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Literature Review of Methodologies for Large Ungulate Habitat Enhancement Concurrent with Industrial Development

Prepared for:

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- Normand Cool, Wildlife Biologist, Parks Canada, Elk Island National Park
- Fraser Corbould, Wildlife Biologist, Peace/Williston Fish and Wildlife Compensation Program
- Chris Ritchie, WLAP, Section Head, Ecosystems, Prince George
- Mike Rowe, WLAP, Wildlife Biologist, Peace Region

Others that contributed significantly by providing literature references and through personal communications included:

- Kirby Smith, Wildlife Biologist, AB Fish & Wildlife
- Rod Backmeyer, WLAP, Wildlife Biologist, Fort. St. John
- Perry Grilz, Field Services Operations Manager, Ministry of Forests, Range Program
- John Krebs, Columbia Basin Fish and Wildlife Compensation Program

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1.0 Introduction

The BC Ministry of Water, Land and Air Protection (WLAP) in Fort St. John retained Triton Environmental Consultants Ltd. (Triton) to conduct a literature review to identify prospective habitat enhancement techniques for large ungulates, specifically moose (*Alces alces*) and Rocky Mountain elk (*Cervus elaphus nelsoni*) that can be applied concurrent with industrial development.

A basic premise in ecology is that animals seek to utilize their habitats in such a way as to maximize their energetic benefit, which in turn allows them to maximize their reproductive potential. The ability of animals to occupy and/or utilize habitats in the most energetically beneficial manner is influenced by variables such as predation, inter-specific competition, intra-specific competition, disease, parasites, human activities, weather patterns, and topography. The manner in which external forces influence habitat utilization often varies with geographic location, therefore it is important to understand variations in habitat requirements across the provincial ranges of moose and elk in British Columbia.

Recognizing the factor(s) that limit moose and elk populations at the landscape level (*e.g.,* climate, habitat availability, seral stage distribution, urban expansion, and agricultural development) is critical for successfully achieving provincial and regional objectives that are aimed at increasing productivity. The juxtaposition and interspersion of various habitats, especially the location of food relative to cover, is a critical landscape and stand level factor that influences survival (Nyberg *et al*., 1990).

Understanding the biology and habitat requirements of moose and elk is critical in identifying and conserving and habitats that might be limiting (*e.g.,* winter range, summer range, breeding grounds, calving areas, and migration corridors). Preserving key habitat elements through planning and locating developments is generally completed at the landscape level (habitat management). Techniques to enhance habitats for moose and elk at the site or operational level are also based on a sound understanding of their biology, but also require knowledge of the application, potential benefits and constraints of each technique. Informing resource managers and industry of effective strategies and techniques for managing moose and elk and their respective habitats is the goal of this project. To be successful, science-based knowledge and monitoring are required for developing and implementing effective policies and standards to achieve long-term goals.

Given that industrial practices largely result in the maintenance or increase of early seral community vegetation that is typically of benefit to moose and elk, habitat enhancement techniques that increase forage quantity and/or quality are the most common and are a primary focus of this report. Consistent with the general focus of this report, the discussion of the effects of practices designed to enhance habitats for moose and elk on non-target species is limited to stand or operational level practices and does not address landscape level modification. Additionally, the discussion of habitat enhancement techniques generally assumes that the footprint location of development has been set and opportunities to mitigate environmental effects have been considered. This helps to focus the discussion on enhancement techniques, although mitigation strategies are also presented and discussed. Where impacts of development on important habitats are unavoidable, the habitat enhancement techniques discussed in this report would provide a means of achieving compensation requirements.

2.0 Methodology

The methodology for completing this project consisted of four main phases, which included:

1. Scientific literature collection.
2. Review and discussion of management techniques.
3. Evaluation of habitat enhancement techniques.
4. Expert review.

Tabular matrices were created in an effort to provide WLAP with decision making tools that will allow them to provide guidance, primarily to resource-based industries (*e.g.,* forestry, mining, oil and gas, hydro, and agriculture), towards maintaining or enhancing habitats for moose and elk. The matrices include a comparison of the potential effectiveness, relative cost and compatibility with industrial uses, of habitat enhancement techniques that are of potential benefit to moose and elk. A thorough review of important forage species was completed for moose and elk and includes plant species responses to management treatments, .

2.1 Phase 1: Scientific Literature Collection

On February 22, 2005 the literature searching and acquisition process commenced. Below is a description of the specific tasks involved in this phase and how Triton completed them.

2.1.1 Searching for and Acquiring Literature

Our search for useful scientific literature included the query of several online library catalogues and journal indices, in addition to some internet sources. The preliminary key search words were:

moose OR *Alces alces*; elk OR *Cervus elaphus*; (large) ungulate

AND

habitat (improvement/alteration/restoration/enhancement); best management practices

In addition to our in-house library, the University of Northern British Columbia (UNBC), the University of British Columbia (UBC), Simon Fraser University (SFU), the University of Washington (UoW), and the Canadian Institute for Scientific and Technical Information (CISTI) library catalogues were directly searched.

The online journal indices that were searched covered a comprehensive assortment of mainstream and less widely distributed wildlife and environmental publications. Important indices that were searched included: Science Citation Index (Web of Science), Biosis (Biological Abstracts), AGRICOLA database, and CAB International Abstracts. The majority of published, primary data was obtained through this search effort. Additional 'grey literature' was sought through interviews with industry professionals and through internet queries of: www.scholar.google.com, www.scirus.com, Canadian provincial and federal websites, and US federal and state websites.

Following the preliminary literature search the list of references that had been compiled were screened to identify the most relevant items based on the titles and abstracts if available. The selected materials were then acquired from their various sources to facilitate a more comprehensive review of the material.

Once the literature that was collected during the first search effort had been reviewed, additional important references that were cited in some of the works were noted. In these cases, an effort was made to obtain the additional references.

2.1.2 Additional Information Sources

It was recognized that there are several important factors that should be considered in making informed decisions with respect to where, what (technique) and when to apply a given enhancement technique. In particular, the capability and suitability of available habitats, and the feasibility of implementing a given technique relative to the nature of the industrial development are key considerations. At the landscape level, the over-riding limitations to ungulate production and survivorship must be considered. At the operational level, site conditions (*e.g.,* soil moisture and nutrient regime) and vegetation management activities must be considered. To address these considerations, several ecosystem classification and rating systems that have been developed and are used within BC are discussed below and in this report, where appropriate.

In British Columbia, Biogeoclimatic Ecosystem Classification (BEC) provides a framework for resource and wildlife managers to plan and implement management strategies to meet their respective objectives and mandates. BEC zones describe broad regional areas of similar climate and vegetation and BEC subzones describe areas of similar sub-regional climate and vegetation, which facilitate the rating of the capability of large areas to support wildlife species such as elk and moose, for which there are Provincial Habitat Capability Maps that may be used to prioritize and focus stock enhancement efforts.

Provincial Wildlife Habitat Suitability Rating schemes utilize the BEC system at the operational level. Habitat suitability ratings are typically developed for stand level assessment and incorporate features (*e.g.* forage species, canopy closure) of particular importance to the target species. Habitat suitability rating schemes often include ratings for different successional stages of biogeoclimatic site series units[1] and for different seasonal requirements (*e.g.,* winter forage and thermal cover). Habitat features (including individual plant species) of particular importance to moose and elk have been identified in this report and can be used to develop rating schemes for local or sub-regional areas. The expanded legends produced for Terrestrial Ecosystem Mapping (TEM) and Vegetation Resources Inventory (VRI) projects identify the dominant and

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[1] Site Series Units have a diagnostic plant species assemblage and occur on sites with similar soil moisture and nutrients. They are identified using regional Site Identification Field Guides published by the Ministry of Forests.

co-dominant plant species for each successional stage of each site series unit, which provides a means of identifying ecosystem units with high capability of providing forage for moose and elk. Where TEM or Priority Ecosystem Mapping projects with wildlife habitat interpretations have been completed, wildlife habitat rating schemes have often been developed for moose and elk and are accessible through the regional offices of the Ministry of Sustainable Resource Management or through their website. These rating schemes provide a means of guiding development away from key habitats, and of prioritizing or focusing management efforts based on field surveys and/or map and aerial photograph interpretation.

2.2 Phase 2: Review and Discussion of Management Techniques

In reviewing the information collected, particular attention was given to the geographic area from which the observations were made. Efforts were made to determine whether strategies and techniques used to increase moose and elk numbers have been successful in different geographic areas. Where there has been variable success with a given technique, we attempted to identify the factors that contributed to the success or failure. The consistency in response of animals to treatment methods contributed to evaluating the relative potential for success.

The response of plant species to disturbance is an important consideration in developing strategies for managing habitats to provide forage for moose and elk. The response of key forage species for moose and elk to various disturbances, including vegetation management and site preparation (*e.g.,* scarification, burning, herbicide) were summarized relative to the applicability and feasibility of habitat enhancement techniques for different resource sectors.

We also investigated seed mixes used by various industries to determine their relative value in providing forage for elk. Seed costs and availability were determined and discussion of ongoing efforts to develop new seed mixtures using more native species was provided. In particular, the efforts of M. Vaartnou & Associates in establishing new native seed production sites and developing new seed mixtures for British Columbia was reviewed.

The potential effects of management techniques on non-target species were examined based on literature sources, as well as interpretation based on the expected habitat alteration associated with a given technique. Results were summarized in the context of species affected to the greatest degree as well as species of special management concern that could be affected. Where studies had not been completed to assess the potential effects of a given treatment on non-target species, we attempted to identify the potential effects based on the nature of the habitat modification. Ultimately, we attempted to identify habitat types that are particularly important for species of management concern where there may be conflict with potential enhancement activities for moose and elk.

Where possible, we attempted to identify variables that should be considered in determining appropriate strategies and techniques for moose and elk such that they can be incorporated into a decision-making matrix or flowchart.

2.3 Phase 3: Evaluation of Habitat Enhancement Techniques

The application of a given technique for enhancing habitats for moose and elk depends on several factors including geographic area, site conditions, the nature of the industrial development, and the type, intensity and frequency of vegetation management programs. It was recognized that a given technique may prove to be reliably effective, but it may not be appropriate for indiscriminate application. An evaluation of the relative compatibility of prospective habitat enhancement techniques with key resource sectors (*i.e.* forestry, mining, hydro, oil and gas, and agriculture) was completed based on existing information, and qualified based on peer review.

A comparison of the relative costs and potential benefits of the common habitat enhancement techniques was completed based on the literature and supplemented with expert opinion where information was sparse. Costs were standardized on a per hectare basis. Quantitative measures of the success or benefits of different techniques in achieving management objectives for moose and elk are not readily available in the literature, largely due to a lack of post-treatment monitoring and non-standardized evaluation techniques.

Due to the inherent variability in the potential benefits and costs of the common habitat enhancement techniques due to site conditions (*e.g.*, edaphic, slope, aspect) and other factors (*e.g.*, access, terrain, nature of development), attempts in developing a decision-making flowchart to guide technique selection were complicated and flawed. In order to provide the necessary flexibility to accommodate varying objectives and constraints, we developed decision-making matrices that incorporated the range of expected conditions and constraints for both moose and elk.

2.4 Phase 4: Expert Review

A key component of this project involved the utilization of peer review to provide comments on the draft report. Members of the review panel included some of the leading elk and moose management professionals in BC and Alberta. Due to the timing of the project and existing commitments and workloads of panel members, a comprehensive review of the draft report was limited the following individuals:

- Normand Cool, Wildlife Biologist, Parks Canada, Elk Island National Park
- Fraser Corbould, Wildlife Biologist, Peace/Williston Fish and Wildlife Compensation Program
- Chris Ritchie, WLAP, Section Head, Ecosystems, Prince George
- Mike Rowe, WLAP, Wildlife Biologist, Peace Region

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- John Krebs, Columbia Basin Fish and Wildlife Compensation Program

3.0 Summary of Life History Requirements

A basic premise in ecology is that animals seek to utilize their habitats in such a way as to maximize their energetic benefit, which in turn allows them to maximize their reproductive potential. With that in mind, it is recognized that variables such as predation, interspecific competition, intraspecific competition, disease, parasites, human activities, weather patterns, topography, *etc.* influence the ability of animals to occupy and/or utilize habitats in the most energetically beneficial manner. In addition, the juxtaposition and interspersion of various habitats, especially the location of food relative to cover, is a critical landscape level factor that influences survival (Nyberg *et al*. 1990). The manner in which external forces influence habitat utilization often varies with geographic location, therefore we have attempted to identify the typical range of habitat requirements across the provincial ranges of Rocky Mountain elk and moose in British Columbia.

All wildlife species have certain habitat requirements that need to be met in order to survive. The habitats utilized for some life requisites such as food and cover tend to vary seasonally, while other requisites such as reproduction habitats and migration corridors tend to be utilized only at specific times of the year (Resources Inventory Committee (RIC) 1999). The growing season (spring, summer, and fall) and winter season are the two seasons considered in this habitat review, as described in RIC (1999), since they effectively capture the fundamental elements that are targeted by most habitat enhancement efforts.

The following habitat descriptions for moose and elk are primarily drawn from texts and scientific reports that provide a synthesis of literature from across the range of moose and elk in North America (where appropriate) and within British Columbia.

3.1 Moose

In the province of British Columbia moose are the most widely distributed ungulate species, since they are only absent from the southern coast, the lower mainland, and the coastal islands, including Vancouver Island and the Queen Charlotte Islands (Cowan and Guiget 1965).

3.1.1 Feeding

3.1.1.1 Diet

Moose utilize a wide variety of plants as forage (Table 1) but are primarily browsers of trees and shrubs during winter. The use of aquatic and emergent vegetation can be significant in summer, however the leaves and succulent leaders of shrubs are also important (Coady 1982).

Table 1. Summary of forage species described in the literature to be utilized by moose.

Trees and Shrubs	**Forbs and Ferns**	**Aquatic Vegetation**	**Graminoids**
willows (*Salix* spp.)[1,2,3,4,6]	forbs[1, 3]	horsetail (*Equisetum* spp.)[3]	sedges (*Carex* spp.)[1,5]
black twinberry (*Lonicera involucrata*)[3,6]	lady fern (*Athyrium felix-femina*)[6]	pond lily (*Nuphar* and *Nymphaea* spp.)[3]	grasses[1]
red-osier dogwood (*Cornus stolonifera*)[1,2,3,4,5,6]		burweed (*Sparganium* spp.)[3]	
highbush cranberry (*Viburnum edule*)[1,2,3,6]		pondweed (*Potamegeton* spp.) [3]	
Saskatoon (*Amelanchier alnifolia*)[1,2,3]			
poplar (*Populus balsamifera*)[1,2,3,6]			
trembling aspen (*Populus tremuloides*)[1,2, 3,5,6]			
prickly rose (*Rosa acicularis*)[1]			
bog birch[2]			
paper birch (*Betula papyrifera)*[2,4,6]			
subalpine fir (*Abies lasiocarpa*)[1,4]			
chokecherry (*Prunus pennsylvanica*)[1,5]			
beaked hazelnut (*Corylus cornuta*)[1,4,5,6]			
soopolallie (*Sheperdia canadensis*)[1]			
gooseberry (*Ribes* spp.)[1]			
green alder (*Alnus viridis* ssp. *fruticosa*)[2]			
Sitka alder (*Alnus viridis* ssp. *sinuata*)[4]			

[1] Romito *et al.,* 1999; [2] Madrone, 1998a; [3] Norecol, 1998; [4] Anonymous, 2001; [5] Cool (pers. comm.), [6] Haussler *et al*. 1990

3.1.1.2 Growing Season

A review of the literature indicates that moose will typically utilize a wide variety of dietary items throughout the growing season, with browse species being most thoroughly represented. In Elk Island National Park, the early emergence of leaves is considered very important as moose and elk spend a great deal of time stripping leaves such as poplar, which has been found to be a rich forage source with a 16% or higher crude protein content (Cool, pers. comm.) Shrub forage is a major dietary component throughout the growing season, with succulent forbs and semi-aquatic plants becoming increasingly important from late spring, through the summer, and into the fall (Coady 1982). Red-osier dogwood is reported to be a favoured species in the spring when the sugar content is elevated in the woody material (Anonymous, 2001). Moose are rarely found in dense forests during the summer, preferring wetlands and riparian areas. Aquatic plants, forbs, grasses, and the leaves of many shrubs are consumed during the growing season, with aquatic plants often forming the bulk of a summer diet. Browse species are also often consumed during the growing season.

3.1.1.3 Winter Season

During the winter, moose depend heavily on shrubby forage, favouring selected species such as willow, which is considered to be the most important winter food in western areas (Peek 1974). A study of willow species that occur on disturbed sites within four biogeoclimatic subzones in the Prince George area indicated that five of fourteen willow species (*Salix bebbiana, S. scouleriana, S. discolour, S. sitchensis, S. lucida* ssp. *lasiandra*) represented nearly all of the willow biomass consumed by moose in logged areas (Porter 1990). Some willow species were browsed in proportion to their abundance but *Salix scouleriana* and *S. lucida* ssp. *lasiandra* were consistently selected preferentially. This suggests that browse regeneration efforts should consider the willow species present when choosing sites and methods.

Regional differences in preferred browse species is largely attributable to local abundance. There are numerous species of willow in the Province, many of which are common and palatable to moose. Species such as red-osier dogwood and Saskatoon are favoured browse species that are widely distributed but tend to be locally abundant. Trembling aspen and paper birch are also widely distributed and young trees are favoured browse. The bark of aspen and some willows are also eaten. The leaves and twigs of falsebox are a favoured winter food, however the small shrub is often buried under the snow. Other shrub species that are widely distributed and utilized regularly but moderately for browse include highbush cranberry, rose, alder, soopolallie, and bog birch. In the Aspen-Parkland ecosystems of Elk Island National Park, aspen, balsam poplar, willows, beaked hazelnut and birch are identified as the most important foods (Blood 1974), however in eastern Canada conifers form a major part of the winter diet and in Alaska bog cranberry is important (Coady 1982).

Moose typically acquire winter forage in low lying areas, although some may linger at higher elevations through some or all of the winter if forage is sufficiently abundant and snow depth does not become limiting (Coady 1982, Norecol 2003). Snow depths of up to 60-70 cm are considered to have little effect on moose mobility (Langin *et al*. 1990, Telfer 1970, Telfer and Kelsall 1971). Referring to other studies, Telfer (1970) states that moose have been shown to move out of cutover areas when snow depths range between 77-86 cm and do not normally venture into areas with snow depths between 107-122 cm, and included a postulated critical limit of 90-100 cm. A transition in habitat selection from open cover and deciduous forest types in early winter, to a concentration in dense coniferous types in late winter occurred when snow depths in all transects except dense conifer was 113 cm (Telfer 1970). Langin *et al*. (1990) indicate that moose are generally not abundant in regions where persistent snow accumulation exceeds 1-1.5 m. This suggests that increasing shrub production in open areas of wetter and colder biogeoclimatic subzones may have limited value in late winter habitat.

