ECOLOGICAL EFFECTS OF MINE RECLAMATION ON GRIZZLY BEARS

B. Cristescu[1], M.Sc.
G.B. Stenhouse[2], M.Sc.
M. Symbaluk[3], M.Sc.
M.S. Boyce[1], Ph.D.

[1]Department of Biological Sciences, University of Alberta, Edmonton, AB T6G 2E9
[2]Foothills Research Institute, Hinton, AB T7V 1X6
[3]Teck Resources Limited, Cardinal River Coals, Hinton, AB T7V 1V5

ABSTRACT

The grizzly bear (*Ursus arctos*) is a threatened species in Alberta and although we have studied grizzly bear response to forest seral stage change, little is known about the response to coal mine reclamation by bears. We addressed basic ecological questions to describe landscape change effects on grizzly bears, focusing on Luscar and Gregg River reclaimed coal mines in west-central Alberta as case studies. We summarize bear use of mine mineral disturbance limits in relation to season, habitat, diet, and designated human access trails. Eight adult bears were monitored intensively during 2008-2010 using GPS radiocollars that allowed tracking of their movement and distribution on the landscape and facilitated collection of scats for diet analysis. Bears were present on reclaimed mines mostly during summer and fed primarily on vegetative matter. Although habitats were similar on the two mines under study, on Luscar mine bears had higher use of undisturbed forested areas and were closer to forest edge than on Gregg River mine. We attribute these differences primarily to higher presence of humans on Luscar mine, but bears responded differently to motorized and non-motorized trails. While reclaimed mines can provide habitat and forage for grizzly bears during summer, maintaining undisturbed forest patches and access management are necessary to ensure persistence of grizzly bears on reclaimed mining areas.

Key Words: Alberta, season, diet, edge, access management, mining

INTRODUCTION

One of the major goals of mine reclamation is provision of habitat for wildlife (Erickson, 1995). Throughout North America ungulates are often chosen as target species for assessing reclamation success (MacCallum, 2003). On predominantly open landscapes, characteristic of reclaimed mines, ungulates are readily visible and can be surveyed by direct observations, with surveys replicated among years (BWT, 2010). Because of their naturally lower population numbers and densities, and often secretive behaviour, carnivores are used less commonly as indicators of mining reclamation success. Surveys that do focus on carnivores typically rely on snow cover to record occurrence based on tracks, sometimes supplemented by opportunistic direct observations (BWT, 2010; HAB-TECH, 2012). Following an animal's path in the snow can provide information on behaviour but is effort intensive and restricted to winter, early spring and late fall. For bear species that spend most of winter denning, such data are not generally obtainable. Remote cameras are another tool useful for monitoring large mammals, having the advantage of not requiring snow cover. While such tools provide basic information on occurrence and may allow density estimation for species with uniquely identifiable individuals (Foster & Harmsen, 2012), they supply relatively little information on animal behaviour because of their stationary/localized nature. More informative data collection schemes are possible but involve careful designs requiring a large number of camera stations.

Recent advances in wildlife monitoring technology allow tracking of mammalian species day and night and across seasons (Cagnacci et al., 2010). GPS radiocollars can be programmed to acquire a GPS location at the rate desired by the investigator providing ample insights into animal occurrence on the landscape. These devices are particularly suited for monitoring wide ranging species that might be important from a reclamation standpoint but are otherwise difficult to monitor. The grizzly bear is such a species because of large home range sizes and ecological role in seed dispersal, soil aeration (Tardiff & Stanford, 1998), nitrogen exchange (Gende et al., 2002) and ungulate population limitation (Zager & Beecham, 2006). This species has experienced range contraction in North America because of human persecution and landscape conversion (Laliberte & Ripple, 2004). While grizzly bears still can be found in large numbers in British Columbia, in Alberta grizzly bears are at the eastern edge of the species' distribution. In 2010, the grizzly bear was designated as Threatened in Alberta in response to estimated low population numbers resulting from legal harvest and increased illegal hunting associated with habitat conversion enabling human access in previously undisturbed areas (AGBRP, 2008).

Many coal mining operations in Alberta occur in areas inhabited by grizzly bears, where the predominant land cover is boreal forest. Following closure of mining, reclamation results in habitat change, from forest to predominantly open landscapes resembling grasslands. Re-vegetated mined lands have low vegetative species richness compared to neighbouring undisturbed lands, because species sown as part of reclamation have typically been selected to improve wildlife forage, primarily for ungulates. Because grizzly bears have a mixed diet that includes herbaceous vegetation, reclaimed mines can provide foraging opportunities for bears. In addition, ungulate use of reclaimed mines also may attract bears to these areas.

