right) = \beta_0 + \beta_1 X_{1ijl} + \cdots + \beta_k X_{kijl} + u_j + v_l$$

$$u_j \sim N(0, \sigma_u^2) \quad \text{for j} = 1, \ldots, \text{J}; \qquad v_l \sim N(0, \sigma_v^2) \quad \text{for } l = 1, \ldots, L;$$

$y_i$: response variable, 1 for used locations and 0 for available locations;

$\mu_{ijl}$: mean of the distribution for the drainage *j*, year *l*, and observation *i*;

$X_{kijl}$: value of the explanatory variable *k* for drainage *j*, year *l*, and observation *i*;

$\beta_k$: coefficient associated with the explanatory variable *k*;

J: number of drainages = 8; $L$: number of years = 11;

$N_{jl}$: number of observations for drainage *j* and year *l*;

In which RSF values were given by:

$$RSF_{ijl} = \exp(\beta_1 X_{1ijl} + \cdots + \beta_k X_{kijl}).$$

To define which variables would be used in the candidate models for habitat selection, a set containing several candidate variables was created and refined to a smaller set that excluded collinear variables. Collinearity between variables was evaluated by pairwise scatterplots and variance inflator factors (VIF; Zuur et al. 2009). Variables with VIF higher than 3 were considered collinear (Zuur et al. 2009). In cases where collinearity was present, two GLMM were fitted using use/available locations as response, and each of the two collinear variables (individually) as the explanatory variable. The variable present in the model with highest Akaike Information Criteria (AIC, Akaike 1973) was then considered the one that was less important in explaining grizzly bear habitat selection, and thus was removed from the set of variables. The variables used in the candidate models for the RSF were:

- **Elevation**: variable obtained in ArcGIS (ESRI 2011) for each available and used location from a Digital Elevation Model (DEM; 10m resolution) downloaded from geoinfo.msl.mt.gov, converted to kilometers. The quadratic term of elevation was included in the models because I hypothesized that grizzly bear use will increase with elevation up to a certain point and decrease afterwards, following availability of whitebark forests;
- **Hillshade:** variable obtained using the tool Hillshade (Spatial Analyst) from the software ArcGIS (ESRI 2011;using azimuth 225 and sun angle equals 45º). It is used to quantify the amount of light the location receives as a function of topography. A positive coefficient associated with this variable indicates selection for "warmer" locations (Ciarniello et al. 2007*a*).
- **Cone year**: binary variable that assumed the value 1 for "good cone years" when whitebark cone production was above the average for the period of the study (16.09 cones per tree; Haroldson and Podruzny 2011) and the value 0 otherwise. The value for cone production used was that for the current year production for signs found after August and, the previous year production for signs found before August. The variable Cone Year was included because we expected that whitebark seeds were the main food resource used by grizzly bears in the Basin (Yonge 2001);

- **Vegetation cover-type**: categorical variable specifying the vegetation cover type. Field work for the base map was conducted in 1990-1991. Vegetation stands were first delineated on aerial photos. Every identified stand was then verified in the field; the mapping boundary was checked and a cover type assigned using the criteria established by Mattson and Despain (1985). From this, a 2 ha resolution base map was created in GIS. The 5 cover types used in this analysis were the result of aggregating over 112 cover types or cover type combinations (mosaics) into the most useful description of the available vegetation patterns in the study area. This variable was included in the models because of its relationship with food availability and natural cover (Mattson and Reinhart 1997, Gibeau et al. 2002). The reference level for Cover-type was Open because we wanted to assess if grizzly selected for whitebark and other conifer forests over open areas in the Basin. The vegetation cover categories of this variable are defined in Table 2 and are presented in the first map of the appendix (A1);
- **Season**: binary variable that assumed the value 1 for signs produced after the first day of August and 0 for signs produced before August. Season was included in the models because it allowed for comparison of relative probability of use between months before and after August, following whitebark seeds availability (Mattson and Reinhart 1997);
- **Primary, secondary and tertiary road densities**: calculated using a GIS road layer from the grizzly bear habitat management database of the U.S. Forest Service by the function line density of the spatial analyst tools from the software ArcGIS (ESRI 2011), the arguments used in the function were: output cell size = 10 m and search radius = 564

m (which produces a circle with area equals 1$km^2$, Mace et al. 1996). An individual GIS layer of the road density given in km/$km^2$ was generated for each road type: primary, secondary or tertiary. Highway 212 was considered the primary road, whereas the County dirt roads that were accessible by 2-wheel drive vehicles were considered secondary roads. Forest service dirt roads that were only accessible by 4-wheel drive vehicles with high clearance were considered tertiary roads. Primary, Secondary and Tertiary road densities were included in the models because of the known influence of roads on grizzly bear habitat selection (Mace et al. 1996, Gibeau et al. 2002).

- **Reclamation within *x* kilometers**: a set of binary variables that are equal 1 for locations within *x* to *x*-1 kilometers from a reclamation site, when *x* equals 1, 2, 3, and 4 km; and 0 for locations outside of this buffer. The variable reclamation within 4 km for example, is equals 1 for all locations within 3 to 4 km of active reclamation, (Figure A2 from maps appendix), and is 0 for locations outside of this buffer. The reference level of Reclamation within x km is a variable that assumes 1 for all locations that are at least 4 km away from reclamation/reconstruction epicenter.
- **Reclamation active**: Binary variable that assumes the value 1 during years of mine reclamation. The variable Reclamation within x km, Reclamation active, and their interaction were used to quantify the possible spatial avoidance associated with mine reclamation. The reference level for the variable Reclamation active is a variable that assumes 1 for "baseline" years.
- **Reconstruction within *x* kilometers**: a set of binary variables that are equal 1 for locations within *x* to *x*-1 kilometers from the highway (*x* = 1, 2, 3, and 4 km) and 0 for

locations outside of this buffer (Figure A3 from appendix). The reference level of Reconstruction within x km is a variable that assumes 1 for all locations that are at least 4 km away from the highway.

- **Reconstruction active**: Binary variable that assumes the value 1 during years of highway reconstruction. The variable Reconstruction within x km, Reconstruction active, and their interaction were used to quantify the possible spatial avoidance associated with highway reconstruction. The reference level for the variable Reconstruction active is a variable that assumes 1 for "baseline" years.

Variables associated with random effects were Year (year when the sign data were collected) and Drainage (the drainage of bear-sign and available locations). The variable Year was included as a random effect because I expected that observations from the same year to be dependent since data were collected by different crew members in different years. Drainages were also included as random effects because I expect that observation from the same drainage can be spatially dependent. The most parsimonious dependence structure was identified by AIC model selection using the full model of fixed effects (Zuur et al. 2009). Candidate models for dependence structure included Drainage, Year, or both variables as random effects.

I developed six candidate models representing competing hypothesis regarding grizzly bear habitat selection in the Cooke City Basin (Table 3). Relative support for competing models was evaluated using AIC (Mao et al. 2005, Ciarniello et al. 2007*a*). Models with high AIC weight were selected as the ones that better described habitat selection by bears in the Basin. As suggested by Arnold (2010), variables were considered good predictors of grizzly bear habitat selection in the Basin only if: i) they were present in the most parsimonious model and, ii 85% confidence intervals of effect sizes did not overlap zero.

Table 2. Vegetation cover types (acronyms used are in bold font) in the Cooke City Basin study area, Montana. For complete descriptions of the 112 vegetation cover types on which these cover classes were based see Mattson and Despain (1985).

| Cover Class Group | Description |
|---|---|
| Whitebark | **(WB)** Uniform or patches of forest dominated by whitebark pine trees. May contain stands of whitebark pine scattered among stands of other conifers or whitebark pine stands with scattered meadows or other open types. |
| Other Conifers | **(OC)** Uniform or patches of other conifer species, dominated by conifers other than whitebark pine (subalpine fir, lodgepole pine, or Douglas fir). May contain scattered stands of different conifer species with scattered meadows or other open types. |
| Disturbed conifer forest | **(Disturbed)** Conifer stands with open canopy due to fire, logging, or wet soil. |
| Open habitats | **(Open)** Vegetative component with no trees including high elevation rocky grasslands, grasslands, meadows, and tundra. |
| Other | **(Other)** Sites with no vegetation (cliff, talus slides, exposed bedrock) and minor (<1% landscape coverage) types such as aspen, standing water, willow, and shrubby avalanche chutes. |

Table 3. Competing models designed to identify factors influencing grizzly bear habitat selection in the Cooke City Basin, Montana.

| Model | Variables |
|---|---|
| **M0** | Intercept only |
| **M1** | Elevation + Elevation$^2$ + Hillshade + Season + Cone Year + Vegetation |
| **M2** | Elevation + Elevation$^2$ + Hillshade + Season + Cone Year + Vegetation + Primary, Secondary and Tertiary road densities |
| **M3** | Elevation + Elevation$^2$ + Hillshade + Season + Cone Year + Vegetation + Primary, Secondary and Tertiary road densities + Reclamation* |
| **M4** | Elevation + Elevation$^2$ + Hillshade + Season + Cone Year + Vegetation + Primary, Secondary and Tertiary road densities + Reconstruction* |
| **M5** | Elevation + Elevation$^2$ + Hillshade + Season + Cone Year + Vegetation + Primary, Secondary and Tertiary road densities + Reclamation* + Reconstruction* |

* Models associated with construction activities included variables of the buffer areas, the indicator variable for the activity and their interaction

The predictive capability of the most parsimonious model was assessed using 10-fold cross validation (Boyce et al. 2002, Johnson et al. 2006). First, the data set was divided in ten parts of equal size. Then, the best model was fit to nine tenths of the data and the remaining tenth was used as validation set. Ten RSF bins were created by predicting RSF values using the fitted coefficients and available locations, ordering these values by RSF, and grouping the predicted values using deciles (quantiles from 10% to 100% by 10% increments). Boyce et al. (2002) advise that RSF bins should be defined in a way that each of them occupy the same proportion of the study area. Because some variables in the analysis changed yearly, obtaining such areas was not straightforward. However, in our case, the number of available locations was probably large enough so that bins of equal number of available locations were similar to bins of same area. At last, the proportion of used locations of the validation set in each RSF bin was calculated. The procedure was repeated using each of the ten parts of the data alternatively as a validation set. Mid-points of the RSF bins were re-scaled to 0-1 and then regressed against the proportion of used location in each bin (Johnson et al. 2006). If the models have high predictive capability, the regression of proportion of used locations and RSF bin midpoints should have high $R^2$, intercept not different than zero, and slope not different than one (Johnson et al. 2006).

## Food Habits

All scats collected during surveys were analyzed for diet composition. Before analysis, scats were air-dried for approximately one week and stored in paper bags. The analysis consisted of rehydrating and washing scats through different diameter sieves to determine frequency and volume of food categories. The categories were: whitebark pine seeds, mushroom, miscellaneous (dirt, debris), berries (huckleberries, whortleberries, gooseberry), vegetation (graminoids, forbs), animal matter (e.g., deer, elk, moose, rodent, bear), anthropogenic (garbage, horse feed, birdseed), invertebrates, and roots. The frequency of each food category was calculated as the number of scats that contained a specific food category over the total number of scats. The proportion of each food category was visually estimated, and correction factors that account for digestibility of different food types were used to determine the corrected fecal volume (Hewitt and Robbins 1996). There were three exceptions in which the correction factors used in this study differed from those proposed by Hewitt and Robbins (1996). I used the average (3.5) between the correction factors for ungulates (3.0) and rodents (4.0) as the correction factor for animal; the average (0.25) of the values provided for graminoids (0.24) and forbs (0.26) as the correction factor for vegetation; and mushrooms were left uncorrected. The lack of correction for mushrooms may have led to inaccurate estimations of mushrooms consumption. However, we expect it to have little influence on our results since mushrooms were rarely consumed. Scats were grouped as follows: scats identified as produced from May to June were grouped as Spring, scats identified as produced from July to August were grouped as Summer, and scats identified as produced from September to October were grouped as Fall (Yonge 2001). The frequency of which each food category appeared in the scats allowed us to determine how persistent food groups were among seasons and years. The probability of a food item to be present and the corrected volume of food items in scats were compared between construction and "baseline" periods using logistic regression and Wilcoxon rank sum test, respectively.

## Hair-Snare Stations

We used camera-snare stations to obtain information about sex and cohorts of bears using the Basin. One station was established in each of the eight drainages in 2007-2011 (Figure 3). Hair-snare stations had at their center an artificial rub tree, created by attaching a creosote-treated plank to the trunk of a tree. These were also baited with a combination of anise and commercial scent lure. A motion triggered camera was installed near the artificial rub tree to take pictures of individual bears to provide information about what cohorts are present in each of the drainages. During 2007-2008, we collected DNA using hair snares created by wrapping the rub surface with chicken wire. In 2009, the quantity of DNA sample was augmented with the addition of a perimeter of barbed wire around each station. Hair samples were then collected from each individual barb to minimize cross-contamination. Hair samples and photos were matched using time-of-collection records and photo date stamps. These DNA and camera data provided a description of population composition in term of sex/cohort. Results from hair-snare stations were summarized by year, sex and cohort of the bears when visual record was available.

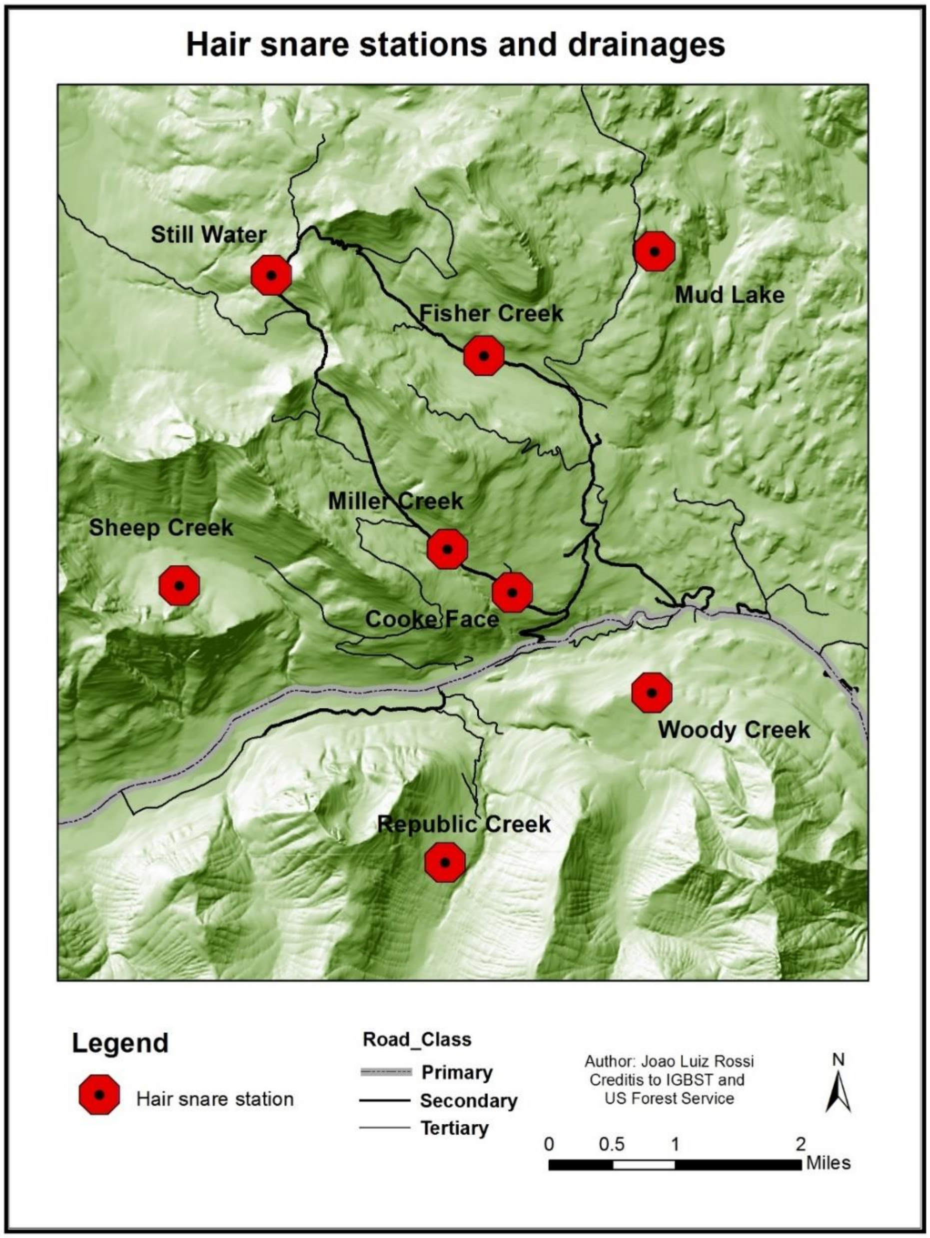


Figure 3. Location of camera and hair-snare stations in each of the drainages of the Cooke City Basin, Montana 1990-2011.