Winter use of burns and clearcut areas has typically been found to be greater than adjacent unburned or cut areas due to the increase in available forage, which tends to peak in abundance at around 10-15 years after the initial disturbance, and sustain high levels of utilization up to 20 to 30 years following disturbance (Romito *et al.,* 1999, Westworth *et al*. 1989, Telfer 1988). In contrast, Osko *et al*. (2004) found that disturbed areas (including clearcuts and burns) were avoided relative to their availability. In studying two groups of moose in areas with different relative abundances of habitat available, Osko *et al*. (2004) found that deciduous uplands and open coniferous forests were preferred but added that habitat preference was not fixed for several habitat classes, suggesting that it would change as available habitat changes.

3.1.2 Cover

3.1.2.1 Security Cover

The most critical time for security cover is during calving in the spring, when cow moose seek out islands and gravel gars on floodplains with associated shrub thickets (Norecol, 2003). Discussion on critical habitats that are selected during that time is covered in the reproduction section below.

While an operational definition of effective moose cover is lacking, Thomas *et al.* (1979) indicate that a widely accepted minimum standard for elk is vegetation capable of hiding 90% of a standing animal at 61 m or less. The minimum height for good security cover is three metres, to ensure that a standing animal is well concealed (Thomas *et al.*, 1979). In the Smith Vents TEM project area, moose utilize dense, tall shrubby areas and mature spruce-poplar stands that have moderate to dense understory. In the winter, dense conifer patches that are adjacent to feeding habitat are preferred (Norecol, 2003). Anonymous (2001) indicates that moose prefer to avoid the centre of large, open cutblocks and other openings.

3.1.2.2 Thermal Cover

Several studies (Collins et al. 1997, Schwab 1986), including one completed 50 km northeast of Prince George, found that moose habitat selection was strongly associated with a need to avoid heat stress in the summer and during warmer days in late winter, and that cold stress did not appear to be an important limitation. In the winter, the upper critical limit for moose prior to becoming heat stressed is reportedly between –5.1°C and –0.4°C, while the lower critical limit has not been firmly established since moose appear well adjusted to temperatures of –20°C or lower (Schwab 1986). It was found that the only location where the upper critical temperature limit was not exceeded for at least part of the day at some point during the winter was in unlogged forest.

In the summer, the need to avoid heat stress appears to have a strong influence on habitat selection (Schwab 1986, Cool pers. comm.). Schwab (1986) found that moose were observed to favour forested areas in late winter and in the summer, while favouring open areas in the spring and mid winter. It was believed that moose are more susceptible to heat stress in late winter than in mid winter because air temperatures are warmer, and the influx of solar radiation occurs for an increasingly longer duration, which is compounded by reflected solar radiation from the snow (Schwab, 1986).

Multi-layered stands provide the best thermal cover, as supported by Norecol's (2003) description of mature mixed and conifer stands with moderate to dense understory in the Smith Vents TEM area that are utilized by moose in the winter and the summer.

In addition, wetlands are described to be an important habitat for staying cool in the summer (Schwab, 1986; and Norecol, 2003). Madrone (1998a) indicated that moose utilize south aspect slopes on cold, sunny days in the winter, or cooler areas for reducing heat stress on warm winter days. Forested and wetland areas are important for reducing heat stress in the summer (Madrone, 1998a). KTPW-Geo (2000) state that dense, mature coniferous forests provide good winter thermal cover and good snow interception, due to their multi-layered structure and trees with interlocking crowns. Thermal cover and snow interception are important for moose calves as they are considered the ungulate least likely to survive a harsh winter due to the fact that they can continue to grow (to their detriment) during the winter (Cool, pers. comm.). Schwab *et al*. (1991) suggest that ideal crown closures are 70 to 75%. Romito *et al.* (1999) mention that moose often seek thermal cover on warm winter days to avoid heat stress.

3.1.3 Reproduction

Reproductive rates in moose are largely determined by ovulation, pregnancy and natality rates, (Coady 1982). Ovulation rates in adults are probably influenced by summer nutrition alone or in combination with winter nutrition (Blood 1974). Coady (1982) indicates that 80-90% of adult females in most populations become pregnant annually and attributes variation in reproductive performance of populations to the number of yearlings, the incidence of pregnancy in yearlings, and twinning in adults. Studies indicate that moose fecundity is related to population density indirectly via the nutritional state of the range (Blood 1974, Coady 1982, Franzmann 1980), therefore increasing forage where it is limiting should increase the fecundity of the herd, provided there are no other controlling factors. Cool (pers. comm.) relates productivity to the beginning and duration of the fat accretion period, with an early green up important for calving and lactating in the spring and early summer months, with good summer range and a late fall to maximize fitness for breeding. Heat stress and harassment by insects are considered to reduce fat accretion (Cool, pers.comm.).

Neonatal mortalities are mostly attributed to accidents, predation, and abandonment. Predation rates are highly variable but can limit population size. Important predators include grizzly bear, black bear and wolf. Moose mortalities due to winter ticks (*Dermacentor albipictus*) have been found to be high when moose density is high (Samuel et al. 1991), suggesting that this could become a factor if moose become too concentrated on a given winter range.

3.1.3.1 Calving

It is believed that calving in the Smith Vents TEM area occurs in late May to early June in valley bottoms (Norecol, 2003). At that time the general strategy displayed by cows is to seek out habitats that are secluded and relatively secure from predators (Romito *et al.,* 1999; and Anonymous, 2001). Cows in the Smith Vents TEM project area are believed to utilize islands and gravel bars on river floodplains, or hide in dense, tall shrubby areas and mature spruce-poplar stands that have moderate to dense understory. Calving in the Fort Nelson area is reported to occur in May, with cows seeking out shrubby islands to avoid wolf predation (per Madrone, 1998a). Shrubby lake borders and coniferous stands near watercourses are also anticipated to be important areas.

3.1.3.2 Rutting

The rut occurs in basins and plateaus from late September to late October, with the post-rut continuing into late December or January (Norecol, 2003). Rutting in the Fort Nelson area is reported to occur in the last two weeks of September (per Madrone, 1998a). Anonymous (2001) state that rutting in the Lower Sukunka occurs in late September to early October but no special habitat features are used.

3.2 Elk

A common theme throughout the literature regarding elk habitat selection in winter reveals that snow accumulation and the availability of forage are the two dominant elements that influence elk distribution on the landscape. With these key criteria in mind other pressures such as predation, interspecific competition, human activities, weather patterns, topography, *etc.* influence the ability of elk to occupy habitats that would be the most energetically beneficial to them, or to utilize those habitats in the most efficient manner. Due to these additional pressures, security (and thermal) cover constitute a third key habitat element that is required by elk. These elements influence the seasonal habitat requirements of elk to varying degrees.

3.2.1 Feeding

3.2.1.1 Diet

A review of key literature sources that have compiled dietary information from various sources indicate that a wide range of forage species are utilized by elk throughout the year (Table 2). Kufeld (1973) found that 159 forbs, 59 grasses, and 95 shrubs have been reported as elk forage, suggesting that elk are generalist feeders that can adapt to local food sources. A few examples are provided (see below) to demonstrate this variability, however some generalizations can be made with respect to summer and winter diet and important species (see following sections). In particular, it is generally accepted that elk are preferential grazers and that grasses will form the bulk of the diet where palatable species are relatively abundant and available.

Depending on the availability of forage species, the diet of elk may substantially be comprised of grasses or shrubs, although conifers have occasionally been important. In much of the northern United States, and in central and southern Alberta and British Columbia, grasslands and open forests are relatively common and are where elk are typically found. In several areas of British Columbia, elk are found in landscapes that provide limited meadow and open forest types where graminoid species are abundant, and the literature indicates that the diet includes greater proportions of shrubs, conifers, and lichen. Kufeld (1973) and Peek (1982) indicated that grasses, mostly *Agropyron* spp., *Poa* spp., *Festuca* spp., *Bromus* spp. and *Melica* spp. are the most important forage species. Corbould (1998) found that lichens, followed by shrubs (Saskatoon, rose, willow, highbush cranberry) were the dominant (dry weight) species in the winter diet of elk in the Peace Arm of the Williston Reservoir. Canon *et al*. (1987) found that the diet of elk was similar in burned and unburned areas (mostly aspen forest), with Saskatoon being the dominant dietary item, and other common species including falsebox, Scouler's willow (*Salix scouleriana*), aster, sticky geranium (*Geranium viscosissimum*) and meadowrue (*Thalictrum fendleri*).

Table 2. Summary of forage species described in the literature to be utilized by elk.

Trees and Shrubs	**Graminoids**	**Forbs**	**Mosses and Lichen**
Saskatoon (*Amelanchier alnifolia*)[1,2,3,4]	wheatgrass (*Agropyron* spp.)[1,2,3]	vetch (*Astragalus* spp.)[1,3]	clubmoss (*Lycopodium* spp.)[3]
sage (*Artemesia* spp.)[1,2,3]	wildrye (*Elymus* spp.)[3,8]	larkspur (*Delphinium* spp.)[3]	*Selaginella* spp.[3]
Oregon-grape (*Mahonia aquifolium*)[1]	hairgrass (*Agrostis scabra*)[1,3]	*Draba* spp.[3]	*Alectoria* spp.[4]
pine (*Pinus* spp.)[3,8]	*Bouteloua* spp.[3]	bedstraw (*Galium* spp.)[3]	*Peltigera aphthosa*[4]
spruce (*Picea* spp.)[3,4]	brome grass (*Bromus* spp.)[1,3]	avens (*Geum* spp.)[3]	
Douglas fir (*Pseudotsuga menziesii*)[3]	carex sedges (*Carex* spp.)[1,3,4,8]	lupine (*Lupinus* spp.)[2,3]	
blackberry (*Rubus* spp.)[1,2, 3]	beaked sedge (*Carex rostrata*)[5]	*Mertenesia* spp.[1,3]	
willow (*Salix* spp.)[1,2,3,4,8]	awned sedge (*C. atherodes*)[5]	coltsfoot (*Petasites* spp.)[3]	
soopolallie (*Shepherdia canadensis*)[3]	*Danthonia* spp.[3]	cinquefoil (*Potentilla* spp.)[3,8]	
wolf willow (*Elaeagnus commutata*)[3]	tufted hairgrass (*Deschampsia* spp.)[1,3]	saxifrage (*Saxifraga* spp.)[3]	
blueberry, bog cranberry (*Vaccinium* spp.)[1,3]	spike-rush (*Eleocharis* spp.)[3]	chickweed (*Stellaria* spp.)[3]	
falsebox (*Pachistima myrsinites*)[1]	fescue (*Festuca* spp.)[1,2,3,5,8]	vetch (*Vicia* spp.)[1,3]	
red-osier dogwood (*Cornus stolonifera*)[1,2,3]	rushes (*Juncus* spp.)[3,4]	agoseris (*Agoseris* spp.)[2]	
highbush cranberry (*Viburnum edule*)[1,3,4]	junegrass (*Koeleria cristata*)[3]	wild onion (*Allium cernuum*)[2]	
rose (*Rosa acicularis*)[1,2,3,4]	bluegrass (*Poa* spp.)[1,3,4,5]	arnica (*Arnica* spp.)[1,2]	
balsam poplar (*Populus balsamifera*)[5]	false melic (*Schizachne purpurascens*)[3]	fireweed (*Epilobium angustifolium*)[2]	
trembling aspen (*Populus tremuloides*)[1,2,3]	*Stipa* spp.[1,3]	sticky geranium (*Geranium viscossium*)[1,2]	
salal (*Gaultheria shallon*)[2,6]	rough fescue (*Festuca scabrella*)[1,3,4]	balsamroot (*Blasamhorriza sagitata*)[2]	
snowberry (*Symphoricarpos albus*)[2]	tufted hairgrass (*Deschampsia cespitosa*)[1]	dandelions (*Taraxacum* spp.)[2]	
raspberry (*Rubus idaeus*)[1]	hairy wildrye (*Elymus innovatus*)[1,4,8]	wild strawberry (*Fragaria virginiana*)[1,3]	
water birch (*Betula occidentalis*)[2,3]	melic grass (*Melic* spp.)[3]	clover (*Trifolium* spp.)[1,5]	
cherry (*Prunus* spp.)[1]	bluejoint (*Calamagrostis canadensis*)[3,4,5]	horsetail (*Equisetum* spp.)[3,4]	

[1] USDA 1988; [2] Peek 1982; [3] Kufeld 1973; [4] Corbould, 1998; [5] Norm Cool (pers. comm.); [6] Nyberg *et al*. 1990; [7] Haussler *et al*. 1990; [8] Salter *et al*. 1980

3.2.1.2 Growing Season

In general, elk forage during the growing season (spring through fall) consists primarily of graminoids, with forbs and the leaves of browse species becoming important in summer (Boyd, 1978, Peek 1982, Jones *et al*. 1986, Kinuthia *et al*. 1992). However, in reviewing a number of studies, Peek (1982) and Norecol (2003) noted that significant diet variation can occur geographically, and that a significant amount of woody browse may continue to be utilized in the spring if green biomass is not available. When browse species are consumed during the growing season, the growing shoots and leaves are preferred over the woody parts (Cool pers. comm.). Grass species of particular value to elk that are found in British Columbia include bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*), hairy wildrye (*Elymus innovatus*) and rough fescue (*F. scabrella*). Crude protein and dry matter digestibility were found to increase in both bluebunch wheatgrass and Idaho fescue with grazing pressure (Clark *et al*. 2000).

Habitats that tend to have preferred elk forage available during the growing season include open conifer stands, deciduous forests, wetlands, riparian areas, and vegetated slides (Nyberg *et al*., 1990). Elk use of agricultural rangeland is also well covered in the literature (Vavra *et al*., 1996; Short *et al*., 2003; and Coe *et al.*, 2004). Subalpine parkland and alpine tundra regions, along with vegetated rock outcrops are considered additional forage locations sometimes utilized by elk (Madrone 1998a).

3.2.1.3 Winter Season

The winter diet of elk has been reported to be comprised primarily of grasses (up to 100% on some ranges), however elk can persist when the availability of forage requires a complete reversal of this diet (Peek 1982, Thomas *et al*. 1979). During the winter months, woody browse often forms a significant component of the elk diet, although graminoids continue to be utilized if available (Boyd 1980). Hairy wildrye, fescue, lodgepole pine, willow and Carex sedges comprised the bulk of the winter diet of elk in lodgepole pine and meadow shrub communities in western Alberta (Salter *et al*. 1980). In the Williston area of northern BC, Corbould (1998) reported that graminoids continued to be the dominant winter forage item in the Peace Arm drainage. In the Ospika drainage, however, arboreal and terrestrial lichens were heavily utilized in similar proportions, with *Alectoria* spp. and *Peltigera aphthosa* being the dominant species consumed. This degree of lichen utilization had not been reported in any other study, and since snow depths were measured up to 50 cm deep, elk likely used mature coniferous forests to access arboreal lichens (Corbould 1998).

In the Peace Arm drainage, Backmeyer (2000) reported that shrub/grassland habitats were preferentially occupied, while conifer and mixed forests were avoided. The ability of elk to utilize these open areas in winter is closely related to (lower) snow accumulation.

3.2.2 Cover

3.2.2.1 Security Cover

In general, the optimal proportion of cover to forage areas typically favours open areas, with a 40% to 60% ratio suggested by Thomas *et al*. (1979). The interspersion of cover to open areas is reported to be critical, although there appears to be increased security with large aggregations using large areas of open terrain (Peek 1982). The minimum criteria for security cover is described by Thomas *et al.* (1979) as vegetation that can hide 90% of a standing elk from a distance of 61 m or less. Open areas interspersed with trees or dense shrubs were described by Madrone (1998a) to be ideal for elk, and Norecol (2003) stated that coniferous and mixed forest stands with a minimum size of 2.6 ha would provide acceptable security cover. Assuming a circular pattern exists, Thomas *et al.* (1979) indicated that the optimum size range for hiding cover is between 2.6 and 10.5 ha, requiring a diameter between 171 and 368 m. Patches smaller than 2.6 ha become decreasingly effective since the elk becomes increasingly more exposed, while patches larger than 10.5 ha become decreasingly effective because increasingly larger interior zones of less than maximum use are created (Thomas *et al.*, 1979).

Nyberg *et al*. (1990) indicated that topographic features can contribute to the value of security cover in an area, and that coniferous stands with 60% crown closure can be effective if they are at least 100 m wide and over three metres tall. TerraMar (2001) stated that security cover is provided by vegetation that is at least two metres high, at a density of 50 to 200 stems/ha. KTPW-Geo (2000) also recommended a minimum vegetation height of two metres, while stating that dense forest understories are optimal and that topographic features such as gullies and hummocky terrain can also help elk to conceal themselves.

3.2.2.2 Thermal Cover

While the benefit of thermal cover for protecting ungulates such as elk from heat, cold, precipitation, and wind have been commonly emphasized in the literature and habitat suitability index models, recent studies suggest that its value may be much less significant then previously believed. In studies involving elk, mule deer, and white-tailed deer, Cook *et al.* (1998 and 2004) found little evidence to support the notion that thermal cover affects herd productivity or demographics, and indicated that in most cases managers should place thermal cover low on the list of habitat priorities. They indicated that climatological circumstances may exist that would make thermal cover a relevant consideration, however, this need should be demonstrated first, since it has yet to be confirmed with empirical data (Cook *et al.,* 1998). This is in contrast to Thomas *et al*. (1979), where a working definition for elk thermal cover (summer and winter) included 12 m or taller trees with a 70% crown closure and was based on 7 years of observations of radio collared animals. While elk may experience a greater degree of thermal comfort from utilizing habitats such as forested areas and south facing slopes that are commonly cited to provide critical thermoregulatory value, reduced snow depths in these locations could be the dominant factor influencing their decision to use them.

