Recommendations for Applying Management Buffers to Mitigate Zone-of-Influence Impacts from Oil and Gas Activities on Terrestrial Wildlife and Habitats in British Columbia

Prepared for:

BC Oil and Gas Commission

399 Harbour Road

Victoria, BC

Prepared by:

Steven F. Wilson, Ph.D., R.P.Bio.

EcoLogic Research

302-99 Chapel Street

Nanaimo, BC

Steven.wilson@ecologicresearch.ca

30 March 2016

Executive Summary

A “management buffer” is an area around an ecological or resource feature where industrial activity is restricted or prohibited. A “zone of influence” is the difference between an activity’s spatial footprint and the extent of the activity’s effects on surrounding habitat and wildlife populations. Creation of edges, as well as noise and activity associated with industrial sites and roads, are the major stressors that generate zones of influence. These stressors create cascading effects that can result in altered ecosystems through a variety of mechanisms. This report presents recommendations for applying management buffers to mitigate the zone-of-influence impacts of oil and gas activities.

Establishing management buffers could be considered for the following designations under the *Environmental Protection and Management Regulation*:

1. Wildlife Habitat Areas (WHAs) of <100 ha;
2. Wildlife Habitat Features (WHFs); and,
3. Karst Resource Features.

The following is proposed guidance for management buffers:

1. No land clearing (defined as tree removal or disturbance to mineral soil) <100 m from boundaries of designated areas;
2. No construction during the breeding season (1 March to 31 July, depending on species) <700 m from boundaries of designated areas established for breeding birds or other high priority wildlife that rely on auditory cues for successful reproduction; and,
3. No placement of compressor stations (or similar facilities designed for continuous operation and generating similar noise) <700 m from boundaries of areas described in (2).

Operational guidance for conducting oil and gas activities should continue to apply (BC Oil and Gas Commission 2015).

Variances from guidance could be allowed under the following circumstances (if signed off by a qualified professional):

1. Active mitigation such as noise abatement;
2. Use of topographical or other barriers to isolate activity and noise from the designated area;
3. Explicit inclusion of buffers around features within the boundaries of designated areas, as described in legal orders;
4. Other evidence that there will be no material adverse effect to the feature by reducing buffers.

In addition, a 100-m buffer could be applied to the current Surface Land Use (SLU) coverage to represent the zone-of-influence of anthropogenic edges on abiotic factors and corresponding effects on habitat in large designated areas such as UWRs, OGMAs, WHAs established for wide-ranging species, or on the matrix of habitats located outside designated areas.

Broader application of management buffers should not be considered until the SLU coverage is revised to accommodate vegetation regrowth and to distinguish among features associated with different types of activities.

Table of Contents

List of Figures

Introduction

Regulation of oil and gas activities in British Columbia (BC) is tied directly to land tenure. Boundaries define areas where proponents are allowed to conduct specific activities under permit; however, laws and regulations governing land use in BC recognize that some industrial activities that occur within permitted areas can have impacts that extend beyond permitted boundaries, such as water consumption or redirection, and the release of deleterious substances into air and water.

Recently there have been provincial and federal policy developments that accommodate impacts to wildlife populations and habitats that can occur outside of project footprints. Wilson (*in press*) reviewed the current state of science regarding these "zone of influence" impacts and this report presents recommendations for applying management buffers to mitigate the zone-of-influence impacts of oil and gas activities regulated by the BC Oil and Gas Commission (hereafter "the Commission").

Background

A "zone of influence" is the difference between an anthropogenic activity's spatial footprint and the extent of the activity's effects on surrounding habitat and wildlife populations. Creation of edges, as well as noise and activity associated with industrial sites and roads, are the major stressors that generate zones of influence. These stressors create cascading effects that can result in altered ecosystems through a variety of mechanisms (Figure 1).