Traffic

To provide information on how traffic volume varied among years in primary and secondary roads, Forest Service personnel performed counts of vehicles on secondary roads, and primary roads (highway). Traffic counts of vehicles occurred every month from July to October, during the years of 2003, 2004, 2007, 2008, 2009, 2010 and 2011. The number of hours counting vehicles in primary and secondary roads of the Basin varied monthly. Counting was done during daylight hours at any day of the week. During counting, all vehicles crossing the road were also classified as construction-related (mine reclamation or road reconstruction; e.g. hauling trucks, machinery, personnel going to work, etc.) or regular traffic (all other vehicles). Results from traffic counts were summarized by the periods of mine reclamation, highway reconstruction and “baseline”.

# RESULTS

## Grizzly Bear Signs on Transects: Overview

A total of 1042 grizzly bear signs were detected in the Basin during the study. The density of sign varied by years ranging from 0.91 signs/km in 2007 to 0.17 signs/km in 1990 (Figure 4). The proportions of each sign type were: 0.72 scats, 0.12 tracks, 0.10 midden diggings, 0.02 torn logs, 0.01 bear hair. The remaining 0.03 of sign included turned rocks, carcasses, sightings, mushroom diggings, feedings on vegetation, root diggings, gopher diggings, foraging on cones in the forest floor, dens, rubbing on trees, and claw marks on trees. The proportion of signs found in south facing aspects was 0.4, while 0.28, 0.20, and 0.12 of the signs were found on east-, west-, and north-facing slopes, respectively. The proportion of available locations was 0.32, 0.29, 0.19, and 0.18, for south-, east-, west-, and north-facing aspects, respectively. The average elevation of locations where signs were found was similar for years of high and low cone production, 2,773 m and 2,783 m, respectively. The proportion of signs found in each of the vegetation cover were 0.57, 0.25, 0.05, 0.08 and 0.03, for the covers “Whitebark”, “Other Conifers”, “Disturbed”, “Open”, and “Other”, respectively. The availability of these covers in the transects, following the same order, was 0.35, 0.27, 0.16, 0.14, and 0.085. Regarding sign density by drainages, Miller Creek had the highest density, 0.61 signs per km surveyed, followed by 0.51 signs/km in the Fisher Creek, 0.50 signs/km in the Mud Lake, 0.39 signs/km in the Sheep Creek, 0.29 signs/km in the Stillwater Basin, 0.23

signs/km in the Republic Creek, 0.17 signs/km in the Woody Creek, and 0.11 signs/km in the Cooke City Face drainage.

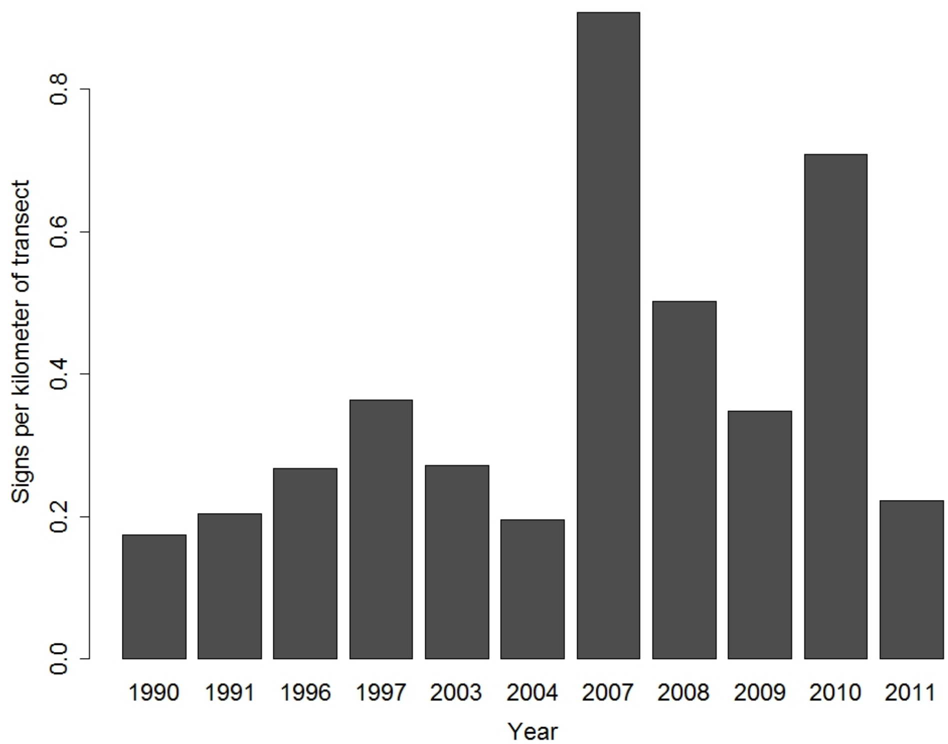


Figure 4. Quantity of grizzly bear sign found per kilometer of belt transects in the Cooke City Basin, MT during surveys done between 1990 and 2011.

## Habitat Selection

The six competing models (Table 3) were fit to the data and ranked by AIC values (Table 4). The difference in AIC from the Null Model to Model 1 (M1) was greater than 200 units, indicating that the set of variables used in M1 had considerable AIC support. The AIC values obtained for Models 1 to 4 were substantially higher than that of Model 5

(M5). Therefore, M5 was selected among the candidates as the model that best represents grizzly bear habitat selection in the Basin.

Table 4. Models for grizzly bear habitat selection ranked according to Akaike Information Criteria (AIC).

| **Model** | **d.f.** | **AIC** | **delta AIC** | **AIC weight** |
|---|---|---|---|---|
| **M5** | 32 | 4997.86 | 0.00 | 1.00 |
| **M4** | 23 | 5015.84 | 17.98 | 0.00 |
| **M3** | 23 | 5016.82 | 18.96 | 0.00 |
| **M2** | 11 | 5036.85 | 38.99 | 0.00 |
| **M1** | 14 | 5039.35 | 41.49 | 0.00 |
| **M0** | 2 | 5376.26 | 378.40 | 0.00 |

This table also contains the degrees of freedom (d.f.), delta AIC, which is the difference between AIC values of the lowest AIC and each model, and AIC weight, which is a measurement of the adequacy of the model relative to candidate models.

Model 5 had more than 99% of the relative support and indicated that habitat selection in the Basin was associated with: elevation, hillshade, season, cone year, vegetation cover type, tertiary road density, reclamation within *x* km, reclamation active, reconstruction within *x* km, and reconstruction active. In this model, the coefficients associated with elevation and its quadratic term indicated that grizzly bear use increased with elevation up to 2,817 m and decreased afterwards (Figure 5). The estimated relative probability of use by grizzly bears increased about 68% during months after August, and 34% during periods of high cone production when those where compared to their reference level (months before August and periods of low cone production, respectively).

Grizzly bears avoided disturbed, open and other vegetation cover types. No difference in selection was observed for other conifers and whitebark cover types. Results from variables associated with anthropogenic activities indicate that grizzly bears avoided areas within 1 and 2 km of active mine reclamation epicenters when mine reclamation was occurring, but no avoidance was observed in areas located beyond 2 km of the reclamation epicenters. Relative probability of grizzly bear use of areas within 1 and 2 km of reclamation epicenters was reduced by 84% and 48%, respectively, during active mine reclamation. No avoidance was observed beyond 2 km of mine reclamation activities. Grizzly bear use of areas within 4 km of the highway was higher during years of highway reconstruction when those were compared with years when the highway was not being reconstructed. Figures A5 and A6 provide a visual representation of the estimated effects of mine reclamation and highway reconstruction on grizzly bear habitat selection in the Basin. Grizzly bears use of areas away from construction remained unaltered during construction years (see the main terms of the variables Reclamation active and Reconstruction active on Table 5). Although areas with higher tertiary road density were avoided by grizzly bears, results provide no evidence about avoidance or selection associated with primary and secondary road densities.

The most parsimonious model for the random effects, indicated by AIC, contained only year as a random effect. Therefore, the random effect for drainages was removed from all models. The estimated effects for years, at the exponential scale, varied from 0.61 to 2.5 for 2009 and 2010, respectively, both years with highest unexplained variability in relative use by grizzly bears (Figure 7).

Results from the 5-fold cross validation indicated model M5 was, in general, good in predicting grizzly bear habitat use in the Basin (Spearman-rank correlation = 0.96, $R^2$ = 0.98, Figure 6). The regression of the proportion of used locations on RSF bins had estimated coefficient and intercept equal to 0.993 (C.I. = 0.861, 1.126) and 0.001 (C.I. = -0.15, 0.16), respectively, also indicating that the model had good predictive capability.

Table 5. Coefficients estimation, standard error and confidence interval from model 5 (M5). Variables shown to have high influence on grizzly bear habitat selection in the Basin were highlighted in bold.

| **Coefficient** | **Estimate** | **Std. Error** | **85% confidence interval** | |
|---|---|---|---|---|
| | | | **Lower** | **Upper** |
| Intercept [a] | -79.01 | 12.73 | -97.34 | -60.68 |
| Elevation [a] | 0.52 | 0.09 | 0.38 | 0.65 |
| Elevation$^2$ [a] | 0.29 | 0.08 | 0.17 | 0.41 |
| Hillshade [a] | 52.85 | 9.15 | 39.68 | 66.01 |
| Season [a] | -9.23 | 1.64 | -11.59 | -6.87 |
| Cone year [a] | 0.35 | 0.09 | 0.23 | 0.48 |
| Cover Whitebark pine [a] | 0.68 | 0.13 | 0.49 | 0.87 |
| Cover Other Conifers [a] | 0.80 | 0.15 | 0.59 | 1.01 |
| Cover Disturbed [a] | -0.38 | 0.20 | -0.67 | -0.09 |
| Cover Other [a] | -0.44 | 0.22 | -0.76 | -0.12 |
| Primary road density | -0.09 | 0.33 | -0.56 | 0.39 |
| Secondary road density | 0.00 | 0.09 | -0.13 | 0.14 |
| Tertiary road density [a] | -0.12 | 0.07 | -0.22 | -0.03 |
| Reclamation Activity | 0.00 | 0.46 | -0.67 | 0.66 |
| Reclamation within 1km | 0.07 | 0.23 | -0.26 | 0.41 |
| Reclamation within 2km [a] | 0.43 | 0.18 | 0.18 | 0.68 |
| Reclamation within 3km [a] | 0.37 | 0.17 | 0.13 | 0.61 |
| Reclamation within 4km [a] | 0.46 | 0.17 | 0.21 | 0.70 |
| Recl 1km × Reclamation Act [a] | -1.81 | 0.80 | -2.96 | -0.66 |
| Recl 2km × Reclamation Act [a] | -0.66 | 0.41 | -1.25 | -0.08 |
| Recl 3km × Reclamation Act | 0.23 | 0.36 | -0.28 | 0.75 |
| Recl 4km × Reclamation Act | -0.11 | 0.40 | -0.69 | 0.46 |
| Reconstruction Activity | 0.30 | 0.31 | -0.15 | 0.75 |
| Reconstruction within 1km | -0.15 | 0.26 | -0.52 | 0.22 |
| Reconstruction within 2km [a] | -0.63 | 0.20 | -0.91 | -0.34 |
| Reconstruction within 3km | -0.09 | 0.14 | -0.28 | 0.11 |
| Reconstruction within 4km [a] | -0.25 | 0.13 | -0.44 | -0.06 |
| Reco 1km × Reconstruction Act [a] | 0.85 | 0.29 | 0.43 | 1.27 |
| Reco 2km × Reconstruction Act [a] | 0.97 | 0.27 | 0.58 | 1.36 |
| Reco 3km × Reconstruction Act [a] | 0.59 | 0.20 | 0.30 | 0.88 |
| Reco 4km × Reconstruction Act [a] | 0.70 | 0.20 | 0.42 | 0.99 |

[a] confidence intervals for these variables did not overlap zero

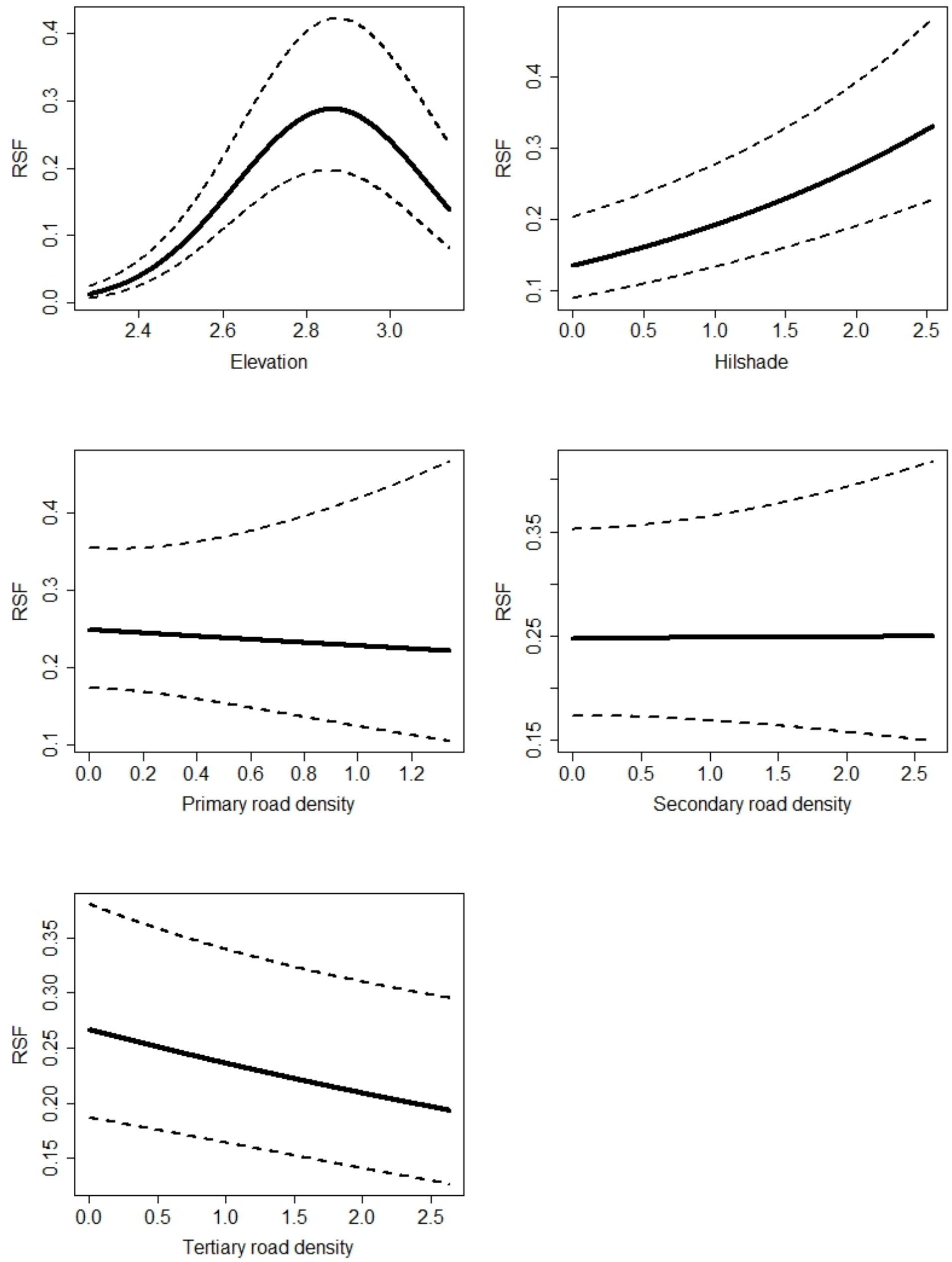


Figure 5. Estimated effects with 85% confidence bands of elevation, hillshade, primary, secondary, and tertiary road densities on grizzly bear use in the Cooke City Basin, Montana 1990-2011. These curves were obtained using resource selection function (RSF) values considering factors fixed at: vegetation cover equals to other conifers, period of good cone production for months after August with no mine reclamation or highway reconstruction, and average hillshade, elevation, and road densities when these were not the variable being plotted.

