MODELLING AND RESTORATION OF BIGHORN SHEEP HABITAT WITHIN AND ADJACENT TO KOOTENAY NATIONAL PARK, BRITISH COLUMBIA

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SUMMARY
Native open forest and grassland habitats are gradually being eroded in British Columbia as a result of forest encroachment, urban development and non-native plant invasions. In the Radium Hot Springs area, located at the southern end of Kootenay National Park (KNP), such habitats provide critical wintering range for bighorn sheep and other species. In this paper, we present an ongoing multi-faceted, ecosystem-based initiative aimed at restoring open forest and grassland habitats as well as ensuring seasonal habitat connectivity for species that depend on these habitats. The first part of the project consisted of a GIS-based modelling exercise completed by M. Tremblay in 2001. Tremblay incorporated information from the literature, key informant interviews and personal observations into a spatially explicit model of potential linkages between seasonal habitats for bighorn sheep. Tremblay's modelling work and accompanying management recommendations served as a basis for a multi-year ecosystem management project initiated by Parks Canada for the south end of KNP. This project, which is part of a broader cooperative, multi-stakeholder effort to restore grassland and open ecosystems in the Columbia Valley, has included a number of restoration activities to date, namely: 1) the selective harvest and brushing, from 2001 to 2003, of parcels of federal and provincial land located within and adjacent to KNP and 2) the removal, in 2001, of three sets of privately owned commercial accommodations from the Sinclair Creek Canyon located within KNP. Subsequent prescribed burn activity is planned to help meet restoration objectives and to maintain open habitat types. In January 2002 a research and monitoring project began with ten adult bighorn sheep (7 ewes and 3 rams) fitted with GPS radio collars. This work will identify future restoration priorities, allow evaluation of completed habitat restoration efforts and provide validation of Tremblay's modelling work.

1. INTRODUCTION

1.1 Background

In the Radium Hot Springs area, located at the southwestern extremity of Kootenay National Park (KNP), grassland and open forests habitats provide key winter range for bighorn sheep (*Ovis canadensis canadensis*) in addition to supporting a number of other large to mid-sized mammalian species. Bighorn sheep are a blue-listed (i.e., considered vulnerable) species in British Columbia due to a low overall population and patchy distribution as well as to the threatened nature of its winter ranges (1). In March 2002, the population of the Radium-Stoddart herd was estimated at approximately 160 individuals. This herd represented roughly 8% of the total provincial population in the late 1990s (2).

In the Radium Hot Springs area, there has long been concern over the degradation of bighorn sheep winter range due to past overgrazing, the invasion of noxious weeds such as leafy spurge, and the encroachment of forests over grasslands resulting from decades of fire suppression (3,4). More recently, federal and provincial land managers have become increasingly concerned about the incremental growth of residential and recreational developments, which is resulting in considerable habitat loss and alienation as well as the disruption of movement corridors linking key habitats. There has also been greater recognition of the need to involve a broader range of stakeholders (beyond provincial and federal agencies) in land-use planning initiatives, including local governing bodies, private landowners, First Nations, industry and other interest groups. This is important because many wildlife species present in the Radium area must travel through multiple jurisdictions in their efforts to meet their biological requirements and as such, are affected by the activities of a variety of stakeholder groups. In this paper we present a number of research and conservation initiatives aimed at addressing these issues.

1.2 Study Area

The study area is centred on the town of Radium Hot Springs located in the Rocky Mountain Trench of southeastern B.C. (*Figure 1: Map and location of study area in southeastern British Columbia. (Source of base map: 6)*.). It covers an area of approximately 350 km^2. The study area can be divided into three physiographic zones: the Columbia River floodplain, the benchlands, and the Rocky Mountains. These zones lie at elevations of approximately 800, 800-1000 and 1000-2600 m, respectively. An important characteristic of the study area is that it encompasses lands that fall under a number of jurisdictions, including federal (i.e., KNP), provincial, and private lands. The Village of Radium Hot Springs represents the main settlement in the study area with a permanent population of 530 in 1990 (5). The area's population tends to increase several-fold during summer with the influx of tourists.