3.2.2.3 Snow Interception Cover

A snowpack depth of approximately 45 cm has been found to cause a significant increase in energy expenditure to acquire food and affect habitat use (Parker *et al*. 1984, Nyberg *et al*. 1990). For the purpose of assessing habitat for deer and elk in the coastal forest of southern BC, Nyberg *et al*. (1990) described four snowpack zones: shallow (usually <30 cm with critical snowpacks occurring less than once in 15 years); moderate (usually 30-60 cm that persist for up to 2 weeks, with critical snowpacks occurring every 5-15 years); deep (often >60 cm and persisting for 2 weeks or more, with critical snowpacks occurring every 3-5 years); and very deep (usually more than 60 cm persist most of the winter). Mature forest types with canopy closures of 60-70% are considered to provide adequate snow interception, although stands with lower canopy closure can be utilized where there are large trees with large crowns. Nyberg *et al*. (1990) indicated that stands at least 10 m tall, with a canopy closure between 60 to 90 % are ideal for snow interception cover in coastal British Columbia.

3.2.3 Reproduction

Reproductive rates in elk are largely determined by ovulation, pregnancy and natality rates, (Peek 1982). Blood 1974 suggests that ovulation rates in adults are probably influenced by summer nutrition alone or in combination with winter nutrition. It is commonly accepted that reproductive success is linked to the beginning and duration of the fat accretion period, with an early green up important for calving and lactating in the spring and early summer months, and good summer range and a late fall to maximize fitness for breeding (Cook et al. 2004, Johnson et al. 2004, Cool pers. comm.). Based on reproductive potential, habitat enhancement or management activities that strive to improve the quality of spring, summer and fall range should be effective for elk.

Peek (1982) indicates that pregnancy rates of adult cows are usually above 90% in most populations and that the incidence of pregnancy in yearlings is dependant on weight and in turn, nutritional status. Cows that lost more than 3% of their body weight between January and May produced smaller calves that were less likely to survive (Peek 1982). Losses due to malnutrition can be significant in severe winters. Ultimately, elk populations appear to be regulated by the quantity and quality of available forage (Peek 1982, Coughenour *et al*. 1996), therefore increasing forage where it is limiting should increase population size.

Neonatal mortalities are mostly attributed to predation and abandonment. Predation rates are highly variable but can limit population size. Important predators, especially on calves, include grizzly bear, black bear, cougar, and wolf.

Bull elk have been found to become predisposed to mortality with early post-rut snowfalls and temperatures below –15C as they are in a negative energy balance and cannot replenish their fat stores after the rut (Cool, pers. comm.).

3.2.3.1 Calving

Optimum calving habitat has been described as containing forage areas, hiding cover and thermal cover within forested stands (Thomas *et al*. 1979). Late May to early June is the commonly cited time for elk calving (Boyd 1978, Nyberg *et al*. 1990, and Buckmaster *et al.* 1999). Calving usually occurs in secluded areas away from the rest of the herd, in order to avoid predators that might focus in on a large, vulnerable group (Nyberg *et al*. 1990). This security cover is utilized for the first two to three weeks following birth, before the cow and calf rejoin the rest of the herd (Nyberg *et al*. 1990). TerraMar (2001) indicated that cow and calf rejoin the herd five weeks after birth. In northeastern BC, calving locations were described to occur in valley bottoms and lower slopes amongst dense shrubs, coarse woody debris, and/or closed canopy coniferous forest (Norecol, 2003). Terraces and gentle benches in steep topographic locations can also be utilized for calving (Anonymous, 2001).

3.2.3.2 Rutting

Rutting activities for elk typically occur from mid September to the end of October (Boyd, 1978). In the Lower Sukunka TEM project area rutting is said to begin in early September, peak in mid September, and conclude in October (Anonymous, 2001). Buckmaster *et al.* (1999) stated that the rut begins in late September and extends to early November. No specific habitats tend to be described in the literature that is unique to the rutting activity.

3.2.4 Migration

Elk herds may exhibit a migratory life history strategy in which they travel annually between distinct summer and winter ranges, or a non-migratory life history strategy in which they largely occupy one range all year (Nyberg *et al*. 1990). Boyd (1978) indicated that elk may remain on their summer range year round, although most migrate to a winter range that is located at a lower elevation to avoid deep snow. Migration can involve long distances of travel in relatively little time, as illustrated by an instance in Colorado where 177 km was covered in only 2.5 months (Boyd, 1978). Petticrew and Fyfe (1981) indicated that winter grounds in northeastern BC tend to be in foothill areas on south and west aspect slopes. The migration route between summer and winter ranges in that region is believed to occur via valley bottoms of main rivers (per Anonymous, 2001). Demarchi *et al.* (1992) indicate that most elk in northern BC are non-migratory, with the summer and winter ranges located together or adjacent to each other.

Ungulates such as moose and elk require numerous habitat types to satisfy their life history requirements throughout the year including: spring, summer, and fall range for food and cover, winter range for food and cover, reproduction areas (*i.e.* calving areas, post-calving areas, rutting areas, and post-rutting areas), and mineral licks (Petticrew and Fyfe, 1981). It is therefore important to recognize and accommodate these requirements at both the landscape and stand levels through mitigation and habitat enhancement actions.

4.0 Mitigation Strategies for Moose and Elk

Development related impacts to moose and elk may be direct (*e.g.,* mortality, habitat loss) or indirect (*e.g.,* disturbance, habitat modification, predator effects). In either instance impacts can often be mitigated in the planning, design, construction, operation, and site reclamation phases of development. The more common strategies and techniques that are utilized to mitigate potential negative effects of industrial development on moose and elk and their respective habitats include:

- Habitat preservation
- Design of cutblock boundaries and buffer strips
- Access management
- Minimizing other human disturbances
- Improved grazing systems
- Herbicide treatment

Avoiding important habitats and modifying layouts to accommodate wildlife objectives are usually accomplished in the planning and design phases of development and are more of a landscape level consideration. Minimizing noise and development related disturbances are typically achieved through planning, construction sequencing and timing, and construction approach. Access management is usually applied following active construction, development, or resource extraction and is usually based on landscape unit objectives, although it is also applicable through early silvicultural phases and seasonally in the recreation industry. Herbicide treatments are generally aimed at reducing animal mortalities due to collisions in transportation corridors. Improved grazing systems provide a means of accommodating "compatible" uses and occurs on an ongoing basis.

4.1 Habitat Preservation

Identifying important habitats (*e.g.* winter range, calving areas, migration routes) and understanding their sensitivities to disturbance, both spatially and temporally is an important first step in mitigating potential impacts to moose and elk populations. In the planning phase of development, wildlife habitat capability is usually interpreted based on a review of existing information such as resource mapping (*e.g.* TEM, PEM, biophysical habitat classes, habitat capability), and supported by field surveys to rate habitat suitability. Based on habitat mapping and field surveys, the location and development footprint can usually be designed (or is required) to avoid and preserve the function of important habitats. To maintain habitat function, it may be necessary maintain adjacent buffer zones, and manage adjacent areas by concentrating activities such as road building, camps, field offices, log sorts, and load-outs in areas removed from important habitats, as well as planning and managing access to minimize disturbance.

At the landscape level habitat preservation is usually achieved through the designation of critical habitat as a Wildlife Habitat Management Area or Ungulate Winter Range. At the operational level, important habitats may be protected in riparian reserves and wildlife tree patches. Locating and designing wildlife tree patches to maximize edge and reduce sight distances have been effective in increasing moose utilization of cutblocks (Payne et al. 1988).

4.2 Cover Treatments

Cover has widely been recognized as an important habitat feature for moose and elk. While the benefits of security cover are more obvious and accepted, the value of thermal cover has often been questioned (Jones *et al*. 2002). Both moose and elk are well adapted to cold (below -20C) and often have not demonstrated preference for forest types that provide the best thermal cover (e.g., dense mature conifer) in winter. The snow interception values of coniferous forests are recognized as important in deep snowpack areas and in general where travel is less costly and forage is available. It has more recently been accepted that moose and elk utilize coniferous forests to avoid heat stress in the summer.

It is commonly felt that elk are more likely (than moose) to flee from disturbance and thus would benefit to a greater extent by the maintenance or creation of security cover. The importance of security cover was emphasized by Churchill (1982) in his study of elk in the White River drainage of southeastern BC, with an observation that elk fled from clearcuts into forested areas 86% of the time at the sight of humans or vehicles. It was also found that elk were generally found further than 200 m from active roads (Churchill, 1982). In a study of the effects of off-road recreation (including horseback riding, ATV use, mountain biking, and hiking) on elk in Oregon, Wisdom *et al.* (2004a) found that the probability of flight was 65%. In a similar study that investigated spatial partitioning of elk and mule deer in relation to traffic, Wisdom *et al.* (2004b) found that elk were generally farther away from roads that experienced traffic patterns of greater than one vehicle every 12 hours, while deer were generally closer. Other researchers have reported decreased use of areas adjacent to roads for distances averaging between 400-800 m (Thomas et al. 1979). Rowland *et al.* (2004) observed that bulls seemed to avoid roads to a greater degree than cows.

A canopy closure of 70% has commonly been cited as the minimum criteria for acceptable thermal and snow interception cover, while vegetation that is dense enough to hide 90% of a standing ungulate at 61 m is a guideline for security cover.

Thus, cover habitat treatments that can be applied concurrent with industrial development would include:

- The modification of cutblock boundaries to restrict sight distances;
- The inclusion of forested doglegs and the maintenance of patches of security cover on seismic, pipeline and hydro corridors adjacent to roads to minimize sight lines and dash distances to cover; and
- The maintenance of forested buffers adjacent to important habitats (*e.g.,* winter range, wetlands, lakes and riparian areas), including secluded calving areas (*e.g.,* riparian areas, islands on river floodplains).

Potential Benefit for Moose and Elk

Protecting high value thermal cover areas to provide relief from (late) winter and summer heat stress and leaving strategic buffer strips adjacent to wetlands, lakes, and riparian zones are two key strategies for providing moose with important thermal and security cover. A related strategy involves planning cutblock boundaries (*e.g.,* shape of block and size of cut) to reduce the distance to security cover, which would also help to maximize the amount of useable forage habitat. Where possible, forested buffers are established adjacent to key habitats through design (relocation, realignment), retention (*e.g.,* wildlife tree patch) or partial retention (*e.g.,* selection cutting).

Examples of Treatment Strategies

Schwab (1986) found a positive association between moose and the use of wetland habitats in the spring, summer, and fall in his study area that was located 50 km northeast of Prince George, BC. Given that part of his research indicated moose are easily heat stressed during the summer months, the need to conserve wetlands and access to them was emphasized. While lakes received limited use in his study, Schwab (1986) recognized their potential value in some areas and recommended the conservation of forested access to lakeshores, since these areas can provide an opportunity for thermal regulation in addition to valuable forage. In terms of security cover, Schwab (1986) recommended that an 80 m buffer be considered adjacent to riparian areas in order to maintain the integrity of the forest-riparian ecotone, and to facilitate the maintenance of travel corridors that can be used to access lakes and wetlands. For lakes, it was recommended that no more than 40% of the lake perimeter be harvested at one time, with further harvest not occurring until regenerated trees are 2 to 4 m tall. Schwab (1986) also recommends maintaining a minimum distance to cover of 200 m from any point within a cutblock or between wetlands.

Security cover can be provided in cleared areas by windrowing slash, which can also function to reduce slash and improve travel and access to forage. Roadside buffers can be employed to screen foraging areas, and doglegs can be incorporated into roads or other types of rights-of-way to reduce sight distance, the latter is a common practice in Alberta where seismic lines and pipelines cross roads. Maintaining periodic cover breaks to reduce line of sight on hydro and oil and gas rights-of-way may also prove effective.

1. Preserve key habitats through avoidance and buffer strips.
2. Maintain patches of cover in cutblocks and along right-of-ways to restrict sight distance.
3. Incorporate doglegs or forested buffers at road and right-of-way intersections.
4. Harvest no more than 40% of a lakeshore perimeter at one time. Allow regenerating vegetation to become 2 to 4 m tall prior to proceeding with additional harvest plans.
5. Retain 80 m buffer strips around wetlands, lakes, and riparian areas for cover and migration.

4.3 Access Management

<u>*Rationale for Application*</u>

Peek (1982) reported that elk populations have commonly shifted to areas where activity on roads is minimal and hunter access is reduced. Johnson *et al*. (2004) found that elk responded to hunting disturbances by fleeing, while deer opted to hide. Habitat use did not seem to change, but the daily pattern of habitat use was affected. The estimated energetic cost of fleeing, combined with lost foraging opportunities over an extended hunting season have the potential to significantly increase elk mortality due to reduced nutritional condition beyond the hunting season.

Rowland *et al.* (2004) cited numerous negative impacts that open roads have on elk including: mortality through collisions with vehicles, avoidance of (foraging) areas near open roads, increased vulnerability to legal and illegal hunting activity, and higher stress levels and movement rates in areas of higher road density. From another perspective, the avoidance of roads by elk and moose could be viewed as a positive effect in reducing mortalities associated with vehicle collisions and hunting.

<u>*Potential Benefit for Elk*</u>

Given that elk appear to be particularly sensitive to human disturbance, especially in association with active roads, access management planning objectives for elk should consider road location, road density, minimizing periods of activity, and access closure.

Examples of Treatment Strategies

One important strategy that was strongly advocated by Rowland *et al.* (2004) involved closing roads or limiting access to roads that transect elk ranges. Some of the potential benefits to road closures include: decreased energy expenditures from fleeing, increased time spent foraging, decreased agricultural conflicts since reduced disturbance on public land may encourage elk to remain there longer in the fall and winter, increased effective habitat area, and the potential to issue more hunting licenses due to reduced hunter mobility. A major challenge to the effectiveness of this management strategy was anticipated to be effectively enforcing road closures (Rowland *et al.*, 2004). Churchill (1982) was also in favour of considering road closures, with a recommendation that roads transecting cutblocks that are known to be utilized by elk in the winter should be closed at that time.

Management implications from the research of Wisdom *et al.* (2004b) suggest that habitat suitability and habitat capability indices for elk should include traffic variables such as the density of open roads and traffic frequency as potential factors that would decrease the habitat quality. Rowland *et al.* (2004) proposed a distance-band approach to modeling elk-road effects instead of the road density approach that is most commonly practiced because it is "a more spatially explicit and biologically meaningful tool". Churchill (1982) pointed out that elk tend to flee uphill, and for that reason main roads should be built below south aspect slopes that are preferred elk wintering areas. He also suggested topographic features or vegetative cover be utilized for screening south aspect slopes from the traffic of main roads (Churchill, 1982).

1. Main roads should avoid known elk ranges.
2. Locate main roads at the base of warm aspect, south or west facing slopes (135° – 285°) to allow uphill flight.
3. Use topographic features and vegetation to screen warm aspect slopes from traffic.
4. Close or deactivate roads to limit access in elk ranges wherever feasible.

4.4 Minimizing Other Human Disturbances

Rationale for Application

Given that elk seem particularly sensitive to human disturbance, minimizing other unnecessary disturbances from industrial and recreational resource users beyond road planning issues is a tool that can be considered. Concentrating development activity in small areas (such as a single sub-watershed area), maintaining zones of non-activity adjacent to zones of concentrated activity, and minimizing the period of disturbance to less critical seasons are strategies to reduce the duration and severity of conflict.

Potential Benefit for Elk

Careful planning of road locations and densities within or in close proximity to known elk range can help to alleviate some of the negative issues associated with disturbance. Concentrating activities in localized areas can help to encourage elk persist in the general area during the period of disturbance.

Examples of Treatment Strategies

With regard to off-road activities, preliminary management implications suggest that certain off-road activities could be limited to specific trails or roads, depending on area specific conditions such as the density of the access network in the area (Wisdom *et al.*, 2004). In particular, mountain biking and ATV activity were found to stimulate a more pronounced flight reaction from elk than disturbances caused from horseback riding or hiking (Wisdom *et al.*, 2004). Churchill (1982) indicated that off-road activities such as snowmobiling should be prohibited from elk winter ranges.

Churchill (1982) emphasized the importance of timing human activities in elk winter areas. He suggested that midday was the best time to perform any activities deemed essential, since elk are the least active during that period. Conversely, early morning hours were stated to be the worst time to enter into elk areas (Churchill, 1982).

To reduce mortality associated with legal and illegal hunting activity, Wisdom *et al.* (2004c) recommended ensuring that suitable security cover is maintained within a watershed planned for timber harvest, with an emphasis on retaining cover on steep, convex slopes that would otherwise make elk particularly visible. Planning timber harvesting to achieve a continuous, spatial mosaic of different seral stages so that a consistent availability of suitable cover and forage are accessible was advised.

Establishing a short hunting season has been suggested to reduce the energetic cost of fleeing and lost foraging opportunities that can occur over an extended hunting period and have the potential to significantly increase elk mortality beyond the hunting season, due to reduced nutritional condition (Wisdom *et al.*, 2004). Through hunting regulations, seasonal closures of motorized vehicle access and restrictions on all terrain vehicle use to designated areas or times within the day provide a means of reducing disturbance.

1. Prohibit snowmobiling in winter range areas.
2. Implement motorized vehicle restrictions (seasonal or area closures, time of day).
3. Avoid industrial activities during winter on winter range areas.
4. Limit essential human activities in elk areas to midday when they are least active; avoid early morning hours.

4.5 Improved Grazing Systems

Rationale for Application

Given that cattle and elk are both predominately grazers, there is potential for conflict between wildlife and agricultural objectives due to the interspecific competition for forage. Improved grazing systems for the utilization of rangeland may contribute to reducing this conflict by maximizing forage use by cattle and improving forage availability for elk. This can be achieved if ranchers carefully time when their cattle are grazing in certain areas, and by diligently monitoring grazing intensity.

Potential Benefit for Elk

Careful application of improved grazing systems in spring and summer ranges can benefit elk by increasing the quantity of graminoids available to them in the spring when recovering from the previous winter, and in the summer when putting on additional weight to survive the next winter. Applying improved grazing systems can also increase the nutritional quality of graminoid forage on winter range.

It is important to recognize that successful application of any grazing system very much depends upon the local conditions (Grilz pers. comm.). Since range management is the application of science and art, it is critical for range managers to understand their plant communities and how they respond to grazing. As such, general prescriptive recommendations are seldom appropriate, and it is important for wildlife managers, local agrologists, and farmers to work together closely in order to achieve targeted goals (Grilz pers. comm.). For example, the application of the spring and summer range enhancement technique that is described (below) for Oregon, may be more difficult to apply in northern BC due to increased recovery time for vegetation following cattle grazing. If fall moisture conditions are favourable for recovery, which sometimes occurs in northeastern BC, the technique could still have some value (Grilz pers. comm.).

In a study in southeastern Washington, spring cattle grazing at a forage utilization of 30-40% was attempted to promote regrowth but did not increase elk use and resulted in a decrease in winter use by 28% in one of three years studied (Skovlin *et al*. 1983).