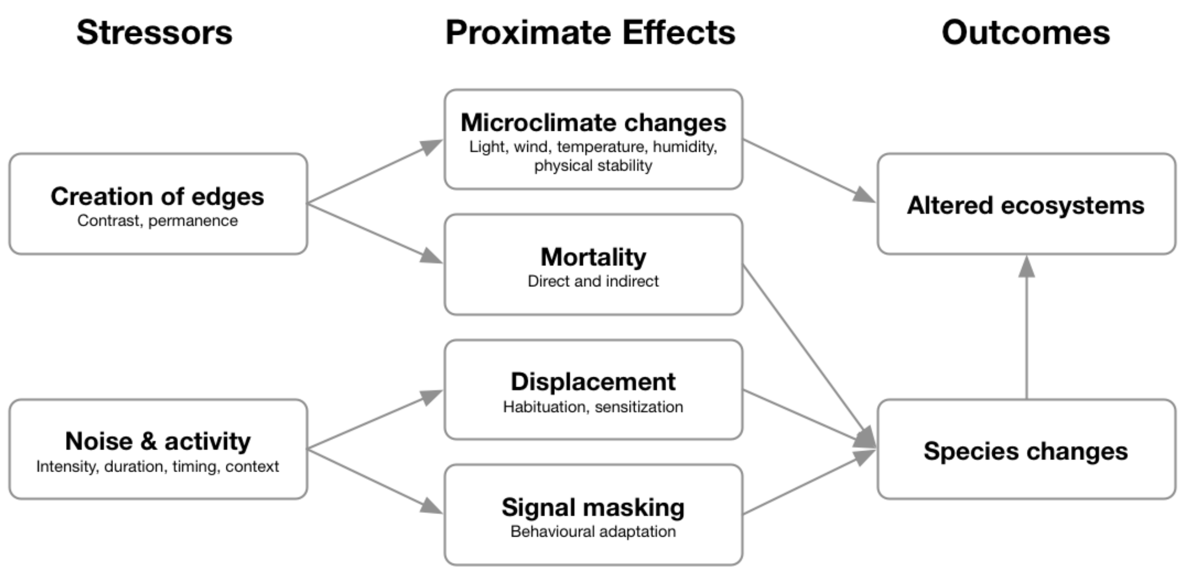

Figure 1. Conceptual framework of zone of influence impacts characterized by potential anthropogenic stressors generated by oil and gas activities and their possible causal effects on wildlife and habitat.

The effects on ecological systems of habitat edges, noise and activity has been the focus of significant research, but the lack of a common analytical framework among studies has contributed to a lack of a consensus on impacts (e.g., Yahner 1988, Paton 1994, Murcia 1995, Parker et al. 2005, Frances and Barber 2013). Basic definitions (e.g., "edge;" Murcia 1995) and associated metrics (e.g., noise characteristics; Francis and Barber 2013) have differed, and treatment effects have often been confounded (e.g., edge effects and patch size; Parker et al. 2005). In addition, many studies have measured zones of influence by correlating displacement or reproductive success with distance from anthropogenic features without assessing the independent effects of individual variation, habitat, noise, activity, or secondary effects such as predation risk (Appendix I).

Broad conclusions regarding zone-of-influence impacts that can be drawn from the literature include:

1. Abiotic (e.g., wind, solar radiation, etc.) and subsequent vegetation changes resulting from edge creation penetrate into surrounding native ecosystems from 30 to >240 m (Chen et al., 1995), although most studies have reported distances of <100 m (Murcia 1995, Avon et al. 2010).
2. Noisy oil and gas facilities (e.g., compressor stations but not wells) can alter songbird abundance at distances up to 700 m (Bayne et al. 2008). Other, correlational studies have recorded effects at much larger distances for some systems (e.g., grassland birds and highways [Kaseloo 2005]).
3. Avoidance of human infrastructure has been studied extensively for ungulates, particularly for woodland caribou (*Rangifer tarandus caribou*). Reported avoidance distances vary between 0 and 5,000 m (Environment Canada 2011), although the most commonly cited distances are <250 m for roads, 100-250 m for seismic lines and 250-1000 m for well sites (Dyer 1999). The mechanisms causing this avoidance are unclear.
4. Zone-of-influence impacts on other species or guilds have been studied only rarely (Robinson et al. 2010).

It is important to emphasize that a zone of influence does not imply a total loss of habitat (Hebblewhite 2011). The distances listed above are the maximums detected through research, and wildlife use is expected to occur to some extent throughout these zones.

Recommendations

Legal, Regulatory and Policy Mechanisms to Protect Wildlife and Habitat

Government's Environmental Objectives are defined for the Commission in the *Oil and Gas Activities Act* (OGAA) and in the Environmental Protection and Management Regulation (EPMR). Section 6 of the EPMR addresses objectives for wildlife and habitat. Protection is enabled through the following mechanisms:

1. Riparian Reserve Zones (RRZs) and Riparian Management Areas (RRAs);
2. Old Growth Management Areas (OGMAs);
3. Ungulate Winter Ranges (UWRs) established for species defined by ministerial order (Appendix II);

4. Wildlife Habitat Areas (WHAs) established for species at risk defined by ministerial order (Appendix III);
5. Wildlife Habitat Features (WHFs) defined by ministerial order for significant mineral licks and wallows, nests of Bald Eagles, Ospreys, Great Blue Herons and bird species-at-risk, or other localized features;
6. Resource Features established to protect surface or subsurface karst systems; and,
7. Prohibitions on physical disturbance of "high priority wildlife" or their habitat.

As of March 2016, a ministerial order for WHFs had not yet been established and policy guidance for management of high priority wildlife was under development.

In addition to the EPMR, Area-based Management (ABA) provides policy guidance for managing rates of incursions in old forest and riparian habitats (BC Oil and Gas Commission 2014a). Guidance will be expanded in future to address additional wildlife and habitat values.

There are two, general strategies that can be used to mitigate zones of influence and reduce potential impacts on important ecological and resource features:

1. On-site mitigations, which are actions taken on permitted areas to reduce the size of the zone of influence of industrial activities; and,
2. Applying a management buffer, which is an area around an ecological or resource feature where industrial activity is restricted or prohibited.

Applying on-site mitigations versus management buffers involves trade-offs. On-site mitigations can increase costs for project proponents, while application of management buffers can increase opportunity costs by limiting development. A mix of both strategies can be also appropriate.