2. MODELLING MOVEMENT CORRIDORS FOR BIGHORN SHEEP

2.1 Model Overview

Tremblay (7) delineated probable movement corridors for three focal species (elk, bighorn sheep and grizzly bear) using a geographic information system-based modelling approach. This approach incorporated a variety of existing modelling techniques and integrated information on habitat use and movement patterns specific to each of the focal species. All analyses were carried out using the E.S.R.I Arc/Info software and a raster environment with a 25 x 25 m cell size. In this paper we focus exclusively on the model developed for bighorn sheep and provide only a brief summary of the methodology used. The full version of Tremblay's corridor modelling study can be accessed on the Web at www2.mtroyal.ab.ca/~mtremblay.

The general structure of the bighorn sheep corridor model was inspired by previous habitat effectiveness and cumulative effects modelling efforts aimed at assessing the effects of human actions on wildlife populations and their use of habitats (8,9,10,11,12). These works provided a useful framework for delineating areas of highest effective habitat, i.e. areas of highest habitat value after human disturbance has been factored in. To this, Tremblay added a movement component to account more fully for the selection of preferred travel routes between key habitat patches. Thus, the sheep model contained three sub-models: a habitat routine, a human disturbance routine and a movement routine (Figure 2: Conceptual diagram of the bighorn sheep model*)*. The sheep model was also consistent with work by Smith et al. (13).

2.2 Habitat Routine

The first part of the model consisted of a habitat routine whereby the inherent quality of the habitat was assessed, without regard for human disturbance. Habitat suitability was mapped using existing biophysical data sets (14,15,16). The habitat suitability ratings from these data sets were standardized and reclassified into "habitat coefficients" ranging from 0 to 1, representing minimal and optimal habitat, respectively. Separate habitat layers were created for the growing and winter seasons.

2.3 Disturbance Routine

The purpose of the disturbance routine was to account for the alienation effect that human disturbance has on bighorn sheep use of habitats. We accomplished this by first identifying all human disturbance features within the study area and then applying a disturbance coefficient (DC) to a specified zone of influence (ZOI) surrounding each feature.

We conducted a comprehensive inventory of all sources of human disturbance including linear developments such as roads, railways and trails, as well as point sources such as settlements, campgrounds and picnic areas. We determined human use levels for each of these features, on a seasonal basis, using a combination of existing traffic data for major roads, a series of 10 automatic counters installed at strategic locations on selected secondary roads and trails throughout the study area, and key informant interviews.

ZOIs and DCs were then determined for each feature based on empirical studies of the effects of humans on sheep (17,18,19) in addition to area-specific information gleaned from personal observations or key informant interviews pertaining to the sensitivity of bighorn sheep to human disturbance. Both the nature and predictability of disturbance were important considerations in determining ZOIs and DCs. For example, roads were given less extensive ZOIs than trails because sheep are generally less sensitive to vehicles than they are to humans on foot due to the greater predictability of disturbances along roads. We rated “disturbance” coefficients on a scale of 0 to 1 (Table 1), representing maximum and minimum disturbance, respectively, and produced separate disturbance layers for summer and winter.

Table 1: Disturbance coefficients and zones of influence for bighorn sheep.

Type of Activity	Intensity of use	Zone of influence (m)	Coefficient
Linear motorized	High	25	0.50
	Low	100	0.75
Linear non-motorized	High	100	0.50
	Low	100	0.75
Point motorized	High	25	0.05
	Low	0	0.75
Dispersed motorized or non-motorized	High	0	0.50
	Low	0	0.75

2.4 Movement Routine

One of the primary considerations in building the movement routine was security. From previous empirical studies of bighorn sheep ecology (20,21,22,23,24,25,26), we determined that the two most important security factors affecting sheep movements were the presence of escape terrain and visibility.

We defined escape terrain as slopes >80%. Areas of slopes greater than 80% were identified using a digital elevation model. Then, “escape terrain” coefficients were applied to bands surrounding these areas reflecting the fact that bighorn sheep use generally decreases with increasing distance from escape terrain (19,23,27). Consistent with the overall modelling scheme, these coefficients were rated from 0 to 1, representing minimal and optimal security, respectively (Table 2).

Areas of high visibility were defined as those areas corresponding to “open” habitats, such as grasslands, rocky ridges and open forests. We assigned an optimal rating of 1.0 to areas of high visibility while areas of lesser visibility were given a rating of 0.5. This rating scheme reflects the belief that visibility enhances corridor suitability but the lack thereof does not act as an absolute constraint on sheep movements.