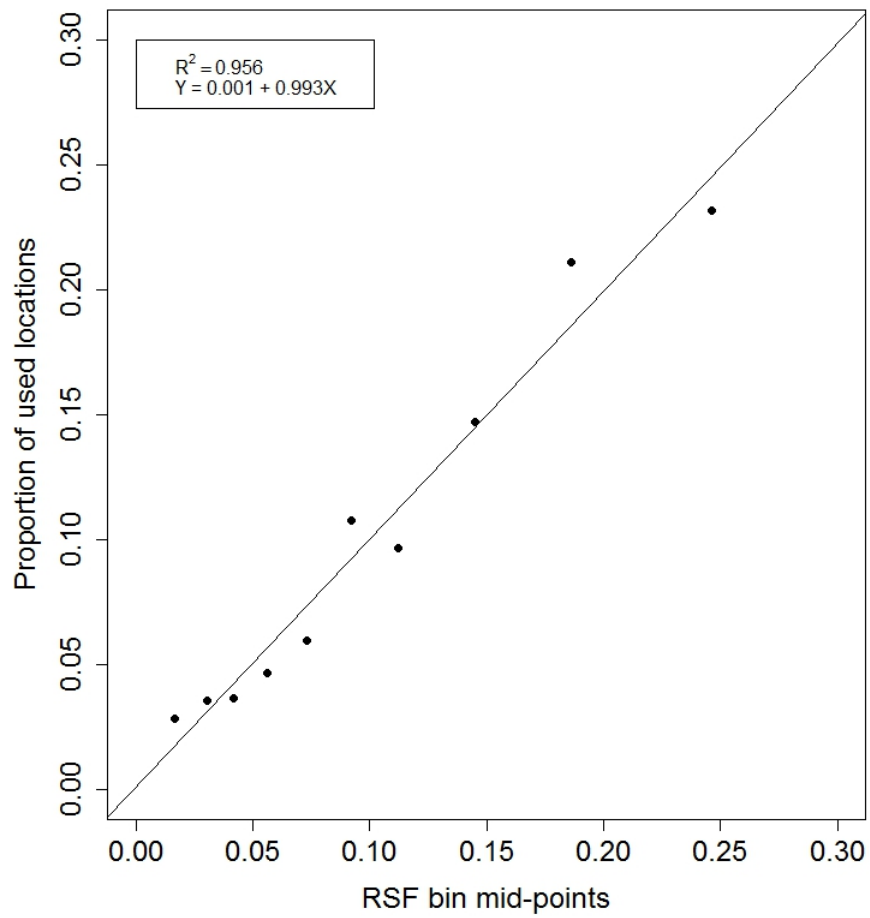


Figure 6. Ten-fold cross validation plot. Rescaled median values of resource selection function bins plotted against the proportion of used locations, estimated regression line, and $R^2$ of the regression. The most parsimonious model had good predictive capability as it had regression $R^2$ close to one, intercept not different than zero, and slope not different than one.

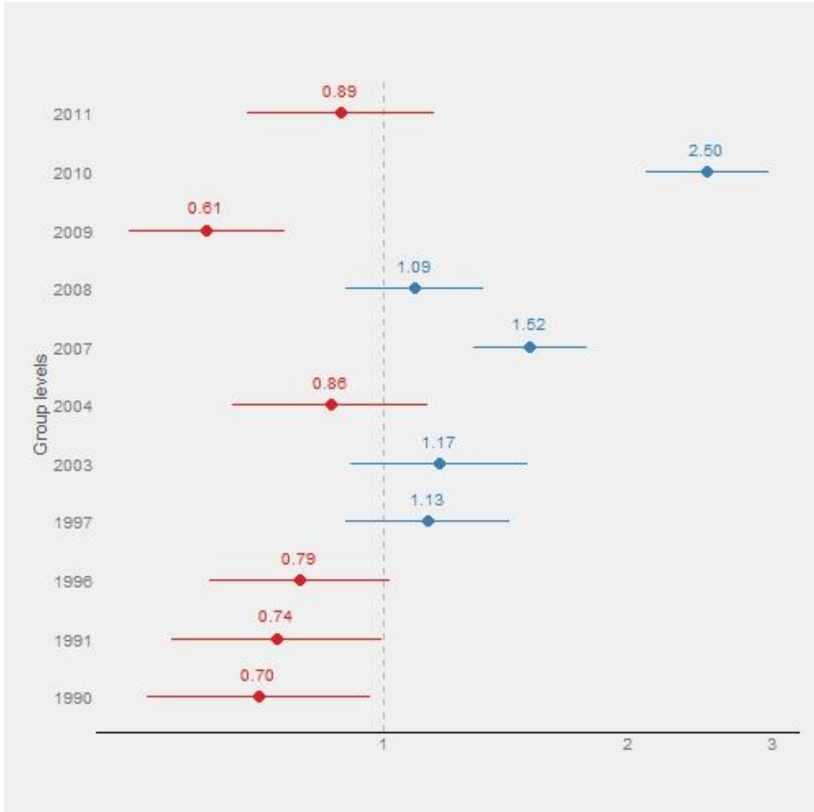


Figure 7. Estimated random effects for years with 95% confidence bands. This plot was obtained using the R package "sjPlot" (Lüdecke 2016). The years of 2009 and 2010 were the years with highest unexplained variability in relative use by grizzly bears in the Cooke City Basin, Montana, 1990-2011.

## Food Habits

A total of 675 grizzly bear scats, collected from 1990 to 2011 (Table 6), were analyzed to determine frequency and volume of each food category. As a general trend, whitebark pine seeds, vegetation, and dirt/debris were the categories most frequently found in grizzly scats, being present in 66%, 62%, and 50% of all scats, respectively. Other notable sources included berries, invertebrates (mostly ants), animal matter, and roots, present in 15%, 14%, 9%, and 2%, respectively. In contrast, scats containing anthropogenic food (primarily trash) and mushrooms were rare, present in 0.3% and

0.7% of the scats. Whitebark seeds were consumed most frequently during spring (90%) and fall (79%), while vegetation was mostly consumed in the summer (72%) and fall (59%). The frequency of whitebark seeds present in scats were similar for years of good (78%) and bad (82%) cone production. Consumption of berries and roots occurred more frequently during fall when they were present in 20% and 2% of the scats, respectively. Spring was the season when animal matter was more frequently found in scats. During this season, 14% of the scats contained animal matter. The frequency of each food category on scats by year and seasons are shown on Figures 8-10.

Table 6. Number of scats analyzed in each season and year.

| **Year \ Season** | **Spring** | **Summer** | **Fall** | **Total** |
|---|---|---|---|---|
| 1990 | 4 | 11 | 6 | 21 |
| 1991 | 0 | 31 | 21 | 52 |
| 1996 | 0 | 14 | 9 | 23 |
| 1997 | 6 | 15 | 5 | 26 |
| 2003 | 5 | 7 | 26 | 38 |
| 2004 | 5 | 23 | 7 | 35 |
| 2007 | 28 | 82 | 39 | 149 |
| 2008 | 5 | 30 | 72 | 107 |
| 2009 | 9 | 7 | 16 | 32 |
| 2010 | 7 | 52 | 96 | 155 |
| 2011 | 2 | 16 | 19 | 37 |
| **Total** | 71 | 288 | 316 | 675 |

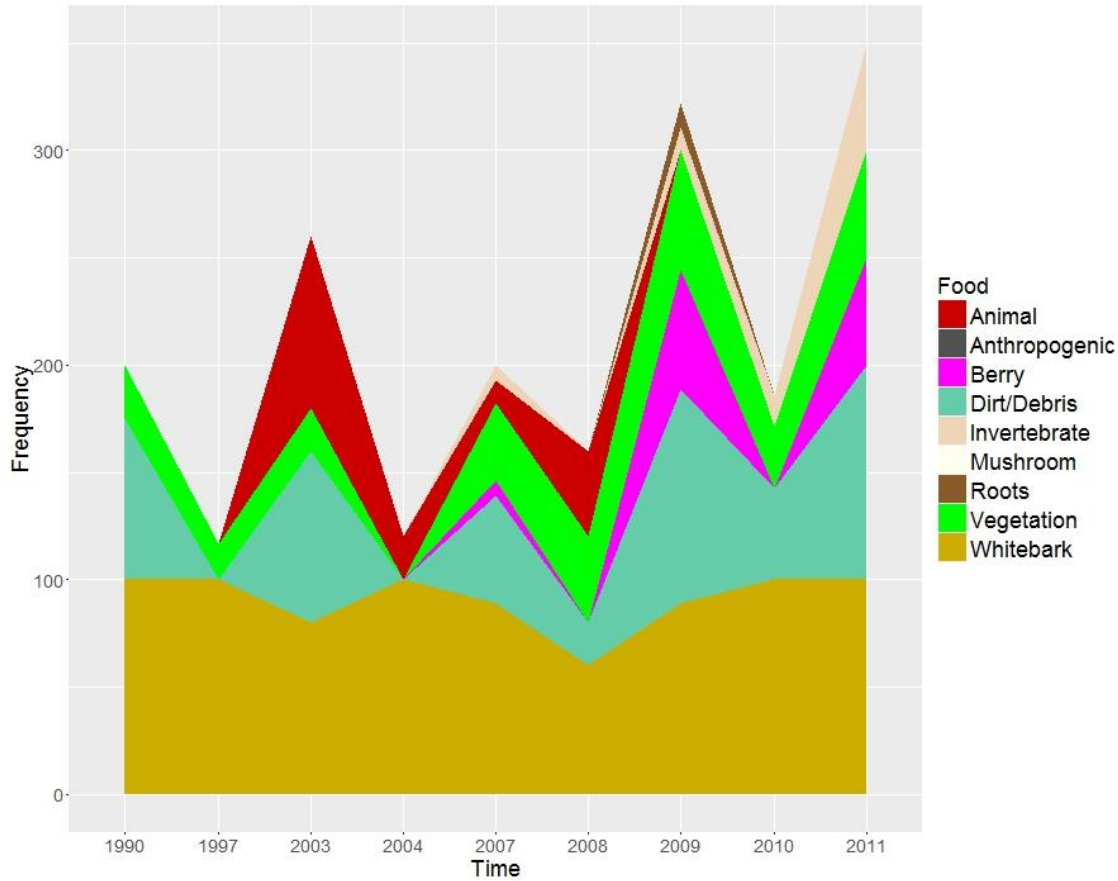


Figure 8. Frequency of diet items consumed during Spring of each year by grizzly bears of the Cooke City Basin, Montana, 1990-2011. The years 1991 and 1996 are absent on this figure because no scats were found during spring.

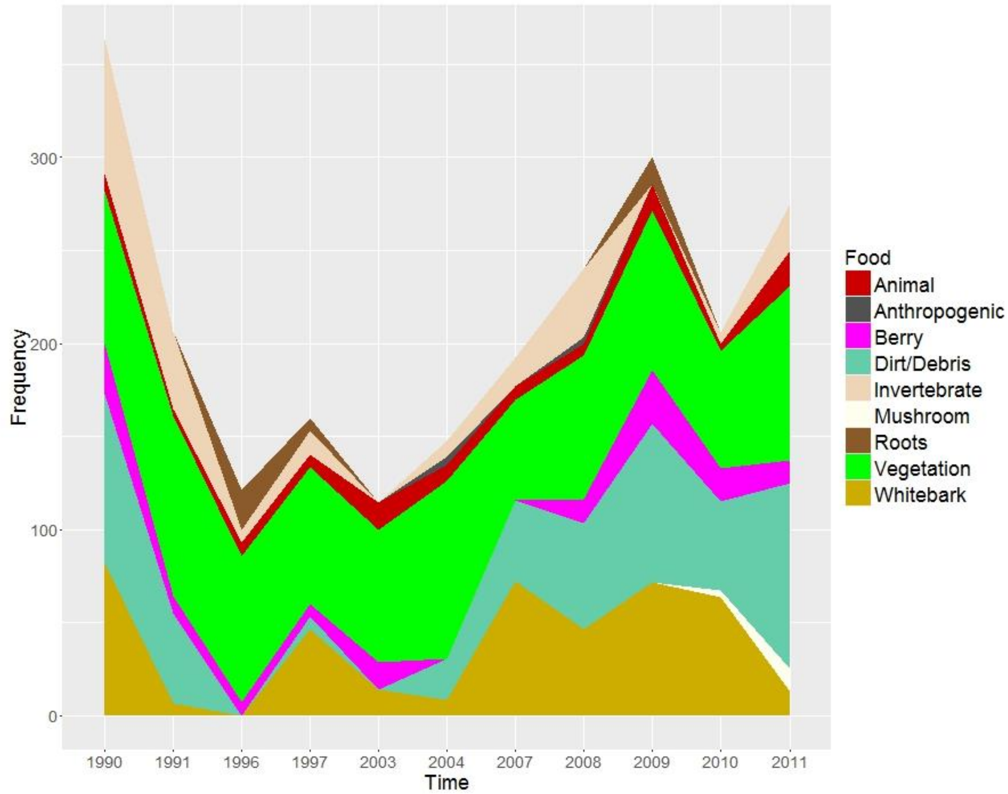


Figure 9. Frequency of diet items consumed during Summer of each year by grizzly bears on the Cooke City Basin, Montana, 1990-2011.