Examples of Treatment Strategies

In Alberta, the general strategy for managing grazing lands and leases for elk is to promote the "late in, early out" approach by establish grazing seasons; the forest grazing period is between June 1st and October 15th (Smith pers. comm.). This provides elk access to early spring grazing of nutritious new growth and provides an opportunity for some recovery (from summer grazing) prior to freeze up.

In a study on spatial and temporal interactions between elk, cattle, and mule deer in Starkey Experimental Forest and Range (Starkey) in Oregon, Coe *et al.* (2004) found that the hypothesis that larger ungulates displace smaller ungulates was strongly supported at all three spatial scales that were tested during spring, summer and fall (cattle weren't present in the spring). This implies that locations where forage is limiting would impact the nutritional health of elk before cattle, and deer would be impacted before elk. The study showed that the degree of spatial separation progressively decreased in the late summer and fall periods suggesting that forage was becoming limiting, a theory supported by previous findings of nutritional deficits in elk and cattle in late summer in the study area by Cook *et al.* (2004). As such, late summer and fall forage management could be particularly important. Since cattle are the easiest ungulates to manipulate in terms of their distribution on the landscape, they can be a valuable tool for managing elk or deer distributions (Coe *et al.*, 2004).

In semi-arid areas dead standing vegetation can take several years to decompose and is seldom touched by elk, which prefer to forage on current year's growth (Vavra and Sheehy, 1996). Thus, elk may 'maintain' small patches of preferred forage, while ignoring the larger rangeland. Cattle grazing in the fall can remove much of the dead standing vegetation, which allows entire pastures of high quality forage to be made available to elk in the spring and summer since new green biomass can proliferate (Vavra and Sheehy, 1996; Short and Knight, 2003).

In a study in Montana on rough fescue grassland, Short and Knight (2003) found that fall grazing of cattle at an average utilization rate of 70% on areas frequented by deer and elk in the spring and summer resulted in improved summer forage. It was found that the percentage of green biomass in the spring and summer increased, with no detrimental impacts measured in terms of altered species richness or altered relative abundance of plants. The researchers cautioned against grazing cattle on identified elk and deer winter forage areas, since that could severely affect their ability to obtain sufficient nutrition through the winter. It was suggested that this information could be incorporated into rest-rotation or deferred-rotation grazing systems to benefit forage utilization by livestock and wildlife.

In terms of improving winter forage for elk and deer, Vavra and Sheehy (1996) indicated that carefully timed cattle grazing in the spring can increase the nutritive quality of forage for elk in the winter by delaying the growth cycle of the plants. This growth delay allows nutrients to be trapped in the above-ground biomass instead of the root system, thereby improving the nutritional quality for wintering wild ungulates. This strategy requires the rancher to carefully time the grazing of their cattle, and also requires a rest period for the range to allow plants to regain vigour (Vavra and Sheehy, 1996).

In agricultural areas in Alberta, there are no proactive feeding programs (other than site specific intercept feeding in deep snow winters) and elk damage to crops is usually viewed as a problem occurrence, where land owners may be compensated if losses can be proven to an evaluator (Smith pers. comm.).

1. To improve spring and summer forage, graze cattle in the fall at an average utilization rate of 70%.
2. To improve winter forage, graze cattle in the spring on winter range. Rest the range for at least one season following this treatment to allow plants to regain vigour.
3. Avoid grazing livestock in known high value ungulate winter ranges.

4.6 Herbicide Treatment

Herbicide application is a technique that is often utilized by industry to control or eliminate vegetation, which is largely detrimental to ungulates as it reduces the available forage. This technique has been included for discussion as it is relevant to mitigating mortalities on transportation corridors and as there are ways of mitigating the impacts of herbicide on forage. Effective brush control along primary transportation corridors can reduce mortalities from vehicle collisions and would therefore be considered as a means of increasing ungulate numbers. Rea (2003) found that brushing early in the growing season would be optimal within transportation RoWs, in an effort to make the regenerating shoots a less attractive food source for ungulates.

Rationale for Application

Similar to mechanical brushing, various industry sectors commonly apply herbicides for the purpose of controlling vegetation. Unlike mechanical brushing, herbicide application is rarely considered as a management tool by ungulate managers for enhancing forage opportunities. Herbicides are often applied to shrubby vegetation along road RoWs to improve sightlines, in hydro and oil and gas RoWs to minimize encroachment by mature vegetation that could potentially damage these values and to maintain access for servicing them, and along railway lines in order to minimize encroachment of vegetation. The forest industry also practices herbicide application in young plantations in order to 'release' young trees from competition with surrounding shrubs.

Potential Mitigative Strategies for Moose

In field use, herbicide application is effective in reducing shrub and herb cover, reducing the available forage for moose, however treatment success is often variable and the effects may be short-lived (Stevenson 1992). However, the longer term presence of chemicals (*e.g.*, glycophosphates) may further reduce the value and palatability of treated vegetation (Corbould pers. comm.). While herbicide application generally results in a reduction in available forage for ungulates such as moose, wildlife objectives can be met through selection of herbicide type, application rates, and partial treatment of cleared areas. For example, herbicide can be selectively applied within a cut-over area to avoid edges and areas of inherently low stocking in order to maintain browse for ungulates. As species-specific responses to herbicides vary greatly (Stevenson 1992), herbicides can be used to change to proportional abundance of forage species, however site assessment and herbicide prescriptions should be completed by qualified individuals and compared (cost/benefit) against other treatment methods.

Herbicides could be used to increase the amount of forage through control of noxious weedy species. For example some species such as sow thistle spread rapidly through underground rhizomes and are not avoided by grazers, which further contributes to their expansion. Manual application of herbicide would be most applicable to avoid damage to forage species.

Examples of Treatment Strategies

In a study conducted by Santillo (1994) in northcentral Maine, glyphosate (nitrogen-phosphonomethyl glycine) treated and untreated clearcuts were studied to compare moose utilization of forage in each area. During the aerial application of herbicides it is common for patches of vegetation to be accidentally missed. Subsequently, it was found that these skipped patches were browsed 3.8 times more heavily than in treated areas, despite having a similar abundance of browseable stems in each plot area. Since moose use of missed patches of herbicide treated cutblocks was so prominent, it was recommended that an effort be made to plan leave-patches whenever possible. It was suggested that areas of inherently low conifer stocking such as wet swales and disturbed areas be intentionally left untreated in order to retain some valuable forage for moose, while ensuring that the effectiveness of the treatment strategy for releasing conifer seedlings is not compromised. Leaving untreated patches in cutover areas has also been recommended to mitigate impacts on bird communities (Easton *et al*. 1998). Details such as the optimal size of the skip areas, and the possibility of plant degeneration following persistent overbrowsing by moose were some of the outstanding questions that still needed to be addressed (Santillo, 1994).

Similar to the study conducted by Posner and Jordan (2002) related to brushing in plantations, generalized application of the leave-patch approach for herbicide application is worth considering, although site specific variables such as moose density and cutblock size in a treatment area could contribute to varying results. For example, if moose density is low in an area they may not apply a suitable degree of browsing pressure on shrubs to achieve optimal release of the seedlings. Also, in large cutblocks moose may be less likely to browse in the middle area, and would spend more time on the outer perimeter. Perhaps a strategy to consider would involve herbicide application in the middle of a large block where moose are less likely to browse, and little to no treatment around the perimeter of the plantation adjacent to mature forest cover.

Effects on Non-target Species

Easton et al. (1998) found that herbicide (glyphosate) treatment in conifer plantations effectively suppressed shrub and deciduous tree growth for three years post-treatment, and resulted in a decrease in the number of bird species and an increase in the total number of birds, favouring common species. In particular, warbling vireos and open-cup nesters were negatively affected in herbicide treated areas.

1. Plan leave-patches when applying herbicides, especially in plantations.
    a. Focus herbicide application on the interior block areas, and omit the outer perimeter within ~100 m from forest cover.
    b. Avoid applying herbicide in areas with inherently low stocking (*e.g.,* moist swales).

5.0 Habitat Enhancement Techniques for Moose and Elk

Recognizing the factor(s) that limit moose and elk populations at the landscape level (*e.g.,* climate, habitat availability, seral stage distribution, urban and agricultural development) is critical for successfully achieving provincial and regional objectives that are aimed at increasing productivity. For that reason, it is assumed that any habitat enhancement activities that are initiated are done so after excluding other potential over-riding limitations such as predation, over-hunting, disease, parasites, climate, *etc.* In short, if sufficient habitat already exists or there are other limiting factors, investing time, effort, and funds to enhance habitat is unlikely to provide the desired result.

Higher level plan objectives and provincial mandates should always be considered before implementing habitat enhancement projects. Potential conflicts of increasing moose and elk numbers in a given area could include increased predation rates on non-target species such as caribou, or increased conflict in agricultural areas.

Where an opportunity exists to apply a technique that improves an existing habitat to the benefit of moose and elk, managers describe this as enhancement. Inherently, other techniques that do not involve habitat manipulation but are aimed at minimizing footprint and temporal disturbance impacts on the animals and their habitats, or reducing mortalities are better described under Mitigation Strategies for Moose and Elk (Section 5.0).

At a site specific or stand level, forage enhancement (quantity and/or quality) techniques are the most common and applicable means of achieving the goal of increasing numbers of moose and elk in the context of industrial development. The following forage enhancement techniques have been selected for discussion in the following subsections:

- Cutblock planning
- Manual brushing
- Mechanical brushing
- Mechanical site preparation
- Juvenile spacing
- Controlled and prescribed burning
- Planting
- Seeding
- Fertilization

Forage enhancement techniques that are most commonly utilized by ungulate managers include manual brushing and controlled burning to rejuvenate browse species for moose, and mechanical brushing, controlled burning and seeding for elk grazing. Recognizing the plant species utilized in the diets of moose and elk, and their respective relative values, is an important step for selecting an appropriate location, technique, timing and application to maximize the potential benefits and reduce costs. A summary of forage species utilized by moose and elk has been provided in the life history sections, and more detailed information on the responses of forage species to management treatments (brushing, herbicide, burning), and commercial availability has been provided in Appendices 2, 3, and 4.

The relative abundance of common plant species may be determined by ground survey or interpreted for sub-regional areas from site identification field guides used for Biogeoclimatic Ecosystem Classification (BEC), Terrestrial Ecosystem Mapping (TEM) and Priority Ecosystem Mapping (PEM) projects. Expanded legends developed in TEM projects identify the dominant and common plant species at the level of biogeoclimatic site series unit and structural stage. Wildlife Habitat Rating schemes incorporate BEC site series units and structural stages to provide a framework for rating habitats, which can be used for prioritizing management to optimize forage values.

5.1 Cutblock Planning

The effects of cutblock size, spatial distribution and seral stage have long been recognized as an important landscape level consideration in ungulate management (Langin *et al*. 1990, Gordon *et al*. 2004, Rempel *et al*. 2003). For example, it has been suggested that forage to cover ratios of 65:35 and 60:40 on the landscape are preferred targets for moose (Romito *et al.*, 1999) and elk (Thomas *et al*. 1979). For elk, a 50:50 forage to cover ratio was considered to be more appropriate in the Foothills Model Forest (Alberta) (Buckmaster *et al.*, 1999). Some models do not explicitly incorporate forage to cover ratios directly but do model forage availability or use surrogate measures for cover (stem density).

Habitat suitability and supply models are becoming an important planning tool to balance timber and wildlife objectives at the landscape level. To be useful to resource managers, habitat suitability models should be tested to ensure they truly reflect habitat preferences and confirm that model assumptions are valid (Jones *et al*. 2002). Studies to document the effectiveness of models is lacking, however Richard *et al*. (1994) found that the rankings of 21 of 25 experts were consistent with model predictions for elk in western Oregon and Washington. As the spatial distribution of resources on the landscape has been found to influence patterns of habitat utilization (Gordon *et al*. 2004, Osko *et al*. 2004), habitat models would at least provide a means of prioritizing and focusing mitigation strategies and habitat enhancement techniques for maximum benefit to moose and elk. Such models can also be used to determine the effects (cost) on timber supply (Rempel *et al*. 2003), and provide a framework for managing to meet Ungulate Winter Range requirements.

Mimicking patterns of natural disturbance especially wildfire, is a guiding objective of forest and wildlife managers in British Columbia. The natural disturbance types recognized in British Columbia encompass subsets of biogeoclimatic subzones and provide a framework for managing to achieve biodiversity objectives at the landscape unit level. The Biodiversity Guidebook developed for the Forest Practices Code, provides direction for meeting biodiversity objectives and is largely based on achieving patch size and seral stage distribution targets for each natural disturbance type. As moose and elk distributions and relative abundance are broadly correlated with climate and vegetation assemblages at the biogeoclimatic subzone or variant level, and as relative abundance is correlated with the quality, quantity and juxtaposition of habitats in localized areas, the pattern of harvest and seral stage distribution can be used to manage to maintain or enhance ungulate populations at the landscape level.

Potential Benefit for Moose and Elk

Landscape level management planning and decision-making are critical for managing ungulate populations to achieve regional and Provincial objectives. Managing the pattern of timber harvest and seral stage distribution at the landscape level can affect the regional abundance (carrying capacity) of ungulates by influencing habitat suitability, intra- and inter-specific competition, population dynamics (breeding, dispersal, disease) and predator effects. Where moose and elk management objectives and strategies are featured in forest planning, the results could include increased population size through landscape level habitat enhancement, depending on the capability and suitability of habitats at the time. The gap between habitat capability and suitability identifies opportunities for habitat enhancement (Davidson *et al*. 1990).

Examples of Treatment Strategies

To some extent, examples of cutblock planning to manage ungulate populations are inherent in integrated forest management planning and practices throughout the Province in the context of guiding legislation and higher level plans, but tempered against competing objectives (e.g., timber production, old growth management). Where elk and moose are featured species of management concern, objectives and strategies have often been developed for application at the landscape and operational levels. At the landscape level, examples of treatment strategies are typically provided in management plans for elk and moose that are developed for application over broad geographic areas that have similar capabilities and constraints. The common elements of moose and elk management plans include the identification and protection of known important habitat areas, and access and hunting regulation. In areas with relatively high densities of moose and elk, management strategies tend to be more detailed and specific.

Cool (pers. comm.) and James (1999) have suggested that maintaining a range of seral stages distributed across the landscape may be a more effective management strategy than concentrating enhancement efforts to avoid effects of intra-specific competition, disease and predation. Schwab (1986) indicated that a heterogeneous landscape that involves alternating logged and unlogged patches that are 4 ha in size would be an ideal configuration for moose, since that strategy was highly successful in the Prince George area. Although it is unlikely to be cost effective to harvest timber in 4 ha patches at the landscape level, and this could lead to more extensive road networks, increased losses due to windthrow, and increased frequency of re-entries into an area, strategies to enhance ungulate habitats can be focused and prioritized to maximize the benefits to ungulates and minimize industry costs.

1. Establish pattern of cut and seral stage distribution targets.
2. Identify ecosystem polygons with the greatest potential to benefit moose and elk.
3. Strive to maintain 35% cover intermixed with forage areas at the landscape unit level.
4. Plan cutblock boundaries to maximize edge and minimize sight distance.
5. Design cutblocks adjacent to key forage areas such that average dash distance to cover is <200 m from any given point.
6. Maintain forested buffers adjacent to important habitats.
7. Maintain connectivity between important habitats at the landscape unit level.

5.2 Manual Brushing

Manual brushing on crown land has consistently been the dominant vegetation management technique applied by the forest industry over the past decade, with 60,000 ha or more being treated each year (Ministry of Forests, 2003). Manual brushing techniques include: manual cutting, manual girdling, stem bending, mulching, and the use of hand-held motorized equipment such as chain saws and brush saws.

Manual cutting of shrubby vegetation to enhance moose foraging opportunities has been a strategy practiced in the Williston Reservoir area of north central BC by the Peace/Williston Fish and Wildlife Compensation Program (PWFWCP), as well as in the Columbia Basin Fish and Wildlife Compensation Program area.

<u>Examples of Treatment Strategies</u>

Hengeveld (1998) described a PWFWCP supported manual cutting project that was completed in 1992 and 1994 in the Omineca River area. The treated areas were dense, tall willow stands that were largely impenetrable to moose, and had become too tall and too thick to be utilized. In the first year, alternate cut (5 m wide) and leave (10 to 17 m wide) strips were brushed by removing all willows less than 15 cm DBH in ‘willow thickets’, and removing every second willow greater than 15 cm DBH in ‘willow forests’; all cottonwoods, aspens, conifers, and snags were retained. In 1994 a similar technique was used but the cut strips were 15 m wide instead of 5 m since the 1992 cut strips did not allow a sufficient amount of light through the remaining canopy, which quickly regenerated to further reduce light penetration. In addition, no willows were retained in the cut strips in 1994, unlike the 1992 treatment. Cut material was generally left on the ground where it fell, except for one site where larger stems were bucked up and piled. The treatment cost in 1992 was $499/ha, while the additional effort expended in 1994 increased the cost to $1,168/ha for that year. The noted benefits of the effort were: ungulates received immediate access to forage; cut lines through the willow thickets opened up access to previously unreachable forage; and sunlight penetration increased to promote understory shrub and herb growth. In review of the project Hengeveld (1998) suggested that prescribed burning might be a more cost effective method of achieving a similar goal, but manual cutting is beneficial when burning is not conducive at the site.

Martin (1994) reported on a PWFWCP project that was initiated 15 km north of Mackenzie in 1993, where willows with a diameter at breast height (DBH) of 7.5 cm or greater were cut to within 60 cm or less of the ground. The intent was to promote sprouting of new, smaller diameter shoots from the remaining stump, thereby increasing the amount of forage available to wintering ungulates. The 7.5 cm DBH criteria was selected since willows of this size are typically at least four metres high, which is beyond a moose’s reach (Martin, 1994).

From a forestry perspective, Posner and Jordan (2002) studied the competitive effects of shrubs on 4 to 16 year old plantation white spruce saplings in northeastern Minnesota, along with the extent of moose browsing on the shrubs. Four shrub density strata were compared, which included low, moderate, and high densities, and a stratum with no shrubs present. It was found that spruce growing amongst low and moderate densities of shrubs grew as well or better than spruce that had no shrubs present, and that the presence of shrubs seemed to reduce frost damage to the young spruce trees. Some reduction in growth was noted in the high density stratum. The height reduction that was observed for most of the shrub species due to moose browsing indicated that moose were acting as a natural release mechanism for the spruce seedlings. The recommended management strategy was to limit costly brushing operations to the minimum necessary to ensure normal growth of plantation seedlings, in order to maximize seedling growth rate and the availability of moose forage (Posner and Jordan, 2002). Generalized application of this approach in other areas and with other plantation species is worth considering, although it seems possible that site specific variables such as moose density and cutblock size in a treatment area could contribute to varying results. For example, if moose density is too low in an area they may not apply a suitable degree of browsing pressure on shrubs to achieve optimal release of the seedlings. A prospective modification of this technique would be to concentrate brushing efforts in the interior of cutblocks where moose are less likely to browse, with little to no brushing around the perimeter adjacent to mature forest cover.

