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Original Research

# Vegetation Recovery on Low Impact Seismic Lines in Alberta's Oil Sands and Visual Obstruction of Wolves (*Canis lupus*) and Woodland Caribou (*Rangifer tarandus caribou*)

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## Abstract

Low-Impact Seismic (LIS) exploration techniques are being increasingly used in northeastern Alberta, Canada to explore for in-situ oil sands deposits. These narrow (2-4-m wide), meandering man-made linear features are often closely spaced (50-100 m apart) in a grid pattern. They were developed to reduce loss of merchantable trees, minimize habitat loss, and minimize the loss of vegetation cover that would open up lines of sight that could result in increased mortality for some animals. In spite of their narrow widths, the dense spacing of LIS can result in a substantial overall physical surface footprint of >10% within a given mineral surface lease. In this 3-year study, we used a paired sampling design to measure the extent of vegetation recovery and visual obstruction of wolves (*Canis lupus*) and caribou (*Rangifer tarandus*) on 7-9-year-old LIS lines in the Boreal Plains of northeastern Alberta. Mean vegetation regrowth cover from 0-2 m above ground was significantly greater on control transects than on paired LIS transects for most ecosites, but particularly in deciduous sites. Bogs and poor fens had a relatively slower vegetation regrowth above 1 m. Our results suggest that after 7 to 9 years, visual vegetation obstruction may be higher for wolves than for woodland caribou, likely due to the shorter stature of wolves. Reclamation and monitoring initiatives should focus on LIS features showing poor vegetation re-growth and should include vegetation obstruction metrics.

**Key Words:** Low Impact Seismic, Vegetation Recovery, Woodland Caribou, Wolf, Visual Obstruction, Oil Sands, Boreal Plain.

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# INTRODUCTION

The surface footprint of in-situ oil sands exploration and development is predominantly linear and extensive, resulting in an array of criss-crossing and overlapping industrial features including: low-impact seismic lines, pipelines (above and below ground), powerlines, bush trails, all season and gravel roads, surface leases, borrow pits, central processing facilities and camps (Devon Canada Corporation 2010; Latham and Boutin 2015). In-situ oil sands development is often located in areas that were previously explored or developed for natural gas as early as the 1960s and 1970s. This "legacy" infrastructure includes mainly seismic lines, pipelines and well sites (van Rensen *et al.* 2015).

Oil and gas development, regardless of era, first involves a process of geophysical exploration to pinpoint, analyse, and map sub-surface hydrocarbon resources. Seismic surveys are typically used to analyse sound waves originating from explosive charges that are set systematically along pre-cut seismic lines. From the 1950s until the 1990s, seismic lines were created by bulldozers that removed all trees and shrubs along with varying amounts of topsoil and subsoil (Lee and Boutin 2005). These lines referred to as "conventional seismic lines", were usually straight, 300-500 m apart, and 5-8 m in width (MacFarlane 2003). Conventional seismic lines were also wide and straight enough to facilitate their use as human access corridors, primarily supporting recreation and traditional land uses (Latham and Boutin 2015). In many cases, these lines grew in width as a result of continued use by humans even after their use by industry was discontinued.

In the 1990s, oil and gas companies started to experiment with seismic survey methods that reduced the amount of merchantable timber affected, minimized disturbance to soil and ground cover, and reduced line-of-sight (of hunters and predators) by following a meandering pattern (Latham and Boutin 2015). The latest of these "low impact seismic" (LIS) programs has resulted in line widths ranging from approximately 2 to 4 m. These lines are made with GPS-outfitted, tracked, mechanical mulchers that manoeuvre around large trees wherever possible and remove shrubs, small trees and ground cover with minimal interruption of topsoil (MacFarlane 2003). Varying amounts of mulch is left on the line to reduce soil compaction and to facilitate faster vegetation re-growth.

Although LIS are being increasingly used by oil and gas companies because they are believed to have less of an impact on some mammal species than conventional seismic lines, sparse data exist concerning their use by mammals. Two mammal species that have received the majority of research attention in the Alberta oil sands are the threatened boreal woodland caribou (*Rangifer tarandus caribou*) and the gray wolf (*Canis lupus*). Research in the last 15 years has focused primarily on the spatial response of wolves and caribou to linear feature proximity, density and types using GPS/satellite radio-telemetry and Resource Selection Function (RSF) analysis methods. Some studies suggested that woodland caribou avoid roads and to a lesser extent conventional seismic lines, at least partially to reduce predation risk from wolves (James and Stuart-Smith 2000; Dyer 1999; Latham *et al.* 2011).

Wolves appear to disproportionately use conventional seismic lines (James 1999; James and Stuart-Smith 2000; Latham *et al.* 2011), a factor that might provide easier travel compared to adjacent forested habitat and increase hunting efficiency through increased line-of-sight and travel speed (Latham 2009; Dickie 2015). Latham *et al.* (2011) found that wolves selected conventional seismic lines in the Alberta oil sands during snow-free months. James and Stuart-Smith (2000) found that predation risk for woodland caribou from wolves was higher on or near these features, and Latham *et al.* (2011) concluded that this has resulted in functional loss of otherwise suitable habitat for caribou. The extent to which wolves use low impact seismic grids for travel or hunting is currently less well understood (Latham *et al.* 2011; Dickie 2015). The same is true for woodland caribou.

The amount of vegetation on LIS is likely to have an effect on the nature and extent of their use by wolves, caribou and other ungulates, and the resulting predator-prey interactions. Therefore, we measured the extent of visual obstruction on LIS after 7 to 9 years of natural (unassisted) vegetation re-growth and compared these levels to those of paired interior (unmodified) habitat for different ecosite types. We also tested if visual obstruction on LIS and adjacent unaffected habitat differs significantly between wolf and caribou vantage points (i.e., eye height).

# STUDY AREA

The study area is located 15 km south of the Hamlet of Conklin in Lac La Biche County in northeastern Alberta, Canada (Figure 1). It occurs fully within the Central Mixedwood Natural Subregion of the Boreal Forest Natural Region of Alberta (Natural Regions Committee 2006). The Central Mixedwood is the largest Subregion in Alberta occupying 167,856 $km^2$ that amounts to 44% of the Boreal Forest Natural Region and 11% of the province of Alberta. The study area is characterized by rolling morainal plain with approximately 60% organic terrain. Upland moraine areas are dominated by aspen (*Populus tremuloides*), mixedwood and jack pine (*Pinus banksiana*) forest while lowland bogs and fens with black spruce (*Picea mariana*) and tamarack (*Larix laracina*) trees and shrubs occur in association with organic soils. Several creeks and associated riparian habitats also occur.

