Response of Bighorn Sheep to Restoration of Winter Range

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Abstract: Winter range for bighorn sheep (*Ovis canadensis*) in southeastern British Columbia declined in both quality and availability due to forest ingrowth over the last several decades. In 2002 and 2003 we applied mechanical treatments to a 200 ha portion of traditional bighorn winter range near Radium Hot Springs, B.C. in an attempt to improve habitat suitability. Treatments included timber removal with retention of clumps of veteran trees, brushing, piling and burning, and noxious weed control. We monitored bighorn sheep response to these treatments by deploying GPS radio collars on 10 sheep each year from 2002 to 2004 and collecting daily location points for each animal. Considered over entire calendar years, study animals increased their use of the treated area from 1.0% of daily locations in 2002 to 8.9% in 2004 ($P < 0.001$). Post-treatment use of the treated area was greatest in March and April when sheep use of the treated area increased from 0% in 2002 to 20.4% in 2004 ($P < 0.001$). Our research demonstrates that mechanical treatments designed to mimic natural open forest ecosystems can result in a rapid increase in use by bighorn sheep, particularly when the treated areas are adjacent to occupied habitat.

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In winter, most populations of bighorn sheep (*Ovis canadensis*) in southeastern British Columbia depend on low-elevation open forest and grassland habitats historically maintained by frequent, low-intensity ground fires (Demarchi et al. 2000) or by mixed fire regimes of frequent low-intensity fires with occasional stand-replacing fires (Gayton 2001). These habitats have declined due to forest encroachment resulting from fire suppression over much of the last century (Davidson 1994). Gayton (1997) estimated that forest encroachment results in an annual loss of 1% of southeastern British Columbia open forest and grassland habitat. Additionally, critical winter range is lost to, or impacted by, competing land uses, including urban and rural settlement, agriculture, resource extraction, and off-road motorized recreation (Demarchi et al. 2000, Tremblay 2001, Tremblay and Dibb 2004). At Radium Hot Springs, B.C. the bighorn sheep population currently consists of about 200 animals, although periodically through the 20th century the herd declined to as few as 20 individuals through disease-induced die-offs (Stelfox 1978). More recently, deteriorating range conditions on traditional bighorn sheep winter habitats were implicated in the partial abandonment of these ranges by sheep in favour of artificial grasslands such as golf courses, residential lawns, and highway rights-of-way within and adjacent to the town (Tremblay and Dibb 2004). This situation is believed to increase habituation of bighorns, expose them to harassment by dogs, and increase mortality of bighorns along highways. Consequently, Tremblay (2001) recommended restoration of portions of historic bighorn winter range in the Radium Hot Springs area.

The potential success of a habitat restoration program will depend, in part, on the ability of the target species to find and then utilize restored habitats. Geist (1971, 1974) reported that bighorn sheep are poorly adapted to dispersing into available habitat, but instead transmit knowledge of seasonal ranges from generation to generation. This lack of exploratory behaviour of bighorn sheep, resulting in part from a reliance on steep, rocky terrain and high visibility, limited the success of translocation programs in the western United States (Goodson et al. 1996, Singer et al. 2000). However, sheep have successfully occupied newly available habitats created through habitat manipulation where the treated areas were adjacent to occupied habitat. In Utah, Smith et al. (1999) reported that within two years sheep made significantly increased use of areas treated with logging. Similarly, Arnett et al. (1998) documented sheep using burned areas in Wyoming within two years where the burned areas had little or no spatial separation from existing sheep winter range. In the Radium Hot Springs area we predicted that bighorn sheep could reoccupy restored habitats adjacent to their currently occupied winter range, provided that treatment prescriptions result in substantial improvements in visibility and forage quality.