Moose have been shown to influence development and succession of natural plant communities (Pastor *et al*. 1988, Coady 1982). Overbrowsing of birch and aspen has been shown to facilitate succession to spruce, and beaver can cut down trees causing them to resprout but moose can overbrowse along conifer-margined streams and allow spruce to invade. Browsing of suckering trees may prevent them from maturing as food for beaver (Coady 1982). The interactions between beaver, moose and elk in Elk Island National Park have proven complementary, with beaver cutting, new and failed beaver ponds maintaining elements of regenerating browse and meadow throughout the park area, and heavy grazing by elk in maintaining open grasslands (Cool pers. comm.). Poor reproduction in moose in Elk Island National Park was attributed to competition for food with elk during a severe winter (Blood 1974).

Studies indicate that timing of brush management activities affects the response of the vegetation (Stevenson 1992) and can influence the nutritional value of the regenerating shrub shoots (Rea and Gillingham 2001). In a study on Scouler's willow (*Salix scouleriana*) in central BC, brushing in early to mid July was found to result in the best winter forage for moose in the winter following brushing. This conclusion was attributed to lower lignin, higher digestible protein, higher digestible energy, and lower or similar tannin levels in the longer, thicker shoots of willows brushed in early July compared to willows that were brushed at other times or not at all. In addition, leaf senescence was delayed into the fall or early winter on regenerated shoots of willows that had been brushed in early July, resulting in prolonged access to succulent forage. Timing of brushing activities is very important, since well-timed brushing can provide optimal benefits to browsing ungulates for the next two winters. Rea and Gillingham (2001) speculated that a brushing rotation of three to four years might be a reasonable timetable that would benefit ungulates and industry, however they pointed out that the effects of multiple brushings have yet to be studied. Repeated brushing may reduce shrub vigour and reduce palatability due to increased woodiness. Ritchie (pers. comm.) also points out that there may be negative effects of maintaining access for re-entry and Cool (pers. comm.) suggests that a better strategy (than repeated brushing in one location) would be to distribute enhancement efforts on the landscape and stagger brushing years to maintain a variety of successional stages.

Manual brushing is often conducted in conjunction with juvenile spacing to remove competing shrub vegetation. While many shrub species successfully regenerate after brushing, the overall recovery can be slow and the effects maintained throughout the rotation.

Girdling aspen and birch trees in over-mature forests has been used as a technique for increasing understory production to enhance ungulate habitat in the Peace/Williston and Columbia Basin management areas, as well as in other areas and for other purposes (*i.e.*, reduce competition with conifers). Girdling kills the tree but leaves it in place where it may be used by cavity nesting birds. The reduction in canopy closure stimulates understory growth and increases browse for moose. Martin (1994) suggests that birch trees should be girdled twice to be effective. Girdling projects have met with variable success, particularly where vigorous sprouting or coppicing can follow treatment unless other species provide sufficient cover to inhibit growth, and is not considered a preferred technique (Newton *et al*. 1990, Krebs pers. comm., Ritchie pers. comm.).

Based on the studies discussed above, it appears that there is an opportunity to coordinate the timing and approach to brushing for conifer release and forage production to optimize all objectives. To further focus efforts and minimize costs, a Geographic Information System (GIS) could be used to intersect forest inventory and logging history data to identify and map candidate (for brushing) forest polygons. Focused brushing activities can then be planned in relation to key features such as wetland and riparian areas, mature coniferous forest (for cover), or travel corridors. Additional stratification could include identifying biogeoclimatic site series with a suitable expected competing vegetation species assemblage, which is typically identified in the Site Identification Field Guides produced by the Ministry of Forests for the purposes of biogeoclimatic classification, as well as in the expanded legends generated in terrestrial Ecosystem Mapping projects. In general, wetter site series units tend to support more vigorous shrub communities and contain a larger proportion of favoured browse species. These principles could also be applied in conjunction with vegetation management programs such as hydro transmission corridors and pipelines.

Effects on Non-target Species

Easton *et al*. (1998) found that the number of bird species, total number of individuals and evenness increased after manual brushing where regrowth of shrubs and deciduous trees occurred.

1. BMPs for forest harvesting (mitigative approach) include timing brushing to coincide with conifer release objectives to occur between 4-6 years post planting, concentrating brushing efforts in areas of overmature shrubs with high shrub density and in the interior of cutblocks (more for elk).
2. Conduct brushing in mid-July to maximize regrowth and nutritional value.
3. Girdle overmature aspen and birch to rejuvenate browse where effects on non-target species (*e.g*. cavity nesters) are a concern.

5.3 Mechanical Brushing

The mechanical alteration of vegetation can occur in many forms and result in varying responses in vegetation. Equipment ranges from excavators and dozers to tractors and mowers, and the mechanisms for brushing are also quite variable and include variations that utilize mower blades, cutting blades, chains, or hydraxe to shear or remove woody vegetation. In industrial applications, the objective of mechanical brushing is usually to reduce or eliminate woody vegetation, which may be beneficial to elk, however the equipment and techniques can also be used to rejuvenate browse for moose and elk. The potential applications of the following mechanical brushing techniques for enhancing forage for moose and elk are discussed below.

Common industrial applications of mechanical brushing often include the following objectives:

- The reduction or elimination of woody vegetation along road rights-of-way and railway corridors to improve sightlines and reduce highway mortalities (elk and moose) due to vehicle and train collisions (see Mitigation Techniques Section 4.2);
- For clearing vegetation in seismic exploration;
- To protect infrastructure and maintain access for maintenance activities within hydro and oil and gas rights-of-way by minimizing the encroachment by woody vegetation;
- To 'release' young conifer trees from competition with surrounding shrubs or deciduous trees, or to thin conifer stands to increase mean annual increment or eliminate competition from non-merchantable timber in the forest industry.

Potential Benefits of Mechanical Brushing

Brushing vegetation can often have foraging benefits to moose since it may allow increased access to previously unreachable forage and may stimulate many tender, new shoots to grow that are highly palatable and digestible by moose. The effects of mechanical brushing tend to be short-lived and periodic treatment would be required to maintain seral stage (Scotter 1980).

Industrial development involving overstory vegetation removal, clearing, grubbing and stripping provides opportunities to manage the regenerating vegetation to enhance forage values for elk. In areas with a deep winter snowpack, treatments that favour shrubs that provide browse for elk would be preferred. In areas with low winter snowpack, elk continue to graze in open areas therefore treatments that favour graminoid communities could have greater value. The maintenance of security (line of sight) cover in open grazing areas is an important consideration.

Thinning brush in maturing stands can benefit moose by increasing light and precipitation penetration to the understory, which can extend the number of years that browse species can flourish in those habitats.

Effects on Non-target Species

Non-target species effects may include a reduction in shrub nesting birds where dense shrub stands are reduced or eliminated, or conversely recovering shrub communities may be converted to younger denser stands that may favour some bird species.

Examples of Treatment Strategies

The primary objectives of vegetation management programs for power transmission corridors and pipelines is to protect infrastructure, and provide access for maintenance and inspection. Trees are generally undesirable, and shrub communities are periodically reduced to maintain access, favouring graminoid communities. In some instances land owners lease or have cooperative agreements with industry to farm crops or graze livestock on RoW's, which maintains graminoid communities.

Vegetation management programs typically develop systems that maximize the likelihood of killing woody vegetation and may include a two-pass system involving the mechanical removal of vegetation followed by the application of herbicide. Long-term prescriptions continue to be developed by BC Hydro for delineated line segments and feature vegetation management objectives that include provision for fish and wildlife in riparian zones, which favour shrub retention.

1. Aggressive vegetation management programs to reduce or eliminate shrub cover can benefit elk under low snowpack conditions.
2. Mechanical brushing can be used to rejuvenate shrub growth and provide late winter browse for elk.

5.4 Mechanical Site Preparation

Based on the Ministry of Forests 2002/2003 Annual Report, site preparation on crown land has steadily decreased over the past decade (Ministry of Forests, 2003). In 1993/94 over 160,000 ha of land had some form of site preparation completed, but in 2002/03 that total had dropped to less than 60,000 ha. Mechanical site preparation is the technique that tends to be utilized more than half of the time in favour of other techniques with greater risk of air and water quality impacts (i.e. burning, chemical treatments). Fire is used less than one third of the time.

Mechanical site preparation techniques are typically used in silvicultural, agricultural and land clearing (*e.g.,* oil and gas) applications to:

- reduce surface organic horizons;
- expose mineral soils;
- loosen or break up compact surface soils; and
- landscape an area for development.

Common mechanical site preparation techniques include disc trenching, chain (drag) scarification, and excavator mounding. Techniques that deeply penetrate soils can severely damage root systems and severely reduce shrub growth (scalping), maintain the overall vegetation community (mounding), or stimulate suckering (mixing). The effects of techniques that result in an initial reduction in shrub cover can truncate succession and persist through mid-seral stages. Studies have shown that ungulate browsing has been found to be lower in scarified than untreated blocks for the first 1-2 years but effects have been observed to persist as long as 17 years (Enns 1994).

The effects of mechanical site preparation on non-target species are largely associated with a reduction in shrub regeneration, although reductions in coarse woody debris and soil fauna are also common and can affect small mammal abundance (Enns 1994). Many techniques can destroy burrows or remove cover and reduce prey (*e.g.*, small mammals, grouse, hare) for furbearers of concern such as fisher, marten and lynx. A reduction in coarse woody debris could affect bears by removing an important source of invertebrate foods.

5.5 Juvenile Spacing and Pre-commercial Thinning

Juvenile spacing refers to the selective removal of coniferous stems to evenly space young conifers and maximize their growth potential. Non-commercial or pre-commercial thinning usually refers to the selective removal of conifers from older overstocked stands to maximize the growth and timber value of the remaining stems. Juvenile spacing activity has generally shown a decreasing trend due to reduced funding for the spacing program, with a drop from about 50,000 ha in 1997/98 to less than 10,000 ha in 2002/03.

While the general forestry objective of spacing and thinning is to reduce competition and maximize tree growth, the resulting increase in light penetration can increase understory shrub production and moose utilization (Waterhouse *et al*. 1988, McLaren *et al*. 2000). From a wildlife management perspective, thinning before or at the time that the forest canopy is starting to close in is optimal for extending the amount of time that useable browse is available. If thinning is not completed until several years after the canopy has closed in, the value of thinning to wildlife is greatly reduced since the majority of understory species will have already died off (Nyberg *et al.* 1990).

Thinning initially reduces canopy snow interception and the quality of security and thermal cover, however leaving strips or undisturbed patches within treatment areas can retain some function. Moderate thinning can promote deep crowns and improve snow interception (Kimball *et al*. 1990), however as the crowns close in, understory vegetation growth is suppressed. When possible removing low quality stems in groups will foster a greater understory response than removing individual trees (McComb 1982).

The accumulation of slash from thinning activities can impair moose and elk movements and increase energy expenditure (Parker *et al*. 1984, Waterhouse *et al*. 1988), therefore piling or windrowing slash to provide for movement may be necessary to improve access to forage. Lyon *et al*. (1980) found a slash depth of 50 cm suppressed the use of clear-cuts by elk. Piling or windrowing slash to improve access to forage for moose and elk can create habitats for small mammals and furbearers. Waterhouse *et al*. (1988) found that wildlife especially deer, made extensive use of man-made trails cut through areas of slash.

Effects on Non-target Species

The effects of juvenile spacing on non-target species may include a reduction in the diversity of canopy dwelling bird species. Many forest birds occupy specific microhabitats among the strata of a forest, however the often shallow canopy of an even-aged forest will have a simplified avian community compared to a mature forest in which natural thinning has occurred (Kimball *et al*. 1990, Thompson *et al*. 1995). Cooper *et al*. (2004) indicate that red and blue listed wildlife species in the East Kootenay Trench would benefit from thinning and slashing activities.

1. Time spacing to occur before or when the canopy becomes >70% enclosed.
2. Pile, burn, buck, windrow or chip slash if >25 cm deep to improve access to forage.

5.6 Selective or Partial Cutting

Selective cutting includes single tree and group selection methods, which have historically occurred to extract the largest and best quality timber from stands, leaving the remaining trees to mature. The objectives and patterns of selection cutting methods have been tested in a wide range of research oriented projects to investigate the effects of various approaches to timber production, logging on sensitive terrain, and for managing wildlife (mostly caribou and moose). Selective or partial cutting techniques have been widely tested yet few are in use today.

Thomas *et al*. (1979) describe two techniques for implementing uneven-aged forest management (*i.e.* selective harvesting); single tree selection and group selection. Generally, uneven-aged forest management gradually decreases species diversity due to the gradual reduction of shade intolerant species from the understory. These stands do have greater structural diversity and height variation, which may function to provide thermal and security cover. Openings greater than 0.4 ha begin producing results similar to what is observed in even aged forest management (*i.e.* increased growth of shade intolerant species that can increase plant and animal diversity).

A wide range of cutting techniques and patterns have been tested in the north-central interior of British Columbia, and although structured long term monitoring is lacking, Langin *et al*. (1990) indicate the older selectively logged stands are heavily used by moose. Wildlife managers have recognized that there are many benefits to selective harvest for wildlife, however the increased cost of harvesting and increased risk of windthrow has likely prevented this technique from becoming an industry standard. In the northern interior, group selection techniques typically occur in subalpine forest where smaller scale natural disturbances occur (Corbould pers. comm.).

Selective harvest techniques that preserve the advanced regeneration in the understory also preserves the shrub layer, both of which are released by opening up the canopy. The resulting mosaic of mature trees or stands of trees in proximity to abundant browse provides optimal habitat for moose. One issue with these techniques is that it is often difficult to bring treated stands to a free-to-grow state (Ritchie pers. comm.).

While selective harvest techniques have not widely been used by the timber industry, the principles and practices may be useful in woodlots where owners have a more intimate knowledge of the area and tend to apply a broader range of techniques.

1. Single tree and group selection harvesting can provide forage and thermal benefits.
2. Openings greater than 0.4 ha function similar to larger openings.

5.7 Controlled Burning, Prescribed Burning and Slash Burning

Burning is a management tool that is commonly applied by ungulate managers in order to 'turn back' the successional clock to an early seral stage that has more useable forage available, or by the forest industry for site preparation. Controlled burns are usually conducted in areas of overmature or non-commercial vegetation to rejuvenate forage, while prescribed burns usually refer to a site preparation technique for replanting. Slash burning may be conducted for a variety of reasons including (after Hawkes *et al*. 1990):

- To reduce a fire hazard
- To providing access for planting and stand tending activities;
- To prepare an environment favourable to seedling establishment and growth;
- To reduce competing vegetation;
- To eliminate disease or insect infestations;
- To enhance browse or grazing potential; and
- To enhance or improve an area for use by some wildlife species, primarily ungulates.

Burning opens up the forest canopy to allow light and precipitation through, which results in enhanced understory growth that increases forage for ungulates like moose and elk (Corbould 1999). This activity can also benefit other wildlife species that utilize early seral communities such as bears and songbirds. In addition, the dead-standing timber can provide valuable wildlife trees for use by primary and secondary cavity users.

Many species of grasses increase more rapidly on burned than unburned sites (*e.g.,* pinegrass) and are favoured by repeated light fires and the abundance of most shrubs is inversely proportional to the severity of fire (Coates *et al*. 1990). The response of individual plant species to fire typically varies in response to site conditions (mostly moisture) and the timing and severity of the burn (refer to Appendix 2 for browse species responses). Burns on wetter sites tend to experience less reduction in above-ground biomass and faster recovery where burns on dry sites can be more intense, damaging or killing root systems and sterilizing soils (Hawkes *et al*. 1990, Stevenson 1992). Prescribing burns for wetter than average sites would therefore be more effective in generating browse for moose and elk where late winter snowpack reduces the availability of grasses.

In a study in southeastern Washington, Skovlin *et al*. (1983) found that fall burning of bunch-forming grass communities to remove dead standing litter and enhance forage palatability provided no significant increase in elk use in winter.

In a comparative study of the effects of elk herbivory versus wildfire in northern Yellowstone National Park grasslands, burning was found to increase aboveground biomass of grasslands by 20% but only increased the digestibility of one of three main forage grasses (*Festuca idahoensis*) and did not affect nitrogen, cellulose and macronutrient concentrations (Singer *et al*. 1996). Elk herbivory was found to have a greater effect than burning in Yellowstone National Park grasslands, with grazing resulting an increase of 21% in nitrogen content and 7% in digestibility (Singer *et al*. 1996). The effects of burning in forests (up to 12 years) are expected to last longer than in grasslands (3-6 years) due to the higher fuel loading and fire intensity (Singer *et al*. 1996). Burning grassland areas is considered beneficial even if nutrient levels are unaffected as burned areas tend to have greater forage abundance and green-up earlier in the spring and result in better condition of elk (Singer *et al*. 1996). The effects of burning on vegetation (primarily increased biomass production with limited improved nutritional status of forage) have been found to last for approximately 1-6 years (Canon *et al*. 1987, Poole *et al*. 2002), with an increase in grass and shrub biomass expected within 3-6 years post burn (Singer *et al*. 1996, Krebs pers. comm.). In the east Kootenay, forb cover remained relatively unchanged, grass cover remained unchanged or decreased, and shrubs (mostly Saskatoon) decreased in the first 3 years after burning in open and closed dry Douglas-fir forest (Page 2004).

Canon *et al*. (1987) found that burning aspen forest resulted in a 19% overall increase in aboveground biomass production after two years post-burn, including a significant increase in grass and forb production, with shrubs reduced to 25% of their pre-burn production. After three years overall production was still 14% greater than pre-burn. Elk feeding (measured by bite count) was three times greater in burned than unburned aspen forest (Canon *et al*. 1987).

<u>*Examples of Treatment Strategies*</u>

The PWFWCP commonly uses controlled burns as an ungulate management tool in the Williston Reservoir watershed in north central BC. At least seven burns were conducted within the Finlay River drainage between 1989 and 1993 (Corbould, 2000), and several other burns have been reported since that time. Ideal burning locations are located on south facing slopes that have mature deciduous trees (Corbould, 1999). In a two phase burn in the Ingenika River area in 2000 and 2001, the objective was to convert 30-70% of the 918 ha area into early seral, grass/shrub community to enhance browsing and grazing habitat quality for moose and elk (Corbould, 2002). The area had the capability of providing high winter habitat quality, partly because the snow depth rarely exceeds 60 cm.