On-site mitigations for many oil and gas activities are required under the EPMR and riparian areas are managed through application of management buffers and practice requirements (BC Oil and Gas Commission 2015). The following recommendations focus on application of management buffers to circumstances identified in the scientific literature where BC's current regulatory and practice requirements may be insufficient to mitigate unacceptable impacts.

Application of Management Buffers

Management buffers could be considered for the following designations under the *Environmental Protection and Management Regulation* (EPMR):

1. Wildlife Habitat Areas (WHAs) of <100 ha;
2. Wildlife Habitat Features (WHFs); and,
3. Karst Resource Features.

Management buffers are most useful for managing zone-of-influence effects for relatively small WHAs because edge effects can affect a larger proportion of small WHAs than large WHAs. In addition, small WHAs are usually established for sessile values (e.g., rare plants, ecological communities or breeding sites) or for wildlife species with limited mobility. These values are more likely to be affected by activities in close proximity to boundaries. WHFs and karst Resource Features are usually small and therefore also have a high ratio of edge-to-area.

Guidance for Management Buffers

The following is proposed guidance for management buffers:

1. No land clearing (defined as tree removal or disturbance to mineral soil) <100 m from boundaries of designated areas;
2. No construction during the breeding season (1 March to 31 July, depending on species; BC Ministry of Environment 2009) <700 m from boundaries of designated areas established for breeding birds or other high priority wildlife that rely on auditory cues for successful reproduction; and,
3. No placement of compressor stations (or similar facilities designed for continuous operation and generating similar noise) <700 m from boundaries of areas described in (2).

Operational guidance for conducting oil and gas activities should continue to apply (BC Oil and Gas Commission 2015).

Allowable Variances from Guidance

Variances from guidance could be allowed in the following circumstances (if signed off by a qualified professional):

1. Active mitigation such as noise abatement;
2. Use of topographical or other barriers to isolate activity and noise from the designated area;
3. Explicit inclusion of buffers around features within the boundaries of designated areas, as described in legal orders;
4. Other evidence that there will be no material adverse effect to the feature by reducing buffers.

Application of Zones-of-influence to Characterize the Industrial Footprint

Applying management buffers to large designated areas for wide-ranging species is of limited value because edge-to-area ratios are small and boundaries of designated areas for wide-ranging species are defined with lower precision than for more sessile species. In addition, buffers are not a practical management technique for common ecosystems that are nonetheless important for maintaining general biodiversity. However, the zone-of-influence concept is still useful for estimating the cumulative, landscape impact of industrial activity.

The Commission maintains a spatial database of all anthropogenic disturbances in northeast BC. This Surface Land Use (SLU) coverage is updated regularly and is a foundational dataset that informs permitting decisions in the context of ABA. SLU does not currently consider zones of influence, but it could be modified to do so. This could provide a more complete estimate of the extent of human-related incursions into large designated areas such as UWRs, OGMAs, WHAs established for wide-ranging species such as caribou, or into the matrix of habitats located outside designated areas.

As with all characterizations of a complex land base, SLU is associated with a variety of analysis assumptions and is only as accurate as currently available data allow; however, it represents the best estimate of the state of the industrial land base in northeast BC. SLU captures oil and gas activities, non-oil and gas activities, geophysical features and forestry cutblocks as separate classes of features, and maps their actual footprint as accurately as possible. Currently there is no additional stratification to distinguish between permanent and seral disturbances (beyond cutblocks) and no associated assumptions are made regarding regeneration or restoration. In addition, sites used for different types of oil and gas activities (e.g., compressor stations versus well sites) are not currently differentiated.

Because all of the features mapped by SLU are by definition associated with anthropogenic edges, the 100-m estimate of abiotic and biotic influence cited above could be applied to the coverage, although doing so would over-estimate edge effects associated with the following features:

1. Restoration activities conducted on former oil and gas operating sites;
2. Vegetation regrowth on conventional seismic lines; and,
3. Geophysical features that follow low-impact guidelines.

All of these features are characterized by lower edge contrast than recently cleared or permanent features and are likely associated with small zones of influence. Over 65% of SLU is composed of conventional and low-impact geophysical features (BC Oil and Gas Commission 2014b), so accommodating the mitigating effects of vegetation regrowth and low-impact practices could have a significant effect on estimates of impacts.

An analysis of the current SLU coverage in relation to available boreal caribou (*Rangifer tarandus caribou*) data from northeast BC found no evidence of overall avoidance of SLU at any buffer distance (Appendix IV). There was evidence of avoidance of non-oil and gas activities and of cutblocks; however, these features comprise only a small proportion of the SLU dataset. An analysis that considers habitat suitability and interactive factors in relations to a revised SLU that further stratifies the characteristics of the industrial footprint is likely to reveal evidence of avoidance, consistent with published research (e.g., Environment Canada 2011, Wilson and DeMars 2015); however, there is currently no evidence of a threshold distance that can be applied generally to SLU to represent a zone-of-influence impact on caribou.