To document ecological effects of reclamation on grizzly bears, we monitored grizzly bears for three years to assess if bears used reclaimed mines or avoided them, and whether use of mines was confined to certain seasons. If bears used mines, our goal was to identify the type of habitat where bears occurred, differentiating between reclaimed (disturbed) and original (undisturbed). Lastly, we were interested in qualitatively assessing bear diet on reclaimed mines and investigating the influence of human access on bear occurrence. The descriptive results of these assessments are presented in comparison for two reclaimed mines chosen as case studies.

METHODS

<u>Study area</u>

Data collection occurred on Luscar and Gregg River reclaimed open-pit coal mines located at the interface between the Eastern Slopes of the Rocky Mountains and Foothills of west-central Alberta. The study area extent was confined to the mineral disturbance limit (hereafter MDL) of each of the two mines (Fig. 1). These limits included actual disturbance (mined land primarily reclaimed to grassland; pit walls terraced to provide bighorn sheep [*Ovis canadensis*] escape terrain [(MacCallum & Geist, 1992)]; and limited early succession reforestation and undisturbed area, i.e. tree islands untouched during active mining). MDL areas are part of the larger mineral surface leases (hereafter MSLs). Luscar mine leased by Teck Coal had a total MDL area of 25.9 km^2, 7.7% of which included undisturbed original forest present in patches in a matrix dominated by grassland reclamation. Of the disturbed (unreclaimed) area, 16.8% continued to support active operations at a mine office, shop, processing plant and haul road. Gregg River mine leased by Sherritt Coal had a total MDL area of 15.8 km^2, 6.1% of which was comprised of undisturbed tree patches. Unlike Luscar mine, Gregg River mine was fully reclaimed and mining operations were closed. No active pit blasting occurred at either of the mines during the study.

Reclamation to grasslands at Luscar and Gregg Rive mines involved a mixture of plants dominated numerically by clovers (*Melilotus* sp., *Trifolium* sp.), alfalfa (*Medicago* sp.), milkvetch (*Astragalus* sp.), dandelion (*Taraxacum* sp.) and Graminoids. All these represent potential forage for wildlife. Ungulates including bighorn sheep, elk (*Cervus elaphus*) and mule deer (*Odocoileus hemionus*) used the MDL area of both mines year-round. In addition to grizzly bears, other large carnivore species in the area were black bear (*Ursus americanus*), wolf (*Canis lupus*) and cougar (*Puma concolor*). Recreational human access was restricted to motorized and non-motorized designated trails and no hunting occurred within the mine MSLs. ATV-ing and hunting were common recreational activities outside mine leases, with recreationists using designated trails that crossed MDL areas primarily in the summer and fall (Cristescu, unpublished remote camera data).