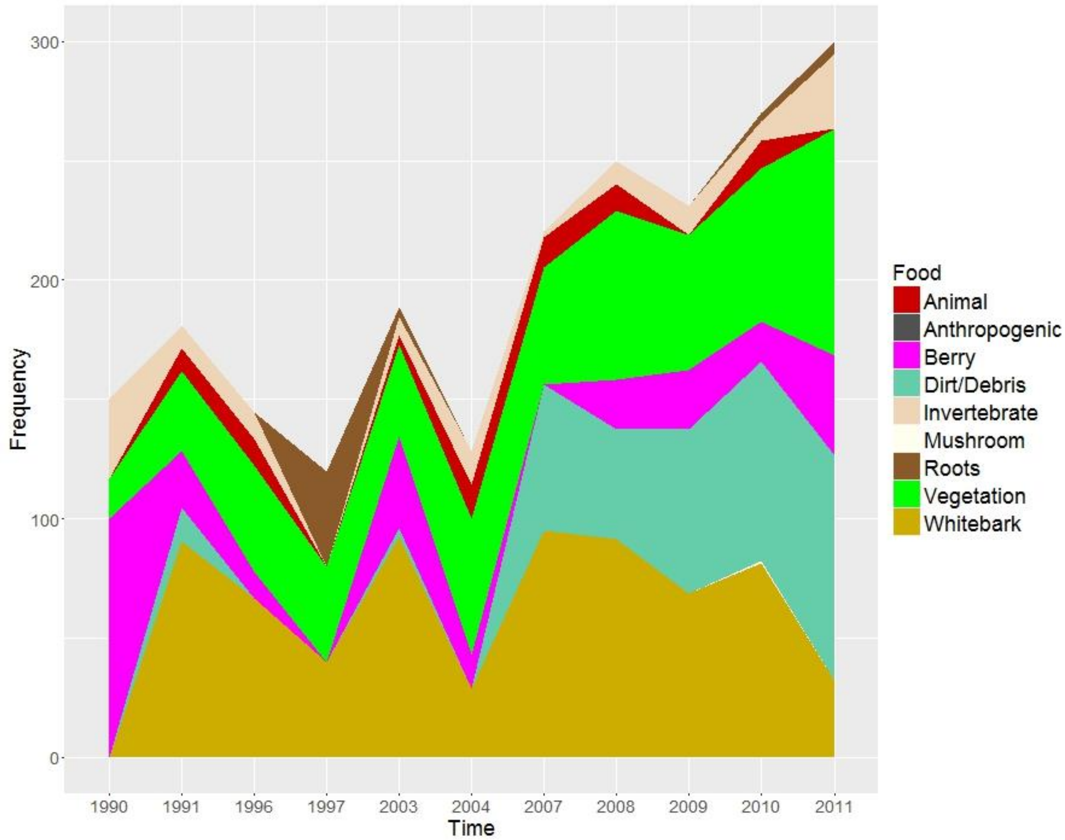


Figure 10. Frequency of diet items consumed during Fall of each year by grizzly bears on the Cooke City Basin, Montana, 1990-2011.

When percent of fecal volume was considered, the most predominant food in all scats was whitebark seeds (58% of the corrected total volume), followed by vegetation (24%), dirt/debris (6%), berries (5%), animal (3%), invertebrate (2%), and roots (1%). Mushrooms and anthropogenic food sources summed less than 1% of scats volume. Whitebark seeds were the dominant food source during spring and fall, composing 83% and 69% of the corrected total volume, respectively. During summer, whitebark seeds and vegetation each composed 40% of the total corrected volume. Higher consumption of food from animal sources was observed during spring and summer of 2003, fall of 2004, fall of 2007, spring of 2008, and summer of 2011 (Figures 11-13).

The mean corrected fecal volume of whitebark seeds found in scats collected in years when no major human activities were happening (baseline) was 48%. During years of mine reclamation, the fecal volume of whitebark seeds was 47%, while in years of highway reconstruction, the mean corrected fecal volume of whitebark seeds found in scats was 72%. The corrected fecal volume of whitebark seeds in all scats was together was 53.8%. There was no difference (p-value>0.05) between whitebark fecal volume found in baseline years (mean = 0.48) versus years when reclamation activities occurred (mean = 0.46). However, when whitebark seed fecal volume found in scats collected in baseline years was compared with that found in reconstruction years (mean = 0.72), a significant difference was found (p-value<0.05). The corrected fecal volume of vegetation in scats was also different during highway reconstruction years (p-value<0.05). The average fecal volume of vegetation in scats was similar (p-value>0.05) for baseline years and reclamation years (29% and 35%, respectively). When the same comparison was made considering baseline and reconstruction years, the average fecal volume of vegetation was shown to be lower (p-value<0.05) in reconstruction years (15%) than in baseline years (29%). Figure 14 illustrates the differences in distribution of those fecal volumes. The probability of scats containing whitebark seed was 36% (C.I. = 24%, 45%) higher during reconstruction years when it was compared with baseline years.

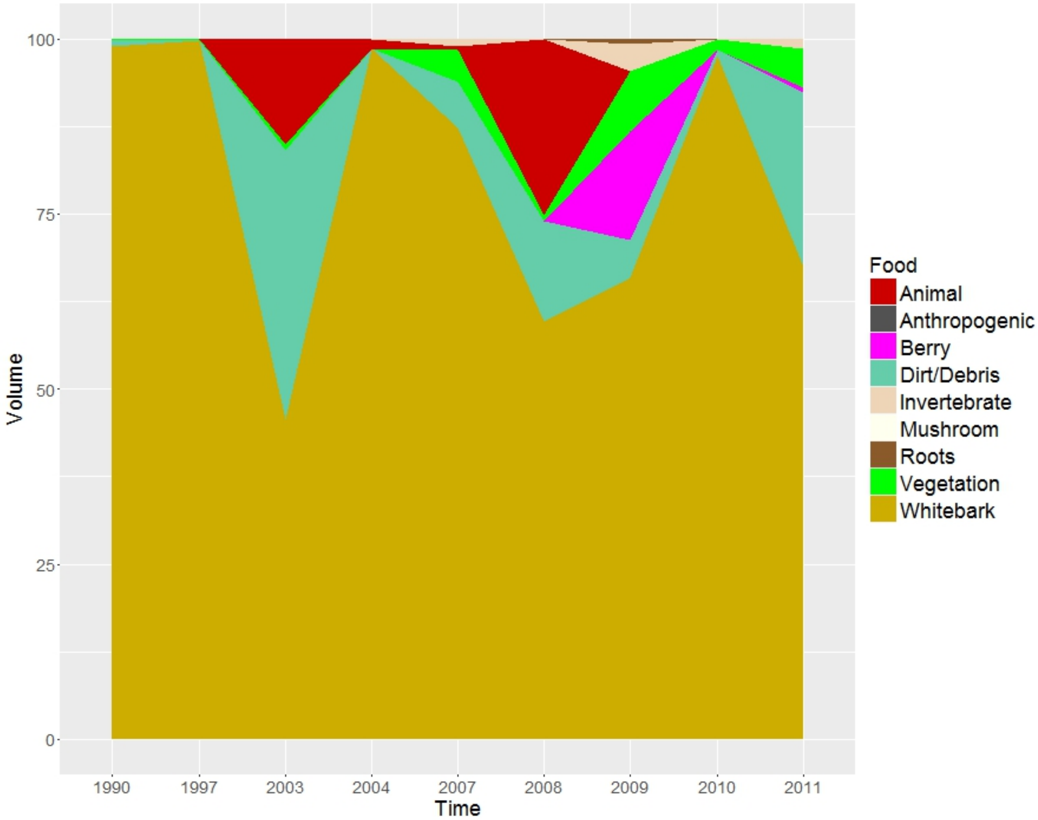


Figure 11. Corrected volume of food categories in grizzly bear scats found during Spring in the Cooke City Basin, Montana, 1990-2011. Among seasons the volume of whitebark seed was the highest during spring. The years 1991 and 1996 are absent on this figure because no scats were found during spring.

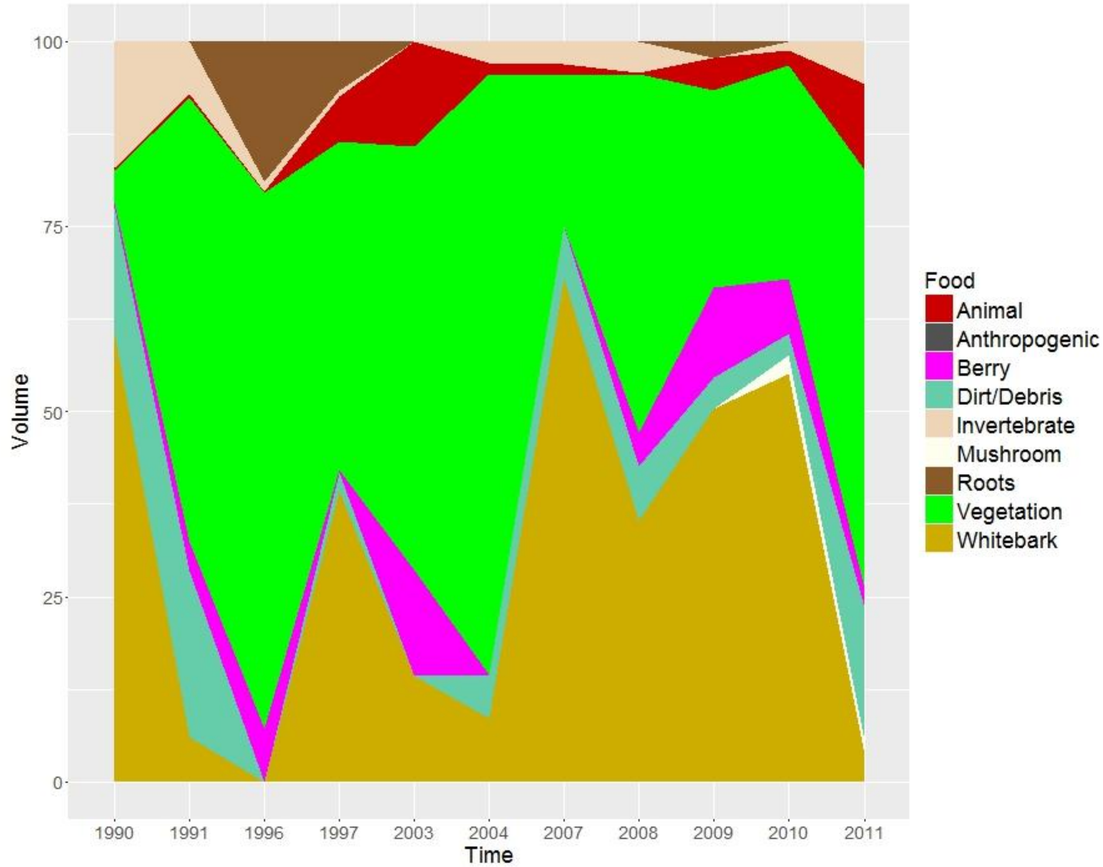


Figure 12. Corrected volume of food categories in grizzly bear scats found during Summer in the Cooke City Basin, Montana, 1990-2011.

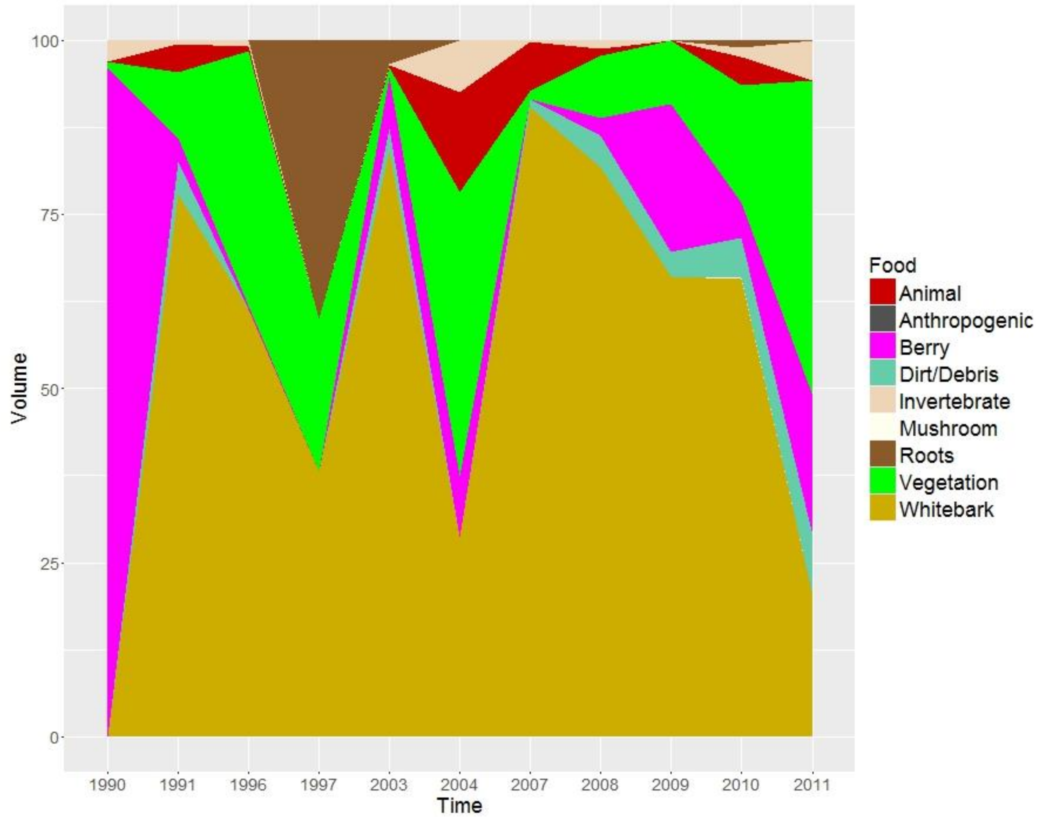


Figure 13. Corrected volume of food categories in grizzly bear scats found during Fall in the Cooke City Basin, Montana, 1990-2011.