Based on the rationale presented above, I recommend applying a 100 m buffer to SLU to represent the zone-of-influence of anthropogenic edge on abiotic factors and effects on habitat, but larger buffers should not be applied until the SLU coverage is further refined and additional analyses suggest a threshold distance of wildlife avoidance.

Opportunities to Improve Recommended Guidance

The following opportunities to improve the recommended guidance for zones of influence could be considered:

- Continue to refine the stratification of SLU to distinguish among features that are associated with activities with different zones-of-influence (e.g., relatively noisy compressor station versus relatively quite well sites);
- Support additional analyses of wildlife use data that examine the effects of proximity to oil and gas infrastructure, particularly in relation to factors that interact with anthropogenic features;
- Support research and adaptive management trials in northeast BC that assess the effectiveness of measures intended to mitigate zones of influence (e.g., noise abatement).

Literature Cited

Avon, C., L. Bergès, Y. Dumas, and J.-L. Dupouey. 2010. Does the effect of forest roads extend a few meters or more into the adjacent forest? A study on understory plant diversity in managed oak stands. Forest Ecology and Management 259:1546-1555.

Bayne, E. M., L. Habib, and S. Boutin. 2008. Impacts of chronic anthropogenic noise from energy-sector activity on abundance of songbirds in the boreal forest. Conservation Biology 22:1186-1193.

BC Ministry of Environment. 2009. Peace region least-risk timing windows: biological rationale. Ecosystem Section, Fort St. John. http://www.env.gov.bc.ca/esd/distdata/Peace_Region_Wildlife_Values/Industrial_Sectors/Best_Management_Practices/MoE%20Timing%20Windows%20Rationale%20Final.pdf.

BC Oil and Gas Commission. 2014a. Area-based analysis results for northeast British Columbia. http://www.bcogc.ca/node/11653/download.

BC Oil and Gas Commission. 2014b. Oil and gas land use in northeast British Columbia. http://www.bcogc.ca/node/12908/download.

BC Oil and Gas Commission. 2015. Environmental protection and management guideline. Version 2.1. http://www.bcogc.ca/node/5899/download.

Benítez-López A, R. Alkemade, P. A. Verweij. 2010. The impacts of roads and other infrastructure on mammal and bird populations: a meta-analysis. Biological Conservation 143:1307-16.

Chen, J., J. F. Franklin, and T. A. Spies. 1995. Growing-season microclimate gradients from clearcut edges into old-growth Douglas-fir forests. 5:74-86.

Dyer, S. J., J. P. O'Neill, S. M. Wasel, and S. Boutin. 2001. Avoidance of industrial development by woodland caribou. Journal of Wildlife Management 65:531-542.

Environment Canada. 2011. Scientific assessment to inform the identification of critical habitat for Woodland Caribou (*Rangifer tarandus caribou*), boreal population, in Canada: 2011 Update. Ottawa, ON.

Environment Canada. 2012. Recovery Strategy for the woodland Caribou (*Rangifer tarandus caribou*), boreal population, in Canada. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa, ON.

Esseen, P.-A., and K.-E. Renhom. 1998. Edge effects on an epiphytic lichen in fragmented forests. Conservation Biology 12:1307–1317.

Flaspohler, D. J., S. A. Temple, and R. N. Rosenfield. 2001. Species-specific edge effects on nest success and breeding bird density in a forested landscape. Ecological Applications 11:32-46.

Francis, C. D., and J. R. Barber. 2013. A framework for understanding noise impacts on wildlife: an urgent conservation priority. Frontier in Ecology and the Environment 11:305-313.

Harper, K. A., and S. E. Macdonald. 2002. Structure and composition of edges next to regenerating clear-cuts in mixed-wood boreal forest. Journal of Vegetation Science 13:535-546.

Harper, K. A., S. E. Macdonald, P. J. Burton, J. Chen, K. D. Brosofske, S. C. Saunders, E. S. Euskirchen, D. Roberts, M. S. Jaiteh, and P.-A. Esseen. 2005. Edge influence on forest structure and composition in fragmented landscapes. Conservation Biology 19:768-782.

Hebblewhite, M. 2011. Effects of energy development on ungulates. Pages 71-94 in E. Naugle [editor]. Energy development and wildlife conservation in western North America. Island Press, Washington, DC.

Hylander, K. 2005. Aspect modifies the magnitude of edge effects on bryophyte growth in boreal forests. Journal of Applied Ecology 42:518-525.

Johnson, C. J., L. P. W. Ehlers, and D. R. Seip. 2015. Witnessing extinction – cumulative impacts across landscapes and the future loss of an evolutionarily significant unit of woodland caribou in Canada. Biological Conservation 186:176-186.

Kaseloo P. A. 2005. Synthesis of noise effects on wildlife populations. Pages 33-35 in: C. L, Irwin, P. Garrett, K. P. McDermott (editors). Proceedings of the 2005 International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC.

Kasworm, W. F., and T. L. Manley. 1990. Road and trail influences on grizzly bears and black bears in northwest Montana. International Conference on Bear Research and Management 8:79-84.

Kroodsma, R. L. 1982. Edge effect on breeding forest birds along a power-line corridor. Journal of Applied Ecology 19:361-370.