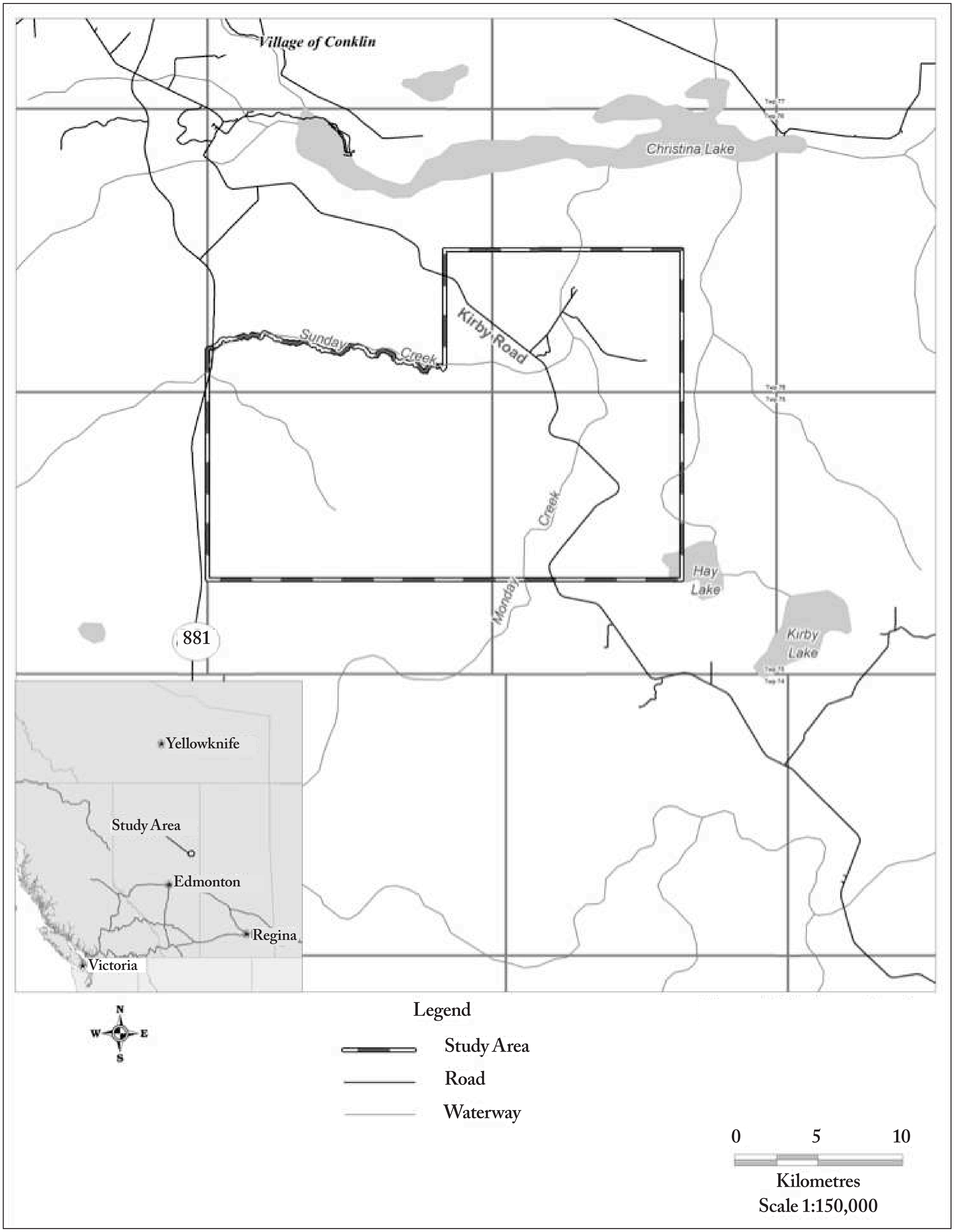


Figure 1. Location of study area in northeastern Alberta - Cold Lake Caribou Range 2010-12.

The study area is located in the Cold Lake Caribou Range, which encompasses 6,724 km$^2$ (Environment Canada 2012). Environment Canada (2012) described the Cold Lake Caribou Range presently as 85% disturbed (based on combined natural disturbance and buffered anthropogenic disturbance), leaving 15% undisturbed. Environment Canada (2012) also identified a target of 65% undisturbed habitat for each boreal caribou range across Canada as the critical habitat definition for this species.

The only major current industrial land use in the study area is petroleum development and primarily in-situ oil sands exploration and development. Anthropogenic linear features include LIS, conventional seismic lines, gravel roads of various widths and classes, pipelines, power transmission lines, and bush trails. Linear feature density in the study area at the time of field sampling was 13.0 km/km$^2$ of which 76% was comprised of low impact seismic lines. Polygonal in-situ infrastructure included: stratification wells, source wells, disposal wells, observation wells, lay down areas, borrow pits, and central processing facilities. No timber harvest had taken place at the time of field sampling.

## METHODS

### Sample site selection

Field sampling was conducted in 2010, 2011 and 2012 during mid-summer (July and August) with full vegetation green-up. Sampling sites were stratified by mapped ecosites, which are defined as homogeneous land types that represent a combined interaction of biophysical factors that dictate the availability of moisture and nutrients for plant growth (Beckingham and Archibald 1996). Sampling transects were located on the nearest east-west running seismic line at the centroid of an individual mapped ecosite polygon, and centred between north-south running lines of LIS grids. Paired control transects were run along the same bearing as and parallel to LIS (disturbance) transects in suitable interior (reference) habitat a distance of 30 m to the north. If suitable reference habitat was not available to the north, transects were placed on the south side of seismic lines. All treatment samples were taken from sites for which either 7, 8 or 9 years had elapsed since line clearing/mulching.

A total of 107 paired sites were sampled among 9 ecosites. According to availability, 7 to 17 (mean = 12) paired transects were sampled for each of 9 ecosites. Biophysical characteristics of ecosites are summarized in Table 1. Due to a low number of available map polygons for the E and F ecosites, these were merged as their vegetation assemblages, moisture and nutrient regimes are similar.

### Sample plot layout and sampling design

Visual obstruction from vegetation was measured in both east and west directions from the centre and along each transect and corresponding reference transect adapting methods by Nudds (1977). A red and white colour-coded cloth measuring 2 m in height was held upright 15 m from the observer at plot centre. The observer viewed the cloth from both caribou eye level (1.7 m above ground) and wolf eye level (1.2 m above ground). An estimate of percent obstructed/hidden (by vegetation) was recorded for each 25 cm x 25 cm blocks which make up the cloth.

Table 1. Biophysical Description of Sampled Ecosites - Cold Lake Caribou Range - 2010-2012.

| Ecosite Code | Ecosite Description | Moisture Regime | Nutrient Regime Regime | Soil Subgroup | Dominant Trees |
|---|---|---|---|---|---|
| A | Lichen | Xeric-Subxeric | Poor | Orthic Brunisols | Jack Pine |
| B | Blueberry | Submesic | Medium | Orthic Luvisols/ Brunisols | Aspen/Jack Pine |
| C | Labrador Tea | Mesic | Poor | Orthic Luvisols/ Brunisols | Jack Pine/ Black Spruce |
| D | Low-bush cranberry | Mesic | Medium | Orthic Luvisols | Aspen/ White Spruce |
| E+F | Dogwood/Horsetail | Subhygric/hygric | Rich | Gleyed Luvisols | White Spruce/ Balsam Poplar |
| G | Labrador Tea-subhygric | Subhygric/hygric | Poor | Gleysols | Black Spruce/ Jack Pine |
| I | Bog | Subhydric | Very Poor-Poor | Organic | Black Spruce |
| J | Poor Fen | Subhydric | Poor-Medium | Organic | Black Spruce/ Tamarack |
| K | Rich Fen | Hydric | Rich | Organic | Tamarack |

### Analysis

The average values for visual obstruction up to 2-m height from both caribou and wolf eye levels by ecosite were calculated in both the LIS plots (treatment) and the paired natural plots (control). Two levels of analysis were undertaken. Differences in mean visual obstruction values between control (off-LIS) versus treatment (on-LIS) for both wolf and caribou were analyzed for each ecosite. Mean values were calculated both by total cover (0 to 2 m combined), and also for each 0.25 m height layer for each ecosite. Second, we analyzed whether there were differences in visual obstruction between wolf and caribou eye levels for both control and treatment sites within different ecosites. Paired *t*-tests, not assuming equal variance, were run to verify whether or not differences in mean values between compared variables were statistically significant ($P<0.05$). All data was analyzed using Minitab v. 17.1.0 (Minitab Inc., State College, PA, USA).