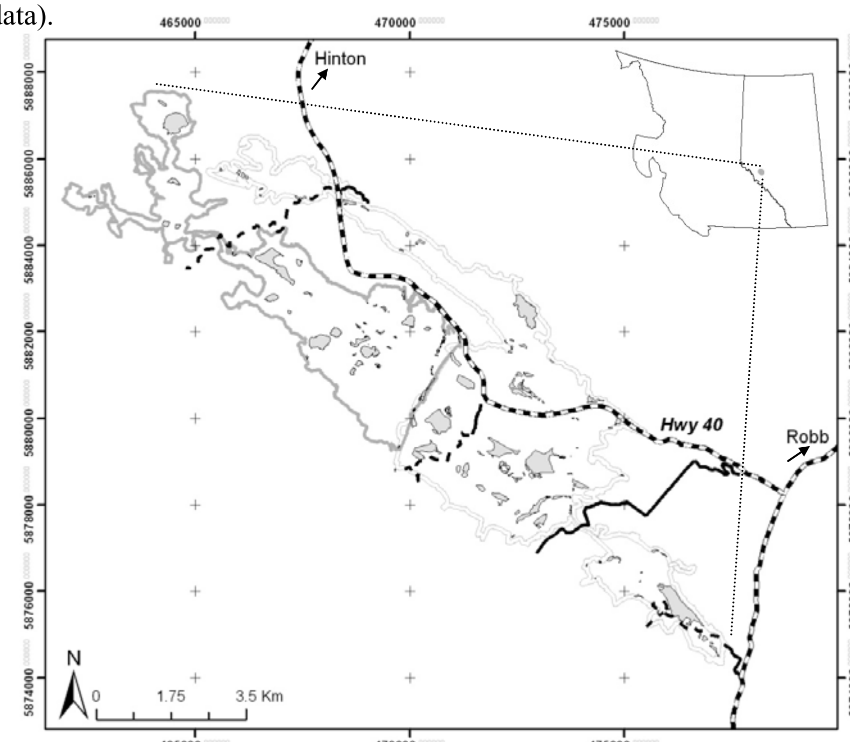

Figure 1. Study area extent in west-central Alberta showing MDLs for Luscar (double light gray line) and Gregg River (single dark gray line). Gray polygons are tree islands in a matrix of mined land. Solid black lines are motorized and dashed black lines non-motorized trails.

Monitoring

In 2008-2010 we attached Televilt Telus UHF (Followit, Sweden) GPS radiocollars to 12 adult grizzly bears captured using culvert traps and helicopter darting within and in the vicinity of MDLs. Two of these bears prematurely removed their collars within a month from capture and 2 other bears did not use the reclaimed area under study. The remaining 8 animals used MDL areas and represented our sample size for assessing bear response to mine reclamation. Collars were programmed to acquire a GPS location every hour during March 15-December 1, 24-h a day, when bears were mostly outside winter dens. GPS relocations acquired at bear capture sites and from winter dens were excluded from all calculations. Every 4-5 week period we approached each bear on the ground or from the air (within a safe distance, typically 0.5-2 km) and triggered its radiocollar to send data remotely via VHF to our radio receiver unit. This enabled us to select sites used by bears for field visitation to collect scat for diet analysis. Spatial analyses described below were carried out in ArcGIS 9.2 and 10.0, and diet analyses were carried out in the lab. An in-depth description of data collection protocols is available in Cristescu, 2012.

Space Use by Bears

In previous work we documented the proportion of grizzly bear home ranges overlapping Luscar and Gregg River MSLs (Cristescu et al., 2011). Herein we use the spatial distribution of all GPS collar relocations to describe seasonal occurrence of grizzly bears within MDLs, differentiating between three seasons relevant to bear feeding in the study region: spring ("hypophagia"; den emergence to June 14), summer ("early hyperphagia"; June 15 to August 7) and fall ("late hyperphagia"; August 8 to den entrance) (Nielsen et al., 2004). In addition, for each season we describe bear occurrence in undisturbed (forest) vs. disturbed (grassland; barren; early succession reforestation) areas within MDLs and compute the distance from each GPS relocation to the nearest edge. We define "edge" as the boundary area between the two above mentioned habitat categories.

Bear Diet

Diet analysis methods are described in detail in (Schwab et al., 2011). In brief, we collected grizzly bear scat whenever we came across it at GPS relocations visited on MDL areas. Scat samples were frozen to preserve them until further analyses in the lab. Following autoclaving a 30 mL sample was extracted from each scat and analyzed for diet contents under a dissecting microscope. Major items were classified as herbaceous vegetation, other plant material (root and berry), mammal (ungulate and small mammals) and insects (primarily ants). More detailed analyses involving biomass estimates for specific foods ingested by bears and a comparison with bear diet in un-mined areas are provided in (Cristescu, 2012).

Response of Bears to Human Access

We report the distance from each GPS radiocollar relocation to the nearest designated access trail crossing MDLs under study, differentiating between motorized and non-motorized trails. Separate calculations were carried out for each season because bears may respond differently to trails according to time of the year, in relation to seasonal variation in human access. Preliminary analyses of motion camera data show highest motorized use during summer, primarily from recreational ATV users, and high non-motorized access in the fall, mainly from hunters.

RESULTS

Space Use by Bears

Grizzly bears used Luscar and Gregg River MDL areas in all seasons. During the 2008-2010 monitoring period we obtained a total of 4,342 bear GPS radiocollar relocations within the study area extent (Table 1). Although the total number of bear relocations was relatively similar between the two mines, Luscar MDL had a 1.6 greater spatial extent compared to Gregg River MDL suggesting higher use of the latter by the bears monitored in this study.

Table 1. Summary of GPS radiocollar relocation data from adult grizzly bears monitored in 2008-2010 on reclaimed coal mine MDL areas in west-central Alberta, Canada.