Moen, J., and B. Gunnar Jonsson. 2003. Edge effects on liverworts and lichens in forest patches in a mosaic of boreal forest and wetland. Conservation Biology 17:380-388.

de Molenaar, J. G., M. E. Sanders, and D. A. Jonkers. 2006. Road lighting and grassland birds: local influence of road lighting on a black-tailed godwit population. Pages 114-136 in: C. Rich and T. Longcore (editors). Ecological consequences of artificial night lighting. Island Press, Washington, DC.

Murcia, C. 1995. Edge effects in fragmented forests: implications for conservation. Trends in Ecology and Evolution 10:58-62.

Parker, T. H., B. M. Stansberry, C. D. Becker, and P. S. Gipson. 2005. Edge and area effects on the occurrence of migrant forest songbirds. Conservation Biology 19:1157-1167.

Paton, P. W. C. 1994. The effect of edge on avian nest success: how strong is the evidence? Conservation Biology 8:17-26.

Polfus, J. L., M. Hebblewhite, & K. Heinemeyer. 2011. Identifying indirect habitat loss and avoidance of human infrastructure by northern mountain woodland caribou. Biological Conservation 144:2637-2646.

Robinson, C., P. N. Duinker, and K. F. Beazley. 2010. A conceptual framework for understanding, assessing, and mitigating ecological effects of forest roads. Environmental Review 18:61-86.

Thompson, S. J., D. H. Johnson, N. D. Niemuth, and C. A. Ribic. 2015. Avoidance of unconventional oil wells and roads exacerbates habitat loss for grassland birds in the North American great plains. Biological Conservation 192:82-90.

Wilson, S. F. Managing zone-of-influence impacts of oil and gas activities on terrestrial wildlife populations in British Columbia. Journal of Ecosystems and Management, *in review.*

Wilson, S. F., C. A. DeMars. 2105. A Bayesian approach to characterizing habitat use and impacts of anthropogenic features on woodland caribou (*Rangifer tarandus caribou*) in northeast British Columbia. Canadian Wildlife Biology and Management 4:107-118.

Yahner, R. H. 1988. Changes in wildlife communities near edges. Conservation Biology 2:333-339.

Appendix I. Summary of Maximum Zones of Influence Reported for terrestrial wildlife and ecosystems

Stressor	Proximate effects and outcomes	Maximum estimated radius of zones of influence (m)	References	Notes
Creation of edges	Light, temperature, moisture in temperate forests	>240	Chen et al. (1995)	Review of available literature for temperate and tropical forests found effects generally extended <50 m (Murcia 1990), which has been corroborated by more recent studies (e.g., Avon et al. 2010)
	Vegetation characteristics in temperate forests	56	Murcia (1995)	Review of available literature for temperate and tropical forests
	Non-vascular plants in boreal forests	50	Moen and Gunnar Jonsson (2003), Hylander (2005), Esseen and Renhom (1998)	
	Structure and composition of mixed-wood boreal forests	60	Harper and Macdonald (2002)	
	Structure and composition among various forest types	<100	Harper et al. (2005)	Review of 44 published studies
	Songbird density in temperate deciduous forest	60	Kroodsma (1982)	Measured next to a powerline corridor, presumably without appreciable noise or activity
	Avian nest success in forests and mixed habitats	50	Paton (1994)	Review of 26 papers focused on predation and brood parasitism of natural and artificial nests
	Avian nest success in temperate forests	300	Flaspohler et al. (2001)	
Light	Breeding bird abundance in	300	de Molenaar et al. (2006)	

Stressor	Proximate effects and outcomes	Maximum estimated radius of zones of influence (m)	References	Notes
	grassland near highways			
Noise & activity	Avoidance of road, single-bore and multi-bore well pads by grassland birds	350	Thompson et al. (2015)	Varied by species, largest avoidance distances for single-bore well pads
	Bird abundance in grassland and woodlands	3,530	Kaseloo (2005)	Review of 19 studies; largest distances for grassland birds near highways with high traffic volumes
	Songbird abundance in boreal forest	700	Bayne et al. (2008)	Based on noise from compressor stations
	Grizzly and black bears avoidance of roads in interior wet belt forests	914	Kasworm and Manley (1990)	
	Ungulate avoidance of well sites	2000	Hebblewhite (2011)	Review of 8 studies
	Ungulate avoidance of roads	2700	Hebblewhite (2011)	Review of 8 studies
All	Birds and infrastructure in a variety of habitats	1000	Benítez-López et al. (2010)	Meta-analysis of studies related to 201 species
	Woodland birds in temperate forests near roads	800	Forman and Deblinger (2000)	Both edge and noise effects
	Mammals and infrastructure in a variety of habitats	5000	Benítez-López et al. (2010)	Meta-analysis of studies related to 33 species
	Boreal ecotype caribou and anthropogenic footprint	500	Environment Canada (2012)	Recommendation based on relevant literature

Stressor	Proximate effects and outcomes	Maximum estimated radius of zones of influence (m)	References	Notes
	Northern ecotype caribou avoidance of infrastructure	4250	Polfus et al. (2011), Johnson et al. (2015)	Highest for oil and gas features in South Peace region of BC, as low as 1000 m for roads

Appendix II. Categories of Ungulate Species

BRITISH COLUMBIA
The Best Place on Earth

Attachment 1 (b)
ORDER: CATEGORY OF UNGULATE SPECIES

This order is given under the authority of section 29(c) of the Environmental Protection and Management Regulation (B.C. Reg. 200/2010) (EPMR) under the *Oil and Gas Activities Act*.