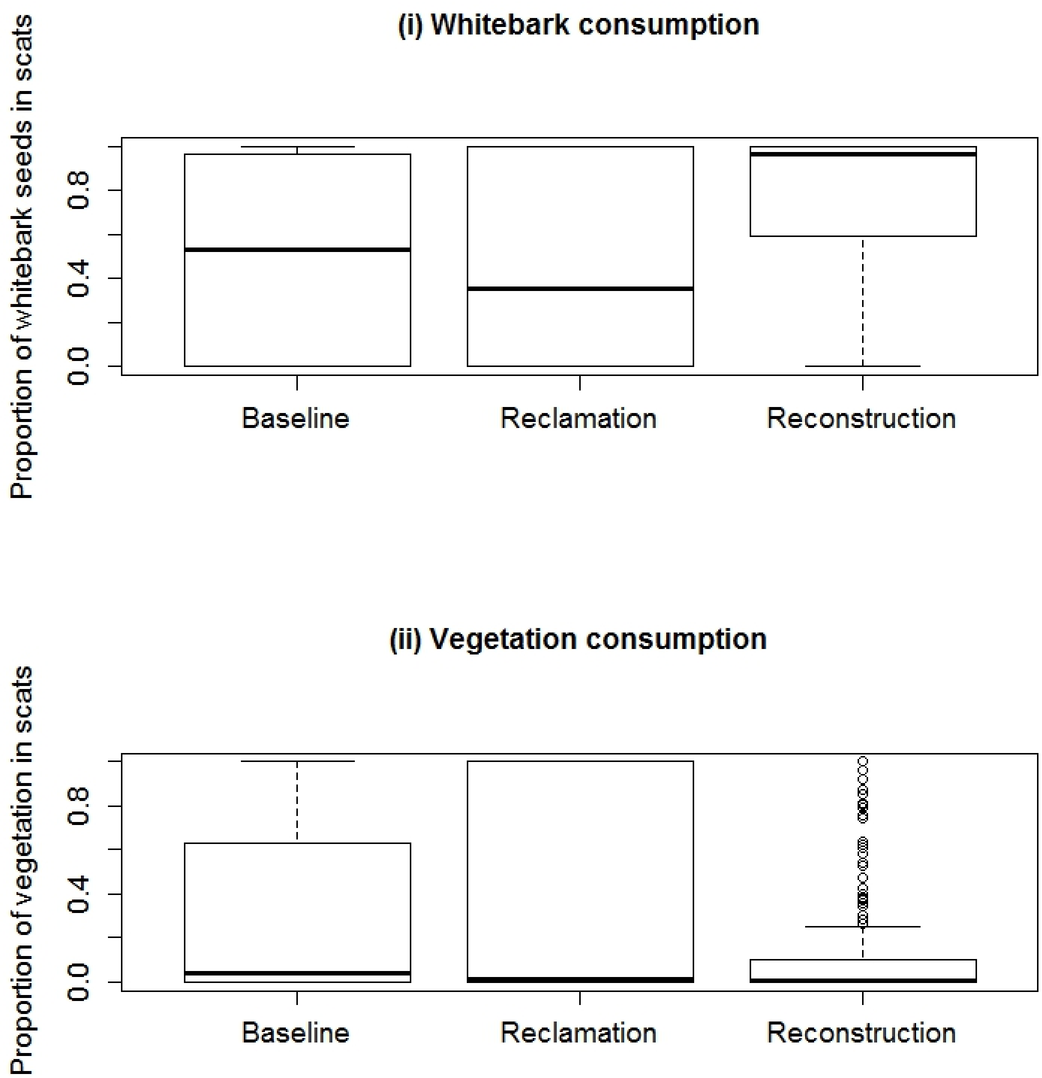


Figure 14. Boxplot of the corrected proportion of whitebark seeds (i) and vegetation (ii) individualized by periods of no major human activities (baseline), mine reclamation and highway reconstruction for grizzly bear scats collected in the Cook City Basin, Montana, 1990-2011.

## Camera-Snare Stations

Results from camera-snare stations indicated that at least twenty-one individual grizzly bears were using the Basin during 2007–2011. Eight (38%) where identified as male through DNA analysis and five out of these eight were identified as adult bears by pictures taken by automatic-triggered cameras placed in each station. No reliable visual record was obtained for the other three males from which DNA was found. Thirteen bears (62%) were identified as females by DNA analysis; three of which were observed with cubs. DNA analysis also indicated that a total of 78 different visits to sites where cameras were set occurred during the study, 61 by females and 17 by males. The drainages with the highest number of female visits were Fisher Creek and Miller Creek, while Miller Creek and Republic Creek had the highest number of male visits. The minimum number of individual grizzly bears using the Basin varied from 4 in 2007 to 12 in 2009 (Figure 15). The years when the highest number of individual females (seven females) were observed were 2008 and 2009, while the year with the highest number of males (five males) was 2009. Cooke City Face and Woody Creek drainages contained the only two hair-snare stations that are located within 1km of the highway 212. Three individual grizzly bears were identified in these stations during highway reconstruction, an adult female and a female with cubs from which we have DNA and visual records, and a female identified only by DNA.

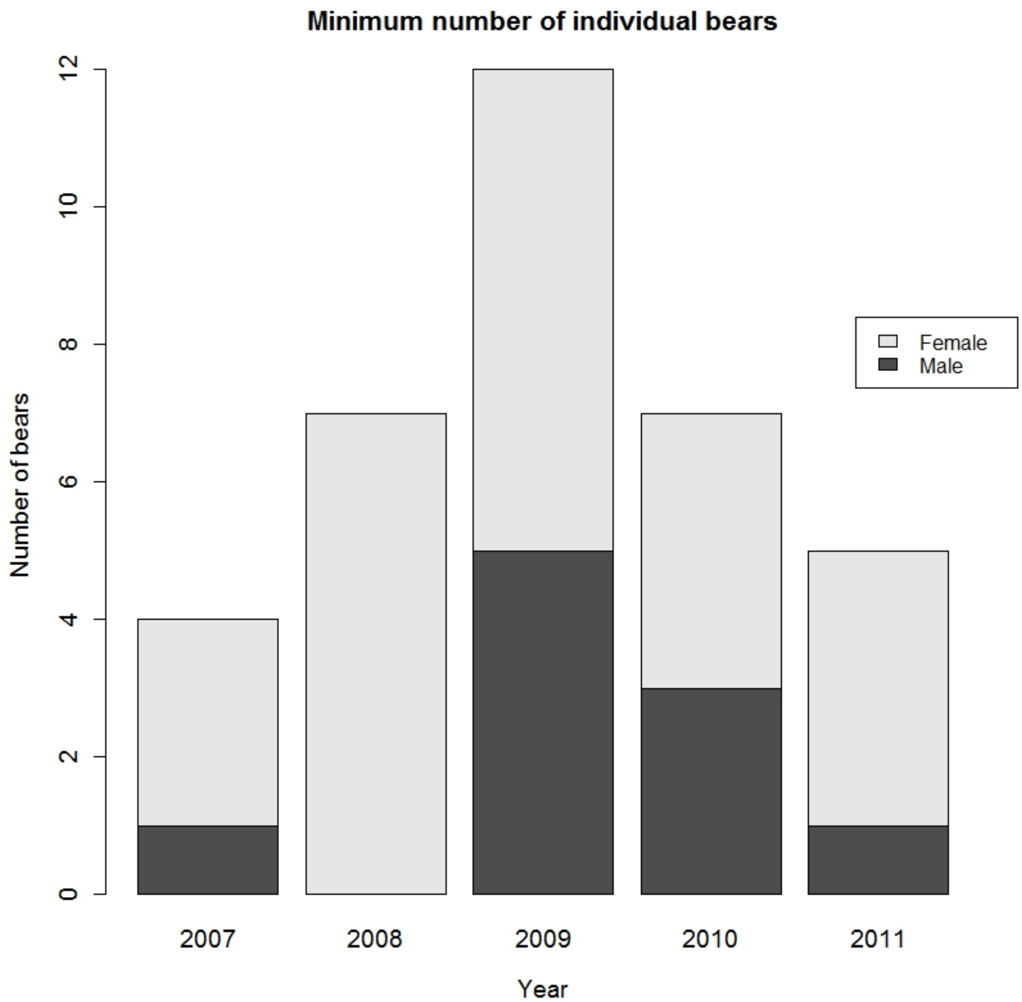


Figure 15: Bar plot of the minimum number of individual grizzly bears over the years in the Cooke City Basin, Montana, 2007 to 2011.

## Traffic

The average number of hours counting vehicles per month was 48, with the minimum number of 24 hours and maximum number of 109 hours. Vehicles were counted for a total of 1,367 hours from 2003 to 2011.The estimated mean vehicle density for the highway 212 (primary road) considering all years was 1.61 vehicles per minute, about 18.7 times greater than the estimated vehicle density of secondary roads (0.09

vehicles per minute). During the first year of mine reclamation activities (2003), the estimated traffic of secondary roads was equal to 0.16 vehicles per minute and about 26% of this traffic was associated with mine reclamation. During the second year of mine reclamation (2004), the estimated traffic density on secondary roads was 0.06 vehicles per minute, with 15% of this density associated with reclamation activities. Less than 2% of the traffic on the primary road was associated with mine reclamation during 2003 and 2004. The average vehicle density in the primary road when it was being reconstructed (in 2007, 2008, and 2009) was equals to 1.68 vehicles per minute, from which about 6.9% were associated with highway reconstruction activities.

# DISCUSSION

Over the past 15 years, the Cooke City Basin has undergone two large scale environmental changes, mine reclamation and highway reconstruction. Despite its high human use levels, the Basin provides good quality foraging for grizzly bears, because of its extensive whitebark pine forest (Mattson and Reinhart 1994, Yonge 2001). Historically, this convergence of circumstances often resulted in bear/human conflicts.

Results from the habitat selection model indicate that grizzly bear habitat selection in the Cooke City Basin is associated with topographic and vegetation characteristics (e.g., elevation, hillshade, cover type), food availability (e.g., season, whitebark cone production), and road density. We observed an avoidance response from bears towards the surroundings of the mine reclamation epicenters in years when mine reclamation was occurring. Also, in contrast to expectations, grizzly bears selected for areas within 4 km of the highway during reconstruction.

Whitebark seeds were shown to be a major component of grizzly bear diet year-round in the Cooke City Basin. Results from scat analysis along with those from RSF (selection for mid/high elevations and higher grizzly bear use during years of good whitebark cone production and months after August) demonstrated the importance of whitebark pine seeds as a food source for grizzly bears in the Basin. Whitebark pine seeds appeared in 66% of grizzly bear scats collected throughout the study. This is four times higher than the average of whitebark seeds found in scats of GYE grizzly bears, which is 15.4% (Gunther et al. 2014). One of the explanations for this high use of whitebark seeds in the Basin is that seeds are the most abundant high-caloric food item present in the Basin and surrounding areas (Gunther et al. 2014). Also, cone producing trees have been less affected by mountain pine beetles (*Dendroctonus ponderosae* Hopk.) in the Basin than in other areas of the GYE (Tyers et al. 2016).

Results from the RSF showed that grizzly bears equally used more areas with “Whitebark” and “Other Conifers” as cover types than those of “Open” and “Disturbed”. This is likely the result of whitebark seed availability. More than 90% of the seed consumed by grizzly bears are obtained through red squirrels (Mattson and Reinhart 1997). Red squirrels collect whitebark pine seeds as part of their diet, however, cone production varies annually (Haroldson and Podruzny 2011), making whitebark pine seeds a highly variable food source. Consequently, red squirrels are more abundant in areas that contain a combination of other conifers and whitebark pine trees (Podruzny et al. 1999, McKinney and Fiedler 2010). Those areas are likely to be selected by grizzly bears as well (Mattson and Reinhart 1997). The avoidance associated with open and disturbed areas, is likely explained by a lack of foraging opportunities on whitebark seeds but also by the cover afforded by forested areas. In an environment with high road density, avoiding humans while accessing whitebark pine middens was best accomplished bears by utilizing forest cover (McLellan 1990, Yonge 2001).

The association between grizzly bears and whitebark pine seeds might also explain grizzly bear habitat use at different elevations. Habitat use in the Basin was lowest for elevation below 2,500 m. These low-elevation areas provide little foraging opportunities on whitebark seeds. A survey conducted in the same transects used in this study for sign data collection showed that seven out of the 178 middens were found in low-elevation areas (bellow 2,500 m, unpublished data). Moreover, Mattson and Reinhart (1997) showed that the probability that a midden was excavated by a grizzly bear was drastically reduced in areas within 500 m of roads and 5 km of town sites. Thus, in the Basin, bears are likely to obtain whitebark seeds in higher elevation areas (>2,500 m) that are away from the highway and Cooke City.

Vegetation is a major diet component for grizzly bears in the Cooke City Basin, especially during summer when overwintered whitebark cones are scarce and cones of the year are not yet available (Mattson et al. 1991). Animal consumption was higher during spring, possibly due to an increased availability of carcasses caused by winterkill (Mattson et al. 1991). All peaks in animal consumption in the Basin (spring of 2003, and 2008; summer of 2003 and 2011; and fall of 2004) were always associated with periods of low whitebark cone production in the GYE (considering cone production of the previous year for spring and summer and the current year for fall ; Haroldson and Podruzny 2011). This result supports the idea that grizzly bears exhibit a degree of flexibility in adjusting their diet in the absence of whitebark pine seeds (Schwartz et al. 2014).

Grizzly bears avoided areas within 2 km of mine reclamation epicenters. The literature documents grizzly bear displacement from areas of high human use (Harding and Nagy 1980, Archibald et al. 1987), and also no displacement (McLellan and Shackleton 1989). The response of grizzly bears towards human activities is influenced by the following factors: i) availability of high-quality food near the disturbance source; ii) availability of high quality food away from the disturbance source; iii) intensity, frequency, and time of the day when the disturbance occurs; iv) intraspecific competition; and v) individual habituation to disturbance (McLellan 1990). In the Cooke City Basin, avoidance from areas within 2 km of reclamation epicenters may be explained primarily by factors ii) and iii). Although the 1 and 2 km buffers from reclamation epicenters included areas of high grizzly bear use (likely related to high quality food sources, figure A4 and A5 of the appendix), there were also areas with high use away (but within range) from the disturbance sources. Thus, it is possible that foraging away from the disturbance source was more profitable (less energy expend in vigilant behavior and flight or fight reactions; White et al. 1999). However, in a population at carrying capacity, it is also possible that submissive cohorts would be displaced back to disturbed areas by dominant males (McLellan and Shackleton 1988, McLellan 1990). The 2-km avoidance observed in this study may be a result of summed effects of disturbance from mine reclamation and intraspecific competition, one effect displacing dominant bears and the other relegating subordinate bears to a more hazardous foraging area.

Grizzly bears selected for areas within 4 km of highway 212 during reconstruction. Available human food and trash can attract grizzly bears (Gunther et al. 2004). In this study, however, construction guidelines included proper food storage and trash disposal. As a result, the volume of human related food in analyzed scats was negligible, so attraction associated with human food sources is not a likely explanation. Nonetheless, the frequency of whitebark seeds in scats collected during reconstruction years was about 21% higher than in baseline years. Mattson and Reinhart (1994) showed that high frequency of seeds in scats is positively associated with whitebark cone production. Our model contains a variable that quantifies the annual whitebark cone production in the GYE, but local cone production may differ from the ecosystem-wide estimation. Thus, higher local cone production may have induced higher grizzly bear use during years of highway reconstruction. The attraction to whitebark seeds probably countered the avoidance caused by highway reconstruction. During highway reconstruction grizzly bear use was higher even for areas near the highway that are characterized by lower whitebark pine seeds availability. Only female grizzly bears (adults with and without cubs) were identified using areas within 1 km of the highway during road reconstruction activities, while males and females were identified using the remainder of the Basin. Thus, the observed high grizzly bear use of areas within 1 km of the highway during reconstruction years may result from an attempt by females to reduce habitat overlap with adult males (Mattson et al. 1987, Wielgus and Bunnell 1994).

The traffic density on Highway 212 was about 18.7 times higher than in secondary roads. Nevertheless, grizzly bears neither avoided nor selected areas with high primary road density located below 2,500 m of elevation, but they avoided tertiary roads, widespread above 2.500 m, that have lower traffic than secondary roads. The lack of avoidance associated with the secondary roads may be explained by the fact that the majority of these roads are located in forested areas of mid/high elevation and south-west facing slopes, so the disturbance caused by these roads could have been countered by the attraction to forage opportunities in whitebark seeds in these areas.