	GPS relocations on Luscar mine disturbance area				**GPS relocations on Gregg River mine disturbance area**			
	Spring	Summer	Fall	Total	Spring	Summer	Fall	Total
Total	482	1,267	365	2,114	144	1,830	254	2,228

Seasonally, occurrence of bears on both MDL areas was highest in the summer (Fig. 2). The maximum number of bears occurring in any one season by MDL was documented for Luscar MDL (*n* = 7; summer), while the minimum occurred for Gregg River MDL (*n* = 4; fall). Half of all radiocollared bears (*n* = 4) were monitored for ≥2 years and all used Luscar MDL in multiple years during spring and summer. Correspondingly, two bears used Gregg River MDL in the spring and summer of multiple years. MDL areas were used in the fall of multiple years by a single bear. The only bear monitored for three consecutive years used both MDL areas in all years in the summer.

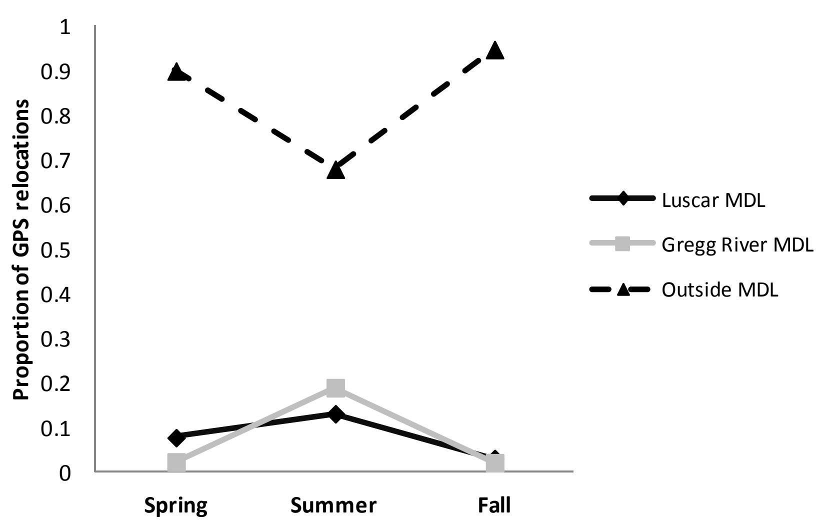

Figure 2. Proportion of GPS relocations recorded within MDLs and in undisturbed areas neighbouring mined lands. These hourly relocation data provide season-specific relative amounts of time monitored bears used mined and un-mined lands.

Irrespective of season, bears used undisturbed (treed) and disturbed (non-treed) areas within both MDL areas. With the exception of summer, use of treed areas occurred in higher proportion on Luscar MDL than on Gregg River MDL, although the two mines had similar treed to non-treed area ratios (Luscar MDL 0.08; Gregg River MDL 0.06) (Fig. 3). Bears on Luscar MDL used treed areas to the highest extent in the fall, a season when bears on Gregg River MDL used treed areas to the least extent.

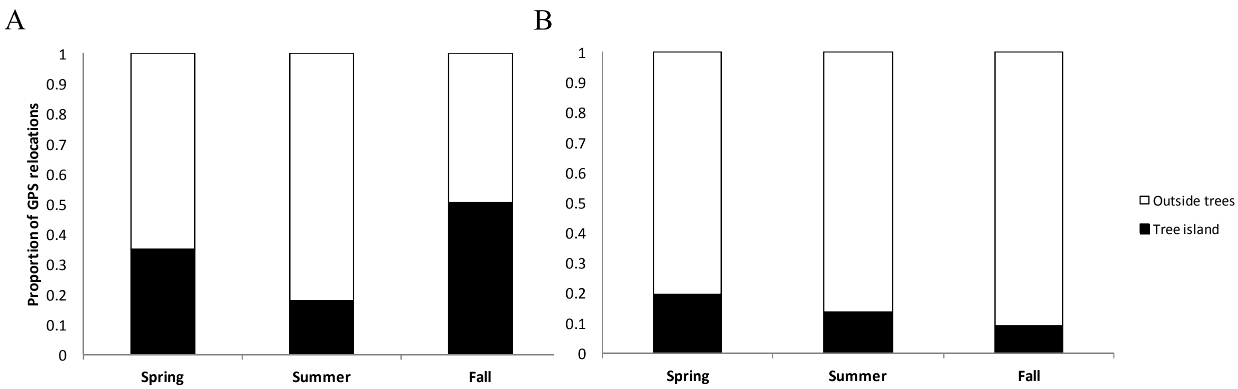

Figure 3. Proportion of GPS relocations recorded in undisturbed areas (tree islands) vs. open disturbed areas (reclaimed grassland; barren; early stage reforestation) within Luscar MDL (A) and Gregg River MDL (B).

