TESTING LANDSCAPE MODELING APPROACHES FOR ENVIRONMENTAL IMPACT ASSESSMENT OF MINING LAND USE ON GRIZZLY BEARS (*URSUS ARCTOS HORRIBILIS*) IN THE FOOTHILLS REGION OF WEST CENTRAL ALBERTA

Marc Daniel Symbaluk, MSc, PAg

Cardinal River Operations, Elk Valley Coal
Bag Service 2570, Hinton, Alberta T7V 1V5

ABSTRACT

The grizzly bear habitat effectiveness model (HEM) was used in west-central Alberta for Cumulative Environmental Assessments (1996 and 1999) of the Cheviot open pit coal mine project. This thesis tested HEM predictions regarding the Cheviot mine with empirical data. The HEM outputs were disproved for grizzly bear response to mining land use. Further, when tested at the mining land use scale, current Resource Selection Function (RSF) modeling is not predictive of grizzly bear occurrence. Grizzly bear movement paths prior to and during mine disturbance determined that mining land use does not present significant landscape or regional barriers to grizzly bears. This study examined regional and mining land use opportunities and risks pertaining to grizzly bears. I provide a critical review of the Cheviot CEA process and the implications of commitments made by governments and conclude with recommendations for mining land use and regional planning for grizzly bear protection.

CASE STUDY: GRIZZLY BEAR AND THE CHEVIOT OPEN PIT COAL MINE

The Cheviot open pit coal mine project [Cheviot project] is located on the front range of the Rocky Mountains in west-central Alberta. It was originally proposed as a 20 year, metallurgical coal mining development by project proponent, Cardinal River Coals Limited (CRC). The regulatory process was initiated in 1994. The EIA requirements for the Cheviot project included an assessment of cumulative environmental effects (CEA), consistent with the federal Canadian Environmental Assessment Act [CEAA] and Alberta's Environmental Protection and Enhancement Act (EPEA). CEA criteria required the proponent to gather and evaluate not only the proposed Cheviot project's impacts, but also to consider cumulatively the past, existing, and "imminent" activities in the defined CEA 3,040 km^2 study area which radiated approximately 25 km around the proposed Cheviot project area. The EIA addressed project and cumulative effects for 99 Valued Ecosystem Components (VEC). The grizzly bear was identified as the flagship VEC for assessing the regional, cumulative effects of the proposed Cheviot project in conjunction with other existing and planned land uses.

At the time of the EIA in 1996, provincial and federal regulators, environmental advocacy groups, and the project proponent all consistently agreed that this species was particularly well suited as a focal species for CEA. This was due to the existence of what was deemed an established, quantitative methodology for CEA for grizzly bear, which had been developed and employed in the United Stated (Christenson, 1986; United States Department of Agriculture (USDA), 1990; Weaver, Escano, Mattson, Puchlerz, & Despain, 1986). Further, as a wide ranging carnivore species, the grizzly bear would serve as an indicator and umbrella species for measuring and managing impacts on other large carnivores (BIOS Environmental

Research and Planning Associates Ltd. [BIOS], 1996; Logan & Ferster, 2002; Paquet & Hackman, 1995; Stenhouse & Munro, 2000). It was proposed that, "if the grizzly survives in the region, then most other carnivores, most of which have significant range overlap with the grizzly, would also likely survive" (BIOS, 1996).

Relatively little field study has been conducted specifically evaluating the response of grizzly bears to open pit coal mining and land reclamation. Yet scientists and decision makers alike have relied extensively on landscape modeling outputs to predict the effects of the Cheviot project on grizzly bears, to guide impact significance ratings (BIOS, 1996; Cardinal River Coals Ltd., 1996a; Herrero, 2000; Natural Resources Canada, 2000), and to influence policy or management processes. Thereby modeled predictions have resulted in significant regulatory, stakeholder, and ecological management implications.