Table 2: Escape terrain coefficients for bighorn sheep.

Distance from Escape Terrain (m)	Coefficient
0-100	1.00
100-200	0.75
200-300	0.50
300-400	0.25
> 400	0.05

Finally, overall “movement” coefficients were obtained by combining the visibility and escape terrain coefficients as follows:

movement coef. = visibility coef. x escape terrain coef.

2.5 Corridor Delineation

The final output of the modelling component of this project consisted of maps representing, on a seasonal basis, the spatial distribution of "corridor value" across the study area for bighorn sheep. Corridor value was defined as the suitability of an area to support the movements of individuals of a given species. Seasonal corridor value was determined by combining the outputs of the habitat, disturbance and movement routines, according to the following equation:

final corridor value = habitat value x disturbance coef. x movement coef.

The seasonal corridor value maps formed the primary basis for delineating probable corridors for bighorn sheep through the study area. In all, 12 potential movement corridors for bighorn sheep were identified (Figure 3: Potential movement corridors for bighorn sheep in the immediate vicinity of Radium Hot Springs, B.C.).

2.6 Conclusions and Recommendations Derived from the Corridor Model

Upon completion of the modelling exercise described above, Tremblay identified key issues affecting the functionality of each corridor and developed management recommendations aimed at addressing each of these issues. While it is beyond the scope of this paper to discuss each corridor in detail, some of Tremblay's most important conclusions and recommendations pertaining to bighorn sheep corridors in the immediate vicinity of Radium Hot Springs are summarized below (Table 3).

Table 3: Summary conclusions and recommendations for bighorn sheep habitat and corridors, Radium Hot Springs area, B.C.

Conclusions	**Recommendations**
Sheep have very specific habitat requirements. Habitat use by sheep appears to be largely tied to the presence of forage in proximity to escape terrain and high visibility.	Protect and restore areas that contain, or have the potential to contain, these important habitat elements for sheep.
Sheep make extensive use of the Lower Sinclair Canyon Corridor. This area appears to be an important part of winter range of the Radium-Stoddart herd. In addition, it provides an abundance of mineral licks and escape terrain and appears to act as an important corridor for seasonal movements between seasonal ranges.	Restore natural habitat conditions within the Sinclair Canyon area. This would include prescribed burning to counter forest ingrowth and the removal of facilities that are not deemed essential to this area (i.e. maintenance compound, accommodations, etc.). The south-facing side of the canyon, because of the greater abundance of forage, appears to be especially important for sheep.
Harassment, resulting from close proximity of sheep and humans, may cause long-term stress in sheep.	Wherever possible, create more distance between sheep and humans. This can be achieved through the reduction of human influence in areas known to be important for sheep.
There is a clear lack of specific information regarding habitat use and movement patterns of bighorn sheep in the Radium area.	Sheep movements should be monitored on a multi-year basis to determine the extent and nature of use of potential corridors identified through the modelling process.
Bighorn sheep movements do not respect jurisdictional boundaries. Connectivity between seasonal ranges can only be assured through coordinated land-use planning and conservation efforts. Of particular concern is the encroachment of human development on the sheep's winter range.	Develop a sub-regional ecosystem advisory committee whose mandate would be to develop a conservation strategy for the Radium area, with particular emphasis on developing a regional habitat connectivity plan.

3. ECOSYSTEM-BASED MANAGEMENT AND RESEARCH INITIATIVES

3.1 Introduction

Tremblay's modelling study and ensuing recommendations served as a basis for a multi-year ecosystem management project initiated by Parks Canada for the south end of KNP as part of a broader, multi-stakeholder effort to restore grassland and open ecosystems in the Upper Columbia Valley. In the Radium area, multi-stakeholder partnerships are assured by the "Bighorn In Our Backyard" project, a community-based bighorn sheep monitoring program described in more detail in Dubois et al. (28), and the Radium-Stoddart Bighorn Sheep Working Group, which brings together land management agencies responsible for bighorn sheep management as well as private and public interests. In this section we describe three habitat restoration projects that have taken place between 2001 and 2003. We also describe a multi-year bighorn sheep telemetry research and monitoring project that has been ongoing since January 2002.