Study area

The study area comprised the winter ranges of bighorn sheep in and adjacent to the village of Radium Hot Springs, British Columbia (50°37’20”N, 116°04’18”W). The restoration sites were situated on benchlands at the foot of Redstreak Mountain in the western ranges of the Rocky Mountains (Figure 1). Elevation was approximately 1000 m, although in the area it ranged from 850 m at the Columbia River to nearly 2,800 m on the highest summits of adjacent mountain ranges. Slope on the restoration sites ranged from flat to approximately 48°, with small areas of steeper rocky cliffs, particularly in the eastern portion along the lower slopes of Redstreak Mountain. Aspects were predominantly west or southwest, although there were some areas of flat terrain with subdued eastern aspects.

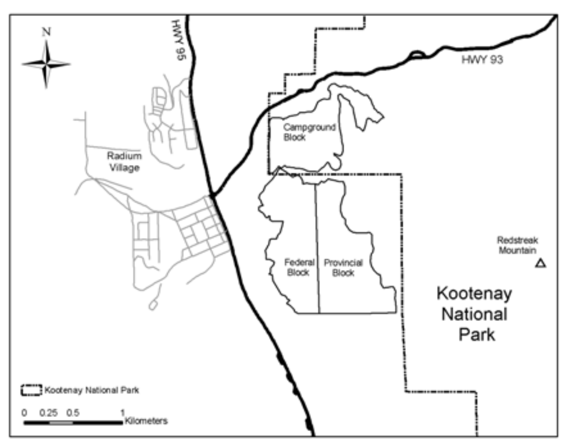

Figure 1. Layout of habitat restoration blocks for bighorn sheep in relation to Radium Hot Springs and Kootenay National Park, 2002 to 2004.

Climate at valley bottom sites was characterized by low precipitation and warm temperatures compared to higher elevation sites in the adjacent mountains (Achuff et al. 1984). Mean annual temperatures were near 5.0^{o} C at Radium Hot Springs and mean annual precipitation was 366 mm at the nearby Kootenay Park west gate (Janz and Storr 1977).

The study area was dominated by stands of Douglas-fir (*Pseudotsuga menziesii*), interspersed with white spruce (*Picea glauca*), trembling aspen (*Populus tremuloides*), and patches of grassland (Achuff et al. 1984). Desirable forage plants for bighorn sheep, including rough fescue (*Festuca campestris*) and bluebunch wheatgrass (*Pseudoroegneria spicata*), occurred in the study area but have been negatively affected by conifer encroachment (Page 2005).

Human facilities featured prominently within the study area. The Village of Radium Hot Springs, a resort community with approximately 750 permanent residents, had about 1000 hotel rooms and two golf courses. A wide variety of activities, including motorized and non-motorized recreation, forestry, mining, and agriculture took place throughout the study area, which was bisected by provincial Highways 93 and 93/95.

Methods

We carried out ecological restoration work on the Redstreak benches in the winters of 2002 and 2003. This consisted of thinning trees to an average of 8 m spacing with retention of individual and small clumps of veteran trees. We also completed brushing, piling and burning, non-native plant control measures, and a limited amount of planting of native grasses. Treatment occurred in three blocks: provincial crown land ("provincial block") treated in 2002, as well as federal crown land belonging to Kootenay National Park ("federal block") and in and around Redstreak campground ("campground block") in Kootenay National Park, both treated in 2003. The campground block treatments had additional objectives of ensuring facility protection and safeguarding against future wildfire or prescribed fire, but were expected to provide ecological benefits similar to the other treatment blocks. In total, 173 ha of land were treated, comprising 9.0% of sheep winter range as defined by the 95% fixed kernel density function for all sheep winter (October through April) telemetry points.

We captured bighorn sheep by free-range darting while the sheep occupied their winter ranges, between January and March inclusive. We used a combination of xylazine-ketamine, or occasionally xylazine-telazol or ketamine-medetomidine (Dibb 2007). We selected adult animals only, and aimed for a ratio of 6 females to 4 males. We selected one-half to three-quarter curl rams, but avoided selecting full-curl rams since those animals could experience increased mortality risk during the fall hunting season. All study animals were fitted with GPS radio collars (Avanced Telemetry Systems Inc., Isanti, MN) programmed to log two or more GPS locations per day for up to 12 months, covering at least the period from just prior to study animals leaving their winter range in spring to just after the animals return to their winter range in the fall. Collars were removed in November or December and were unavailable for approximately 8 weeks during annual refurbishment. Refurbished collars then were deployed on a new sample of sheep for the subsequent year.