Results from the summary of bear sign on transects indicated high variation in sign density among years (Figure 4). Some of this variation is explained by environmental factors used as fixed effects in our models, but some is left unexplained and modeled by random effects (Figure 7). The estimates of random effects indicated that 2010, for example, was a year of high grizzly bear use that is not explained by the fixed effects in the model (Figure 7). Even though our training procedures were standardized to reduce heterogeneity in grizzly bear sign detection between different crews, we acknowledge the fact that the high variation in sign density between years may be an effect of different detection rates. Another possible reason for the unexplained variability in grizzly bear use is environmental factors that were not considered in the models. For example, unmeasured local production of whitebark pine cones could have influenced the higher use in 2010. The GYE wide whitebark cone production used in our model indicated a low cone production of 5.25 cones per tree in 2010 (Haroldson and Podruzny 2011), while the proportion of whitebark seeds in scats is relatively high during this year (Figures 11,12, and 13), which could have attracted bears to the Basin.

Results from the habitat selection model were obtained under the assumptions of homogenous detection of grizzly bear signs for different seasons and vegetation cover types, and correct identification of the period when scats were produced. Even though scats are the signs from which detection is less affected by environmental conditions (Posillico et al. 2004), we understand that non-constant detection rates and errors in identifying the age of the scats may have affected the estimation of coefficients in our habitat selection model, e.g., hillshade, vegetation cover, and the season when scats were produced. Thus, results from these variables should be interpreted with caution in both habitat selection and food habits analysis.

Data from hair snares and cameras confirmed the presence of at least 21 grizzlies over a 5-year period, including large males, females with cubs, and sub-adults. This may suggest that the Basin is not a refuge for a few subordinate bears taking additional risks near humans to avoid intraspecific competition. It also reinforces the idea that the Cooke City Basin provides important grizzly bear habitat despite the static level of human activity and the periods of intense construction activity. These results also indicate that the sign data used in the RSF presented in this study were likely produced by both dominant and submissive cohorts. If a habitat characteristic is avoided by one cohort and selected by the other, the model may show no avoidance or selection at the population level. Thus, since we do not have information on how individuals from each cohort select habitat, caution should be used while interpreting the results of our RSF.

The minimum number of grizzly bears in the Basin varied from 4 in 2007 to 12 grizzly bears in 2009. This variation in density may be associated with two factors: i) the different methods of DNA collection used before and after 2009 - chances of collecting individual DNA were probably augmented with the inclusion of the barbed wire perimeter in the hair-snare station; ii) variation in home-range overlap between individual bears (Mcloughlin et al. 2000).

# CONCLUSION

As the GYE grizzly bear population reaches carrying capacity, grizzly bear use of areas like the Cooke City Basin is likely to increase. These environments contain important foraging opportunities, as well as high levels of human activity. Understanding how bears and humans can coexist in such a landscape is a continuing management priority.

Our study indicated that in the Cooke City Basin, grizzly bears selected for south-west, mid elevation, forested areas, where whitebark pine seeds are abundant. Grizzly bear use of the Basin was higher during months after August and during good cone production years. Among the two major human activities that occurred in the Basin, only mine reclamation took place in areas with this convergence of favorable conditions for grizzly bears. We detected an avoidance response of grizzly bears in areas within 2 km of mine active reclamation epicenters. No avoidance was observed in areas of highway reconstruction, probably because it occurred in an area of lower grizzly bear use. In fact, grizzly bears selected for areas within 4 km of the highway during reconstruction, likely because of high whitebark cone availability in the Basin during these years, which probably attracted bears to the area. Thus, under the specific set of conditions presented in this study (e.g., similar food sources, elevation, topography, vegetative cover) managers can expect similar habitat loss for construction activities that occur in high grizzly bear use areas, and less impact in areas of low grizzly bear use.

We found ample evidence of grizzly bear activity in the Cooke City Basin among all years sampled, in spite of comparatively high human use levels and the fact that the

53% of the Basin is within 500 m of motorized routes. Grizzly bear avoidance of open areas in the Basin may suggest that vegetation cover plays a major role in grizzly bear habitat selection in areas with high human use (Yonge 2001). This emphasizes the need for managers to retain cover along roadways, especially near secondary and tertiary road systems.

The Cooke City Basin was consistently a foraging area for grizzly bears during the 2-decade sampling period. Grizzly bears continued to use the Basin despite two major construction events in the later study years- reclamation of the historic New World District and reconstruction of Highway 212. The two major Federal projects that occurred in the Basin were carefully regulated. This included restricting work times to daylight hours and vehicles to specific roads and sites. Presumably, bears adjusted foraging times and travel routes to these construction schedules and locations. Therefore, we suggest that the restrictions governing the highway road work and mine reclamation, and the information about ecological factors that affected grizzly bear habitat use, be applied to managing areas with high human activity levels and major construction projects in grizzly bear habitat.

# REFERENCES


Akaike, H. 1973. Information theory and an extension of the maximum likelihood principle. 2nd International Symposium on Information Theory 2:267–281.

Archibald, W. R., R. Ellis, and A. N. Hamilton. 1987. Responses of grizzly bears to logging truck traffic in the Kimsquit River Valley, British Columbia. International Conference on Bear Research and Management 7:251–257.

Arnold, T. W. 2010. Uninformative parameters and model selection using Akaike's information criterion. Journal of Wildlife Management 74:1175–1178.

Bates, D., M. Maechler, B. Bolker, and S. Walker. 2015. Fitting linear mixed-effects models using lme4. Journal of Statistical Software 67:1–48.

Benn, B., and S. Herrero. 2002. Grizzly bear mortality and human access in Banff and Yoho National Parks. Ursus 13:213–221.

Berland, A., T. Nelson, G. Stenhouse, K. Graham, and J. Cranston. 2008. The impact of landscape disturbance on grizzly bear habitat use in the Foothills Model Forest, Alberta, Canada. Forest Ecology and Management 256:1875–1883.

Bjornlie, D. D., D. J. Thompson, M. a. Haroldson, C. C. Schwartz, K. a. Gunther, S. L. Cain, D. B. Tyers, K. L. Frey, and B. C. Aber. 2014. Methods to estimate distribution and range extent of grizzly bears in the Greater Yellowstone Ecosystem. Wildlife Society Bulletin 38:182–187.

Boulanger, J., M. Proctor, S. Himmer, G. Stenhouse, J. Cranston, J. Boulanger, M. Proctor, S. Himmer, and G. Stenhouse. 2006. An empirical test of DNA mark – recapture sampling strategies for grizzly bears. Ursus 17:149–158.

Boyce, M. S., and L. L. Mcdonald. 1999. Relating populations to habitat using resource selection functions. TREE 14:268–272.

Boyce, M. S., P. R. Vernier, S. E. Nielsen, and F. K. A. Schmiegelow. 2002. Evaluating resource selection functions. Ecological Modelling 157:281–300.

Ciarniello, L. M., M. S. Boyce, D. C. Heard, and D. R. Seip. 2007*a*. Components of Grizzly Bear Habitat Selection: Density, Habitats, Roads, and Mortality Risk. Journal of Wildlife Management 71:1446–1457.

Ciarniello, L. M., M. S. Boyce, D. R. Seip, and D. C. Heard. 2007*b*. Grizzly bear habitat selection is scale dependent. Ecological applications : a publication of the Ecological Society of America 17:1424–1440.

Craighead, F. C. J., and J. J. Craighead. 1972. Grizzly bear prehibernation and denning activities as determined by radiotracking. Wildlife Monographs 32.

Craighead, J. J., J. S. Summer, and J. A. Mitchell. 1995. The grizzly bears of Yellowstone. Their ecology in the Yellowstone ecosystem 1959-1992. Island Press, Washington, D. C.

Cristescu, B., G. B. Stenhouse, and M. S. Boyce. 2015. Grizzly bear diet shifting on reclaimed mines. Global Ecology and Conservation 4:207–220. Elsevier B.V.

Cristescu, B., G. B. Stenhouse, and M. S. Boyce. 2016. Large Omnivore Movements in Response to Surface Mining and Mine Reclamation. Scientific Reports 6:19177. Nature Publishing Group.

Elith, J., S. J. Phillips, T. Hastie, M. Dudík, Y. E. Chee, and C. J. Yates. 2011. A statistical explanation of MaxEnt for ecologists. Diversity and Distributions 17:43–57.

ESRI. 2011. ArcGIS Desktop. Environmental Systems Research Institute Release 10.

Fernández, G. J., J. C. Corley, A. F. Capurro, and J. Fernandez. 1997. Identification of cougar and jaguar feces through bile acid chromatography. The Journal of Wildlife Management 61:506–510.

Fitzpatrick, M. C., N. J. Gotelli, and M. E. Aaron. 2013. MaxEnt versus MaxLike : empirical comparisons with ant species distributions. Ecosphere 4:55.

Follmann, E. H., and J. L. Hechtel. 1990. Bears and Pipeline Construction in Alaska in Alaska Bears and Pipeline Construction. Arctic 43:103–109.

Frąckowiak, W., J. Theuerkauf, B. Pirga, and R. Gula. 2014. Brown bear habitat selection in relation to anthropogenic structures in the Bieszczady Mountains, Poland. Biologia 69:926–930.

French, S. P., M. G. French, and R. R. Knight. 1994. Grizzly Bear Use of Army Cutworm Moths in the Yellowstone Ecosystem. Bears : Their Biology and Management 9:389–399.

Frid, A., and L. Dill. 2002. Human-caused disturbance stimuli as a form of predation risk. Ecology and Society 6:11–26.

Gibeau, M. L., A. P. Clevenger, S. Herrero, and J. Wierzchowski. 2002. Grizzly bear response to human development and activities in the Bow River Watershed, Alberta, Canada. Biological Conservation 103:227–236.

Guilday, J. E. 1968. Grizzly bears from Eastern North America. The American Midland Naturalist 79:247–250.

Gunther, K. A., M. A. Haroldson, K. Frey, S. L. Cain, J. Copeland, and C. C. Schwartz. 2004. Grizzly bear–human conflicts in the Greater Yellowstone ecosystem, 1992–2000. International Association for Bear Research and Management 15:10–22.

Gunther, K. a., R. R. Shoemaker, K. L. Frey, M. a. Haroldson, S. L. Cain, F. T. van Manen, and J. K. Fortin. 2014. Dietary breadth of grizzly bears in the Greater Yellowstone Ecosystem. Ursus 25:60–72.

Haaverstad, M. 2011. The relationships between forest structure and red squirrel midden density in Mud Lake study area, Cooke City Basin, Montana. Norwegian University of Life Sciences, Norway.

Harding, L., and J. A. Nagy. 1980. Responses of grizzly bears to hydrocarbon exploration on Richards Island, Northwest Territories, Canada. Bears: Their Biology and Management 4:277–280.

Haroldson, M. A., F. T. Van Manen, and D. D. Bjornlie. 2014. Estimating number of females with cubs. Pages 11–20 *in* F. T. Van Manen, M. A. Haroldson, and S. C. Soileau, editors. Yellowstone grizzly bear investigations: annual report of the Interagency Grizzly Bear Study Team, 2014. US Geological Survey, Bozeman, Montana, USA.

Haroldson, M. A., and S. Podruzny. 2011. Whitebark cone production. Interagency Grizzly Bear Study Team. US Geological Survey, Bozeman, Montana, USA.

Hewitt, D. G., and C. T. Robbins. 1996. Estimating grizzly bear food habits from fecal analysis. Wildlife Society Bulletin 24:547–550.

Hobbs, N. T. 2003. Challenges and opportunities in integrating ecological knowledge across scales. Forest Ecology and Management 181:223–238.

Johnson, C. J., M. S. Boyce, C. Charles, and M. A. Haroldson. 2004. Modeling survival : applications of the Andersen - Gill Model to Yellostone grizzly bears. Journal of Wildlife Management 68:966–978.

Johnson, C. J., S. E. Nielsen, E. H. Merrill, L. Trent, M. S. Boyce, E. Science, M. Program, N. British, and P. George. 2006. Resource selection functions based on use – availability data: theoretical motivation and evaluation methods. The Wildlife Society 70:347–357.

Johnson, D. H. . 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecological Society of America 61:65–71.

Jones, J. 2001. Habitat selection studies in avian ecology: A critical review. The Auk 118:557–562.

Karterud, H. N. 2009. Site characteristics and habitat features of bear bed sites in the Cooke City Basin, Montana. Norwegian University of Life Science.

Kendall, K. C., J. B. Stetz, J. Boulanger, A. C. Macleod, D. Paetkau, and G. C. White. 2009. Demography and Genetic Structure of a Recovering Grizzly Bear Population. Journal of Wildlife Management 73:3–17.

Knight, A. R. R., B. M. Blanchard, and L. L. Eberhardt. 1988. Mortality patterns and population sinks for Yellowstone grizzly bears, 1973-85. Wildlife Society Bulletin 16:121–125.

Li, B., H. F. Lingsma, E. W. Steyerberg, and E. Lesaffre. 2011. Logistic random effects regression models: a comparison of statistical packages for binary and ordinal outcomes. BMC medical research methodology 11:77.

Lüdecke, D. 2016. sjPlot: Data Visualization for Statistics in Social Science. R package .

Mace, R. D., J. S. Waller, T. L. Manley, L. J. Lyon, D. Mace, L. J. Lyont, and H. Zuuringt. 1996. Relationships among grizzly bears, roads and habitat in the Swan Mountains, Montana. Journal of Applied Ecology 33:1395–1404.

MacKenzie, D. I., J. D. Nichols, G. B. Lachman, S. Droege, J. Andrew Royle, and C. A. Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83:2248–2255.

Major, M., M. K. . Johnson, W. . S. Davis, and T. F. . Kellogg. 1980. Identifying scats by recovery of bile acids. Wildlife Society Zoology and Microbiology 44:290–293.

van Manen, F. T., M. A. Haroldson, D. D. Bjornlie, M. R. Ebinger, D. J. Thompson, C. M. Costello, and G. C. White. 2016. Density dependence, whitebark pine, and vital rates of grizzly bears. The Journal of Wildlife Management 80:300–3013.

Manly, B., L. Thomas, and D. McDonald. 1993. Resource selection by Animals - Statistical design and analysis for field studies. Health promotion journal of Australia : official journal of Australian Association of Health Promotion Professionals. Volume 25. Chapman & Hall, London-Glasgow-New York-Tokyo-Melbourne-Madras.

Mao, J. S., M. S. Boyce, D. W. Smith, F. J. Singer, D. J. Vales, J. M. Vore, and H. Evelyn. 2005. Habitat selection by elk before and after wolf reintroduction in Yellowstone National Park. Journal of Wildlife Management 64:1691–1707.

Martin, J., M. Basille, B. Van Moorter, J. Kindberg, D. Allaine, and J. E. Swenson. 2010. Coping with human disturbance: spatial and temporal tactics of the brown bear (Ursus arctos). Canadian Journal of Zoology-Revue Canadienne De Zoologie 88:875–883.

Mattson, D. J., B. M. Blanchard, and R. R. Knight. 1991. Food habits of Yellowstone grizzly bears, 1977–1987. Canadian Journal of Zoology 69:1619–1629.

Mattson, D. J., B. M. Blanchard, and R. R. Knight. 1992. Yellowstone grizzly bear mortality, human habituation, and whitebark pine seed crops. Journal of Wildlife Management 56:432–442.

Mattson, D. J., and D. G. Despain. 1985. Grizzly bear habitat component mapping handbook for the Yellowstone Ecosystem. U.S. Department of Agriculture, U.S. Forest Service, Yellowstone National Park.