## RESULTS

Mean visual obstruction from ground level to 2 m was significantly greater on control transects than on paired LIS transects for most ecosites (Table 2, Figure 2) with the exception of the A ecosite ($P$ = 0.671 and 0.491 for caribou and wolf, respectively) and E+F ecosites ($P$ = 0.157 and 0.183 for caribou and wolf, respectively). Mean visual obstruction from ground level to 2 m on control transects was greater than on LIS transects by an average of 215% (range = 118% to 401.4%) from wolf eye height and 201% (range = -130.7% to 425.5%) from caribou eye height. Bog and fen ecosites with hygric to hydric moisture regimes (I, J and K) had the most significant differences ($P<0.001$) in visual obstruction between control and treatment (Table 2; Figure 2).

Some ecosites showed differences in visual obstruction between control and treatment by specific height layer(s) above ground. In the D ecosite (mesic deciduous forest), differences in visual obstruction were significantly higher from 1 m and up in control plots from both caribou and wolf perspectives ($P<0.05$). No significant differences were observed in the 0 to 0.75 m layers from the perspective of either species ($P$=0.109 to 0.508) (Figure 2-D). Differences in mean visual obstruction between control and LIS transects was notably greater above 0.50 meters especially for bog (I) and fen (J and K) ecosites (Figure 2-G, 2-H and 2-I). The fen sites showed some increasing obstruction in the 0-1-m height layer, however the cover values were still significantly lower than in control plots for all but the 0.25 m layer ($P>0.05$).

Overall visual obstruction (all 8 height layers combined) on control transects was greater for wolves than caribou for all ecosites except C (mesic lodgepole pine forest). On regenerating LIS transects visual obstruction for wolves was greater than for caribou in 7 of 9 ecosites, with the exceptions being A and G. Statistically significant differences in the amount of visual obstruction from

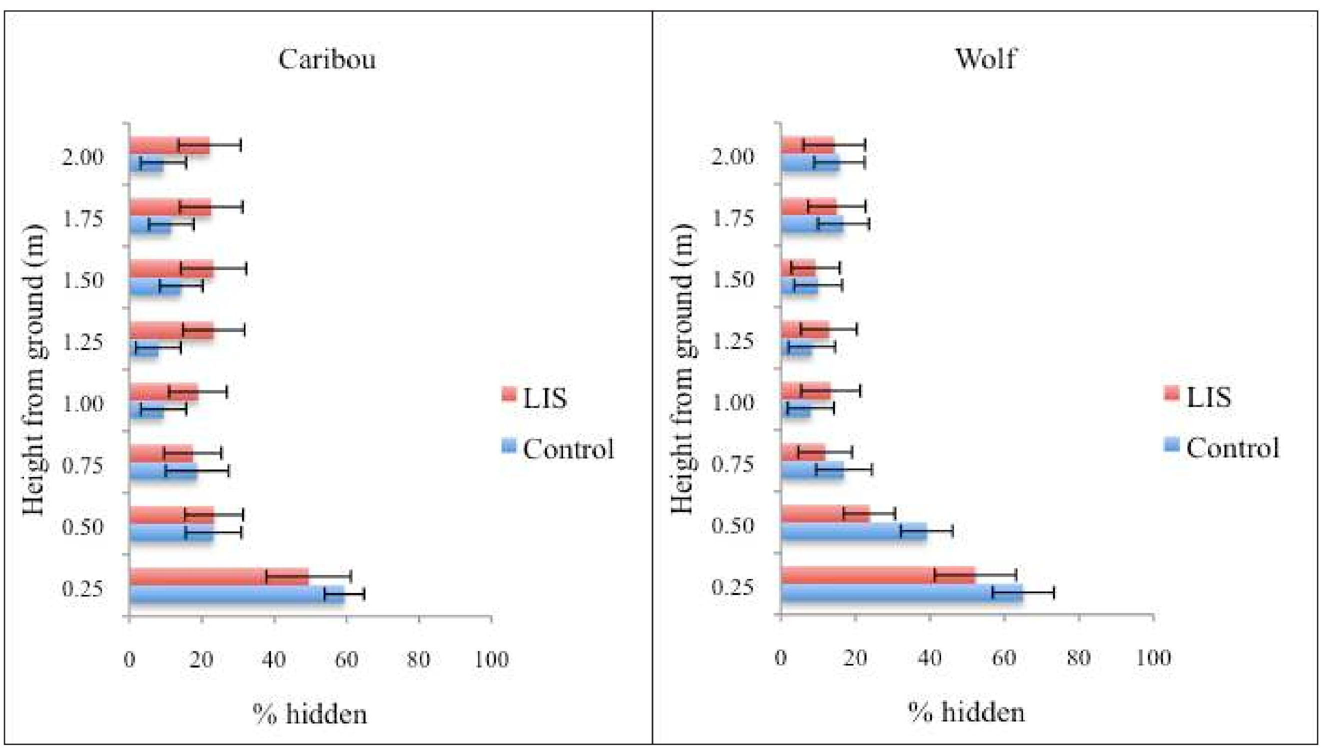


Figure 2-A. Visual obstruction in A Ecosite ($n$=7) on LIS versus control from caribou and wolf perspectives. The error bars are standard errors around the means. No significant differences in hiding cover were found in any height layers for caribou or wolf ($P>0.05$) in LIS versus control.