3.2 Restoration of the Sinclair Canyon within KNP

Sinclair Canyon is located in the western portion of KNP (Figure 4: Map of bighorn sheep habitat restoration sites near Radium Hot Springs, B.C.). It is part of the traditional winter range of bighorns, includes frequently used mineral licks, and is an important corridor for sheep moving between winter, lambing and summer ranges (4). However, three sets of commercial cabins, totalling 53 cabins, were built in the canyon beginning in the 1930s. Although bighorns appear to have adapted to human activity in this area, the presence of built facilities constrains park managers in using fire as a tool to maintain open forest/grassland habitat. Consequently, in 2001 Parks Canada purchased the cabins from their owners, removed all facilities and cleaned up and rehabilitated the site. Rehabilitation included removal of roads, landscaping, and seeding of a portion of the site with native grasses.

3.3 Restoration of Sheep Winter Range on Provincial Land Adjacent to KNP

Prior to the late 1980s, the most important winter range for the Radium bighorns was at Stoddart Creek near KNP's southwestern corner (4). Most of this range was on provincial crown land. Historically, the ecosystems represented in this area were open forests with a diverse understory of grasses, herbs and shrubs maintained by frequent, low to moderate intensity fires (29). Decades of fire suppression have resulted in a progressive wave of conifer establishment from high to low elevations, a situation which has degraded habitat quality for bighorns. Deteriorating range conditions appear to have contributed to the subsequent abandonment of this range by bighorns in favour of artificial grasslands such as golf courses, lawns, and road rights-of-way in or near the village of Radium Hot Springs (30). This situation is believed to have increased habituation of bighorns, exposed them to harassment by dogs, and increased mortality of bighorns along highways immediately adjacent to the village.

Approximately 72 ha of the Stoddart Creek range on provincial crown land were restored in winter 2001 followed by restoration of a 58 ha block on provincial crown land in the Redstreak area in winter 2002 (the latter is identified as “Provincial Block” in Fig. 4). The restoration work was intended to be consistent with the historic pattern of structure and disturbance associated with frequent low to moderate intensity fires. The restoration prescription included the use of selective harvest, thinning, brushing, piling and burning, and some seeding with native grasses. Selective harvest achieved an 8 m spacing between individual leave trees (Fig. 5: Aerial view, from the east, of the Federal Block (upper portion of open area) and Provincial Block (lower portion) after restoration (Photo taken April 2003). The resultant open forest structure is expected to benefit bighorns by improving graminoid production and visibility to escape terrain.

On January 20, 2003 a total of 54 bighorns was observed in or just above the Stoddart Creek restoration block. This was the largest count of bighorns in this area in over 13 years (30). While it is too early for forage conditions to have changed significantly since the restoration work, we speculate that improved visibility of escape terrain may have contributed to the increased use by bighorns.

3.4 Restoration of the Redstreak Area

The Redstreak area is located just south of Sinclair Creek on the edge of historic winter range for the Radium bighorns. Although the area lacks escape terrain, Tremblay (7) identified it as part of a possible linkage for bighorns between the Columbia Valley and Sinclair Creek, and noted that sheep are frequently observed here. Stand density in this area is high (31), reducing forage production and sight lines for bighorns. Moreover, high fuel loads create considerable potential for wildfire in this area, representing a threat to built facilities and public safety. Restoration objectives and prescriptions were developed for three sites within the Redstreak area (Fig. 4) (31). Restoration work in all three blocks was completed in March 2003.

Federal Block. This 81 ha lot is managed by Parks Canada but located outside of KNP. On this site, trees were left in clumps spaced approximately 20 m apart. Five areas of up to about 1.5 ha were left untreated in order to retain snags and wildlife trees, to provide visual screening from an adjacent residential area, and to maintain thicker forest cover in north facing gullies (Fig. 5). The primary objective for this block was ecological restoration.

Redstreak Campground Block. This 44 ha block encompasses the 242-site Redstreak Campground and land immediately west of it. The treatment prescription was similar to that used in the Federal Block. Facility protection and public safety were the primary objectives in this case, although ecological restoration was also an objective.

Prescribed Burn Guard Block. This 10 ha block is located just east of Redstreak Campground along the lower slopes of Redstreak Mountain. The treatment prescription here was for consistent 8 m spacing of individual leave trees. It is intended to provide a fuel break to safeguard the campground and other built facilities from future prescribed fire restoration work on Redstreak Mountain planned for spring 2004 (Fig. 4). Here a series of burns will be used to establish and then maintain historic open forest conditions within bighorn transitional ranges between winter and summer range.