TESTING OF THE CHEVIOT GRIZZLY BEAR CEA MODEL: HABITAT EFFECTIVENESS FOR MINING LAND USE

The original Cheviot project specific and cumulative effects assessment regarding grizzly bears utilized an inductive cumulative effects model (CEM) over the 3,040 km^2 Cumulative Effects Analysis (CEA) study area. This boundary was established by forming a polygon whose perimeter extended approximately 25 km outward from the proposed Cheviot project area, then adjusted to conform to watershed divides and watercourses.

CEM quantitatively estimates individual (specific) and collective (cumulative) effects of various land uses and activities in space and through time (BIOS, 1996; USDA, 1990). The various existing and planned anthropogenic activities were assigned disturbance coefficients. These disturbance coefficients were developed in the United States version of the grizzly bear CEM because there was no empirical data on human influences in the Canadian Rocky Mountains (Gibeau, 1998).

While these modeling assumptions were used to *predict* impacts for the proposed Cheviot project, they were also applied to Luscar and Gregg River mines. Both of these mines were *existing* operations located twenty kilometers north of the Cheviot Project and within the cumulative effects study area (Alberta Environmental Protection, 1995). These provide the opportunity for testing of these model assumptions and predictions of grizzly bear habitat effectiveness using empirical data collected after the CEA model predictions were made.

Between 1999 and 2004, the Foothills Research Institute (formerly Foothills Model Forest) Grizzly Bear Research Program FRIGRP conducted an intensive field study of grizzly bears within the 10,000 ha FMFGRP study area (Figure 1) that included the Cheviot CEA study area. Field data was obtained through the use of extensive GPS collaring and DNA census efforts. FMIGRP personnel captured 78 grizzly bears and radio-collared and monitored 64 individuals (Stenhouse, Munro, Graham, 2004). The deployment of these GPS radio collars on grizzly bears allowed researchers to collect detailed movement data, where point data was collected at a maximum 4 hour intervals on a 24-hour basis over a 9-10 month period (Stenhouse & Munro, 2000).