The Minister of Environment orders that the species outlined in Schedule 1 are ungulate species for which an ungulate winter range may be established under the EPMR.

Schedule 1 – Category of Ungulate Species

English Name	*Scientific Name*
Mule and Black-tailed Deer	*Odocoileus hemionus*
White-tailed Deer	*Odocoileus virginianus*
Elk	*Cervus canadensis*
Mountain Goat	*Oreamnos americanus*
Caribou (3 populations: boreal, southern mountain, northern mountain)	*Rangifer tarandus*
Bighorn Sheep	*Ovis canadensis*
Thinhorn Sheep	*Ovis dalli*
Moose	*Alces americanus*

Signed this 18 day of July, 2011
Honourable Terry Lake, Minister

Appendix III. Categories of Species-at-risk

BRITISH COLUMBIA
The Best Place on Earth

Attachment 1 (a)
ORDER: CATEGORY OF SPECIES AT RISK

This order is given under the authority of section 29(a) of the Environmental Protection and Management Regulation (B.C. Reg. 200/2010) (EPMR) under the *Oil and Gas Activities Act.*

The Minister of Environment orders that the species outlined in Schedule 1 are identified as species at risk in the identified categories for the purposes of section 29(a) of the EMPR.

Schedule 1 – Category of Species at Risk

English Name	Scientific Name
Amphibians and Reptiles	
Blotched Tiger Salamander	*Ambystoma mavortium*
Coeur d'Alene Salamander	*Plethodon idahoensis*
Great Basin Spadefoot	*Spea intermontana*
Gopher Snake, *deserticola* subspecies	*Pituophis catenifer deserticola*
Northern Leopard Frog	*Lithobates pipiens*
Northern Red-legged Frog	*Rana aurora*
Pacific Giant Salamander	*Dicamptodon tenebrosus*
Pacific Tailed Frog	*Ascaphus truei*
Racer	*Coluber constrictor*
Rocky Mountain Tailed Frog	*Ascaphus montanus*
Western Rattlesnake	*Crotalus oreganus*
Birds	
American White Pelican	*Pelecanus erythrorhynchos*
Ancient Murrelet	*Synthliboramphus antiquus*
Bay-breasted Warbler	*Dendroica castanea*
Black-throated Green Warbler	*Dendroica virens*
Brewer's Sparrow, *breweri* subspecies	*Spizella breweri breweri*
Burrowing Owl	*Athene cunicularia*
Cape May Warbler	*Dendroica tigrina*
Cassin's Auklet	*Ptychoramphus aleuticus*
Connecticut Warbler	*Oporornis agilis*
Flammulated Owl	*Otus flammeolus*
Grasshopper Sparrow	*Ammodramus savannarum*
Great Blue Heron, *fannini* subspecies	*Ardea herodias fannini*
Great Blue Heron, *herodias* subspecies	*Ardea herodias herodias*
Hairy Woodpecker, *picoideus* subspecies	*Picoides villosus picoideus*
Lewis's Woodpecker	*Melanerpes lewis*

Long-billed Curlew	*Numenius americanus*
Marbled Murrelet	*Brachyramphus marmoratus*
Nelson's Sharp-tailed Sparrow	*Ammodramus nelsoni*
Northern Goshawk, *laingi* subspecies	*Accipiter gentilis laingi*
Northern Pygmy-Owl, *swarthi* subspecies	*Glaucidium gnoma swarthi*
Northern Saw-whet Owl, *brooksi* subspecies	*Aegolius acadicus brooksi*
Prairie Falcon	*Falco mexicanus*
Sage Thrasher	*Oreoscoptes montanus*
Sandhill Crane	*Grus canadensis*
Sharp-tailed Grouse, *columbianus* subspecies	*Tympanuchus phasianellus columbianus*
Short-eared Owl	*Asio flammeus*
Spotted Owl	*Strix occidentalis*
Western Screech-Owl, *macfarlanei* subspecies	*Megascops kennicottii macfarlanei*
White-headed Woodpecker	*Picoides albolarvatus*
White-tailed Ptarmigan, *saxatilis* subspecies	*Lagopus leucura saxatilis*
Williamson's Sapsucker, *nataliae* subspecies	*Sphyrapicus thyroideus nataliae*
Williamson's Sapsucker, *thyroideus* subspecies	*Sphyrapicus thyroideus thyroideus*
Yellow-breasted Chat	*Icteria virens*
Fish	
Bull Trout	*Salvelinus confluentus*
Cutthroat Trout, *lewisi* subspecies	*Oncorhynchus clarkii lewisi*
Vananda Creek Benthic Stickleback	*Gasterosteus* sp. 17
Vananda Creek Limnetic Stickleback	*Gasterosteus* sp. 16
Invertebrates	
Gillette's Checkerspot	*Euphydryas gillettii*
Half-moon Hairstreak	*Satyrium semiluna*
Johnson's Hairstreak	*Callophrys johnsoni*
Quatsino Cave Amphipod	*Stygobromus quatsinensis*
Sonora Skipper	*Polites sonora*
Mammals	
American Badger	*Taxidea taxus*
American Water Shrew, *brooksi* subspecies	*Sorex palustris brooksi*
Bighorn Sheep	*Ovis canadensis*
Caribou (3 populations: boreal, southern mountain, northern mountain)	*Rangifer tarandus*
Fisher	*Martes pennanti*
Fringed Myotis	*Myotis thysanodes*
Grizzly Bear	*Ursus arctos*
Keen's Myotis	*Myotis keenii*