We assessed bighorn response by using a GIS to determine the number of telemetry points inside and outside the

Table 1. Bighorn sheep daily telemetry locations inside restoration areas, 2002 and 2004.

	Locations in Restoration Area					
	2002		2004			
	N	% Inside	N	% Inside	χ2	P
Females and males; all months	1830	1.0	1721	8.9	121.0	<0.001
Females and males; Mar-Apr	466	1.1	329	20.4	87.1	<0.001
Females; Mar-Apr	329	0.0	183	10.9	37.4	<0.001
Males; Mar-Apr	137	3.6	146	32.2	38.4	<0.001
Females; May	113	0.9	137	19.0	21.0	<0.001
Males; May	78	1.3	117	12.8	8.3	0.004

restoration area in each period during each year from 2002 to 2004. We considered the 2002 data, collected before completion of the restoration work, to be pre-treatment data. The telemetry data used for the comparison was limited to a maximum of one point per day from daylight hours to reduce the potential for temporal autocorrelation of successive data points, and was restricted to 3D GPS points with position dilution of precision (PDOP) values of less than 6.0, guided by British Columbia Resource Inventory Committee standards (Geographic Data BC 2001). We made various comparisons based on particular months and sex classes. Pre-treatment and post-treatment telemetry results among years were compared using chi-square tests and Fisher's Exact Test (O'Rourke et al. 2005). We compared the average annual days of use of the restoration area per animal among the three years of the study using two-sample t-tests (Schlotzhauer and Littell 1997). We examined several terrain variables in order to make habitat comparisons between restoration sites and other winter range areas: slope and aspect were calculated from a 30-m resolution digital elevation model, and elevation was derived directly from GPS telemetry data or from the digital elevation model. We characterized space use of sheep in selected periods of each year using 90% fixed kernel density functions provided in the Animal Movements extensions for ArcView 3.3 (Hooge and Eichenlaub 1997).

Results

Bighorn sheep made increasing use of the restoration areas over the period from 2002 to 2004 (χ^2 = 121.0, $P \leq 0.001$). Pooled location data for both sexes over the entire year yielded an increase in the use of treatment habitat from 1.0% (percentage of total daily points in restoration area) in 2002 to 3.2% in 2003 to 8.9% in 2004 (Table 1).

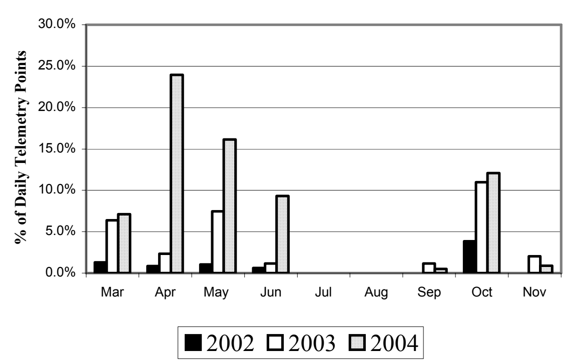

Figure 2. Bighorn sheep use of restoration areas by month. Restoration treatments were completed by March 2003.