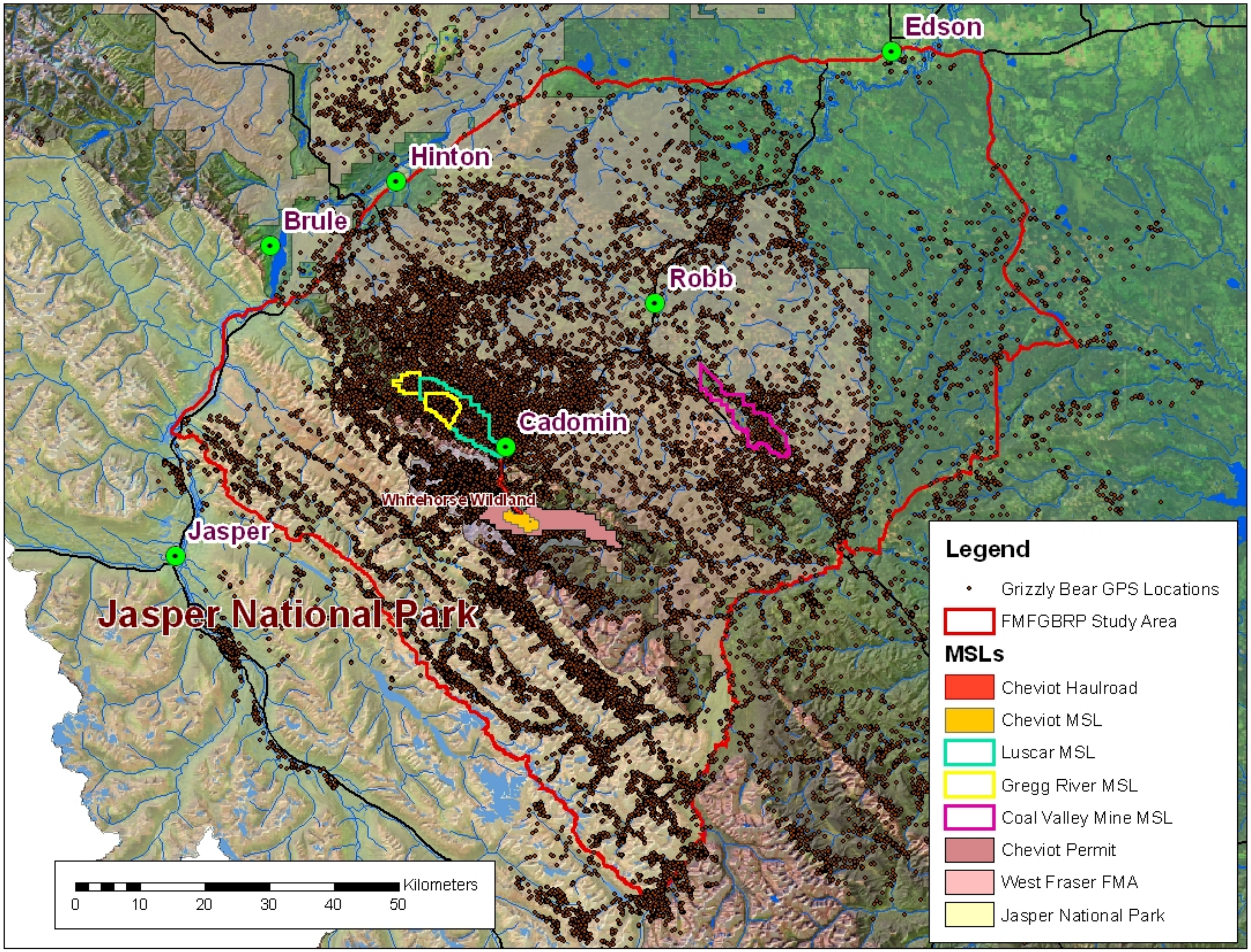

Figure 1. FRIGRP All GPS Points

GIS was used to overlay the Luscar and Gregg River mines with all grizzly bear GPS location from the 1999-2004 FRIGRP field program. These were two active mining operations during that period. Fourteen grizzly bears provided a total of 36 individual annual ranges which occurred within the mines' disturbance and zone of influence in the 5 year period. It is important to note that these 36 grizzly bear ranges are only from those bears that were successfully collared in the 1999-2004 field program, and serves only as a subset of the regional grizzly bear population. The dataset is used in this study to understand grizzly bear occurrence. A consistent and continued occurrence of grizzly bears within the mine disturbance and zone of influence is evident. Of the 19,942 total point locations, 23.8% occurred within the Luscar and Gregg disturbance ZOI. The percentage of locations occurring for individual home ranges were from 0.1% to 82.9% (mean 23.2%, n=36). Given the prediction of no grizzly bear use of these mines, haul roads and associated buffers, this analysis has proven the hypothesis that modeling employed for both the 1996 and 1999 grizzly bear CEA was not predictive of actual grizzly bear use or movement within mining land use areas and Habitat Effectiveness outputs were not significantly correlated to the distribution of bears from DNA data. These outputs were not correlated to level of use by GPS collared bears and were negatively correlated to the distribution of GPS collared bears.

Little to no testing of HEM has been conducted of an actual mining life cycle that includes aspects of undisturbed, disturbed, and reclaimed lands within mining land use. This is most notable in consideration of the spatial and temporal components of a phased mine development life cycle within a greater mine permit area, and this mine land use's effects on grizzly bear habitat and its effectiveness. Modeling assumptions for the Cheviot mine were based on 100% of the proposed disturbance area being under 100% active mining activity for 20 years, the duration of the project life. The Cheviot project grizzly bear HEM assumption was that upon project start-up, the total 2,800 ha planned disturbance, plus the additional one km zone of influence, for a total area of 12,710 ha (127.1 km^2), would have a HE rating of zero over the planned 20 years of the mine project.