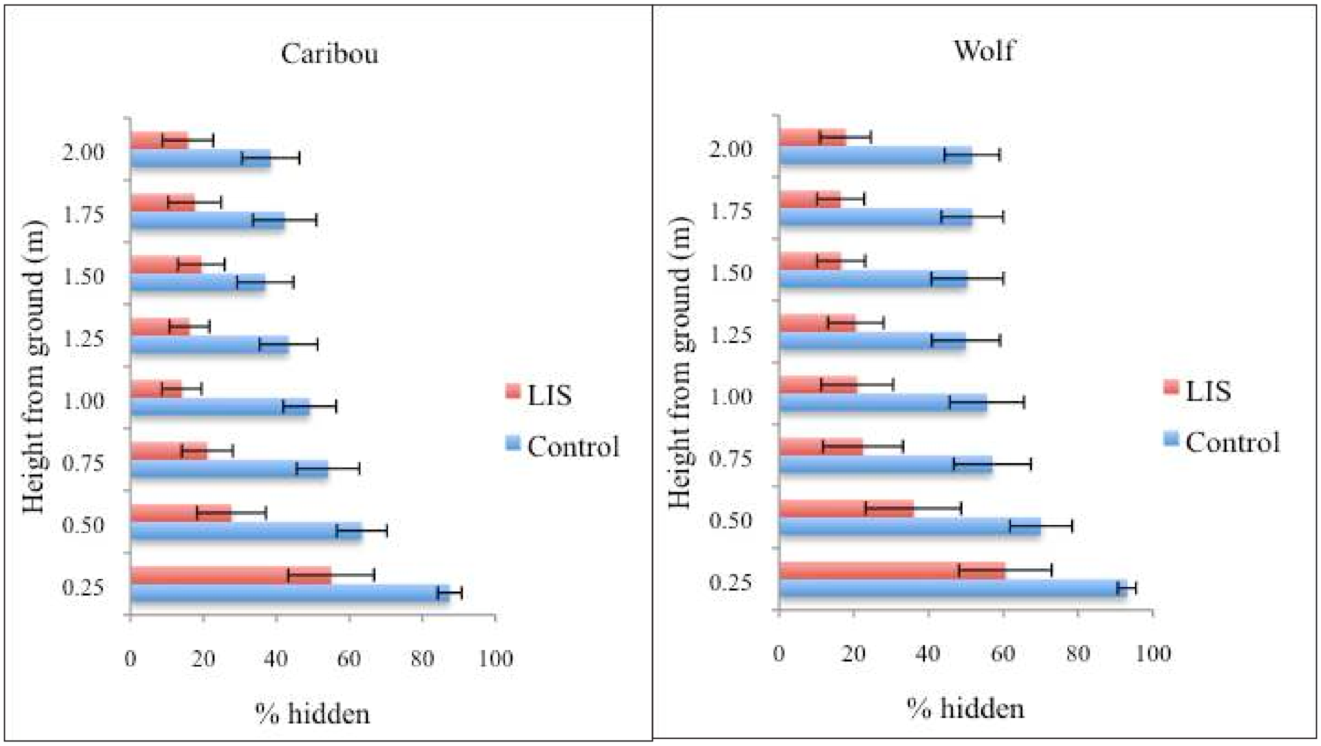


Figure 2-B. Visual obstruction in B Ecosite (*n*=9) on LIS versus control from caribou and wolf perspectives. The error bars are standard errors around the means. Difference in hiding cover was overall higher fort all height layers for both caribou and wolf, although not significantly in the 1.50 to 2.00 m layers for caribou (*P*=0.126-0.200), and the 0.50-to 1.00 m layers for wolf (P=0.054-0.063).

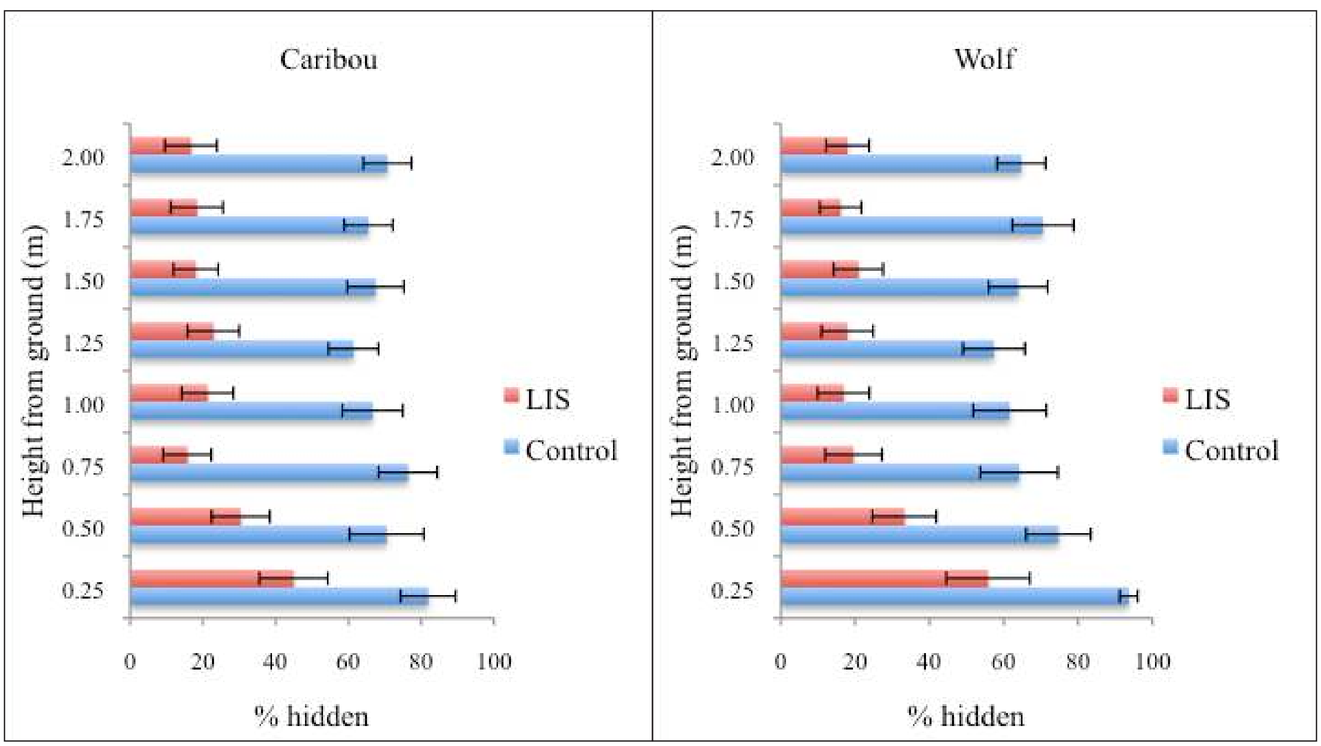


Figure 2-C. Visual obstruction in C Ecosite (*n*=9) on LIS versus control from caribou and wolf perspectives. The error bars are standard errors around the means. Difference in hiding cover was significantly higher for all height layers in control plots for both caribou and wolf (P<0.050).