Burning is also a preferred forage enhancement strategy used by the Columbia Basin Fish and Wildlife Compensation Program (CBFWCP) in the Kootney region of southeastern BC (Krebs, pers. comm.), and a primary technique for restoring and maintaining natural ecosystem types and wildlife species of management concern (Rocky Mountain Trench Ecosystem Restoration Steering Committee 2000, Cooper *et al*. 2004). Burning typically occurs on steep, south facing slopes in the west Kootneys, and has been very successful for maintaining early seral communities. In the east Kootneys burning success has been more variable due to the potential for droughty conditions that reduce the natural rejuvenation of vegetation (Page 2004). If converting forested areas to grassland is the objective, it has been found that slashing or knocking down the trees first then burning a year or two later produces more desirable results, since burning alone is not usually sufficient (Krebs pers. comm.). Once desired grassland conditions have been achieved, periodic subsequent burns have proven to be very effective at maintaining those conditions (Krebs pers. comm.).

Controlled burns have long been a beneficial management technique for accelerating succession in Elk Island National Park, Alberta. In the park, burns are viewed as a means to enhance the variability of stands (age, structure) and enhance the biodiversity of plants and animals. Norm Cool (pers. comm.) cautions that repeated burning of an area retards shrub and sapling growth and may lead to the area becoming dominated by a monoculture of species such as bluejoint reedgrass (*Calamagrostis canadensis*), which is reported to have low palatability in its mature form. Heavy grazing by elk where controlled burns are conducted repeatedly in one location has also been found to retard shrub and sapling growth and can impede the benefits of long-term forage production (Huff *et al*. 1999, Cool pers. comm.).

Grilz (pers. comm.) indicated that burning rangeland early in the spring when the surface is dry but a moist humus layer still exists (the ground may even still be frozen) is usually ideal for improving plant vigour and above-ground biomass production, since the root crowns are less likely to be damaged. Conversely, burning in the fall is generally not advised, since the fire tends to be hotter and penetrate deeper into the soil, often damaging the root crowns and reducing forage production. The effect of burning on shrubs is species dependent. Generally, for suckering shrubs, there is an increase in the density, providing for an increase in available browse. However, if soils are dry, there can be a reduction in available browse (Grilz pers. comm.).

Effects on Non-target Species

The most significant effects of burning on wildlife results from the modification of the plant community, including changes in vertical structure and the relative abundance of plant species, favouring species adapted to early seral habitats over those with requirements for mature and old stages (Poole *et al*. 2002). Birds that nest or feed in early seral vegetation would benefit by burning, unless it is conducted during the nesting season where it may impact birds more than in other seasons. Cooper *et al*. (2004) indicated that some red and blue-listed species in the East Kootenay Trench area would benefit from prescribed burning (Lewis's woodpecker, white-headed woodpecker, long-billed curlew, sharp-tailed grouse, badger, bighorn sheep) where other species (Williamson's sapsucker, flammulated owl, northern goshawk would not.

1. Warm aspect, south or west facing slopes (135° – 285°) that have mature deciduous trees are ideal locations for applying this technique.
2. Burns on wetter sites can increase browse where winter snowpacks exceed 50 cm, and can also minimize site and soil damage.
3. Avoid repeatedly burning the same sites.
4. Distribute burns areas and stagger burning years to maximize benefits.

5.8 Planting

Rationale for Application

Planting programs provide a relatively economical means of restoring browse species where there has been complete vegetation removal such as with clearing and road building.

Potential Benefit for Moose

Planting provides a means of accelerating the establishment of browse where there has been severe ground disturbance. Fertilizing can benefit moose by increasing biomass production and nutrient value in forage.

Examples of Treatment Strategies

The most economical technique is live-staking, which is typically completed using stem cuttings taken from donor shrubs prior to bud break in the spring. The 50-80 cm long stakes are typically cut from a relatively straight and vigorously growing stem, and soaked overnight in a rooting hormone before and planting them in holes piloted with steel rods such that most (80%) of the stake is below the ground surface. Depending on site and soil conditions, an average of between 300-500 cuttings can be taken per person-day and between 150-250 cuttings can be planted in a person-day. Most shrub species are suitable for live-staking and often produce numerous basal stems and will spread vegetatively, which can generate a significant quantity of forage within 3-5 years. Live-staking is most effective in moist sites with loamy to fine-textured soils.

Live-staking is generally most useful where vegetation has been removed through land clearing, stripping, landscaping, and mining. Site conditions including dry or compact soils, and existing competing vegetation may limit live-staking success.

1. Live-staking is an effective means of rapidly establishing shrub cover in cleared areas.
2. Live-staking is most successful when completed in the spring.
3. Live-staking success may be poor on compact soils and dry sites.

5.9 Seeding

Rationale for Application

Seeding has long been used throughout industry for a wide range of purposes but perhaps has most widely been used as a means of stabilizing exposed soils to prevent surface erosion after disturbance caused by logging operations, the completion of transportation corridors such as highways and pipelines, and prior to the closure of mines. Potential benefits of seeding include:

- erosion and dust control;
- reduction of siltation of fish streams;
- provision of forage for wildlife and domestic species;
- reduction of more competitive undesirable species;
- improvement of aesthetic values; and

- improvement of soil through conditioning, nitrogen fixation (legumes), and provision of organic matter.

Commercial agronomic grass seed mixes have been available for many years, however there were initially relatively few supply companies and limited mixtures. The development of individual grass species for commercial seed production requires relatively extensive testing to purify strains, determine seed viability, yield and other parameters, and generate sufficient quantities of seed to move into production phases. Most of the commercial seed development, production and supply has traditionally been done in the United States. Today, there are more suppliers and a broader range of seed mixes for various applications such as soil and slope stabilization, non-competitive mixes, roadside mixes, riparian mixes, and forestry mixes. Commercial sources of grass seed for native British Columbia species have recently been developed and several additional species are currently moving into production phases, although supply may lag behind demand and initially be a more costly alternative to more common commercial species.

There are numerous non-native agronomic species of high forage value, some of which have become naturalized and are utilized as forage by elk. For example, it is generally felt that timothy was introduced from Europe but first cultivated in North America, and has since become naturalized. The USDA (1988) range plant handbook describes timothy as one of the primary and most profitable commercial hay species and one of the most successful species in the reseeding of ranges. Timothy produces a great abundance of nutritious forage. Timothy is also well adapted for seeding cutover and burned areas and will produce large stands but does not produce well on dry sites and is not a strong reseeder so decreases in abundance over time.

Sound ecological restoration includes the use of native species, which have been recommended for use since the 1970's (Vaartnou 2004). In particular, the use of native grass species would reduce the rate of introduction and establishment of undesirable, invasive non-native species. Other possible benefits of native species include:

- the conservation of local biodiversity;
- higher long-term survival potential of species adapted to local climate;
- greater reseeding potential because of adaptation to the local photosynthetic regime (Vaartnou 2005); and
- reduced costs through lower fertilization and seeding rates.

In selecting native grasses that are adapted to a given regional area and site conditions, the odds are that they will grow and survive, however they must prove to be effective in achieving reclamation or habitat restoration objectives at a reasonable cost. Recognizing the need to further the development of native grass seed sources for use in British Columbia, research has been conducted over the past several years. In particular, funding for a 10 year (1996-2005) applied research program to test and develop native grass seed stock was provided through Forest Renewal British Columbia and later the Forest Investment Account, as well as timber companies, seed suppliers and others. This research, which has been led by Dr. Manivalde Vaartnou has continued to date and been extended to include interior and northern species, however the future of this work depends on funding and demand.

The performance of native grass species in Vaartnou's field trials demonstrates the variability in response and longevity. The most successful species to date have been *Bromus sitchensis*, *Elymus glaucus*, *Festuca rubra* ssp *arenicola*, *Festuca rubra* ssp *pruinosa*, *Deschampsia elongata*, *Deschampsia cespitosa*, *Agrostis scabra*, *Agrostis exarata*, *Poa compressa*, *Calamagrostis stricta* and *Elymus trachycaulus* (see Appendix 3 for forage value of listed species). Note that the most successful agronomic grass was red fescue (*Festuca rubra*), which is an introduced, naturalized species with good forage value for elk, which suggests that the two indigenous subspecies listed above may also provide valuable forage.

Large seed production plots have been established in Dawson Creek so that the cost of native selections can be determined over the long-term. On the native grass plots the most successful species were Alaska brome (*Bromus sitchensis*), blue wild rye (*Elymus glaucus*), both of fair forage value to elk, and two native subspecies of red fescue (*Festuca rubra* ssp *arenicola* and *F. rubra* ssp *pruinosa*) with good forage value for elk. Other northern species that provide good forage value for elk and are moving into seed production phases include *Agropyron violaceum*, *Deschampsia elongata*, *Poa glauca*, *Poa palustris*, *Festuca rubra* ssp *arenicola, Festuca saximontana*, *Agropyron subsecundum*, and a northern variety of *Agropyron trachycaulum* that is reported to be a leafy form collected from a northern area (Vaartnou pers. comm.).

As more grass species that are native to British Columbia become commercially available, it will be possible to develop custom mixes where there is sufficient demand. Seeding trials in developing mixtures for various industry applications have shown that multi-species blends often achieve better results. For example, legumes are commonly mixed with grass seed to improve soil stability through surface (grasses) and subsurface (legumes) rooting and legumes are better soil conditioners and nitrogen-enhancers. In Alberta, a grass/legume seed mix is used as an industry standard for elk management in the oil and gas sector (Smith pers.comm.).

Pickseed Canada Inc. offers a reclamation mix for the west coast including 6 native species and has initiated seed multiplication of 6 new promising selections with field scale production possible by the fall of 2005 or spring of 2006 (Vaartnou 2005). The seed from production plots for many of Vaartnou's trial species can function as the first step in seed multiplication if anyone has a northern project, such as a pipeline (regardless of route) or mine, with sufficient lead time to grow their own seed. Dr. Manivalde has indicated that the Mackenzie Pipeline project is investigating native seed mixes.

In Alberta, native seed mixes have been developed for different physiographic regions and include wet sites, average sites and dry sites (Table 3) and are used as industry standards for elk management (Native Plant Working Group 2001). Alberta Fish and Wildlife also maintain lists of desirable native species that are recommended for use if and when they become commercially available (Table 4). Some agronomic grass species and clover are still used, with the latter reported to be an important ground cover as it provides nutritious forage, remains green late in the season and is greened up early in the season, especially over heated pipelines where the soils remain warmer (Smith pers. comm.). A point of concern using the native seed mixes was noted with respect to observations of increased elk use of woodland caribou range, which may, in turn, draw more wolves and lead to increased depredation on caribou, particularly where elk road kills are more common (Smith pers. comm.).

Table 3. Native seed mixes used as industry standards in Alberta.

Common name	Scientific name	Status		PRP[2]	Mesic sites[3]	Moist sites[4]	Sub-xeric sites
		BC	AB				
western porcupine grass*	*Stipa curtiseta* (or *S. spartea* var. *curtiseta*?)	R	C	X			
June grass	*Koeleria macrantha* (or *K. cristata*)	C	C	X	X		X
northern wheatgrass	*Agropyron dasystachyum*	U	C	X	X		
western wheatgrass	*Agropyron smithii*	U	C	X			
awned wheatgrass*	*Agropyron trachycaulum* var. *unilaterale* (or *A. caninum* ssp. *majus* var. *unilaterale*?)	C	C	X	X	X	
green needlegrass	*Stipa viridula*	U	C	X			
Rocky Mountain fescue	*Festuca saximontana*	C	C	X			X
fringed brome*	*Bromus ciliatus*	C	C		X	X	
nodding brome*	*Bromus anomalus*	U	C		X		
fowl bluegrass	*Poa palustris*[1]	C	C		X	X	
tufted hairgrass	*Deschampsia cespitosa*	C	C		X	X	
slough grass	*Beckmania syzigachne*	U	C		X		
American vetch*	*Vicia americana*	C	C		X	X	X

[1] *Poa palustris* is considered to be introduced but is naturalized and widespread, [2] PRP – Peace River Parkland,
[3] Boreal forest and dry mixed wood subregion mixes combined, [4] Upper foothills in Foothills Natural Region,
* limited quantities available, C – common, U – uncommon, R - rare

Table 4. Native (Alberta) plant species designated as desirable for inclusion in seed mixes as they become commercially available.

Common name	Scientific name	Status	
		BC	AB
fireweed	*Epilobium angustifolium*	C	C
cream-coloured peavine	*Lathyrus ochroleucus*	C	C
smooth fleabane	*Erigeron glabellus*	U	C
Canada goldenrod	*Solidago canadensis*	C	C
yarrow	*Achillea millefolium*	C	C
Idaho fescue	*Festuca idahoensis*	C	C
purple oatgrass (or false melic)	*Schizachne purpurascens*	C	C
Canada wildrye	*Elymus canadensis*	C	C
spike trisetum	*Trisetum spicatum*	C	C
hairy wildrye	*Elymus innovatus*	C	C
ticklegrass	*Agrostis scabra*	C	C
mountain ricegrass	*Oryzopsis asperifolia*	C	C
northern ricegrass	*Oryzopsis pungens*	C	C
plains reedgrass	*Calamagrostis montanensis*	R	C
blunt/hay sedge	*Carex obtusata*	C	C
wild strawberry	*Fragaria virginiana*	C	C
northern sweet-vetch	*Hedysarum boreale*	C	C
twinflower	*Linnaea borealis*	C	C
harebell	*Campanula* (*rotundifolia*?)	C	C

C – common, U – uncommon, R – rare

Alberta Fish and Wildlife also maintains a list of undesirable non-native species (Table 5).

Table 5. Non-native plant species designated as undesirable for industry seed mixes in Alberta

Common name	**Scientific name**
crested wheatgrass	*Agropyron pectiniforme*
timothy	*Phleum pratense*
creeping red fescue	*Festuca rubra*
smooth brome	*Bromus inermis*
reed canary grass	*Phalaris arundinacea*
Kentucky bluegrass	*Poa pratensis*
sweet clover	*Melilotus spp.*
Cicer milkvetch	*Astragalus cicer*
Sainfoin	*Onobrychis viciifolia*

The results of seed selections that have been extensively tested over the last twenty-five years in northern British Columbia, northern Alberta, Yukon Territory and the N.W.T. were used to write the specifications found in the Yukon Revegetation Manual (Kennedy 1993, vol. 1; Hill *et al*. 1996, vol. 2). The results of these studies would be useful in developing seed mixes for northern British Columbia.

In developing native grass seed mixtures that are appropriate for industrial applications and provide forage for elk, several factors to be considered should include regional climate, soil and light conditions, and seasonal forage value. Site conditions and management objectives must also be considered. A coordinated effort between regional agrologists, wildlife managers, industrial stakeholders, and commercial seed growers to develop native seed mixes would support the expansion of native grass seed production to ensure future supply. With the existing information from field trials and a knowledge of regional grass species, native seed mixes could be developed to meet reclamation and forage objectives. Examples of relative groupings of compatible industrial applications and site conditions that could be considered for developing standard seed mixes include:

- Mesic, dry and high elevation sites for oil and gas exploration, hydro and pipeline rights-of-way, hydro compounds and transfer stations, well site leases, in-block landings, deactivated roads;
- Stream riparian and wetland for all sectors;
- Community pastures, forest grazing leases, mine sites; and
- Major transportation corridors (roads and railways).

In selecting species for seed mixes, consideration of growth form (*e.g*. sod-forming, bunchgrass), ecological tolerance and nutritional value as forage for elk in different seasons should be considered. Leafy growth forms of grasses provide nutritious forage during the growing season and may provide less nutritious but important late winter forage. Some grasses produce loose panicles with numerous small seeds that are dispersed soon after maturing (*e.g., Agrostis*) and are of less value than species producing larger seeds that may be retained later into the winter (*Apropyron*). To some extent, the value of range plants is subjective and interpreted based on observations of utilization by livestock and wildlife. Grass species that are generally of lesser value include those that are diminutive or produce little above-ground forage, and those that are adapted or armoured (long awns or bristles) to resist grazing. Some species also become flattened with fall moisture or snow cover where others will remain standing and available in deeper snowpack areas. It is therefore important to carefully consider the site conditions and objectives in selecting an appropriate species mix.

Some native species, for example slender hairgrass (*Deschampsia elongata*), and hair bentgrass (*Agrostis scabra*) are short-lived perennials that are important in restoration activities because they provide considerable initial cover, minimizing soil erosion, however, they decrease in abundance over time and do not provide long-term ground cover. Tetraploid varieties of some non-native species are available for some species such as those used in erosion control mixes. Tetraploid species are often used as they establish rapidly to stabilize and condition soils for other species. These species may prove useful in combination with native species that are weak initial surface soil stabilizers.

From a forage value perspective, the *Poa*'s are large genera with a broad ecological range that include numerous rangeland species that are primarily valued for pasturage. The tender nutritious forage is of high value through the growing season and most species withstand grazing pressure. Many species rank as the most palatable of all range grasses and are rated as excellent for elk. Most species are sod-forming and are effective in preventing erosion. Non-native species that have become naturalized in British Columbia and are a common component of reclamation seed mixes include fowl bluegrass (*Poa palustris*), Kentucky bluegrass (*P. pratensis*) and Canada bluegrass (*P. compressa*), the latter two species are considered the most important pasture and lawn species (USDA 1988). Canada bluegrass is believed to have been introduced from the Old World but has since become naturalized and is a valuable forage species. Canada bluegrass also does better than other grasses on stiff clay soils of low fertility, recovers well from trampling, and constant grazing stimulates tender nutritious new growth (USDA 1988). However, on better soils Canada bluegrass cannot compete with other species such as Kentucky bluegrass, which is also considered more nutritious as it contains less crude fiber (USDA 1988). With native species such as *P. glauca* being developed, it may be feasible to replace non-native species over time.

Sedges (*Carex* spp.) and Rushes (*Juncus* spp.)

In general, sedge and rush species that occur on wet sites are large robust plants with broad leaves where those of drier sites are smaller and have narrow leaves. Wet site species are rarely commercially produced as there is no demand for livestock, crop production and limited demand for reclamation.

The use of sedges by elk is well documented in the literature, however there is little reference to individual species. Newly sprouted *Carex rostrata* and *C. atherodes* are reported to be favoured by elk in Elk Island National Park during spring (Cool pers. comm.).