Comparatively, following more than 3 years of active mining, the Cheviot project disturbance footprint is less than 300 hectares, within which reclamation and revegetation has been conducted on 15 hectares. This disturbance footprint is within the current 1,100 ha (11 km^2) Cheviot Mineral Surface Lease (MSL). Of the 7,150 ha Cheviot permit area, 1,100 ha is currently within MSL, or mining land use. Of this, less than 300 ha of the planned 2,800 ha have been disturbed. This temporal component, omitted in the CEA assessment of mining land use is important. Not only does mining not extend to the planned development footprint immediately, but all lands within the Cheviot permit area not under MSL remain susceptible to multiple land use activities (pressures) under provincial jurisdiction.

Based on the model outputs and expert opinion in the original Cheviot project application, it was concluded that the entire Cheviot mine area would become lost to grizzly bears by the end of the mine's 20 years of operation. Further, it was predicted that "grizzly bear habitat effectiveness, due to the effects of the extensive development [within the modeled mature mining disturbance footprint], was so low that [it] predicted only occasional use of this area by grizzly bears" (BIOS, 1996); and "effective mitigation is improbable, even within a 100 year post-mining framework" (BIOS, 1996).

These HEM outputs were referred to extensively to predict the effects of the Cheviot project on grizzly bears, and to guide impact significance ratings (BIOS, 1996; Cardinal River Coals Ltd, 1996; Herrero, 2000; Natural Resources Canada, 2000). This research concludes that disturbance coefficients assigned for mining land use for the Cheviot project CEA, as tested empirically in this study, were not valid and model assumptions for mining land use were erroneous.

TESTING NEW MODELING TOOLS DEVELOPED FOR GRIZZLY BEARS: RESOURCE SELECTION FUNCTION MODEL APPLICABILITY FOR MINING LAND USE

Scientists have developed new predictive and probabilistic modeling tools through the innovation of the FMFGRP and other grizzly bear research programs in North America. The Resource Selection Function (RSF) habitat models may be developed in part using Landsat satellite imagery to classify landcover. In the FMFGRP study area, McDermid (2004) created the Integrated Decision Tree (IDT) map by classifying the raw imagery into 13 land cover classes. The IDT map is then combined with grizzly bear points to create the RSF surface (Nielsen, 2007). The RSF raster is a probability surface that reflects the relative attraction of a particular location to a bear. The RSF output values range from 0 (no probability) to 10 (highest probability).

Testing RSF for mining land use was conducted by overlaying the current version of RSF (2007) onto Luscar and Gregg River mines. The Phase 6 RSF version was used for this testing. It is based on 2005 conditions and was released in 2007. The result is the predicted grizzly bear occurrence by RSF class within mining land use areas. This was then overlaid with occurrence of grizzly bear GPS locations for a measure of grizzly bear occurrence per RSF class.

This RSF model for grizzly bear habitat quality within the boundaries of the Luscar & Gregg River MSLs is significantly limited in its capacity to accurately predict probability of bear occurrence within the mining land use features which include the undisturbed, disturbed and reclaimed lands. Over 1/3 of all grizzly bear locations occurred within RSF class 0. This class is rated as the least probable location that a grizzly bear would use. Its actual level of grizzly bear use however, was similar to that of class 10, which is the highest probability classification. Nominally, the class 0 is assigned to disturbed lands, while higher ranking is provided to undisturbed lands. Grizzly bear occurrence on mining land use areas is not incidental but most likely purposeful and methodical. While much of these areas are characterized by RSF with a *no habitat value* mask, they are infact adjacent to portions of undisturbed lands which provide secure forest cover. These open, early succession reclaimed landscapes offer herbaceous forage and abundant ungulate populations in what is otherwise largely a closed forest environment with limited forage resources. Stevens & Duval (2005) found that grizzly bears with home ranges overlapping the Luscar and Gregg River mine land use areas support higher body condition indices than grizzlies with home ranges overlapping the un-mined Cheviot permit area. This is particularly significant for female bears. Grizzly bears with home ranges overlapping the existing Luscar and Gregg River mine land use areas return to previously used home ranges at least as regularly as bears in the un-mined Cheviot area. This implies regular as opposed to sporadic use of the mined lands (Kansas, 2005).