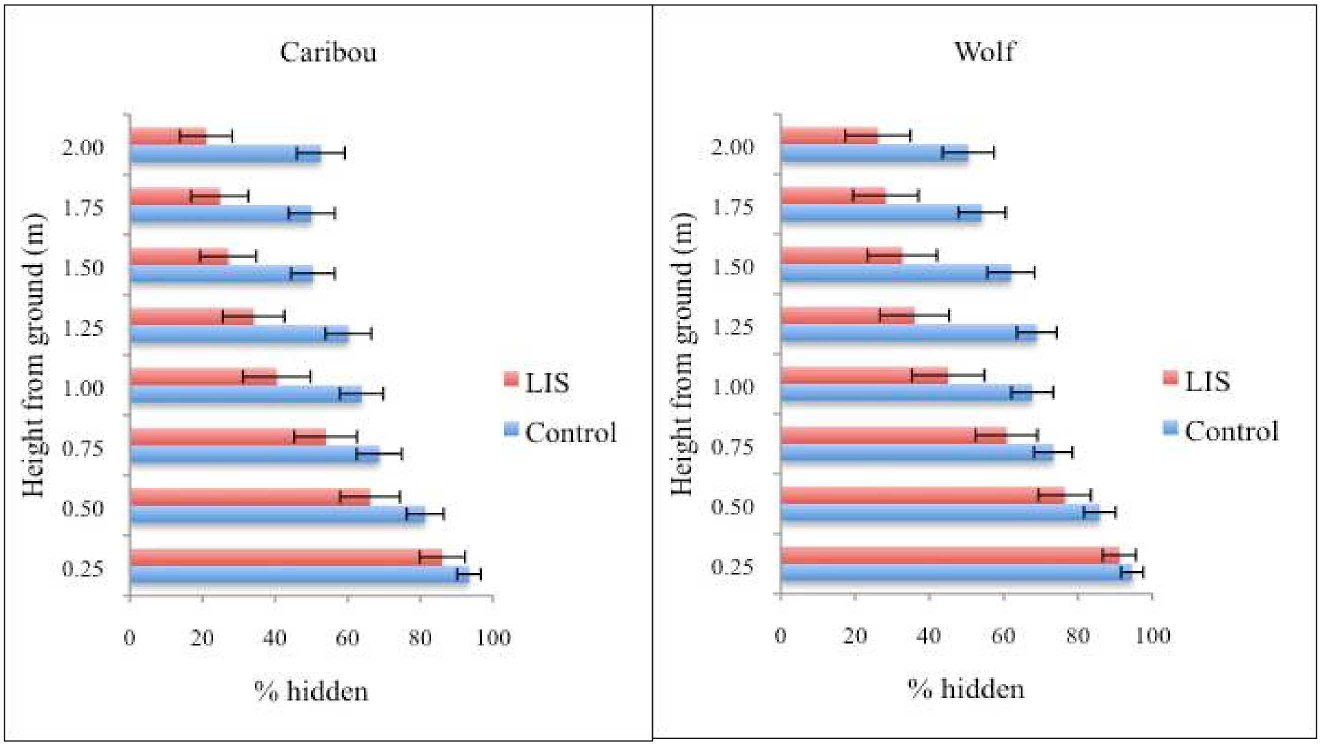


Figure 2-D. Visual obstruction in D Ecosite (*n*=18) on LIS versus control from caribou and wolf perspectives. The error bars are standard errors around the means. Differences in hiding cover were significantly higher from the 1.00 m and up in control plots for both caribou and wolf ($P<0.050$). No significant differences were observed in the 0.00 to 0.75 m layers for either species ($P=0.109$-$0.508$).

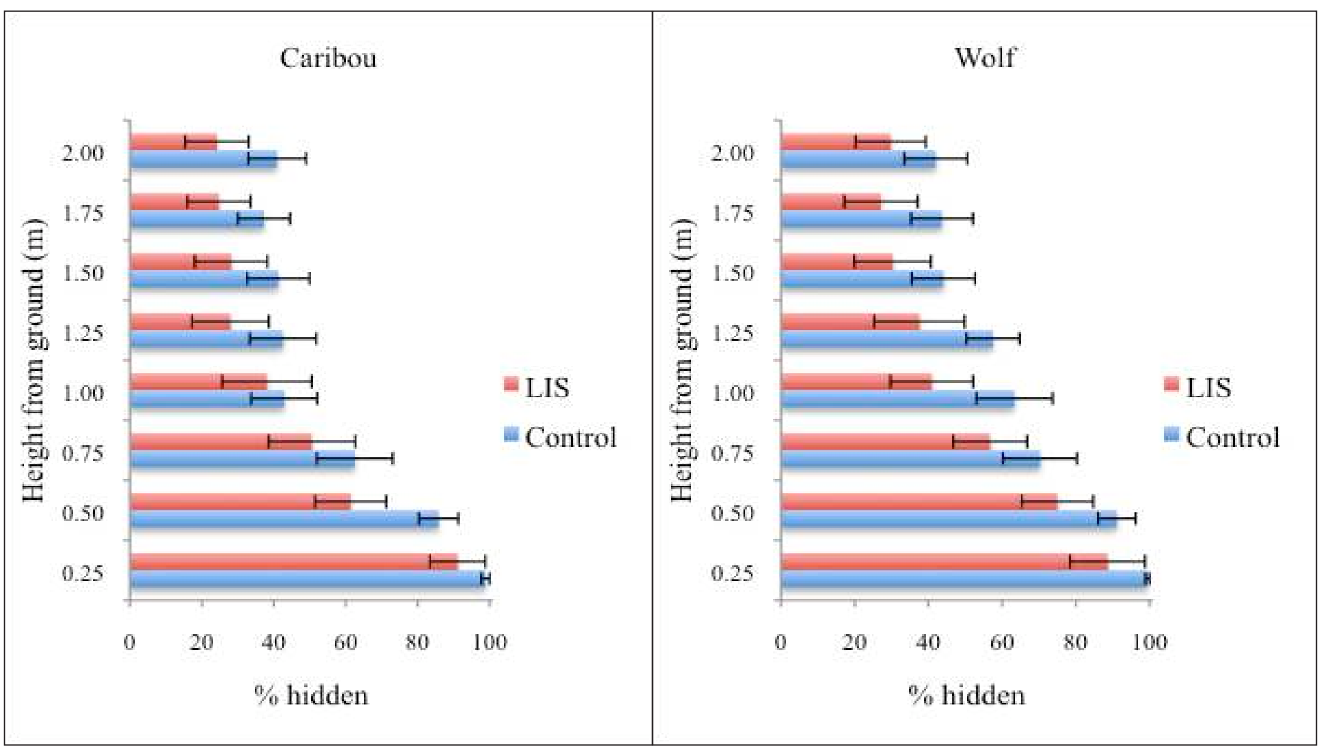


Figure 2-E. Visual obstruction in E + F Ecosite (*n*=9) on LIS versus control from caribou and wolf perspectives. The error bars are standard errors around the means. No significant differences in hiding cover in any layers were found for caribou or wolf ($P>0.050$) in LIS versus control, with the exception of layer 0.50 m for both species ($P=0.011$ for caribou, $P=0.022$ for wolf).