On Luscar MDL GPS locations occurred closer to the edge between disturbed area and tree islands compared to Gregg River MDL (Fig. 4). As seasons progressed bears used areas further from edge, with the exception of bears using Gregg River MDL in spring. During this season bears on Gregg River MDL were on average two times further from forest edge than bears on Luscar MDL.

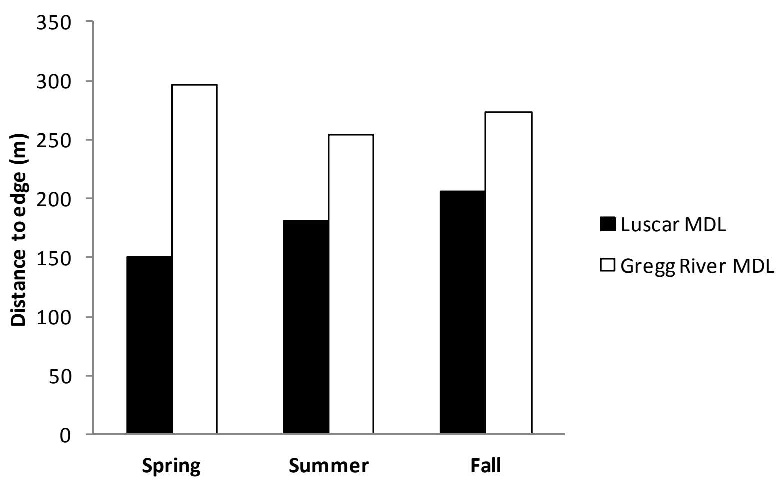

Figure 4. Mean distance to habitat edge for GPS relocations acquired within MDLs.

<u>Bear Diet</u>

Of the 59 grizzly bears scats collected in 2009 and 2010 (Luscar MDL *n* = 31; Gregg River MDL *n* = 28), for both MDL areas an average scat contained primarily vegetative material grazed by bears. Herbaceous material occurred at higher frequency in samples collected on Gregg River MDL compared to Luscar MDL (Fig. 5). Plant foods other than herbaceous (i.e., roots and berries) occurred on average 3.4 times more on Luscar MDL than on Gregg River MDL. Mammals and insects occurred in relatively similar proportions in scats collected on the two mines.

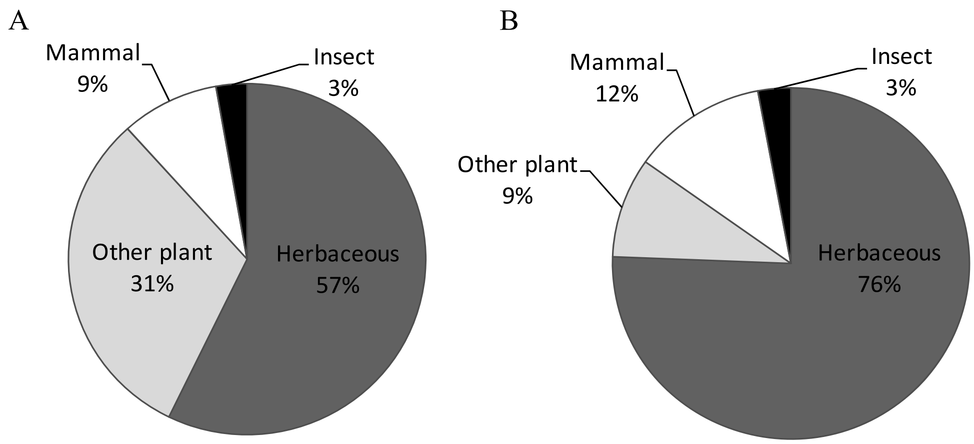

Figure 5. Frequency of occurrence of broad food items in grizzly bear scats collected within Luscar MDL (A) and Gregg River MDL (B).

Response of Bears to Human Access

On both MDL areas, bears were furthest from non-motorized trails in the fall (Fig. 6). On Luscar MDL, which had motorized trails, bears were furthest from these in summer. For both MDLs, bears were closest to trails during spring, with the exception of non-motorized trails on Luscar MDL.