Based on nutritional value, sedges have similar nutritional properties as grasses and produce less crude fiber and ash, and more crude protein and nitrogen free extract (USDA 1988). Sedges have also been found to show a slower decline in crude protein content rate, and increase in nutritional value at a greater rate than common bluegrasses and bromes (USDA 1988).

Sedges are often considered to be mostly associated with the wettest and driest sites, however there are numerous species that are typically found in meadow habitats in association with other grasses and forbs. A relatively few species represent the dominant vegetative cover in British Columbia marsh wetlands, the most common including *Carex. aquatilus*, *C. rostrata* (or *C. utriculata*), and *C. retrorsa*, with a wider variety of more diminutive species found in bogs and fens.

Elk sedge (*Carex geyeri*) is one of the comparatively few sedges that are common in dry open timber types, often appearing in dense stands in dry ponderosa pine and lodgepole pine stands in association with pinegrass (*Calamagrostis rubescens*). Elk sedge commonly forms a heavy sod in almost pure stands on open hillsides and burns, which it readily invades. Elk sedge is only rated to have fair to good palatability for elk but it is drought resistant and provides an important early spring, fall and late winter forage in dry exposed areas and dry coniferous forests where other species would not.

Although for the most part, sedges are not commercially available, large quantities of seed stock can easily be collected from wet site species and seed for many dry site species can likely either be collected or cultivated on demand. The feasibility of collecting seed from natural sources or cultivating seed for commercial application will depend ion demand and is best coordinated between regional agronomists. As natural wetlands are provided some level of protection on the landscape, reclamation demands are not expected to be high, however site specific applications such as in mining reclamation plans, wetland creation or restoration in the agricultural landscape.

Potential Benefit for Elk

As discussed in the life history section of this report, elk reproductive success is strongly associated with nutritional status, which reflects the quality of the available forage on their range. Therefore increasing the abundance of important forage species would logically be an effective means of increasing elk numbers. There are a wide range of opportunities for the application of native grass seed mixes in most development sectors but perhaps the most significant opportunities will be in association with pipeline and transmission corridors, secondary roads (*e.g.,* cutblock or lease roads), and mine reclamation sites. Other potentially important opportunities may include recreational developments such as ski resorts or parks. Further consideration may be given to cooperative grazing leases or possibly in the guiding industry where horses are often free grazed in natural areas, which may be degraded by an increase of non-forage plants over time.

There is some literature on the nutritional value of different native and agronomic grasses, however one can't claim that one is better over the other (Grilz pers. comm.). Rather, studies tend to focus on forage species utilization by wildlife in order to make inferences about its nutritional value. It is important to recognize that 'native' seed mixes have the potential to dilute the natural gene pool, since distributors usually select for certain preferred traits when mixing natural strains (not unlike most seed mixes including those containing agronomic species). To reduce this undesirable effect, Ducks Unlimited has pursued the use of 'Ecovars', which are cultivars that utilize the broadest genetic composition possible (Grilz, pers. comm.).

Examples of Treatment Strategies

Examples of grass seeding targeted at ungulate range enhancement appear to be sparse in the literature. One example includes a habitat restoration project for Roosevelt elk in Strathcona Park on Vancouver Island, where scarification and seeding with two agronomic seed mixtures were applied (Ursus 2002). The seeded sites included a 0.6 ha and a 1.5 ha site, which were scarified using an excavator and seeded with agronomic seed mixtures. One seed mix was comprised of ryegrass, red fescue, bentgrass, timothy and legumes (clover, trefoil), and the other was exclusively grasses (brome, wildrye, bluegrass, hairgrass, red fescue). The costs at the 0.6 ha and 1.5 ha sites were $1,667/ha and $2,667/ha for the excavator, and $1,957/ha and $2,376/ha for grass seed and fertilizer (0.6 ha site only), respectively. Qualitative monitoring one year after treatment indicated both sites were successful and were heavily utilized by elk.

Seeding costs depend on the seed mix and application rate. The typical range of costs for agronomic mixes starts at around $200/ha and the native grass seed mix that is currently available retails for around $400/ha.

1. Both agronomic and native seed mixes can be used to enhance elk forage, however native seed sources are only beginning to be developed in BC and large quantities may need to be ordered well in advance.
2. Seeding can be completed in spring through early fall.
3. Fertilizing is most effective on nutrient deficient sites.

5.10 Fertilization

In terms of fertilization application on crown land, the trend over the past decade has been extremely since the need for this vegetation enhancement technique depends upon site specific forest conditions (Ministry of Forest, 2003).

Nyberg *et al*. (1990) indicate that fertilizing forest stands, particularly those that are growing on nutrient poor conditions, can help to improve thermal and snow interception cover more quickly but effects on deer and elk are generally minor. Fertilizer can be applied at any time but is usually applied immediately after thinning. Nitrogen in the form of urea is the only ingredient common to fertilization mixtures, and is usually applied at a rate of 200-225 kg N/ha. Nitrogen-phosphorus or nitrogen with micronutrient supplements may be a more effective formula based on recent studies.

In a study in southeastern Washington, elk use was found to increase 49% in the first year after fertilizing (56 Kg N/ha) bunch-forming grass communities, however no significant carry over effect was observed in subsequent years and it was suggested that fertilization may not be a cost effective technique (Skovlin *et al*. 1983). Other studies have also reported little effect of fertilization on elk use (Scotter 1980).

Fertilization vegetation has been used to bolster plant growth and seed production, particularly when used in an initial application. Fertilizing also generally increases the nutritional value of forage. There are few literature references to the use of fertilizer for enhancing wildlife habitat.

1. Fertilizing can be effective in increasing growth rates and nutritional value of forage, although beneficial effects are usually limited to the first year after treatment.

6.0 Prioritizing Enhancement Treatments for Industry

The intent of this project was to identify prospective habitat enhancement techniques that can be applied concurrently with industrial development. Other than urban expansion, examples of major industrial activities where habitat manipulation occurs includes linear developments (roads, railways, seismic lines, hydro lines, pipelines), timber harvesting, and land clearing for agriculture. Examples of industrial developments that tend to be more localized include mines, drill sites, pumping stations, railway load-outs and recreational developments (ski hills, resort areas), which may have more severe but limited (area) effects.

The opportunities for habitat enhancement are often constrained by the nature of the development, or avoided by design to achieve other objectives. In highway and railway developments vegetation management is conducted to maintain safe sight distances and discourage wildlife from utilizing RoWs where animals are a safety hazard. Vegetation management is conducted within power transmission corridors to protect the infrastructure and maintain access for maintenance and inspection purposes. In the forestry sector, shrubs and herbaceous vegetation are often viewed as competing with the plantation species, thus reducing the mean annual increment and consequently the potential revenue. In the agricultural landscape, ungulates can impact crop production or damage fences and are often viewed as a competitor with livestock for food.

Recognizing the inherent differences between the various types of industrial development, it is appropriate to apply habitat enhancement techniques that are compatible with each sector. It should be recognized that the effectiveness of many habitat enhancement techniques may depend on several factors such as regional climate, site conditions (terrain features, existing vegetation, edaphic conditions), timing of application, habitat connectivity and adjacent land use. These site specific differences also have implications on the cost of applying the various treatments, as illustrated by the significant variation within and between techniques (Table 6). The selection of appropriate techniques should therefore consider both physical site constraints and industry constraints.

Brushing tends to vary greatly in cost depending on how and where it is applied. Mechanical brushing appears to generally be more cost effective than manual brushing, and works well in linear corridors and RoWs where machinery such as tractors equipped with brush cutters can steadily knock back vegetation in a non-selective manner. The higher cost associated with manual brushing is largely attributed to lower relative productivity due to less efficient equipment and the time required to select the targeted brushing species. The density of existing shrubs is another factor that can greatly influence manual brushing efficiency.

Table 6. Approximate costs and benefits of various habitat management treatments.

Technique	Cost/ha	Benefits/Limitations	Duration of Effects
Manual brushing	(348[2]-913[1]) [3]	Effective in stimulating nutritious new growth for moose and elk through suckering. Cost effective in remote areas and areas with difficult terrain.	Benefits realized in 1-6 years and may persist for 10-15 years.
Mechanical brushing	266-300[9] 442[1]	Effective for removing large areas of vegetation in an unselective manner. Can be particularly beneficial for converting areas from shrub to herbaceous to favour elk.	Depending on technique and timing but generally shrub recovery is good in the first year with production gradually decreasing in subsequent years.
Mechanical site preparation	101[2]-881[1]	Intensive site preparation favours graminoid communities of particular benefit to elk.	Conversion to herbaceous community in 1-2 years but shrub cover returns within 10-15 years.
Juvenile spacing	305-1585[1]	Increases forage production but has greater effects with manual brushing.	Effects may be short-lived and persist through the rotation.
Pre-commercial thinning	640-800[8]	Increases forage production but effects may be short-lived due to rapid increase in canopy closure.	Effects may be short-lived.
Controlled and prescribed burning	134-375[5], 200-300[6]	Very effective in increasing forage for ungulates. Costs vary with burn area and access. May require periodic burning to maintain seral stage.	Effects in 1-6 years and may persist for 12 years.
Shrub planting	3000-5000	Rapid establishment of browse in cleared areas.	5-20 years required to fully restore or create shrub-dominated communities.
Hand seeding	300-500[7]	Grass/legume mixes effective for elk.	Effects in 1-2 years.
Fertilization	164-353[1, 4]	Not usually conducted for forage enhancement but elk show preference for the more nutritious growth.	Beneficial effects in first year but little carry over effect in subsequent years.

[1] Ministry of Forests 2001/02 Annual Report (includes cost of transportation and wages for crews, equipment, and materials unless otherwise stated).
[2] Ministry of Forests 2002/03 Annual Service Plan Report (includes cost of transportation and wages for crews, equipment, and materials unless otherwise stated).
[3] Considers motorized (*i.e.* power saw, brush saw and other hand-held motorized cutting equipment) and non-motorized (*i.e.* manual cutting, manual girdling, stem bending, and mulching) manual brushing.
[4] Excludes the cost of fertilizer.
[5] Columbia Basin Fish and Wildlife Compensation Program.
[6] Peace/Williston Fish and Wildlife Compensation Program (note the $1000 per ha cost was associated with several delays and intensive pre-burn activities and is higher than other burns conducted by the PWFWCP).
[7] Largely based on numerous small scale seeding projects completed by Triton.
[8] Lowell et al. 1999.
[9] Ministry of Transportation (Ron Marshall pers. comm.)

Prescribed burning is reported to be a very cost effective forage enhancement strategy for the both the Peace/Williston Fish and Wildlife Compensation Program and the Columbia Basin Fish and Wildlife Compensation Program, with an average cost per hectare of around $200-$250. Burn size has ranged from around 200 ha to 600 ha, although numerous smaller burns have been completed in the Kooteney area. In total 62 burns have been conducted in the west Kootenay area over the past 20 years (Poole *et al*. 2002). A reasonable range of costs for burning would start at around $35/ha where little preparation or "mop-up" is required, to around $1,000/ha where access is difficult, pre-burn preparations and mop-up requirements are intensive, and/or delays due to climatic conditions are significant (Krebs pers. comm.).

7.0 Potential Effects of Habitat Enhancement Techniques for Moose and Elk on Non-target Species

Consistent with the general focus of this report, the discussion of the effects of practices designed to enhance habitats for moose and elk on non-target species has largely been limited to stand or operational level practices and does attempt to address landscape level modification. Higher level plan objectives and provincial mandates should always be considered in planning industrial developments and habitat enhancement projects.

Potential conflicts of increasing moose and elk numbers in a given area could include increased predator abundance and predation rates on non-target species such as caribou (James 1999). Although James (1999) showed there was spatial separation between moose and caribou, and that caribou mostly avoided linear corridors, most caribou killed by wolves were closer to corridors (than random locations). James (1999) speculated that caribou could be negatively affected by increased industrial activity, particularly in more remote areas where hunting pressure is not a factor in controlling moose populations.

At the stand or operational level, the habitat enhancement techniques and practices identified in this report are associated with vegetation modification. For moose, techniques designed to increase shrub production would favour species of birds that forage and/or nest in shrubs. For elk, techniques that promote grass production would favour habitat generalists such as deer, small mammals (mice, voles) and their associated predators, and seed eating and insectivorous bird species. In one respect, promoting the abundance of shrubs versus grasses provides a softer ecotone (*i.e*., less harsh edge transition) that may favour a broader range of species such as edge users. Greater understory foliage has been associated with increased number of individuals and species richness (Willson and Comet 1996). Species with requirements for interior forest conditions are likely to receive limited or no benefit from the conversion of forest to early successional stages.

The technique of prescribed burning may not be readily applicable for use concurrent with industrial development, unless it is used in adjacent areas to mitigate the loss of habitats within the development footprint. The effects of prescribed burning on non-target species was examined in the Williston Reservoir watershed, primarily in the context of converting overmature aspen forest (Giroux 1995). The conversion of mature and over-mature hardwood to early successional stages is commonly considered to rejuvenate forage for moose and elk. Based on studies evaluated by Giroux (1995) and Enns *et al*. (1993), the primary wildlife species groups affected by conversion projects include primary and secondary cavity nesting birds, small mammals and ungulates. Species identified in Giroux (1995) and Enns *et al*. (1993) that could be negatively affected by the conversion of mature hardwood forest include:

Birds	Birds	Mammals
Barrow's goldeneye	Warbling vireo	Little brown myotis
Common goldeneye	Red-eyed vireo	Long-legged myotis
Bufflehead	Northern oriole	Silver-haired bat
Ruffed grouse	Lincoln's sparrow	Big brown bat
Yellow-bellied sapsucker	White-crowned sparrow	Flying squirrel
Red-breasted sapsucker	Brown creeper	
Pileated woodpecker	Alder flycatcher	
Hairy Woodpecker	Dusky flycatcher	
Northern saw-whet owl	Canada warbler	
Lewis woodpecker	Wilson's warbler	
Band-tailed pigeon	Yellow warbler	
Northern flicker	Ruby-crowned kinglet	
Black-throated green warbler	Common yellowthroat	
Mourning warbler	Black-capped chickadee	
McGillivray's warbler	Bald eagle (interior)	
American redstart	Great blue heron	
Swainson's thrush	Ovenbird	
White-breasted nuthatch	Great grey owl	
Philadelphia vireo	Long-eared owl	

In general, small mammals and ungulates benefit from the conversion of hardwood forests to early successional stages due to the increase in available forage, however red-backed voles and masked shrew have been found to be more abundant in old forest (Giroux 1995).

The regional importance of hardwoods to wildlife includes areas of isolated or concentrated breeding. For example, several species with nesting or foraging requirements in aspen only occur within one geographic location in British Columbia (Peace-Fort Nelson aspen forests), including the Common grackle, chestnut-sided warbler, Connecticut warbler, Black-throated green warbler and Canada warbler (Enns *et al*. 1993). The importance of hardwood management was considered critical in the northeast, important on the coast, and of future concern in the interior (Enns *et al*. 1993). Projects or developments that result in the conversion of hardwoods to coniferous plantations, or that involve harvesting or burning should therefore consider the potential impacts on non-target species.

Where habitat is directly altered as a result of industrial development, it may be feasible to mitigate impacts to non-target species through design and construction practices. Enhancing habitats adjacent to developed areas can also provide a means to mitigate or compensate for undesirable effects on non-target species. The appropriate pre-field studies and project planning steps would be required to address potential impacts to species other than moose and elk. The techniques described in this report may be useful to mitigate development-related effects but should only be considered as a means to mitigate effects that cannot be addressed through the selection of alternative locations or designs.

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APPENDICES

Appendix 1. Compatibility of habitat enhancement and mitigation techniques for moose with industrial activity.

	Compatibility with physical conditions											Compatibility with industrial sector								
	wet/cold biogeo zone	warm/dry biogeo zone	snowpack>90 cm	snowpack<90 cm	wet sites	dry sites	warm aspect	cool aspect	steep slopes	gentle-moderate slopes	non-target species	agriculture	transportation corridors	hydro corridors	pipeline corridors	infrastructure protection	timber production	recreation	mining	Row total
Mitigation Techniques																				
Habitat preservation	3	1	2	2	1	1	1	3	1	1	4	4	2	4	2	4	1	2	4	43
Cover treatments	1	1	1	2	1	1	1	2	1	1	2	3	4	2	2	4	1	2	4	36
Access management	3	1	2	2	1	2	1	3	1	2	4	4	4	2	2	2	1	1	2	40
Grazing systems	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	76
Herbicide treatment	3	2	3	1	2	1	1	3	4	1	4	3	1	3	3	3	3	3	3	47
Enhancement Techniques																				
Cutblock planning	3	1	2	1	1	1	1	2	2	1	4	4	4	4	4	4	1	4	4	48
Manual brushing	3	1	2	1	1	2	1	3	1	1	4	4	2	2	2	2	1	2	4	39
Mechanical brushing	3	2	2	1	1	3	1	3	4	1	4	4	1	1	1	1	2	1	4	40
Mechanical site preparation	3	2	2	1	1	2	1	3	2	1	4	4	4	4	4	4	1	4	4	51
Juvenile spacing and thinning	3	2	2	1	2	1	1	3	2	1	4	4	4	4	4	4	1	4	4	51
Selective cutting	3	1	2	2	1	2	1	2	2	1	1	4	4	4	4	2	2	2	4	44
Controlled burning	3	2	3	1	1	2	1	3	4	1	2	3	4	4	4	4	2	2	2	48
Hardwood girdling	3	1	3	1	2	1	1	3	1	1	1	4	4	3	3	4	1	4	4	45
Large stock planting	3	1	2	2	1	2	1	3	2	1	2	4	4	4	4	4	2	4	4	50
Live-staking	3	2	2	1	1	2	1	2	2	1	4	4	4	4	2	4	2	2	1	44
Seeding	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	76
Fertilization	3	1	2	1	2	1	1	3	2	1	4	4	4	3	3	4	2	3	1	45

1 - highly compatible, no significant limitations; 2 - moderately compatible, some limitations; 3 - marginally compatible, significant limitations;
4 - not compatible and/or of little or no value as a mitigation/ehancement technique

Notes:

Non-target species scores indicate techniques that can be used to mitigate non-target species effects

Herbicide treatments are considered for eliminating forage along transportation corridors, or noxious weeds in other sectors

Lower scores in the row total column generally indicate techniques that have broad applicability and value for moose.

Appendix 1. Compatibility of habitat enhancement and mitigation techniques for elk with industrial activity.