3.5 Bighorn Sheep Telemetry Research and Monitoring

3.5.1 Objectives

In January 2002 we commenced a radio-telemetry study of bighorn sheep at Radium Hot Springs. The objectives of this study are to determine the following: seasonal range selection, movement corridors between seasonal ranges, location of important point-source features such as lambing ranges and mineral licks, and bighorn response to restoration activities (32). These objectives are to be accomplished over two or more years of monitoring. Results are expected to guide future restoration initiatives, particularly those occurring in mid-elevation transitional ranges. Additionally, we anticipate that information on seasonal ranges, movement routes and concentrated activity sites will be used in land use planning and human use management in the Radium Hot Springs area.

3.5.2 Methods

In January and March, 2002, with the sheep concentrated on their winter range, we captured seven adult ewes and three adult rams and fitted them with GPS (*Advanced Telemetry Systems*, Isanti, Minnesota) radio collars. These collars were programmed to obtain and store a Global Positioning System (GPS) location every six hours on average, with sampling occurring more frequently between May and October, and less frequently during winter (32,33). For the second year of the study radio collars were refurbished and reprogrammed, then fitted on six adult ewes and four adult rams during winter 2002-03. These radio collars will remain on the study animals for nearly a year and then will be retrieved in December 2003. Subject to funding availability, we plan to redeploy the radio collars for a third year in December 2003 or January 2004.

3.5.3 Preliminary Results From 2002

Six of the ten radio-collars obtained GPS locations for their entire period of deployment. Of the ten study animals, one ram died in a vehicle collision in August. All others survived through the entire study period. In total over 9,000 location points were obtained.

Data from the first year of the study have not been analyzed in detail but we present here some preliminary findings. Six of seven radio-collared ewes had lambs, all of which survived at least until fall 2002. All five ewes for which the GPS telemetry record extended into the lambing period lambed in the Brisco Range north of Radium Hot Springs. Three of these ewes lambed within six km of Radium in what was previously suspected to be lambing range for the Radium Bighorns (4). However, two other ewes lambed approximately 14 and 33 km north of Radium in areas previously not known to be lambing areas.

All ewes were closely synchronous in migrating from winter to lambing range, with the dates of departure ranging from May 17 to May 21 for five animals. Ewes also moved abruptly from summer to winter range, typically in one to several days, arriving on the lower elevation winter range between September 20 and October 2. There was no evidence of significant use of transitional, mid-elevation ranges. All ewes in the study made several brief excursions to lower elevations during summer, possibly to visit mineral licks near Sinclair Creek.

The timing of use of seasonal ranges was less clear with rams, in part because only three rams were radio-collared. One of these was killed on highway 93/95, just south of the village of Radium Hot Springs, on August 2. Prior to its death, this ram had not yet travelled to alpine summer range. The other two rams travelled to summer range on June 12 and July 4, and returned to winter range on October 2 and October 14. Little use of mid-elevation ranges was detected.

Future analyses of radio-telemetry data will investigate routes that individual sheep used to travel between seasonal ranges, habitat and terrain characteristics of sheep movement routes, and bighorn response to ecosystem restoration initiatives.

4. CONCLUSIONS

Tremblay's modelling exercise represented the first attempt at systematically mapping probable movement corridors for bighorn sheep in the greater Radium area. While the study raised more questions than it provided answers, it demonstrated that modelling can constitute a useful "coarse filter" approach to identify movement corridors in an area. The study also helped identify assumptions or testable hypotheses regarding factors believed to affect the movements of bighorn sheep, which can be viewed as directions for future research. In addition, the study provided a systematic and rational framework from which preliminary recommendations could be formulated, aimed at preserving and restoring key habitats as well as a functional network of linkages between these throughout the greater Radium landscape.

We believe the information presented in this paper also demonstrates how science and management can work in tandem within a comprehensive ecosystem-based conservation strategy. Tremblay's modelling work provided a valuable basis for the habitat restoration initiatives described in this paper. In turn, the telemetry research and monitoring component of the project will be instrumental in the evaluation of these habitat restoration efforts and allow for the identification of future restoration priorities. Moreover, ongoing monitoring of bighorn sheep movements will provide validation of Tremblay's modelling work and lead to refinement of the model through the testing of its underlying assumptions.

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