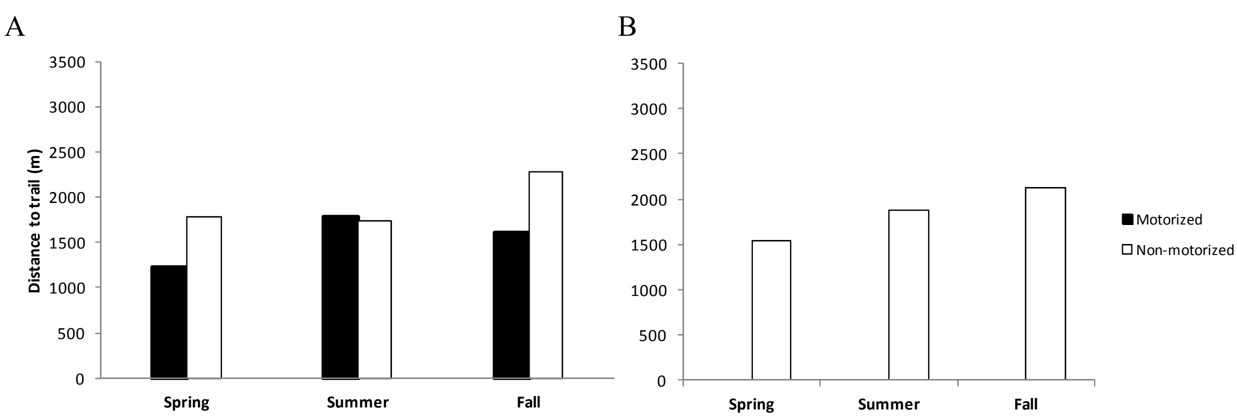

Figure 6. Mean distance to motorized and non-motorized trails for GPS relocations acquired within Luscar MDL (A) and Gregg River MDL (B).

DISCUSSION

Grizzly bears used Luscar and Gregg River MDL areas in all seasons, with the peak use occurring in summer. During this season, grazing material sown as part of reclamation was highly available within

MDLs, attracting wildlife including ungulates and grizzly bears. However our data show that throughout the year bears spent overall most time outside MDLs, which suggests that areas outside mines are necessary to fulfill grizzly bear food requirements and ensure population persistence. In spring, bears dig sweet vetch (*Hedysarum* sp.) roots outside mines whereas in the fall huckleberries (*Vaccinium* sp.), Canada buffaloberry (*Sheperdia canadensis*) and crowberry (*Empetrum nigrum*) are major foods consumed in preparation for winter denning (Munro et al., 2006; Cristescu, 2012). Ungulates are consumed on and outside MDLs but they occur substantially more in the diet of bears outside mines (Cristescu, 2012). Ungulate risk of predation is likely low on the largely open areas characteristic of reclamation (Hebblewhite et al., 2005). Given that bighorn sheep, elk and mule deer populations have been increasing on mines (BWT, 2010), it is possible that MDL areas may act as sources of ungulates for the surrounding landscape. Further studies accounting for ecological succession are necessary to assess if neonate ungulates settle on mines or disperse in the surrounding landscape.

Original tree patches left undisturbed during mining were used by bears especially on Luscar MDL. Such patches may serve multiple roles including providing thermal cover during bedding and hunting opportunities for predatory bears seeking ungulates. Forested areas provide shade which may be important during hot summer days, whereas on cold days tree cover may prevent body heat loss from atmospheric precipitation. All field-confirmed ungulate carcasses used by bears in 2009-2010 within MDL areas were located in the shelter of forest and represented predation as well as scavenging events (Cristescu, 2012). In addition to being important for bears, tree patches likely have functional value for other mammals. For example, we often located ungulate rub trees and bedding sites on tree islands within MDLs. Patches of original forest also supply native plant dispersers that can colonize reclaimed areas. Their role as dispersal reservoirs can facilitate ecological succession from non-native clovers, alfalfa and dandelion to a community dominated by native vegetation. However, this process is lengthy in harsh mountainous environments (Smyth, 1997) such as in this study and it is unlikely that introduced species would be completely replaced. On the contrary, these plants are spread by wildlife through direct consumption or attachment to their bodies when travelling through non-native grassland areas within MDLs. A more ecologically sound approach to reclamation is to use native plant species, such as currently under way at Teck Coal Ltd.'s nearby Cheviot operation, 20 km's south of this study area.