Pacific Water Shrew	*Sorex bendirii*
Spotted Bat	*Euderma maculatum*
Vancouver Island Marmot	*Marmota vancouverensis*
Wolverine, *luscus* subspecies	*Gulo gulo luscus*
Wolverine, *vancouverensis* subspecies	*Gulo gulo vancouverensis*
Plants	
Scouler's corydalis	*Corydalis scouleri*
tall bugbane	*Actaea elata var. elata*
Plant Communities	
alkali saltgrass - Nuttall's alkaligrass	*Distichlis spicata var. stricta - Puccinellia nuttalliana*
antelope-brush / bluebunch wheatgrass	*Purshia tridentata / Pseudoroegneria spicata*
antelope-brush / needle-and-thread grass	*Purshia tridentata / Hesperostipa comata*
Douglas-fir / Alaska oniongrass	*Pseudotsuga menziesii / Melica subulata*
Douglas-fir / common juniper / clad lichens	*Pseudotsuga menziesii / Juniperus communis / Cladonia* spp.
Douglas-fir / common snowberry / arrowleaf balsamroot	*Pseudotsuga menziesii / Symphoricarpos albus / Balsamorhiza sagittata*
Douglas-fir / dull Oregon-grape	*Pseudotsuga menziesii / Mahonia nervosa*
hybrid white spruce / ostrich fern	*Picea engelmannii* x *glauca / Matteuccia struthiopteris*
ponderosa pine / bluebunch wheatgrass - silky lupine	*Pinus ponderosa / Pseudoroegneria spicata - Lupinus sericeus*
Vasey's big sagebrush / pinegrass	*Artemisia tridentata* var. *vaseyana / Calamagrosti rubescens*
water birch / roses	*Betula occidentalis / Rosa* spp.
western hemlock - Douglas-fir / electrified cat's-tail moss	*Tsuga heterophylla - Pseudotsuga menziesii / Rhytidiadelphus triquetrus*
western redcedar - Douglas-fir / vine maple	*Thuja plicata - Pseudotsuga menziesii / Acer circinatum*
western redcedar / devil's club	*Thuja plicata / Oplopanax horridus*
western redcedar / devil's club / ostrich fern	*Thuja plicata / Oplopanax horridus / Matteuccia struthiopteris*

Signed this 18 day of July, 2011
Honourable Terry Lake, Minister
Ministry of Environment

Appendix IV. Do caribou avoid Surface Land Use?

Methods

I analyzed the distribution of available GPS telemetry data for boreal caribou collected in northeast BC (http://www.bcogris.ca/sites/default/files/20150707cariboutelemetry.zip) against the June 2014 version of SLU (BC Oil and Gas Commission 2014a). I first calculated the total area of boreal caribou ranges (Environment Canada 2011) and the area of SLU within ranges. I then determined the number of GPS telemetry locations located within SLU polygons located within ranges, as well as the total number of locations within ranges.

I calculated the "selection ratio" according to the following formula:

Selection ratio = (*number of locations in SLU within ranges / number of locations within ranges) / (area of SLU within ranges / area of range)*

Ratios of <1 represented avoidance by caribou. I also repeated the analysis considering only core areas instead of range areas.

I rasterized the SLU coverage at resolutions of 100 m, 200 m, 500 m, 1000 m, and 2000 m to approximate buffers of 50 m, 100 m, 250 m, 500m, and 1000 m respectively, and then repeated the analysis of selection ratios to detect threshold distances at which the ratio approached 1, indicating no avoidance. I then stratified the analysis by SLU classes and repeated the calculation of selection ratios.

Results

Of the GPS telemetry locations available for northeast BC, 98,017 were located within boreal caribou ranges. Total area of ranges was 39,910 km^2. The total area of SLU within ranges was 1,873 km^2 or 4.7%. There were 6,066 caribou telemetry locations located within SLU polygons within ranges (6.2%). The selection ratio was 1.32, suggesting that caribou were found within SLU more than expected by chance. Restricting the analysis to core areas resulted in similar results: 4.5% of core areas were within SLU and 6.6% of telemetry locations within core areas were located within SLU polygons, resulting in a selection ratio of 1.46.