Within mining land use, there is a phased life cycle of development and reclamation. Habitat quality within mining land use areas is misrepresented by an assigned low RSF score within the model. Wherever mine disturbance has occurred, this ‘mask’ has been applied. This likely results from an issue of process in scale for mining land use within the application of this tool for regional mapping and its broad assumptions applied.

Contrary to actual empirical data, a ‘mask’ has been applied to disturbed areas within the mining land use areas to further discount their probability of grizzly bear occurrence. Grizzly bear occurrence may result from reclamation forage, ungulate utilization, or public access management on mining land use areas. Given their regional significance for grizzly bear use, areas within active MSLs, with their specific public access designation and habitat value, should be reflected accordingly by RSF.

CASE STUDY OF GRIZZLY BEARS AND MINING LAND USE

This author conducted research on case studies of two grizzly bears to determine finer scale grizzly bear movement and occurrence within and adjacent to mining land use areas. The first grizzly bear, G008 an adult male, was twenty two years old in 2007. Data was collected on movements and habitat selection through the use of GPS radio collars during two years of pre-disturbance and two years of concurrent active mining land use within the Cheviot project area. The second, G040, was 8 years old in 2006. She is an adult female that provides 4 years of data collected on movements and habitat within and adjacent to existing mining land use of the Luscar and Gregg River mines. Each bear provided large data sets for analysis of grizzly bear movement and human disturbance. Although the sample size of individual grizzly bears presented is small (n=2), they contributed a large amount of occurrence and movement data over 8 years, reducing GPS collar bias (Frair et al., 2004). The two grizzly bears collared in this study have been previously collared over multiple years. The FRIGRP (1999-2004) dataset for these grizzly bear occurrences was also utilized to augment the statistical power of the analysis, to conduct analysis including multiple annual datasets, and assess shifts in grizzly bear occurrence over time and with mining land use.

GPS locations and their spatial orientation were used to determine grizzly bear occurrence within mining land use areas based on a percentage of total number of GPS locations collected. G008 GPS point data is identified from the FRIGRP 1999-2004 dataset (*before* Cheviot project) to compare to repeated G008 GPS data collected through this 2006 and 2007 (*with* Cheviot project) thesis research collection period.

Grizzly bear G040 occurrence and her association with mining land use between years allowed the assessment of changes in grizzly bear use over time. An occurrence distribution of each of 4 years (2001-2003, 2006) for G040 compared her high occurrence (> 55%, n=4) within active mine land use over this period of time. In addition, multiple per day collected GPS points along with sensor data which records continuous movement path within and adjacent to active open pit mining was processed for a two week period, from April 15 to May 1 2006 for grizzly bear G040. Extracting continuous movement paths within and adjacent to the Luscar and Gregg River Mines demonstrates actual spatial and temporally correct grizzly bear movements within mining land use. Continued use of adjacent high quality habitat indicates no sign of displacement. Repeated grizzly bear crossings have occurred across the active Cheviot haul road. This technology demonstrates a marked and significant improvement in resolution of monitoring of actual grizzly bear movement from which behavior and habitat selection may be researched empirically. Although active mining may present inherent temporary habitat loss and episodic local movement barrier, such as active mining pits, the analysis conducted suggests that mining land use has not resulted in landscape level movement barriers for grizzly bears within the current Cheviot or Luscar/Gregg River mine areas.