The calculations of distance to nearest habitat edge confirm the importance of tree cover for bears on mined areas. Seasonal differences and overall lower distance to edge on Luscar compared to Gregg River MDL point to variation in feeding on the two MDLs as well as potential influence of human use. Forested edges may be used by bears as cover enabling surprise chase attempts to capture ungulates. On Luscar MDL bears used tree islands extensively and were closest to edge in spring, a season during which many bears exhibited predatory behaviour in response to availability of ungulate calves and lambs. Although frequency of mammalian food items in bear scat was similar on the two MDLs, field visitation of GPS locations showed a higher number of ungulate carcasses consumed by bears on Luscar MDL, located exclusively within tree islands near the grassland edge (Cristescu, 2012). On Gregg River MDL where bears consumed ungulates to a lower extent, spring locations were furthest from edges than in any other season.

On the other hand, grizzly bears may have been using areas closer to edge on Luscar MDL because edges may be perceived as secure by this species (Nielsen et al., 2004). Luscar MDL had higher human activity (larger number of recreational access trails and mining operations). However, overall levels of mining activity were similar across seasons, whereas human use of mine trails differed. Human access along motorized trails peaked in summer, while in fall non-motorized trails received high use by hunters (Cristescu unpublished remote camera data). Bears responded to human activity on Luscar MDL by using tree islands substantially, more so in the fall than any other season. Also in the fall, bears were furthest from non-motorized trails, suggesting an avoidance of humans. Similarly, on Gregg River MDL bears were furthest from non-motorized access in the fall. However, inferences on bear occurrence in relation to distance to trails for this MDL must be interpreted with caution, because only one designated trail crosses Gregg River MDL. As expected, motorized trails on Luscar MDL were mostly avoided during the summer season of high but unpredictable human use.

RECOMMENDATIONS

Habitat enhancement during mine reclamation can promote use of mined lands by wildlife such as grizzly bears but should be designed to decrease human-caused mortality risk. Maintaining original vegetation cover such as treed areas should be a major goal in mine and reclamation planning. For areas disturbed by active mining, native plants are excellent alternatives to non-native species and can be used to achieve the same goal of wildlife colonization on MDLs. Planting sweet vetch and berry shrubs on mines may promote increased grizzly bear use of these areas in spring and fall but such attractants may work against the long-term goal of promoting grizzly bear population viability. Even in the absence of legal hunting within MDLs, risk of illegal killing on these predominantly open areas may be greater in the fall when many trail users carry firearms. Access management is a key component of bear population recovery (AGBRP, 2008). Strict enforcement of access regulations and firearms regime along designated MDL trails is needed to prevent human-bear conflict.

Wildlife monitoring programs should be implemented not only following reclamation, but during all phases of mining and ideally pre-mining for the proposed MDL area. When detailed behavioural data are required, focused studies that employ GPS radiocollars provide unmatched resolution in tracking animal movements on the landscape (Cagnacci et al., 2010). If detailed data are not essential, then non-invasive techniques such as remote cameras (O'Connell et al., 2011) can be used to document trends in wildlife occupancy. Remote cameras have many advantages over other methods, including non-invasiveness, low cost and ability to monitor a variety of species, including human trail users. Monitoring programs with long-term vision will enable key insights, such as use of MDLs by the same individual animals across multiple years, as demonstrated for some of the grizzly bears monitored in this study.

ACKNOWLEDGEMENTS

We thank all funding sources that made this project possible: Alberta Conservation Association, Alberta’s Conservation Collaboration, Alberta Ingenuity Fund, Alberta Society of Professional Biologists, Alberta Sport, Recreation, Parks & Wildlife Foundation, American Society of Mammalogists, Canadian Wildlife Federation, Foundation for North American Wild Sheep – Alberta Chapter, International Association for

Bear Research and Management, Mountain Equipment Co-op, Safari Club International – Northern Alberta Chapter, TD Friends of the Environment Foundation, Teck Resources Limited, and the University of Alberta. Valuable in-kind consultation and/or on the ground support were provided by: Alberta Parks, Alberta Sustainable Resource Development, Athabasca Bioregional Society, Bighorn Wildlife Technologies, Foothills Research Institute Grizzly Bear Program, Hab-Tech Environmental, Parks Canada, Sherritt Coal and Teck Coal's Cardinal River Operations. The primary and secondary authors worked closely with Bernie Goski, Terrence Larsen, John Saunders and Steve Wotton to ensure safe bear captures. Karen Graham and Julie Duval provided GIS support. Several dedicated field technicians volunteered their time to visit locations used by bears.

REFERENCES

AGBRP. 2008. Alberta Grizzly Bear Recovery Plan 2008-2013. Alberta Sustainable Resource Development, Fish and Wildlife Division, Alberta Species at Risk Recovery Plan No. 15. Edmonton, Alberta. 68 p.