Mattson, D. J., R. R. Knight, and B. B. M. 1987. The effects of developments and primary roads on grizzly bear habitat use in Yellowstone National Park. Bears: Their Biology and Management 7:259–273.

Mattson, D. J., and M. M. Reid. 1991. Conservation of the Yellowstone grizzly bear. Conservation Biology 5:364–372.

Mattson, D. J., and D. P. Reinhart. 1994. Bear use of whitebark pine seeds in North America. Pages 212–220 *in*. Proceedings - International workshop on subalpine stone pines and their environment: the status of our knowledge. US Forest Service General Technical Report INT-GTR-309.

Mattson, D. J., and D. P. Reinhart. 1996. Indicators of red squirrel (tamiasciurus hudsonicus) abundance in whitebark pine zone. The Great Basin Naturalist 56:272–275.

Mattson, D. J., and D. P. Reinhart. 1997. Excavation of red squirrel middens by grizzly bears in the whitebark zone. Journal of Applied Ecology 34:926–940.

McKinney, S. T., and C. E. Fiedler. 2010. Tree squirrel habitat selection and predispersal seed predation in a declining subalpine conifer. Oecologia 162:697–707.

McLellan, B. N., and D. M. Shackleton. 1988. grizzly bears and resource-extraction industries: effects of roads on behaviour, habitat use and demography. Journal of Applied Ecology 13:451–460.

McLellan, B. N., and D. M. Shackleton. 1989. Grizzly bears and resource-extraction industries: habitat displacement in response to seismic exploration, timber harvesting and road maintenance. Journal of applied ecology 26:371–380.

McLellan, B. N. 1990. Relationships between human industrial activity and grizzly bears. Bears: Their Biology and Management 8:57–64.

Mcloughlin, P. D., S. H. Ferguson, and Ë. O. I. S. Messier. 2000. Intraspecific variation in home range overlap with habitat quality : a comparison among brown bear populations. Evolutionary Ecology 14:39–60.

Mealy, S. P. 1975. The natural food habits of grizzly bears in Yellowstone National Park, 1973-74. Montana State University.

Morrison, M. L., B. G. Marcot, and R. W. Mannan. 2006. Wildlife habitat relationships: Concepts and application. Third edit. Island Press, Washington, D. C.

Olivier, F., and S. J. Wotherspoon. 2005. GIS-based application of resource selection functions to the prediction of snow petrel distribution and abundance in East Antarctica: Comparing models at multiple scales. Ecological Modelling 189:105–129.

Olson, T. L., K. G. Gilbert, and R. C. Squibb. 1997. The effects of increasing human activity on brown bear use of analaskan river. Biological Conservation 82:95–99.

Peterson, R. L. 1965. A well preserved grizzly bear skull recovered from a late glacial deposit near Lake Simcoe, Ontario. Nature 208:1233–1234.

Picton, H. D. 1991. The use of thin layer chromatography for the species identification of bear scats. Final report to National Park Service, INT-88351-COA.

Podruzny, S. R., D. P. Reinhart, and D. J. Mattson. 1999. Fire, red squirrels, whitebark pine, and Yellowstone grizzly bears. Ursus 11:131–138.

Posillico, M., A. Meriggi, E. Pagnin, S. Lovari, and L. Russo. 2004. A habitat model for brown bear conservation and land use planning in the central Apennines. Biological Conservation 118:141–150.

R Core Team. 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Reinhart, D. P., and D. J. Mattson. 1992. Grizzly bear and black bear habitat use in the Cooke city, Montana, area 1990-1991.

Roever, C. L., M. S. Boyce, and G. B. Stenhouse. 2008. Grizzly bears and forestry. Forest Ecology and Management 256:1262–1269.

Schwartz, C. C., J. K. Fortin, J. E. Teisberg, M. a. Haroldson, C. Servheen, C. T. Robbins, and F. T. Van Manen. 2014. Body and diet composition of sympatric black and grizzly bears in the Greater Yellowstone Ecosystem. The Journal of Wildlife Management 78:68–78.

Schwartz, C. C., M. a Haroldson, and G. C. White. 2010. Hazards affecting grizzly bear survival in the Greater Yellowstone Ecosystem. Journal of Wildlife Management 74:654–667.

Schwartz, C. C., M. A. Haroldson, G. C. White, R. B. Harris, S. Cherry, K. A. Keating, D. Moody, and C. Servheen. 2006. Temporal, spatial, and environmental influences on the demographics of grizzly bears in the Greater Yellowstone Ecosystem. Wildlife Monographs 1–68.

Schwartz, C. C., S. D. Miller, and M. A. Haroldson. 2003. Grizzly Bear. Pages 556–586 *in* A. Feldhamer, G., C. Thompson, B., and A. Chapman, J., editors. Wild Mammals of North America: Biology, Management, and Conservation. Second Ed. Johns Hookins University Press, Baltmmore. Marveland. USA.

Storer, T. I., and L. P. Tevis. 1996. California grizzly. Univ of California Press.

Tyers, D. B., M. B. Tyers, J. L. Rossi, and L. R. Irby. 2016. Condition assessments of mark whitebark pine trees in the northern portion of the greater yellowstone ecosystem 2008-2012. Unpublished paper.

U.S. Dept. of Agriculture Forest Service. 1987. Gallatin National Forest : Forest plan. Bozeman, Montana, USA.

U.S. Fish and Wildlife Service. 1993. Grizzly bear recovery plan. Missoula, Montana.

U.S. Fish and Wildlife Service. 2003. Final conservation strategy for the grizzly bear in the Greater Yellowstone Area. Missoula, Montana.

Ulvund, K. R. 2007. The distribution of black and grizzly bears in the Cooke City Basin in relation to a high quality food source. Norwegian University of Life Sciences.

Waits, L. P., and D. Paetkau. 2005. Nonivasive genetic sampling tools for wildlife biologists: A review of applications and recommendations for accurate data collection. The Wildlife Society.

Waller, J. S., and C. Servheen. 2005. Movements and habitat-use of grizzly bears along U.S. highway 2 in northeast Montana 1998-2001. University of Montana.

White, D., K. C. Kendall, and H. D. Picton. 1999. Potential energetic effects of mountain climbers on foraging grizzly bears. Wildlife Society Bulletin 27:146–151.

Wielgus, R. B., and F. L. Bunnell. 1994. Sexual segregation and female grizzly bear avoidance of males. Journal of Wildlife Management 58:405–413.

Yonge, S. R. 2001. The ecology of grizzly bears and black bears in the Cooke city, Montana area. Montana State University.

Zuur, A., E. N. Ieno, N. Walker, A. A. Saveliev, and G. M. Smith. 2009. Mixed Effects Models and Extensions in Ecology with R. Springer.

# APPENDIX A

MAPS

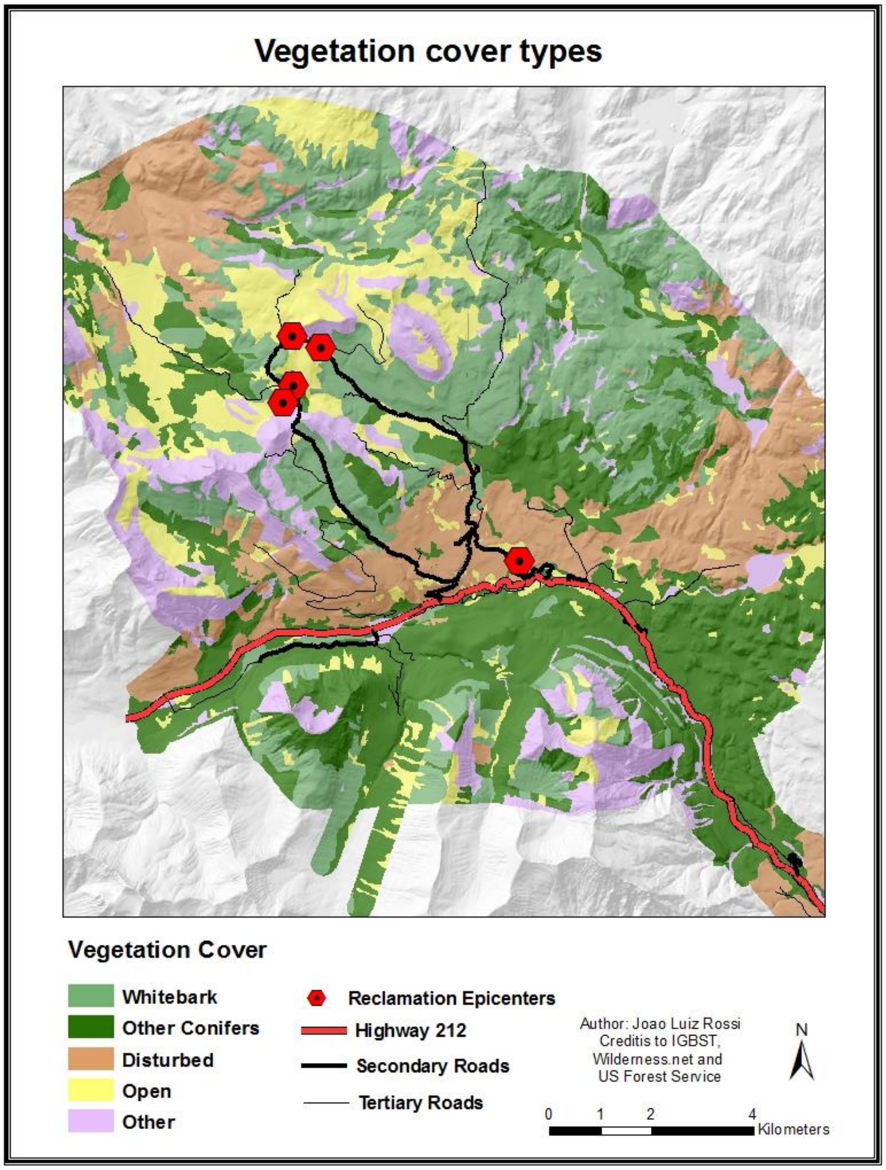


**Figure A1.** Vegetation cover map containing forested areas dominated by whitebark, forested areas dominated by other conifers, disturbed, open, and other cover areas. Complete definition of these vegetation cover categories can be found in Table 2.

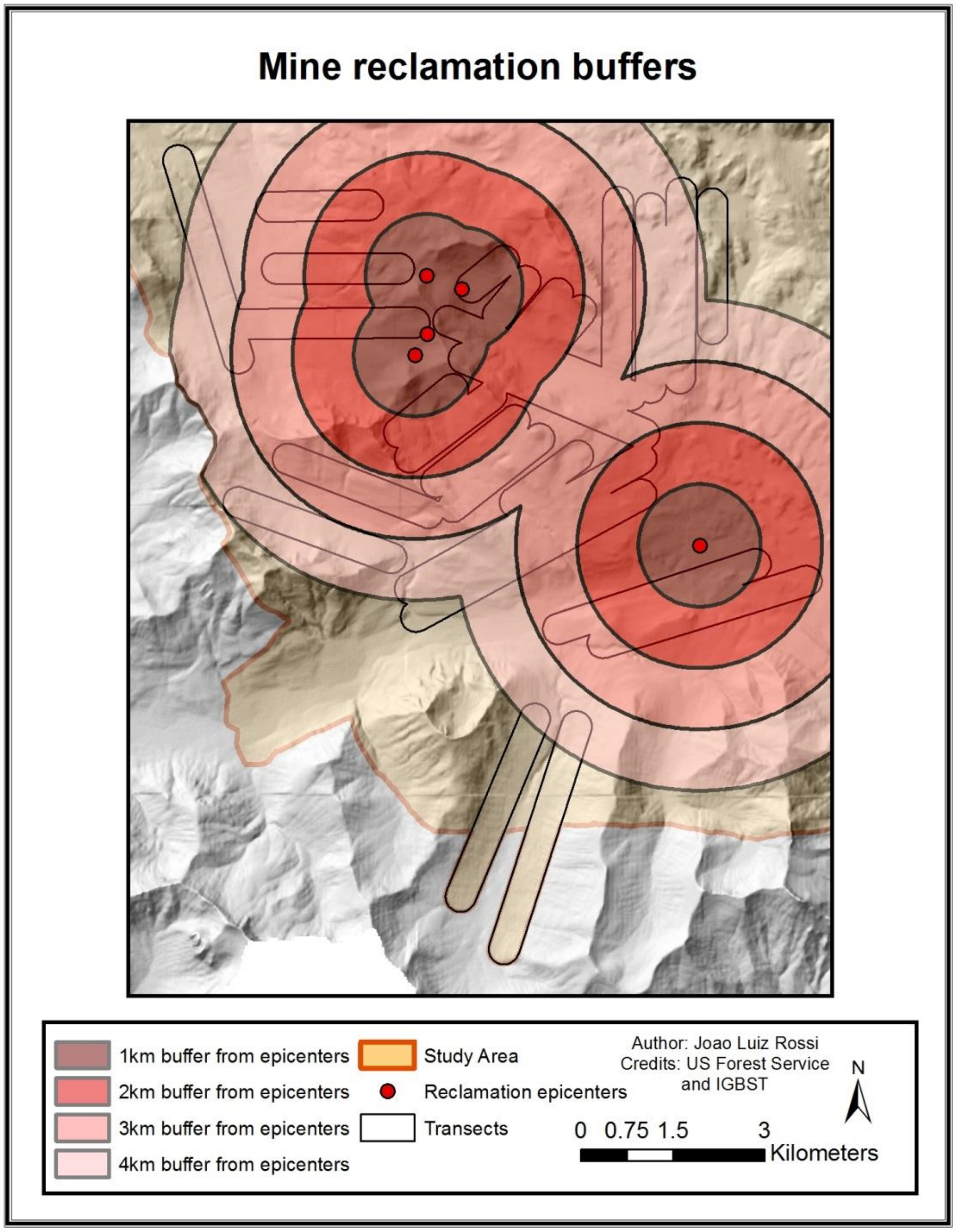


**Figure A2.** Buffers for the variables "**Reclamation within x kilometers**" obtained for 2003. These buffers were built around reclamation epicenters to allow us to study the impact of mine reclamation on grizzly bear habitat selection. The "2km buffer from epicenters" (see legend of the map), for example, contains all pixels that are between 1 and 2km from a reclamation epicenter.