	Compatibility with physical conditions											Compatibility with industrial sector								
	wet/cold biogeo zone	warm/dry biogeo zone	snowpack>60 cm	snowpack<60 cm	wet sites	dry sites	warm aspect	cool aspect	steep slopes	gentle-moderate slopes	non-target species	agriculture	transportation corridors	hydro corridors	pipeline corridors	infrastructure protection	timber production	recreation	mining	Row total
Mitigation Techniques																				
Habitat preservation	1	1	2	1	1	1	1	2	1	2	1	4	2	4	2	4	1	1	4	36
Cover treatments	1	1	2	1	1	1	1	2	1	2	1	3	4	2	2	4	1	2	4	36
Access management	1	1	1	2	2	1	1	2	1	2	3	2	2	2	2	2	1	1	1	30
Grazing systems	2	1	3	1	3	1	1	3	4	1	4	1	4	2	2	2	2	3	2	42
Herbicide treatment	1	1	2	1	1	1	1	1	4	1	4	3	1	3	3	3	2	3	3	39
Enhancement Techniques																				
Cutblock planning	4	4	4	4	4	4	4	4	4	4	2	4	4	4	4	4	1	4	4	71
Manual brushing	2	3	2	3	2	3	2	3	2	2	3	4	4	1	1	2	1	1	4	45
Mechanical brushing	2	3	2	3	2	3	3	2	4	2	4	3	4	1	1	2	2	1	4	48
Mechanical site preparation	4	4	4	4	4	4	4	4	4	4	4	2	4	4	4	4	1	2	2	67
Juvenile spacing and thinning	3	2	3	2	3	2	2	3	2	3	3	4	4	4	4	4	2	4	4	58
Selective cutting	2	3	2	3	3	2	2	3	2	2	2	4	4	4	4	3	1	2	4	52
Controlled burning	1	1	2	1	2	2	1	2	4	1	3	2	4	4	4	4	1	3	3	45
Hardwood girdling	3	2	2	3	3	2	2	3	2	2	2	4	4	3	3	3	2	4	4	53
Large stock planting	3	2	2	4	2	3	2	3	3	2	4	4	4	4	4	4	2	4	2	58
Live-staking	3	2	2	4	2	3	2	4	2	3	4	4	4	4	2	4	2	3	2	56
Seeding	2	1	3	1	2	1	1	3	1	1	2	1	1	1	1	3	2	2	1	30
Fertilization	2	2	3	2	2	3	2	4	2	3	4	2	4	3	3	4	2	3	2	52

1 - highly compatible, no significant limitations; 2 - moderately compatible, some limitations; 3 - marginally compatible, significant limitations;
4 - not compatible and/or of little or no value as a mitigation/ehancement technique

Notes:

Non-target species scores indicate techniques that can be used to mitigate non-target species effects

Herbicide treatments are considered for eliminating forage along transportation corridors, or noxious weeds in other sectors

Lower scores in the row total column generally indicate techniques that have broad applicability and value for elk.

Appendix 2. Response of selected tree and shrub species with forage values for moose and elk to management treatments.

Common name	Scientific name	Forage Value Moose	Forage Value Elk	Response to manual treatments	Response to mechanical site preparation	Response to burning	Response to herbicide		
							2,4-D	Gly.	Hex.
Saskatoon	*Amelanchier alnifolia*	G	G	sprouts	damaged stems sucker but cover unchanged or decreases	sprouts from root crowns or rhizomes, decreases, slow to recover			
sage	*Artemesia tridentate*	none	F	sprouts?	sets back growth but increases stems?	set back by severe fire, maintained in light fire?			
Oregon-grape	*Mahonia aquifolium*	F?	G	sprouts?	decreases in abundance, slow to recover?	reduced or eliminated by severe burns, increases following light burns?			
water birch	*Betula occidentalis*	G	G	mod-vig sprouter?	stimulates seeding in, damaged stems sprout?	stimulates seeding in on mineral soil?			
paper birch	*Betula papyrifera*	G	G	mod-vig sprouter	stimulates seeding in, damaged stems sprout	stimulates seeding in on mineral soil	4	4	4
red-osier dogwood	*Cornus stolonifera* or *C. sericea*	E	G	sprouts and suckers	damaged stems sucker but cover unlikely to change	set back by severe fire, favoured by light fire, increases on subhygric sites	1-2	3	2
wolf willow	*Elaeagnus commutata*	F?	F	sprouts and suckers	invades mineral soil, broken stem parts may sprout?	increases in abundance?			
salal	*Gaultheria shallon*	F?	G	sprouts and suckers	varied response, sets back growth but increases stems	reduced by severe burns, increases following light burns on wetter sites	1	1	1-(4)
juniper	*Juniperus* spp.	P?	P/F?						
black twinberry	*Lonicera involucrata*	F	F	sprouts	no information	Reduced by moderate to severe burns, slow to recover, vigorous resprouting after light burns	unk	4-5	1-5
spruce	*Picea* spp.	F/G?	P/F?						
pine	*Pinus* spp.	F/G?	P/F?						

Appendix 2. Response of selected tree and shrub species with forage values for moose and elk to management treatments.

Common name	Scientific name	Forage Value Moose	Forage Value Elk	Response to manual treatments	Response to mechanical site preparation	Response to burning	Response to herbicide		
							2,4-D	Gly.	Hex.
balsam poplar	*Populus balsamifera*	F	G	sprouts and suckers vigorously	promotes suckering, provides seedbed, stems and roots regenerate	stimulates sprouting, reduced by severe burns	1-2	4-5	4
trembling aspen	*Populus tremuloides*	G	G	suckers vigorously	promotes suckering	promotes suckering, density can be dramatically increased, severe burns can reduce suckering	3-4	4-5	4
Douglas fir	*Pseudotsuga menziesii*	P/F?	F/G?						
rose	*Rosa acicularis*	G	G	sprouts with moderate vigour	sprouts with moderate vigour	persists or increases slightly, reduced or eliminated by severe burns	3	2-4	4-5
raspberry	*Rubus idaeus*	F?	F	sprouts and suckers, density increases	sprouts and suckers, seeds in on mineral soil	invades burned areas using buried and new seed, sprouts after light-moderate burns	2	3-4	3(4)
willow	*Salix* spp.	G/E	G/E	sprouts vigorously, recovers rapidly, density increases	invades mineral soil, broken stem parts may sprout	sprouts, quick hot fire maximize sprouting, long slow fires reduce sprouting	4	3-5	2-5
soopolallie	*Shepherdia canadensis*	F?	F/G	sprouts with moderate vigour	decreases in abundance, slow to recover	sprouts, increases in cover			
snowberry	*Symphoricarpos albus*	P	F	suckers and sprouts	exposed mineral soil improves germination	suckers and sprouts, severe fires reduce sprouting	4	4-5	unk
blueberry, bog cranberry	*Vaccinium* spp.	F	F/G	sprouts and suckers, slow to recover	decreases in abundance, slow to recover	decrease in abundance or eliminated, slow to recover	2-5	1-3	2?
highbush cranberry	*Viburnum edule*	F/G	F	sprouts with low to moderate vigour	damaged plats sprout, seeds in on exposed mineral soil	sprouts, quick light fires stimulate germination of buried seed	unk	2-4	1(2)

Appendix 3. Commercial availability of grass and sedge species with forage values for elk.

Common name	Scientific name	Origin	Forage value	Commercially Available[1]	Comments
crested wheatgrass	*Agropyron cristatum*	I	G	Yes	common in seed mixes, highly drought tolerant but poor regrowth, grazed all year, somewhat higher protein content than *A. pauciflorum* & *Bromus inermis*
wheatgrass	*Agropyron* spp. [1, 3]	N, I	G/E	Yes	grazed all year by elk, *A. dasytachyum* is N and commercially available but of unkown? forage value
awned or bearded wheatgrass	*Agropyron subsecundum*	N	G	soon?	Northern species moving into seed production phases in BC
bluebunch wheatgrass	*Agropyron spicatum* or *Pseudoroegneria spicatum*	N	G/E	yes	grazed by elk throughout year, hay of high feeding value
slender wheatgrass	*Agropyron trachycaulum* N. var. or *Elymus trachycaulus*	N	G	yes	very successful in BC test productions but may need to order 1 year ahead
violet wheatgrass	*Agropyron violaceum*	N	G	yes	Northern species moving into seed production phases in BC
redtops and bentgrasses	*Agrostis* spp.	N, I	G	yes	creeping to sod-forming, common in seed mixes, highly valuable range species
redtop	*Agrostis alba* or *A. stolonifera* or *A. gigantea*	I	G/E	yes	common in seed mixes, naturalized, choice elk feed
spike redtop	*Agrostis exarata*	N	G	soon?	important range plant, elk favour foliage, very successful in BC test productions but may need to order 1 year ahead
hair bentgrass	*Agrostis scabra*	N	F/P	yes	very successful in BC test productions but may need to order 1 year ahead
smooth brome	*Bromus inermis*	I	G	yes	highly palatable and nutritious for livestock, important agronomic for pasture and forage crops, tolerates drought and short-term flooding
Alaska brome	*Bromus sitchensis*	N		soon	very successful in BC test productions but may need to order 1 year ahead
brome grass	*Bromus* spp.[3]	N, I	P/G	yes	species with long awns (B. tectorum) of lower value, some species provide good forage in the growing season, *B. ciliatus* is N to central and S BC and commercially available
bluejoint	*Calamagrostis canadensis*	N	F/G	yes	low to moderate value winter and spring food for elk, common and widespread
slimstem reedgrass	*Calamagrostis stricta* or *C. neglecta*	N	F/G?	soon?	mesic to wet meadows and open coniferous forest in montane to alpine zones, very successful in BC test productions but may need to order 1 year ahead

Appendix 3. Commercial availability of grass and sedge species with forage values for elk.

Common name	Scientific name	Origin	Forage value	Commercially Available[1]	Comments
pinegrass	*Calamagrostis rubescens*	N	G/E	no	important elk forage in dry areas of the central and southern interior, increases more after fire
carex sedges	*Carex* spp. [1, 3]	N	F/E	no	important elk forage but largely undifferentiated at species level, shown to have more crude protein and less crude fibre than grasses
beaked sedge	*Carex rostrata*	N	G	no	often dominant in BC marshes, easy to collect seed
water sedge	*Carex aquatilus*	N	F/G	no	often dominant in BC marshes, easy to collect seed
elk sedge	*Carex geyeri*	N	F/G	no	important elk forage in dry open conifer forests
sedges	*Cyperaceae* spp. [3]	N	F/G	no	some species may be available but most are not, variable in value
orchardgrass	*Dactylis glomerata*	I	G	yes	common in seed mixes but often an invasive exotic
oatgrasses	*Danthonia* spp. [3]	(N), I	F	yes	introduced species common in seed mixes, no native species available
tufted hairgrass	*Deschampsia cespitosa*	N	G	yes	very successful in BC test productions but may need to order 1 year ahead
slender hairgrass	*Deschampsia elongata*	N	G?	soon?	wide range of mesic to moist sites, very successful in BC test productions but may need to order 1 year ahead
hairgrasses	*Deschampsia* spp. [3]	N	G	yes	widely distributed, will form almost pure colonies in moist meadows and is relished by most livestock
spike-rush	*Eleocharis* spp. [3]	N	F?	no	generally a coarse or tough wetland species, seed heads have some value but are small
blue wild rye	*Elymus glaucus*	N	F	yes	coarse forage, northern species, drought tolerant, very successful in BC test productions but may need to order 1 year ahead
hairy wildrye	*Elymus innovatus*[1]	N	P/F	yes	important elk forage especially in winter, meadows to open rocky hillsides and open pine or spruce forest
dunegrass	*Elymus* spp. [3]	N, I	P/F	yes	foliage and seed heads coarse and bristly
tall fescue	*Festuca arundinacea*	I	F/G?	yes	bunchgrass, deep-rooting, common in seed mixes, tolerates drought and wet soils
creeping red fescue	*Festuca rubra*	I	G	yes	sod-forming, common in seed mixes but often invasive, most successful agronomic species in BC test production
red fescue	*Festuca rubra* ssp *arenicola*	N	G	soon?	very successful in BC test productions but may need to order 1 year ahead
western fescue	*Festuca occidentalis*	N	G	yes	streambanks, lake margins and open woods, usually in loose stands
red fescue	*Festuca rubra* ssp *pruinosa*	N	G	soon?	very successful in BC test productions but may need to order 1 year ahead
Rocky Mountain fescue	*Festuca saximontana*	N	G	yes	Northern species moving into seed production phases in BC

Appendix 3. Commercial availability of grass and sedge species with forage values for elk.

Common name	Scientific name	Origin	Forage value	Commercially Available[1]	Comments
rough fescue or altai fescue	*Festuca scabrella*[1] or *F. altaica* or *F. campestris*	N	G/E	yes	thickly tufted species in dry areas, considered a highly nutritious and important elk forage, suitable for grazing systems
fescue	*Festuca* spp. [1, 3]	N, I	G	yes	common in seed mixes, some species important
rushes	*Juncus* spp. [3]	N, I	(P/F)	no	generally a coarse or tough forage, fine-leaved meadow types more important
junegrass	*Koeleria cristata*[3]	N	F/G	(yes)	smaller plants, rarely abundant, *K. macrantha* is a commercially available native species that provides good forage
ryegrasses	*Lolium* spp.	I	G	yes	annual ryegrass is extensively used in erosion control, perennial ryegrass produces good forage
melic grass	*Melic* spp. [3]	N	G	no	often in moist to dry meadows and forests in S BC, rarely abundant
ricegrass	*Oryzopsis* spp.	N	(F/G)	yes	*O. hymenoides* available but *O. asperifolia* common in woodland forests is not
timothy	*Phleum pratense*	I	G	yes	common in seed mixes, very successful range plant, favoured by elk
Canada bluegrass	*Poa compressa*	I	G	yes	creeping, hardy naturalized species, widely used for revegetation, very successful in BC test productions but may need to order 1 year ahead
glaucous bluegrass	*Poa glauca*	N	G	soon	Northern species moving into seed production phases in BC
fowl bluegrass	*Poa palustris*	I	G	yes	Generally viewed as introduced from Europe but circumboreal and found throughout Canada and much of the U.S. Northern species moving into seed production phases in BC
Kentucky bluegrass	*Poa pratensis*	I	G	yes	sod-forming naturalized species, drought tolerant, favoured by elk, common in seed mixes
bluegrass	*Poa* spp.[3]	I, N	G/E	yes	naturalized species of high range value and favoured by elk
purple oatgrass or false melic	*Schizachne purpurascens*[3]	N	P/F	no	moist to dry open forests and rocky slopes, circumpolar
needlegrasses	*Stipa* spp. [3]	N, (I)	(F/G)	yes	durable and valuable year-round forage species for dry areas, awns on some known to cause eye damage
spike trisetum	*Trisetum spicatum*	N	F/G	yes?	wide altitude and ecological range on drier sites

[1] Commercially available refers to large quantities, as most species are available from various sources in small quantities

Appendix 4. Commercial availability of herbaceous species with forage values for elk.

Forbs	Scientific name	Origin	Forage Value	Commercially available	Comments
agoseris	*Agoseris* spp.	N, I	(F)	no	weedy low-growing species
wild onion	*Allium cernuum*	N	G	no	elk extensively feed on onions in spring
asters	*Aster* spp.	N	F/G	(yes)	most species of fair value
showy aster	*Aster conspicuus*	N	G	yes	an important fall and winter forage for elk
milk-vetch	*Astragalus* spp. [3]	N, I	P(X)/G	no	some species poisonous, others provide good forage
balsamroot	*Balsamhorriza sagitata*	N	G	no	limited to dry BG, PP zones, elk eat leaves and heads, leaves dry up by mid-summer
spotted knapweed	*Centaurea maculosa*	I	P	no	noxious weed
Canada thistle	*Cirsium arvense*	I	P	no	invasive weed
edible thistle	*Cirsium edule*	N	P	no	weedy species
tall larkspur	*Delphinium glaucum*	N	P(X)	no	young plants especially toxic to cattle and horses not sheep, non-toxic in late summer following maturity
larkspur	*Delphinium* spp. [3]	N, I	F?	no	most species noted to be poisonous to cattle at least during some growth stages, a few are eaten by sheep
draba	*Draba* spp. [3]	N, I	F?	no	generally diminutive plants of rocky areas
fireweed	*Epilobium angustifolium*[4]	N	P/F	yes	of low to moderate value to elk in summer and fall
wild strawberry	*Fragaria virginiana* [3]	N	F	no	poor for livestock, fair for elk
northern bedstraw	*Galium boreale*	N	P	no	relatively coarse plant with low nutritional value
bedstraw [3]	*Galium* spp.	N	P/F	no	generally coarse, small plants, some bristly
avens	*Geum* spp. [3]	N	P	no	
cow parsnip	*Heracleum lanatum*	N	G/E	no	livestock and wildlife relish the abundant foliage, early stems and green seeds of this species
peavine	*Lathyrus* spp.	N	G/E	no	Ours (*L. ochroleucus*, and *L. nevadensis*) provide good summer forage for elk
lupine	*Lupinus* spp. [3]	N	P(X)/G	yes	many species poisonous to livestock but provide fair to good forage for elk
alfalfa	*Medicago* spp.	I	G	yes	deep tap root, exceptional high-yielding quality hay, nitrogen soil enhancer
sweet clover	*Melilotus* spp.	I	(F/G)	yes	invasive weedy species, often used for soil improvement qualities
bluebells	*Mertenesia* spp. [3]	N	G	no	favoured by elk throughout the growing season

Appendix 4. Commercial availability of herbaceous species with forage values for elk.

Forbs	Scientific name	Origin	Forage Value	Commercially available	Comments
coltsfoot	*Petasites* spp. [3]	N	G?	no	
cinquefoil	*Potentilla* spp. [3]	N	P/F	no	elk forage lightly on herbage spring-fall
saxifrage	*Saxifraga* spp. [3]	N	F/G?	no	generally small plants of rocky places
chickweed	*Stellaria* spp. [3]	I, N	G?	no	generally small, weedy species
dandelions	*Taraxacum* spp.	I	F/G	no	our common species are introduced weedy species but provide fair summer forage
clovers	*Trifolium* spp.	I	G/E	yes	unexcelled for pasturage and hay, equal to timothy in digestible nutrients with 3 times as much protein
alsike clover	*Trifolium hybridum*	I	F	yes	does well on poorly drained sites and heavy soils
red clover	*Trifolium pratense*	I	F	yes	larger, coarser plant used for its soil improvement qualities (deep taproot, N-fixing)
white clover	*Trifolium repens*	I	E	yes	naturalized, wide temperature tolerance (suited to cool, moist regions), extremely nutritious, withstands grazing and trampling
vetch	*Vicia* spp. [3]	I	F/G	yes	occurs in mixed communities and is palatable but decreases with grazing pressure