Grizzly bear G008 occurrence and his association with mining land use between years allowed the assessment of changes in grizzly bear use and movement between years with and without the presence of mine related development activity. An occurrence distribution of each year for G008 compared between years *before* (1999 & 2002) and *with* (2006 & 2007) mine related land use in the Cheviot project area. Grizzly bear G008 has been referred to as a 'Cheviot bear', due to his use of the Cheviot permit area prior to, and now during the development and operation of the Cheviot project area as a portion of his home range. Interestingly, empirical analysis of his GPS locations prior to the Cheviot project also indicate an average of 2.7% (3.6% and 1.9%, 2 years) of his annual locations occurring within the Luscar and Gregg River mining land use areas. His average use of the Cheviot mine permit area in relation to total GPS locations collected per year increased slightly following the start-up of the Cheviot project (8.6%, n=2 years; 9.0%, n=2 years).

Aside from the active Cheviot haul road, it is important to qualify the mining activity occurring within active mining land use areas. Grizzly bear G008 movement is within and adjacent to the active Cheviot project's intensive land alteration as the mine is in its early development phase of coal extraction in its life cycle. Large areas of landform re-development and reclamation have not yet been fully initiated. During this pit development, vehicular traffic of mine support equipment and coal hauling are underway on the Cheviot haul road, generally on a 24 hour/day basis. Further, these mining land uses within the Cheviot area were only initiated in late 2004. Construction of the Cheviot haul road, pit development and operation: these are all recent activities within the area. There is no significant shift of movement or avoidance observed.

This research indicates no significant observed barriers to grizzly bear movement as a result of mining land use such that their use of areas is impeded. Grizzly bears routinely move through reclaimed, unreclaimed, and undisturbed areas within mining land use areas. This includes occurrence in unreclaimed disturbed areas with active mine activity including active mine haul roads. Further outputs of the continuous movement sensors will greatly enhance the ability to examine individual grizzly bear behavior based on movement, activity and habitat selection.

IMPLICATIONS OF RESEARCH RESULTS AND RECOMMENDATIONS FOR MINING LAND USE AND REGIONAL GRIZZLY BEAR MANAGEMENT

The Cheviot 1996 and 1999 CEAs employed what was deemed fitting and scientifically appropriate tools of the day. Since that time, there has been an evolution of knowledge and tools appropriate for use in conservation of grizzly bear populations in the region. We now know that the reclaimed portions of mining land use areas are attractive food sources for grizzly bears (Stevens & Duval, 2005; Kansas, 2005). Grizzly bears forage routinely on abundant high-energy food sources (ungulates and herbaceous forage) available on the reclaimed mine areas. Stevens & Duval (2005) and Kansas (2005) identified that grizzly bears ingest significantly greater amounts (2.5 times more) of animal protein and herbaceous forage in the Luscar and Gregg River MSL area than in the un-mined Cheviot project area.

The Cheviot project application raised issues, which resulted specifically from scientific uncertainty regarding regional grizzly bear response to mining and regional human land use influences. Results of empirical testing of grizzly bear occurrence and mining activity demonstrate regular grizzly bear use of mining land use areas and its resultant landscape development. This author suggests that grizzly bear conservation is not a project specific endeavor, but rather a regional commitment. This is especially important in retrospect of the Cheviot project CEA. It has been learned that the greatest human-caused effect on grizzly bears is mortality. It is imperative from a regional conservation perspective that appropriate recognition of grizzly bear values within mining land use areas be garnered by decision makers.

Protecting continued grizzly bear habitat use and managing human caused mortality should be a critical consideration for post-mining land use closure planning. Creative, effective, long term, public access management and in field enforcement that considers grizzly bear protection, following their return to the Crown, these mine lands must be managed responsibly and effectively by the Province. While this is specific to mine lands, such policy is required from a regional perspective to manage the persistence of grizzly bears in a region of multiple and often competing land uses.