Most use of the restoration area occurred in March through June, prior to the sheep migrating to their lambing or summer ranges, and in October, when the sheep were moving between summer and winter ranges (Figure 2). We collected few sheep GPS points in December through February during annual collar refurbishment, but ground surveys of the restoration area confirmed that little use occurred during this period. In March and April 2002 1.1% of location points for both sexes were within the restoration area (Table 1). By 2004 this increased to 20.4% (χ^2 = 87.1, $P \leq 0.001$). The 90% fixed kernel density function for location points in March and April in each year illustrates that sheep extended their occupied habitat east to include the campground and federal blocks by 2004 (Figure 3). Use of the restoration area by rams in this same period increased from 0% in 2002 to 32.2% in 2004 (χ^2 = 38.4, $P \leq 0.001$). For female sheep the effect appeared to be strongest in May, with use increasing from 0.9% in 2002 to 19.0% in 2004 (χ^2 = 21.0, $P \leq 0.001$).

The increased use of the restoration area was distributed among all study animals in the post-treatment years of our study. In 2002, prior to treatment, 6 of 10 animals were recorded on at least 1 day within the boundaries of the restoration sites (range = 1–5, SD = 2.0) for an average of 1.8 days per animal. In 2003, all 10 study animals were recorded using the restoration area (range = 1-25, SD = 7.4) for an average of 73 days per animal. . In 2004, all nine study animals

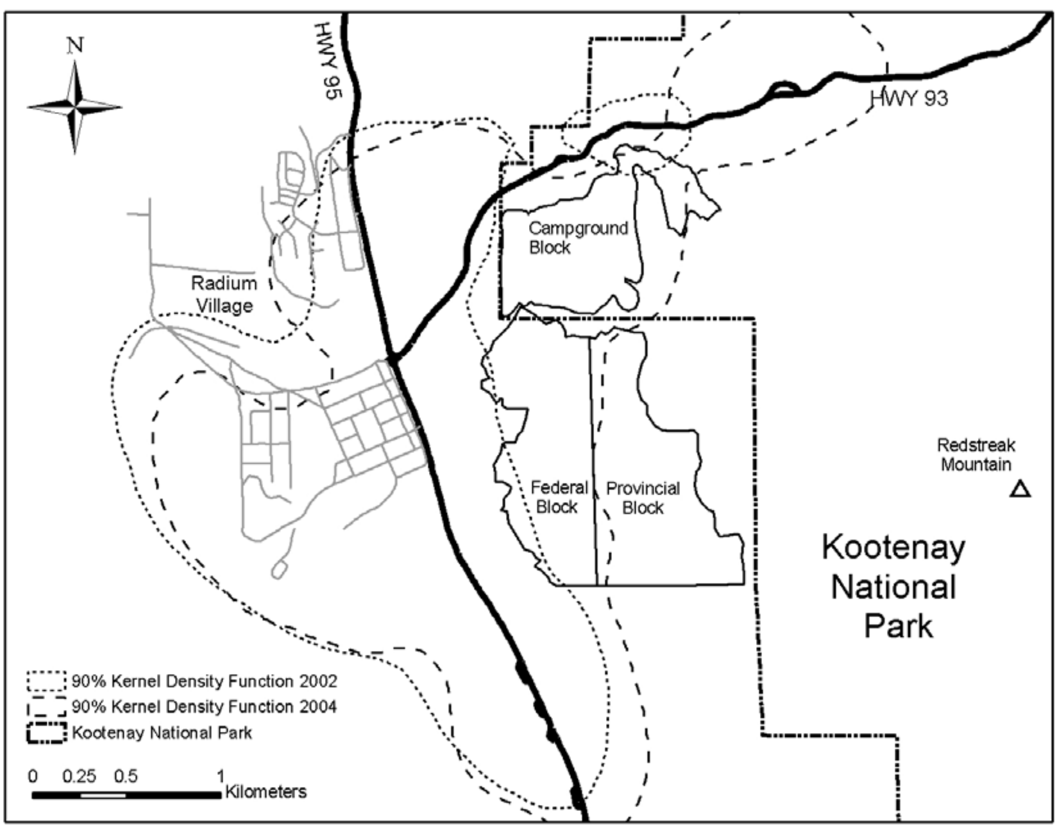

Figure 3. Pre-treatment (2002) and post-treatment (2004) 90% fixed kernel density functions for daily telemetry points of all collared bighorn sheep in March and April.

used the restoration area (range = 1-43, SD = 15.6) for an average of 17.0 days per animal. The difference in average annual days of use per animal from 2002 to 2004 was 15.2 ($T_{17} = 3.06$, $P = 0.007$; Figure 4).