BWT. 2010. Cheviot and Luscar mine Wildlife Inventory 2009. Created for Teck Coal Limited, Cardinal River Operations, by Bighorn Wildlife Technologies Ltd., Hinton, AB. 35 p.

Cagnacci, F., L. Boitani, R.A. Powell and M.S. Boyce. 2010. Animal ecology meets GPS-based radiotelemetry: a perfect storm of opportunities and challenges. Philosophical Transactions of the Royal Society B-Biological Sciences, 365, 2157-2162.

Cristescu, B., G.B. Stenhouse, M. Symbaluk and M.S. Boyce. 2011. Land-use planning following resource extraction – Lessons from grizzly bears at reclaimed and active open-pit mines. Mine Closure 2011 — A.B. Fourie, M. Tibbett and A. Beersing (eds.), Proceedings of the Sixth International Conference on Mine Closure, 207-218.

Cristescu, B. 2012. Ecology and behaviour of grizzly bears (*Ursus arctos*) in response to open-pit mining and implications for management and conservation. Ph.D. Thesis, Department of Biological Sciences, University of Alberta, Edmonton, Canada.

Erickson, D.L. 1995. Policies for the planning and reclamation of coal-mined landscapes: An international comparison. Journal of Environmental Planning and Management, 38, 453-467.

Foster, R.J. and B.J. Harmsen. 2012. A critique of density estimation from camera-trap data. Journal of Wildlife Management, 76, 224-236.

Gende, S.M., R.T. Edwards, M.F. Willson and M.S. Wipfli. 2002. Pacific salmon in aquatic and terrestrial ecosystems. Bioscience, 52, 917-928.

HAB-TECH. 2012. Project and cumulative impact statement for mammalian carnivores. Robb Trend Project. Created for Coal Valley Resources Inc., by HAB-TECH Environmental Ltd., Calgary, Alberta. 140 p.

Hebblewhite, M., E.H. Merrill and T.L. McDonald. 2005. Spatial decomposition of predation risk using resource selection functions: an example in a wolf–elk predator–prey system. Oikos, 111, 101-111.

Laliberte, A.S. and W.J. Ripple. 2004. Range contractions of North American carnivores and ungulates. Bioscience, 54, 123-138.

MacCallum, B. 2003. Reclamation to wildlife habitat in Alberta's Foothills. Technical Paper #14 in Price, W., W. Gardner and C. Howell. Proceedings of the 27th annual British Columbia mine reclamation symposium, Kamloops BC, September 15-18, 2003. The British Columbia Technical and Research Committee on Reclamation. Bitech Publishers Ltd., Richmond, BC.

MacCallum, B.N. and V. Geist. 1992. Mountain restoration: Soil and surface wildlife habitat. GeoJournal, 27, 23-46.

Munro, R.H.M., S.E. Nielsen, M.H. Price, G.B. Stenhouse and M.S. Boyce. 2006. Seasonal and diel patterns of grizzly bear diet and activity in west-central Alberta. Journal of Mammalogy, 87, 1112-1121.

Nielsen, S.E., M.S. Boyce and G.B. Stenhouse. 2004. Grizzly bears and forestry I. Selection of clearcuts by grizzly bears in west-central Alberta, Canada. Forest Ecology and Management, 199, 51-65.

O'Connell, A.F., J.D. Nichols and K.U. Karanth. 2011. Chapter 1 – Introduction in Camera traps in animal ecology. Methods and analyses. A.F. O'Connell, J.D. Nichols and K.U. Karanth (eds.). Springer, New York, 1-8.

Schwab, C., B. Cristescu, J.M. Northrup, G.B. Stenhouse and M. Ganzle. 2011. Diet and environment shape fecal bacterial microbiota composition and enteric pathogen load of grizzly bears. PloS ONE, 6, e27905.

Smyth, C.R. 1997. Early succession patterns with a native species seed mix on amended and unamended coal mine spoil in the Rocky Mountains of Southeastern British Columbia, Canada. Arctic and Alpine Research, 29, 184-195.

Tardiff, S.E. and J.A. Stanford. 1998. Grizzly bear digging: Effects on subalpine meadow plants in relation to mineral nitrogen availability. Ecology, 79, 2219-2228.

Zager, P. and J. Beecham. 2006. The role of American black bears and brown bears as predators on ungulates in North America. Ursus, 17, 95-108.