RECOMMENDATIONS FOR MINE LAND USE AND REGIONAL PLANNING FOR GRIZZLY BEAR CONSERVATION

This author concludes with the following personal insights and applications for mining and other resource development industries:

- For project EIA, aside from engaging qualified professionals and experts in their field of environmental assessment, ensure that these individuals appropriately understand mining land use, mining life cycles, and can clearly display expertise to identify precautionary, yet reasonable prediction of impacts under proposed development scenarios.
- Although only one of 99 VEC in the Cheviot EIA, the grizzly bear served as an umbrella species for cumulative environmental effects assessment. Caution should be employed by practitioners during

impact assessment when assigning single species as indicators, and further recognize that single species management is not a surrogate for all other ecological values.

- Seldom are impact predictions from project EIAs tested. Retrospective and follow-up, as per the FMFGRP and this study, is an important component of adaptive management. Testing and validation of prediction tools can serve to provide meaningful projection tools for future impact assessments.
- Efforts should be made to develop empirically-based resource selection functions that provide direct evidence of the probability of occurrence of grizzly bears in a given study area of specific cultural and ecological conditions and the behavioral adaptations of grizzly bears given these conditions. Arbitrary suitability ratings of habitat types should be avoided.
- Throughout an industrial project life cycle, the proponent should regularly engage in a review process and given current state of knowledge, measure performance metrics, and improve plans as appropriate based on the premise of adaptive management.
- Resource development proponents have the shared responsibility to promote the evolution of knowledge and tools to mitigate grizzly bear impacts. Innovation, validation, and application of new tools should be pursued. Partnerships with government agencies, academia, and communities of interest should be encouraged and fostered.
- Share gained knowledge and embrace input from communities of interest. Engage these in planning processes and scenario development. Regulators, academics, and the public at large need to understand the mining life cycle. Awareness dispels myth and allows informed dialogue.
- Creative measures to reduce human caused mortalities, such as modified late season hunting for ungulates, should apply to areas of grizzly bear conservation and areas of demonstrated firearm mortality. At a minimum, this should be considered in areas surrounding mining land use areas and high fall season grizzly bear use habitats along the Rocky Mountain front ranges.
- Post-mining land use planning should include scenario development which optimizes wildlife values, including grizzly bear conservation, while accommodating future land uses, such as recreational uses. Land use plans, mining or regional, will not be successful without adequate enforcement and in-field stewardship to prevent human caused mortality of grizzly bears. Policy is not sufficient to protect wildlife values or the environment. Measurable, in field enforcement, plan stewardship, education, and awareness programs are critical tools to the success of policy objectives.
- A regional focus for data collection and analysis and for ongoing monitoring can provide the continuity in information and the institutional oversight of land and resource use that are required for cumulative effects management. CEA predictions should be reviewed periodically by provincial agencies. Regulatory industrial approvals and provincial land use policy should be amended to reflect results.
- Inductive modeling tools should be applied only at appropriate scales and validated using site specific empirical data. These tools may apply assumptions developed and tested elsewhere that do not apply in specific EIA conditions. These models are relatively well standardized and outputs are easily interpreted, making them valuable tools for decision makers and for communication. Caution should be used in their application to ensure that project parameters are well understood by the modeler and that assumptions are appropriate for site specific conditions. These should be supported with empirical data.
- The Cheviot project was the catalyst to a world class grizzly bear research program. The FMFGRP has since continued to evolve and expand across the province. This partnership of governments,

industry, and academia exemplifies the outstanding innovation and knowledge, and development and application of tools that can result from enterprise with common purpose. Focused research should be based on prioritization of needs by these partners.

Our increasing knowledge of mining land use effects on ecological values, the development and application of tools, and the continued testing and evaluation ensure that we learn through adaptive management and continually improve. This framework will ensure continued benefit of the economy and our communities, while minimizing impacts to the environment. This exemplifies this author's learned belief in sustainable mining and sustainable resource management.