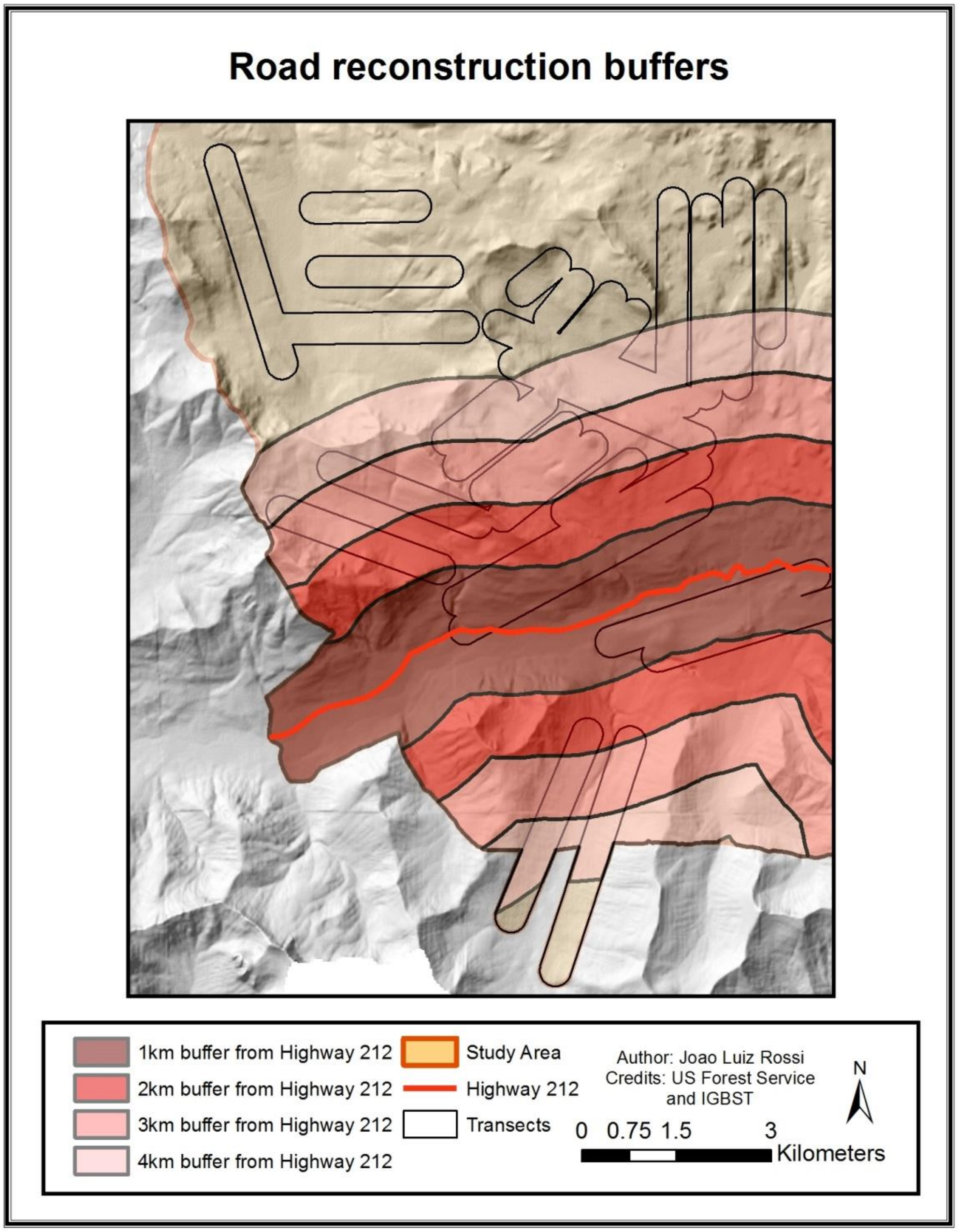


**Figure A3.** Buffers for the variables "**Reconstruction within x kilometers**". These buffers were built around Highway 212 for years when it was being reconstructed to allow us to study the impact of highway reconstruction grizzly bear habitat selection. The "2km buffer from Highway 212", for example, contains all pixels that are between 1 and 2km from the highway.

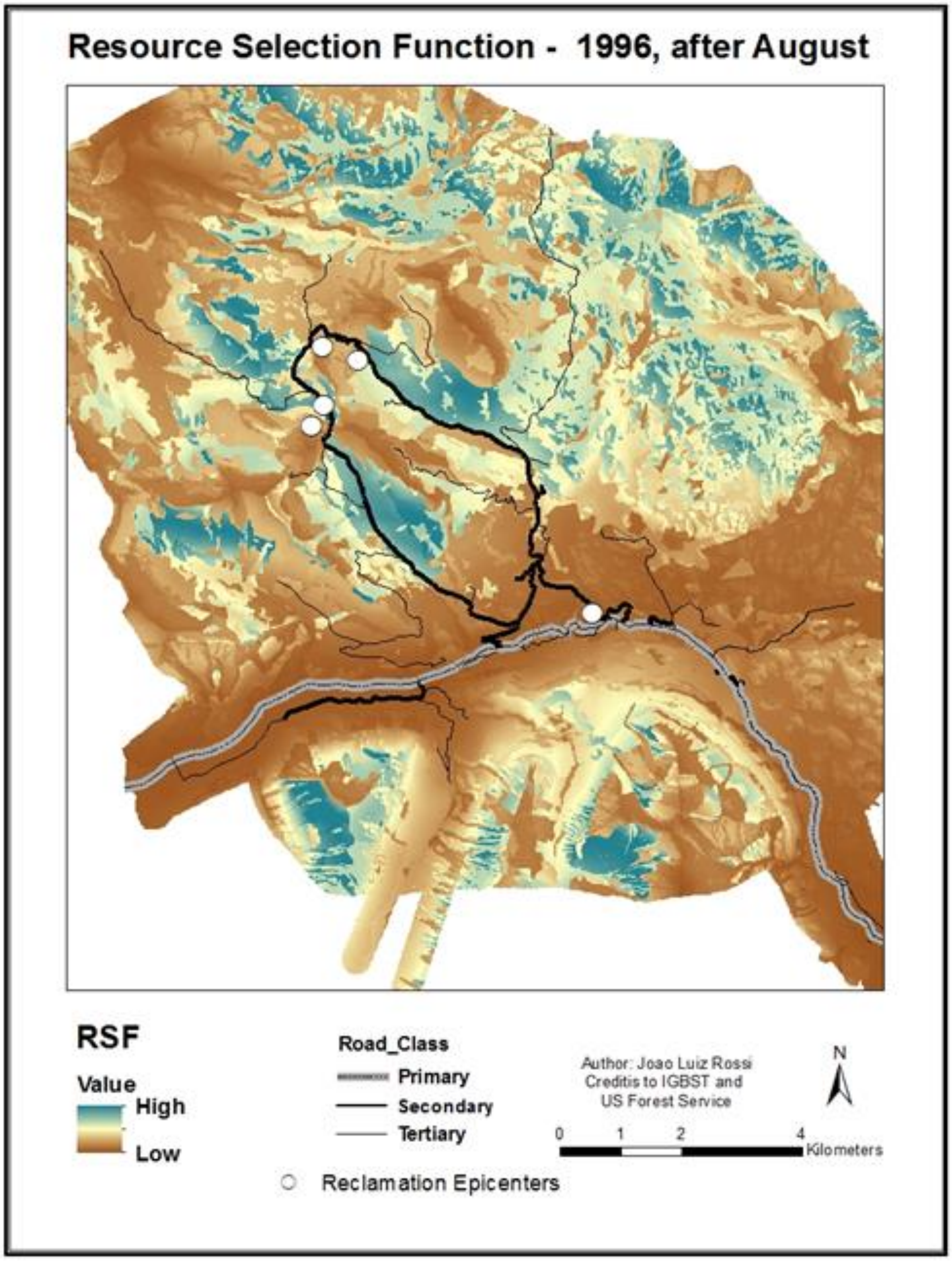


**Figure A4.** Map of estimated resource selection function (RSF) values for months after August in 1996, a period of good whitebark cone production when no major construction activities were occurring in the Basin. This map was obtained by the procedure "Raster Calculator" of the software ArcGIS and the use of the coefficients of the model M5. Higher RSF values (in blue) represent higher grizzly bear selection. Areas of high RSF values can be observed in the surroundings of the upper reclamation epicenter points while the use was low in areas surrounding the primary road (highway 212).

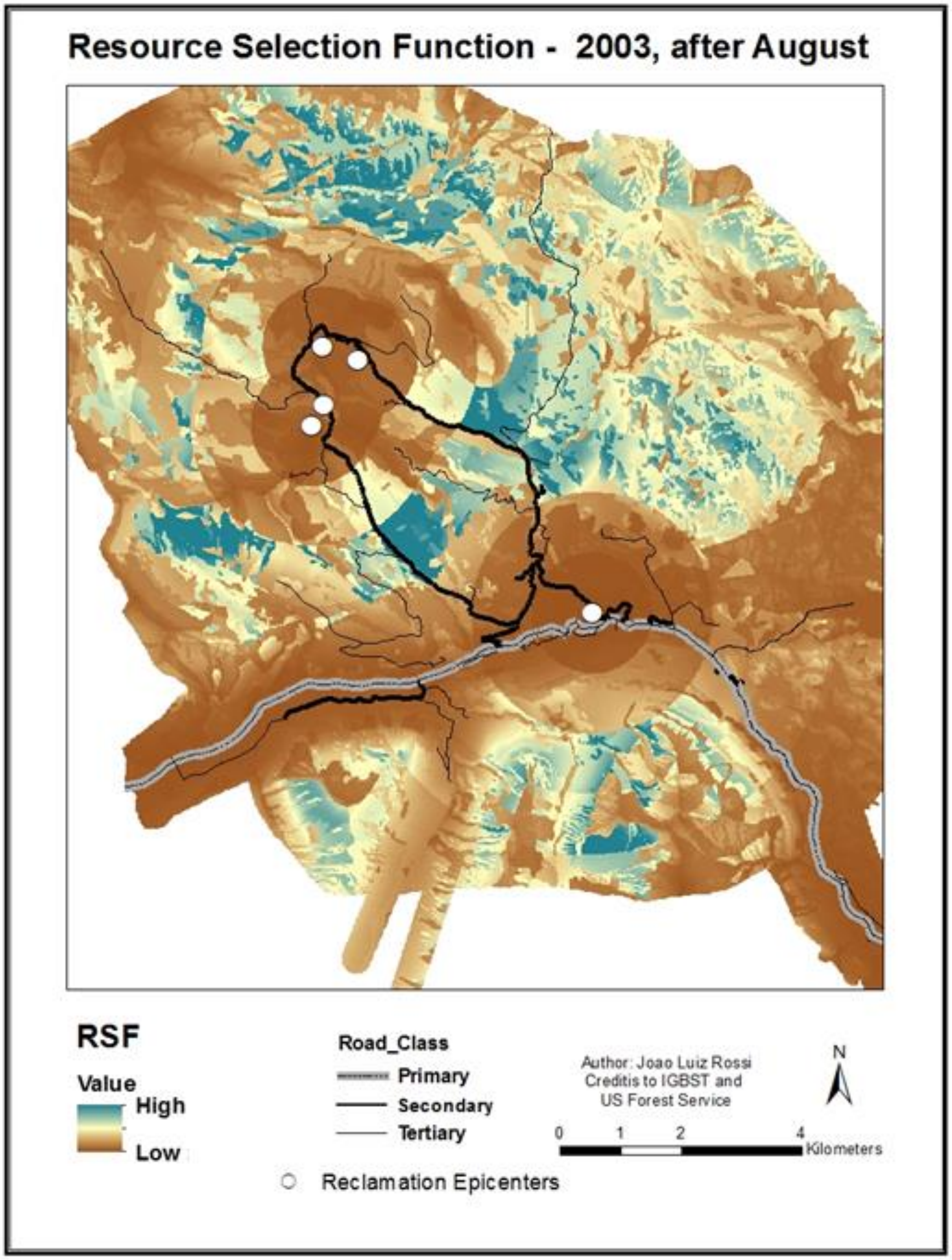


**Figure A5.** Map of estimated resource selection function (RSF) values for months after August in 2003, a period of good whitebark cone production during mine reclamation. This map was obtained by the procedure "Raster Calculator" of the software ArcGIS and the use of the coefficients of the model M3. Higher RSF values (in blue) represent higher grizzly bear selection. Avoidance was observed within 1 and 2km of the active reclamation epicenters.

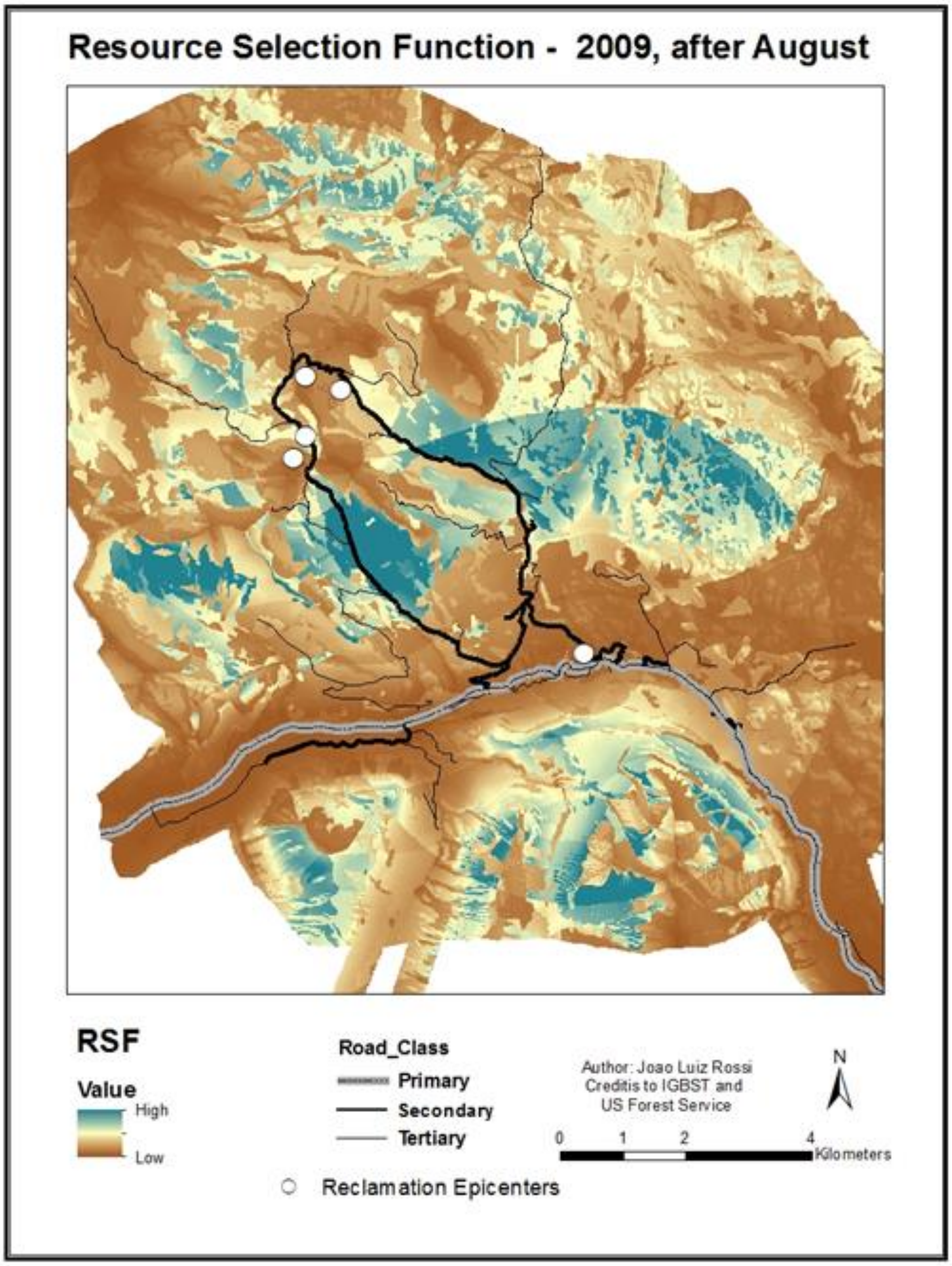


**Figure A6.** Map of estimated resource selection function (RSF) values for months after August in 2009, a period of good whitebark cone production during highway reconstruction. This map was obtained by the procedure “Raster Calculator” of the software ArcGIS and the use of the coefficients of the model M3. Higher RSF values (in blue) represent higher grizzly bear selection. The use of areas within 4km of the highway was higher when it was being reconstructed compared to years of no construction.