The selection ratios varied by SLU class and by resolution, with evidence of caribou avoiding non-oil and gas features and cutblocks, but not avoiding oil and gas and geophysical features (Figure 2).

Discussion

The analysis revealed no single threshold avoidance distance that could be applied to all SLU classes. Avoidance of oil and gas and geophysical infrastructure by caribou was not apparent at any distance, with the analysis generating positive selection ratios at short buffer distances. In contrast selection ratios were <1 for non-oil and gas features and cutblocks for all buffers examined.

Without any buffers being applied, caribou demonstrated apparent attraction to oil and gas and geophysical activities. This might be occurring because oil and gas activities and caribou are "selecting" the same portions of the land base while non-oil and gas activities and forestry are "selecting" portions of the land base used less frequently by caribou. If displacement effects are minor, this could result in positive selection ratios. Controlling for habitat types or other factors might explain this potential bias; however, if would still not lead to a single threshold distance that could be applied to all SLU features across the land base.

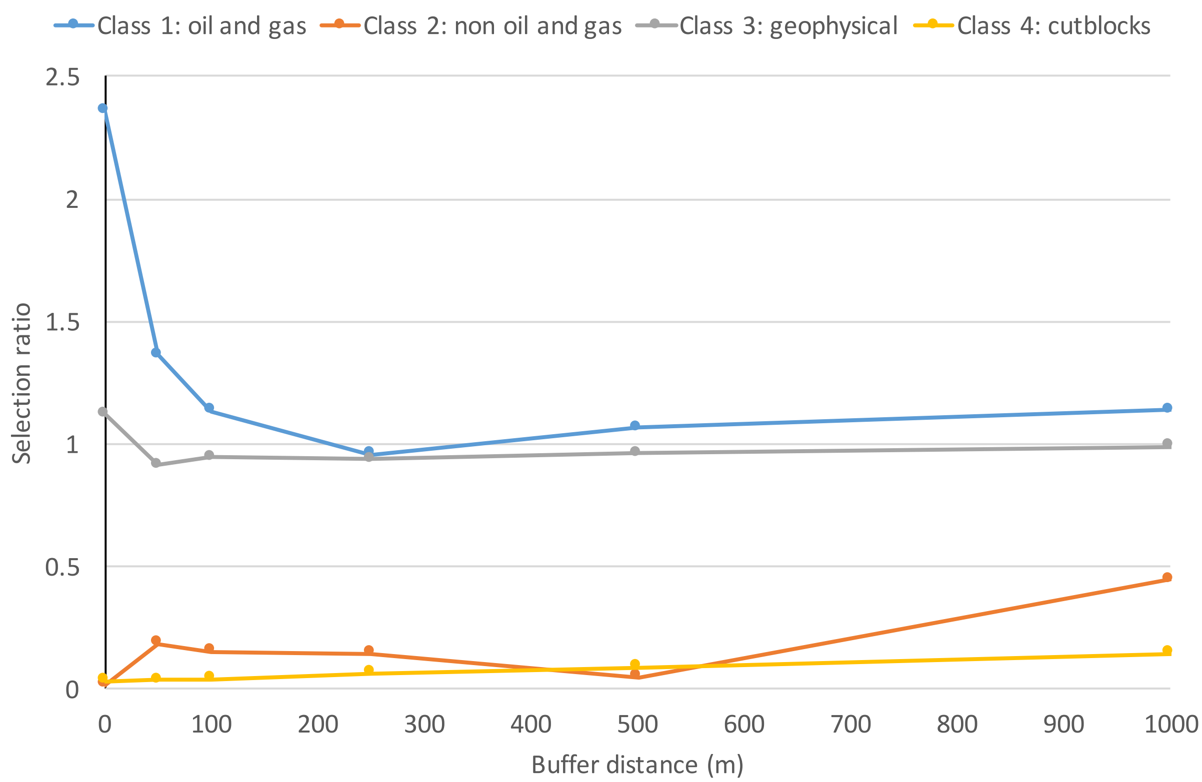

Figure 2. Relationship between classes of activity in the Surface Land Use (SLU) coverage (2014) and avoidance by boreal caribou, as measured by the selection ratio. Ratios of <1 indicate avoidance and >1 indicate selection.

The selection for oil and gas and geophysical features may not be an artefact of the analysis and may be an actual effect, if caribou use these features for travel or foraging more than the surrounding forest matrix. There are instances in the telemetry data where caribou were clearly using linear features for travelling. This behaviour, while adaptive from a habitat use standpoint, may ultimately be maladaptive for caribou if predators are travelling on the same features and encountering predators more often.

Selection ratios may become less reliable as buffer distances get larger because buffers associated with different SLU classes overlap. In this analysis each raster pixel was assigned the SLU class at its centre. Because caribou appear to be responding to different SLU classes differently, the SLU class influencing caribou behaviour at a location on the land base might not always be the SLU class assigned to that area. Along with the analysis becoming less reliable, the ecological mechanisms resulting in selection and avoidance by caribou at large buffer distances from features is not clear. For these reasons the value of analyzing large buffers is suspect.