Sheep made far greater post-treatment use of the federal and campground blocks treated in 2003 than they did of the provincial block treated in 2002. Of 244 daily telemetry points within the combined restoration areas recorded in all three years of our study, only one point (in 2003) was within the provincial block even though this block comprised 40.1% of the treated area. Slopes in the provincial block ranged from 0^o to 23.2^o and averaged 9.2^o (SD = 4.96), and were similar to those in the combined federal and campground blocks (range of 0^o to 25.7^o, average of 9.36^o, SD = 5.11). These slopes also were similar to the average slope of 11.6^o (SD = 8.9, n = 2060) selected by sheep over the entire study area in winter, but are much gentler than the average slope of 25.3^o (SD = 12.2, n = 3776) selected in summer. There was little difference in the elevations of restoration sites, with the federal and campground blocks averaging 1057.0 m (SD = 48.7) and the provincial block averaging 1010.3 m (SD = 19.3).

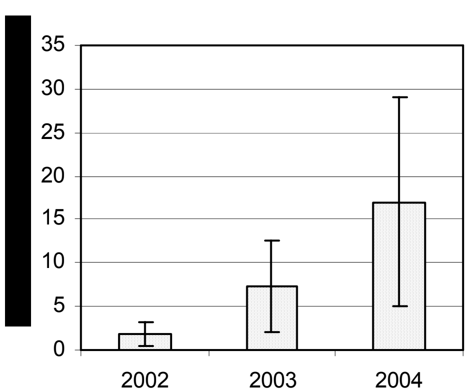

Figure 4. Average annual number of daily telemetry points in restoration area per animal, 2002 to 2004. Error bars represent 95% confidence intervals.

These elevations all were slightly higher than average elevations selected by sheep in winter (914.0 m, SD = 98.3, n = 2060). We also detected little difference in the slope aspects characterizing the restoration sites, with subdued east and west aspects being prevalent on most sites. Post-treatment overstory and understory vegetation characteristics were broadly similar on the federal and provincial blocks (Page 2005), although some areas within the campground block retained greater cover in order to provide visual screening and privacy for campers.

Discussion

Most post-treatment use of the restoration area by bighorn sheep occurred in October, and March through June, periods when prior to treatment the sheep were still on winter range elsewhere in the Radium area. We speculate that this reduced the amount of bighorn grazing pressure on limited natural winter range, although the sheep also used artificial grasslands that do not seem to be in short supply, such as lawns and golf course fairways. In all three years of our study, the sheep selected rutting ranges (November through December) and post-rut winter ranges (January through February) almost exclusively in Radium village, on the golf course, and along highway 93/95 road allowances, with some use of natural habitats on the edge of these developed areas. This continued use of artificial habitats during November through February could have been a response to the availability of high quality forage prior to normal green-up, due to the shallower snow packs on the lower elevation artificial habitats, or simply a result of strong traditional affinity to these sites. The restoration areas seem to be used as fall and spring “transitional” ranges between summer and winter ranges. The restored sites provide sheep the opportunity to forage on mainly native plants in areas with relatively little human activity, thereby reducing the potential for habituation. Use of these sites also may reduce interactions with domestic dogs and reduce the risk of collisions with motor vehicles. Continued monitoring of the sheep population will be needed to assess how sheep respond to expected recovery of forage plants in the restoration sites, and whether after a period of adaptation sheep will begin to adjust their rut and post-rut ranges in response to the availability of these restored habitats.