REFERENCES

Alberta Environmental Protection (EPA). (1995). *Cardinal River Coals Ltd. terms of reference for the proposed Cheviot Mine development environmental impact assessment.* Edmonton, AB: Author.

BIOS Environmental Research and Planning Associates Ltd. (1996). Cheviot Mine Project: Specific and cumulative environmental effects analysis of mammalian carnivores. In *Cardinal River Coals Ltd. Cheviot Mine Project application, February, 1996* (Appendix 34). Hinton, AB: Cardinal River Coals Ltd.

Cardinal River Coals Ltd. (1996). *Cheviot mine project application*. Hinton, AB: Author.

Christensen, A.G. (1986). Cumulative effects analysis: Origins, acceptance and value to grizzly bear management. In: G. P. Contreras, & K. E. Evans (Eds.), *Grizzly Bear Habitat Symposium* (pp. 213-216). Inter. Res. Sta., General. Technical Report. INT-207.252.

Gibeau, M. L. (1998). Grizzly bear habitat effectiveness model for Banff, Yoho and Kootenay National Parks, Canada. *Ursus 10*, 235-241.

Herrero, S. (2000). *The proposed Cheviot mine: cumulative effects, conservation and management issues regarding grizzly bears.* Report prepared for Cardinal River Coals Ltd., Hinton, AB.

Kansas, J. L. (2005). *Grizzly bears and mining in the Cheviot region: Retrospective analysis* (Report Prepared for Cardinal River Operations). Calgary, AB: URSUS Ecosystem Management Ltd.

Logan, B., & Ferster, R. (2002). Cumulative environmental effects assessment and management: the Cheviot mine experience. In A. Kennedy (Ed.), *Proceedings from Alberta Society of Professional Biologists Symposium 2000. Cumulative environmental effects management-Tools and Approaches* (pp. 17-30). Edmonton, AB: Alberta Society of Professional Biologists.

McDermid, G. (2004). *Geospatial tools for large-area, multi-jurisdiction habitat mapping.* Unpublished doctoral dissertation, Department of Geography, University of Waterloo. Waterloo, ON, Canada.

Natural Resources Canada. (1997). *Federal Government responds to Cheviot panelrecommendations.* Ottawa, ON: Author. Retrieved February 24, 2007 from http://www.rncan.gc.ca/media/archives/newsreleases/1997/1997hq41_e.htm

Nielsen, S.E. (2007). Seasonal resource selection function (RSF) models for grizzly bears in the Foothills Model Forest region of Alberta. Edmonton, AB: Conservation Analytics.

Paquet, P., & Hackman, A. (1995). *Large carnivore conservation in the Rocky Mountains. World Wildlife Fund.* Toronto, ON.

Stenhouse, G. B., & Munro, R. (2000). *Foothills Model Forest Grizzly Bear Research Program 1999 Annual Report.* Hinton, AB: Foothills Model Forest Grizzly Bear Project.

Stenhouse, G. B., Munro, R., & Graham, K. (2004). *Foothills Model Forest Grizzly Bear Research Program 2003 Annual Report.* Hinton, AB: Foothills Model Forest Grizzly Bear Project.

Stevens, S., & Duval, J. (2005). *Ecology of grizzly bears in the Cheviot, Luscar and Gregg River mine areas (1999-2004).* Hinton, AB: Cardinal River Operations and Foothills Model Forest Grizzly Bear Research Project.

United States Department of Agriculture (USDA). (1990). *Cumulative effects model: A model for effects on grizzly bears.* Missoula, MT: USDA Forest Service.

Weaver, J. L., Escano, R., Mattson, D., & Puchlerz, T. (1986). *A cumulative effects assessment model for grizzly bear management in Yellowstone ecosystem.* In G. P. Contreras & E. K. Evans (Eds.). *Proceedings of the Grizzly Bear Habitat Symposium,* (pp. 234-246). (Inter. Resource Station, General Technical. Report. INT-207). U.S. Forest Service.