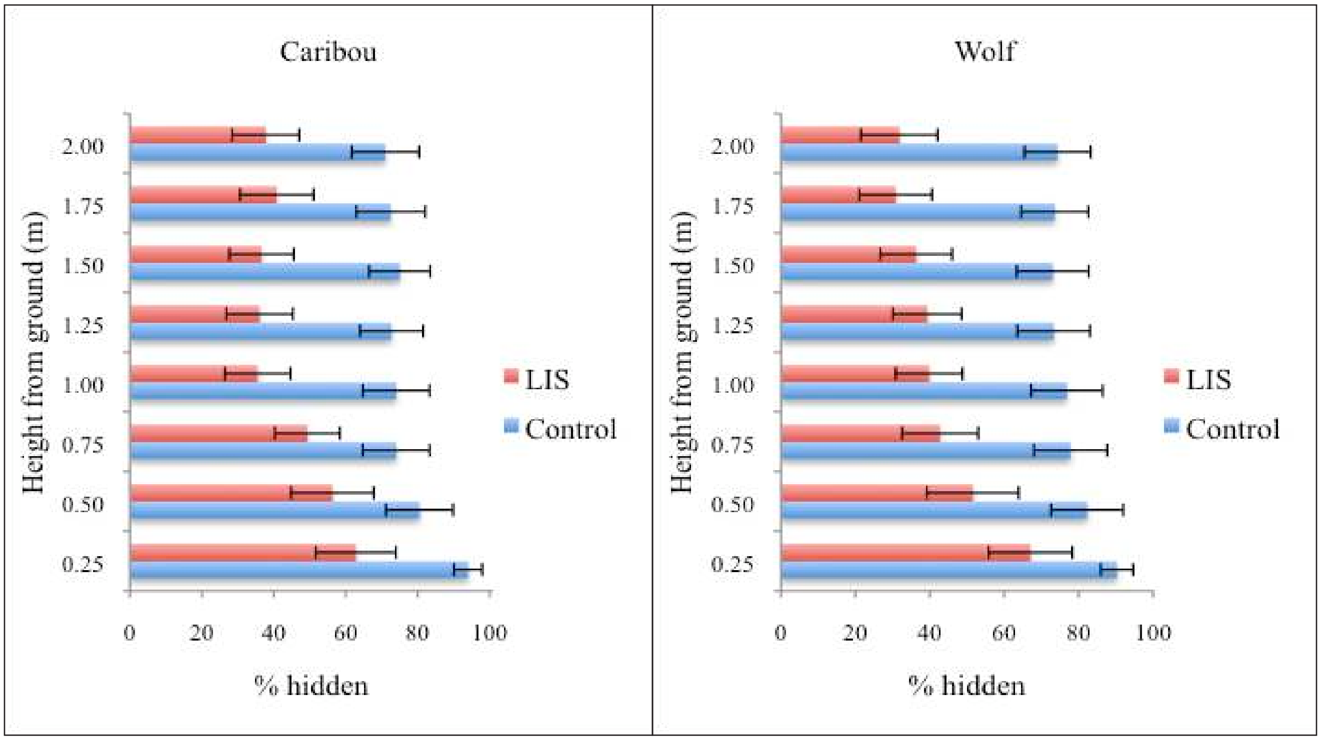


Figure 2-F. Visual obstruction in G Ecosite (*n*=10) on LIS versus control from caribou and wolf perspectives. The error bars are standard errors around the means. Difference in hiding cover was overall higher fort all height layers for both caribou and wolf, although not significantly in the 0.50 m and 1.75 m layers for caribou (*P*=0.094 and 0.056), and the 0.25-to 0.50 m layers for wolf (*P*=0.059-0.070).

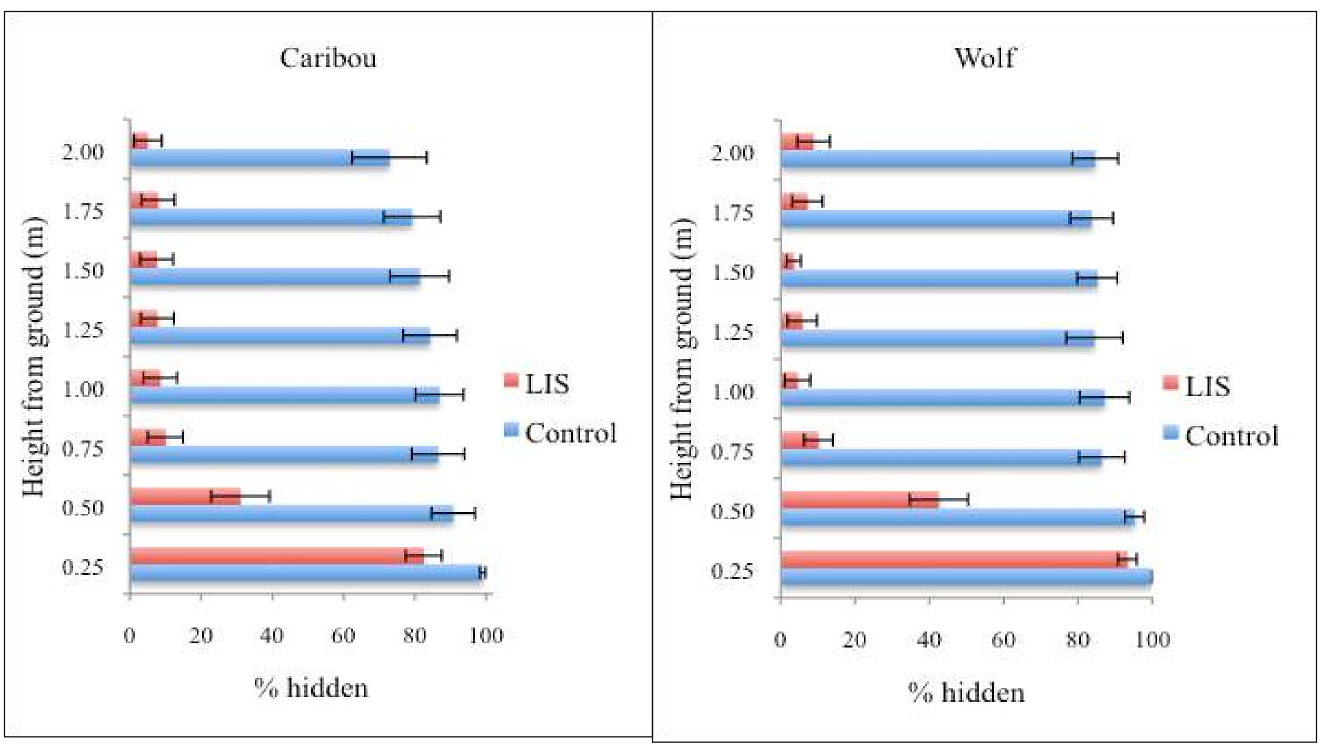


Figure 2-G. Visual obstruction in I Ecosite (*n*=13) on LIS versus control from caribou and wolf perspectives. The error bars are standard errors around the means. Differences in hiding cover were significantly higher in control plots for both caribou and wolf for all height layers (*P*<0.050).