Sheep did not make significantly more post-treatment use of the 2002 restoration site (provincial block) compared to pre-treatment use in spite of this site having terrain and vegetation characteristics similar to the 2003 treatment sites. The 2003 sites were immediately adjacent to occupied sheep winter range, whereas the 2002 site was 500 to 1500 m distant. In addition, anecdotal observations of sheep from the five years prior to our study indicate that at least some sheep made occasional prior use of the 2003 sites, but not the 2002 site (Parks Canada, unpublished data). We believe this is consistent with the hypothesis that bighorn sheep are reluctant to colonize available habitats that are not immediately contiguous with currently occupied habitats (Geist 1971, Smith et al. 1999, Arnett et al. 1998). Since the 2003 federal block was located adjacent to the provincial block and is now used by sheep, it remains possible that sheep will eventually colonize the 2002 block. Continued monitoring of the population will be useful in determining the extent to which this occurs.

Researchers developing bighorn sheep habitat models typically define escape terrain as slopes exceeding approximately 27^{o} and suitable habitat in a narrow buffer of escape terrain, usually 100 to 300 m wide (Singer et al. 2000, Zeigenfuss et al. 2000, Tremblay 2001, McKinney et al. 2003). Similarly, observational or telemetry evidence indicates bighorn sheep prefer slopes exceeding 31^{o} (Fairbanks et al. 1987) or even exceeding 45^{o} (Risenhoover and Bailey 1985, Rubin et al. 2002). Female desert bighorns (*Ovis canadensis mexicana*) using urban environments selected areas with gentler slopes than did a neighboring population that did not use urban areas, although even the urban sheep selected slopes greater than 55^{o} relative to availability (Rubin et al. 2002). These authors determined that adult survival rates were similar in the two areas, but lamb survival was low in the urban population, suggesting increased predation due to use of riskier terrain. Our results indicate that bighorn sheep at Radium generally did not winter on or close to escape terrain, either within the restoration areas or elsewhere on their winter range. We speculate that optimal foraging behavior and predator avoidance may have led to selection in winter of human-dominated habitats with relatively flat terrain. Predation rates were low during our study, but the use of urban habitats exposes sheep to increased risk of mortality from motor vehicle collisions. Mortality of 5 collared sheep included 3 due to highway collisions, 1 due to disease, and 1 suspected due to a fall; no predation was recorded.

Management implications

Mechanical treatments designed to mimic natural open forest ecosystems can result in a rapid increase of use by bighorn sheep, particularly when the treated areas are adjacent to occupied habitat. We recommend application of similar treatments at Radium and elsewhere in southeastern British Columbia to maintain bighorn winter and transitional range. Similar treatments also might be applicable to movement corridors. The scale of the forest ingrowth problem is such that prescribed fire, as well as mechanical treatment, will be necessary to treat large areas and to treat steep slopes or other areas where mechanical techniques may be impractical. We recognize that in many cases treatment costs will not be offset by revenue generated from sales of harvested wood, and that treatment areas may have to be priorized. Consequently, it will be important to continue monitoring the response of bighorn sheep to different treatments in order that limited resources available to carry out treatments can be targeted to have the most benefit. In particular we recommend monitoring bighorn sheep response to prescribed or natural wildfire, and monitoring over long enough periods to assess whether and how sheep adapt over time to the availability of new habitat. We also recognize that the loss of habitat to forest ingrowth is detrimental to other species and ecological processes beyond bighorn sheep. Restoration of these other ecological values is part of the greater research and management program of the region, but is beyond the scope of this paper.

Urban development is proceeding rapidly in southeastern British Columbia but little information is available on the effects such development may have on bighorn sheep. Our results suggest the potential value of manipulating habitat for bighorn sheep in an experimental context with the aim of enabling sheep to occupy natural sheep habitat where they are less at risk of mortality from predation, motor vehicle collisions, or disease from domestic livestock. At Radium Hot Springs this could be achieved by restoration of habitats within or near escape terrain and adjacent to currently occupied sheep ranges. These results could be used in managing sheep populations on the urban fringe of other areas.

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