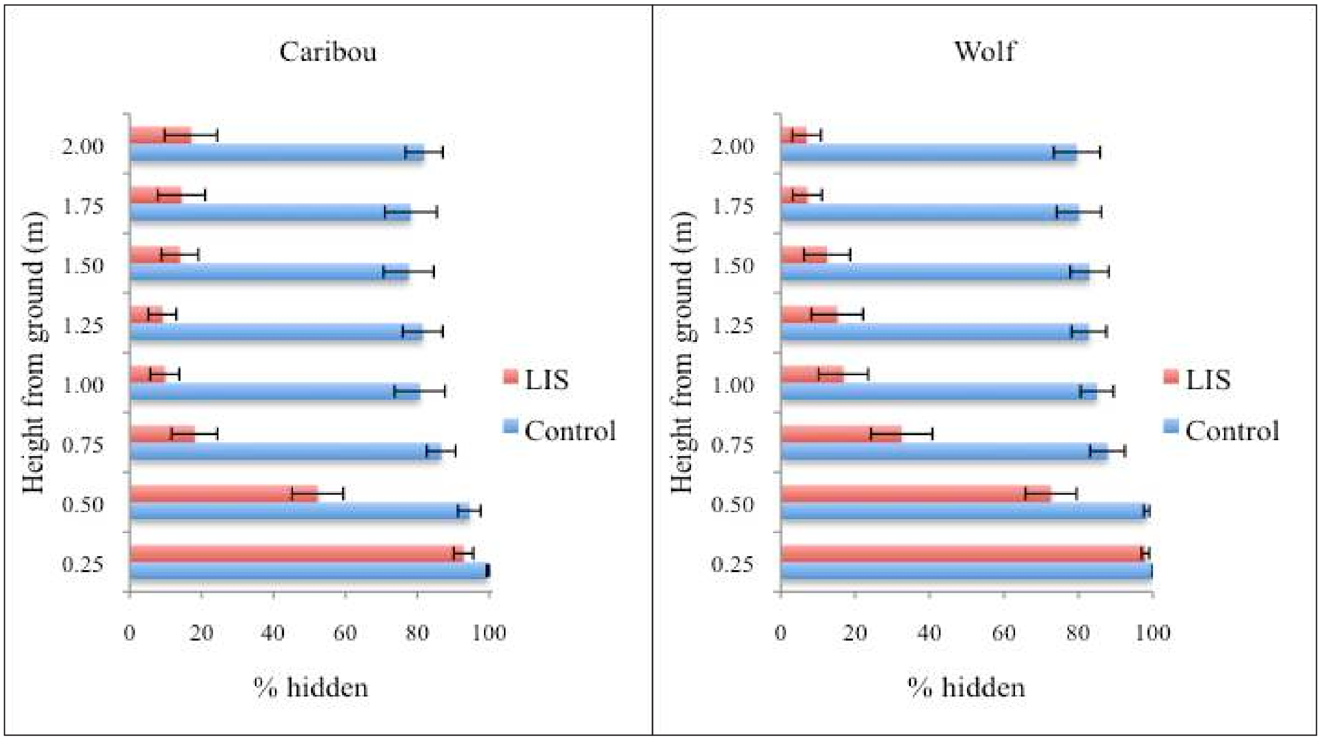


Figure 2-H. Visual obstruction in J Ecosite (*n*=16) on LIS versus control from caribou and wolf perspectives. The error bars are standard errors around the means. Differences in hiding cover were significantly higher in control plots for both caribou and wolf for all height layers ($P<0.050$), except for the 0.25 layer for wolf ($P=0.075$).

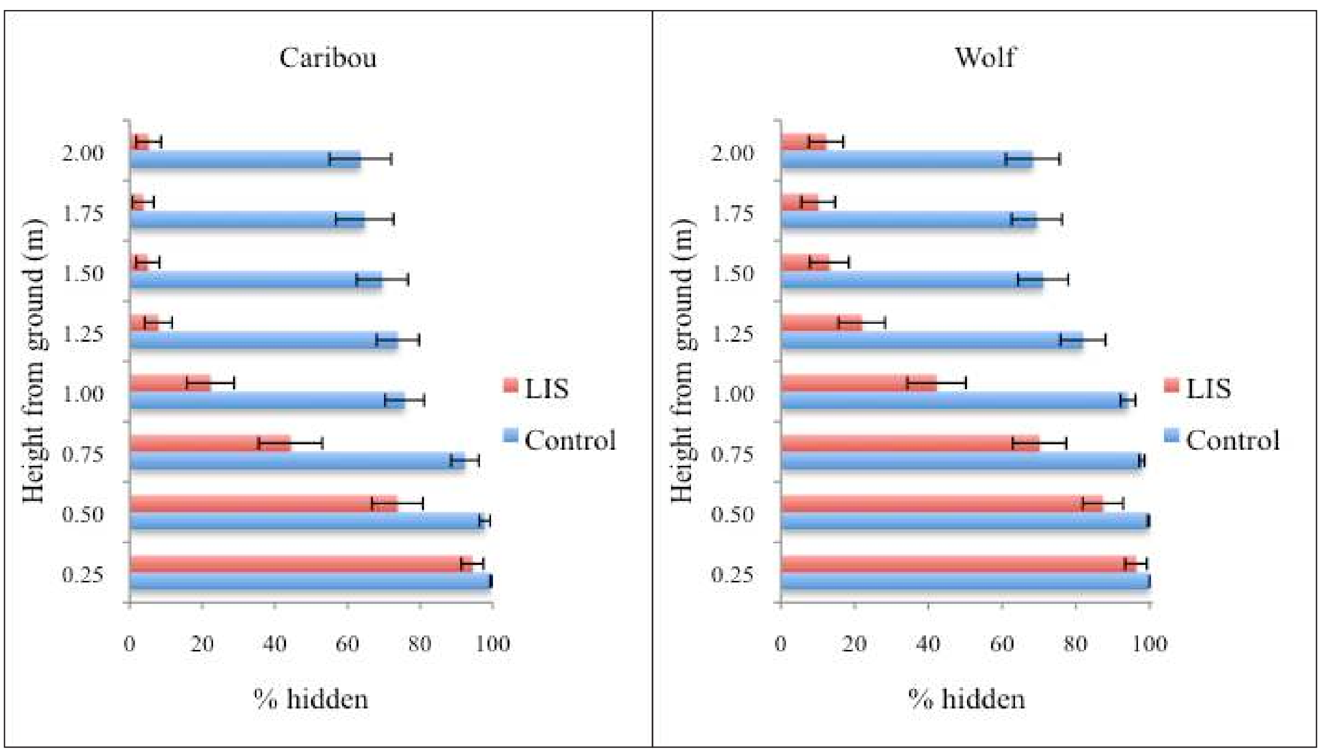


Figure 2-I. Visual obstruction in K Ecosite (*n*=17) on LIS versus control from caribou and wolf perspectives. The error bars are standard errors around the means. Differences in hiding cover were significantly higher in control plots for both caribou and wolf for all layers ($P<0.050$) with the exception of the 0.25 m layer for both caribou ($P=0.117$) and wolf ($P=0.229$).

Table 2. Test statistics for vegetation obstruction differences between Control and LIS transects - Cold Lake Caribou Range 2010-2012.

| Ecosite | Metric | *n* | Average Control** | Average LIS | Difference in mean | *t*-valuew | *P*-value |
|---|---|---|---|---|---|---|---|
| A | Wolf | 7 | 22.5 | 19.1 | 3.4 | 0.45 | 0.671 |
| | Caribou | | 19.2 | 25.1 | -5.8 | -0.73 | 0.491 |
| B | Wolf | 9 | 60.0 | 26.4 | 33.6 | 2.85 | 0.021 |
| | Caribou | | 51.9 | 23.4 | 28.6 | 2.91 | 0.020 |
| C | Wolf | 9 | 69.2 | 25.1 | 44.2 | 5.25 | 0.001 |
| | Caribou | | 70.6 | 23.8 | 46.8 | 6.11 | <0.001 |
| D | Wolf | # | 69.6 | 49.6 | 20.1 | 2.70 | 0.015 |
| | Caribou | | 65.0 | 44.2 | 20.9 | 2.90 | 0.010 |
| E+F | Wolf | 9 | 63.9 | 48.3 | 15.7 | 1.56 | 0.157 |
| | Caribou | | 56.5 | 43.3 | 13.2 | 1.46 | 0.183 |
| G | Wolf | # | 77.7 | 42.4 | 35.3 | 2.91 | 0.017 |
| | Caribou | | 76.8 | 44.4 | 32.4 | 2.84 | 0.020 |
| I | Wolf | # | 88.3 | 22.0 | 66.4 | 11.42 | <0.001 |
| | Caribou | | 85.1 | 20.0 | 65.1 | 8.00 | <0.001 |
| J | Wolf | # | 87.1 | 32.7 | 54.4 | 7.30 | <0.001 |
| | Caribou | | 85.1 | 28.4 | 56.7 | 7.47 | <0.001 |
| K | Wolf | # | 85.3 | 44.2 | 41.1 | 7.09 | <0.001 |
| | Caribou | | 79.6 | 32.1 | 47.6 | 8.10 | <0.001 |

**Mean percent hidden/obstructed by vegetation

Table 3. Test statistics for vegetation obstruction differences between wolf and caribou heights - Cold Lake Caribou Range 2010-2012.

| Ecosite | Metric | *n* | Average Wolf** | Average Caribou | Difference in mean | *t*-value | *P*-value |
|---|---|---|---|---|---|---|---|
| A | Control | 7 | 22.5 | 19.2 | 3.3 | 1.47 | 0.191 |
| | LIS | | 19.1 | 25.1 | -6.0 | -1.36 | 0.224 |
| B | Control | 9 | 60.0 | 51.9 | 8.1 | 1.38 | 0.206 |
| | LIS | | 26.4 | 23.4 | 3.1 | 0.75 | 0.475 |
| C | Control | 9 | 69.2 | 70.6 | -1.4 | -0.35 | 0.735 |
| | LIS | | 25.1 | 23.8 | 1.3 | 1.19 | 0.268 |
| D | Control | # | 69.6 | 65.0 | 4.6 | 2.18 | 0.043 |
| | LIS | | 49.6 | 44.2 | 5.4 | 2.20 | 0.042 |
| E+F | Control | 9 | 63.9 | 56.5 | 7.4 | 1.54 | 0.163 |
| | LIS | | 48.3 | 43.3 | 5.0 | 1.70 | 0.128 |
| G | Control | # | 77.7 | 76.8 | 0.9 | 0.45 | 0.666 |
| | LIS | | 42.4 | 44.4 | -2.0 | -0.65 | 0.533 |
| I | Control | # | 88.3 | 85.1 | 3.2 | 1.65 | 0.124 |
| | LIS | | 22.0 | 20.0 | 2.0 | 0.80 | 0.441 |
| J | Control | # | 87.1 | 85.1 | 2.0 | 1.34 | 0.203 |
| | LIS | | 32.7 | 28.4 | 4.3 | 1.63 | 0.126 |
| K | Control | # | 85.3 | 79.6 | 5.7 | 2.56 | 0.021 |
| | LIS | | 44.2 | 32.1 | 12.1 | 5.02 | <0.001 |

**Mean percent hidden/obstructed by vegetation wolf as opposed to caribou eye heights occurred for 2 ecosites (Table 3). These were the D ecosite ($P$=0.043 for control and $P$=0.042 for LIS) and the K ecosite ($P$=0.021 for control and $P$<0.001 for LIS). For these 2 ecosites, visual obstruction was greater for wolves than for caribou.

# DISCUSSION

**Factors affecting visual obstruction on regenerating LIS**

Our results show that after 7 to 9 years of natural recovery following vegetation clearing/mulching of LIS, visual obstruction remained significantly greater on control than cleared samples for most ecosites. Ecosites with a deciduous vegetation component that occurred on subhygric and mesic sites with rich to medium nutrient regimes had greater amounts of vegetation re-growth than other ecosites. Visual obstruction differences between paired control and cleared transects were progressively greater at heights above approximately 0.75 m with this difference being considerably more pronounced in bog and fen ecosites.

Minimal differences in visual obstruction between control and cleared samples in the xeric ecosite A (lichen) reflect the open tree canopy and limited amount of shrub understory in this ecosite under natural conditions. LIS routing in these open jack pine-lichen stands tends to avoid trees and does not alter shrub cover significantly. The greater amount of regenerating vegetation and visual obstruction on nutrient-rich mixedwood ecosites E/F is consistent with past studies on conventional seismic lines. For example, several studies have observed quicker vegetation re-growth on nutrient rich ecological site conditions (van Rensen *et al.* 2015) and on sites that promote deciduous (as opposed to coniferous) shrub regeneration (Revel *et al.* 1984; Lee and Boutin 2006; Bayne *et al.* 2011).

Vegetation re-growth and associated visual obstruction on regenerating LIS was severely limited on very moist to wet sites. Bog (I) and fen (J and K) ecosites had significantly less visual obstruction on regenerating LIS than drier ecosites, particularly at heights above 0.75 m. Van Rensen *et al.* (2015) also observed that ecosite moisture class in combination with depth to water were major factors affecting vegetation regeneration on conventional seismic lines in the Central Mixedwood Sub-region of Alberta.

**Influence of animal height on visual obstruction of vegetation**

Our results indicate that the vantage point of the observer, as measured by wolf versus caribou eye heights, influenced the amount of visual obstruction at a distance of 15 m. The amount of visual obstruction as seen from a wolf's eye height is greater than for caribou eye height for most ecosites in both control sites and on regenerating LIS. Wolves are shorter than caribou and it is not unexpected that the amount hidden by vegetation cover for wolves would be greater than for caribou especially in sites with dense low- to mid-shrub (<1.0 m) understory. The two ecosites (D and K) where there was significantly more visual obstruction at wolf height compared to caribou generally comprise a dense mid-shrub understory (Beckingham and Archibald 1996).

Very few studies have compared visual obstruction for both predators and prey in different habitat types. Rahme (1991) compared visual cover for mule deer (*Odocoileus hemionus*) and coyote (*Canis latrans*) at heights of 1.5 m and 0.75 m, respectively, and found that visual obstruction did not differ significantly between these 2 heights. Rahme's (1991) study was conducted, however, in the Thompson Plateau of interior British Columbia, which is dominated by semi-open conifer forest that tends to support less robust mid-shrub understory than found in the Central Mixedwood subregion of Alberta.

Although it is currently poorly understood how and to what extent wolves or caribou use regenerating LIS for travel, foraging or hunting, our results suggest that the shorter stature of wolves may lead to greater visual obstruction than for caribou during the summer green-up period. A recent study in the Cold Lake Caribou Range by Dickie (2015) found that wolves selected all linear feature classes except for LIS in summer, and that wolf movement rates were slower on LIS than surrounding forest. It was also found that wolves generally moved faster on linear features with shorter vegetation and that vegetation reaching >1-m height reduced wolf movement by 23% in summer. Assuming that wolves utilize visual cues for at least the attack phase of prey capture (McNulty *et al.* 2007), the difference in visual obstruction on cleared and regenerating LIS between these 2 species during summer months may be important.

# MANAGEMENT IMPLICATIONS

Currently, vegetation re-growth and hiding cover on LIS after 7-9 years post-clearing is not sufficient to significantly obstruct visibility by wolves or caribou, especially in bogs and fens. Shrub and sapling cover will, however, continue to expand on LIS and based on growth after 7-9 years (especially on sub-mesic to sub-hygric deciduous sites) will likely obstruct wolf and caribou visibility significantly in from 15 to 20 years post-clearing. In bogs and poor fens, the current trajectory toward natural hiding cover indicates a longer time frame to significantly obstruct wolf or caribou visibility.

Restoration of cleared LIS within mesic to subhygric and nutrient-rich deciduous and mixedwood sites (D, E and F ecosites) is not recommended as natural vegetation recovery is likely to result in similar vegetation re-growth (and associated visual obstruction) to unaffected habitat from both wolf and caribou perspectives. Delayed regeneration of vegetation re-growth and associated visual obstruction on bog and fen ecosites on cleared and mulched LIS is similar to that of conventional seismic lines (van Rensen *et al.* 2015) and warrants management attention including enhanced restoration through coniferous shrub and tree plantings (Caners and Liefers 2014).

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## LITERATURE CITED

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