An overview of the forage resource and beef production on Crown land in British Columbia

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Wikeem, B. M., Mclean, A., Bawtree, A. and Quinton, D. 1993. **An overview of the forage resource and beef production on Crown land in British Columbia.** Can. J. Anim. Sci. **73**: 779–794. This paper reviews the geographic extent, distribution, plant communities, forage productivity and animal production of Crown range in British Columbia. Over 10 million ha of Crown range is distributed among 11 biogeoclimatic zones. Forestland comprises nearly 80% of the landbase grazed. In the southern interior, the most important zones include the Bunchgrass, Ponderosa Pine, Interior Douglas-Fir and Montane Spruce zones. Forage yields vary from as much as 2700 kg ha^{-1} on grassland to <100 kg ha^{-1} under dense forest canopy. On seeded clearcuts, however, production may exceed 1500 kg ha^{-1}. Average daily gains for steers and calves on forest range vary from 0.8 to 1.1 kg d^{-1}. In the central interior and Peace River areas, the Sub-Boreal Pine–Spruce, Sub-Boreal Spruce and Boreal White and Black Spruce zones provide most of the forage for beef cattle. Seventeen community pastures, comprising nearly 170 000 ha, produce almost 50 000 animal-unit months (AUMs) of forage for cattle in this region. Forage production potential is high, especially on community pastures, but the grazing period is generally only 4-5 mo. Management of livestock and forage on Crown range in British Columbia may be more complex than in other regions of Canada because of the diversity of vegetation and climate and the extensive overlap of range use with other resource interests. Consequently, livestock and forage management needs to be modified to produce optimal returns to the livestock industry within an integrated-use framework.

Keywords: Animal production, beef cattle, British Columbia, forage production

Wikeem, B.M., McLean, A., Bawtree, A. et Quinton, D. 1993. **Survol des ressources fourragères et de la production des bovins de boucherie sur les terres de l'état en colombie-britannique.** Can. J. Anim. Sci. **73**: 779-794. L'article passe en revue l'étendue géographique, la répartition, les communautés végétales, la productivité fourragère et la production animale dans les terres de l'État en Colombie-Britannique (C.-B.). Plus de 10 millions d'hectares (ha) de parcours de l'État se répartissent entre 11 zones biogéoclimatiques. La forêt couvre près de 80 % du territoire pâturé. Dans le sud de l'intérieur, les zones les plus importantes sont la zone à graminées cespiteuses, la zone du pin Ponderosa, la zone du Douglas de l'intérieur et la zone montagnarde à épinette. Le rendement fourrager peut aller de 2700 kg ha^{-1} sur prairie à moins de 100 kg ha^{-1} sous couvert forestier dense. Dans les coupes à blanc ressemées, la production peut toutefois dépasser 1500 kg ha^{-1}. Le QMQ das bouvillons et des veaux dans les parcours de forêt va de 0,8 kg à 1,1 kg j^{-1}. Dans le centre de l'intérieur et dans la région de la Rivière-de-la-Paix, la zone sub-boréale à pin et épinette, la zone sub-boréale à épinette et la zone boréale à épinette blanche et noire procurent la plus forte quantité de fourrage. Dans cette région, 17 pâturages collectifs, couvrant près 17 000 ha, produisent pour 50 U.A.M. le fourrage. Les possibilités de production fourragère sont fortes, surtout dans les pâturages collectifs, mais la période de paissance se limite en général à 4 à 5 mois. La conduite des pâturages et des animaux sur les grands parcours de l'État peut être plus complexe que dans les autres parties du Canada, à cause de la vaste concurrence pour l'utilisation des parcours qu'elle subit de la part d'autres intérêts. Par conséquent, la gestion des productions herbagères et animales doit être modifiée afin de fournir au secteur de l'évelage

les recettes potimales dans un cadre d'utilisation intégrée.

Mots clés: Production animale, bovins de boucherie, Colombie-Britannique, production fourragère

The forage and grazing resource in British Columbia totals more than 10 million ha and is comprised of forage crops, improved pasture, native range and community pastures (Agriculture Canada 1989). Crown range, which is administered by the BC Ministry of Forests, accounts for about 85% of the area used for grazing in the province. Over most of this area, native grasses and forbs are the primary source of feed with little or no grain supplementation.

There are more than 330 000 beef cattle distributed among six forest regions in British Columbia (Agric. Can. 1989) (Fig. 1). About 90% of the range resource in British Columbia is grazed by cow–calf and yearling operations for spring, summer and fall forage. Crown range provides nearly one million AUMs (BC Ministry of Forests 1992) or 60% of their total annual forage requirement on pasture. The remaining 40% (600 000 AUMs) is produced on about 1.5 million ha of private rangeland and irrigated pasture.

Extending from the U.S. border to approximately 55°N, most of the range resource in British Columbia lies between the Coast Mountains on the west and the Rocky Mountains on the east (Fig. 2). East of the Rocky Mountains, in the Peace River area, beef cattle are grazed from 55 to 57°N although some range permits are issued as far north as Fort Nelson at nearly 58°N.

Biogeoclimatic Zones Used for Grazing in British Columbia

Wide variations in climate, soils, elevation, latitude and topography throughout British Columbia combine to produce a diversity of plant communities available for grazing, including grassland, wetland, forestland, subalpine and alpine (Nordstrom 1984). Indeed, 11 of the 14 biogeoclimatic zones in British Columbia are used for grazing. Forestland is particularly important, accounting for nearly 80% of the provincial-crown range resource. This reliance on the forestland base sets the BC forage resource apart from most other grazing areas. For example, in the United States, only 10% of the forage resource occurs on forestland.

Considerable information is available describing grassland and low-elevation forested zones in the southern interior (Tisdale, 1947; Tisdale 1950; Tisdale and McLean 1957; van Ryswyk et al. 1966; McLean 1970; McLean et al. 1971), but considerably less is known about mid- to high-elevation forests, northern forested zones and community pastures.

Plant Communities in the Southern Interior

Most ranches in the southern interior range cattle over an altitudinal migration incorporating several vegetation types. Indeed, combinations of seven biogeoclimatic zones may be used for different portions of the grazing season depending upon their availability. The Bunchgrass, Ponderosa Pine, Interior Douglas-Fir and Montane Spruce zones are the most important for grazing in the southern interior. The Interior Cedar Hemlock, Engelmann Spruce – Subalpine Fir and Alpine zones may be locally important to ranchers, particularly west of Kamloops. Coastal zones, such as the Mountain Hemlock, Coastal Douglas-Fir and Coastal Western Hemlock are not considered part of the range resource.

Bunchgrass Zone. This zone comprises the grasslands between 300 and 1000 m in the southern interior from the U.S. border north to Williams Lake (Nicholson et al. 1991). It lies below the Ponderosa Pine Zone but meets with the Interior Douglas-Fir Zone in several locations and contains the area formerly classified as the lower and middle grasslands

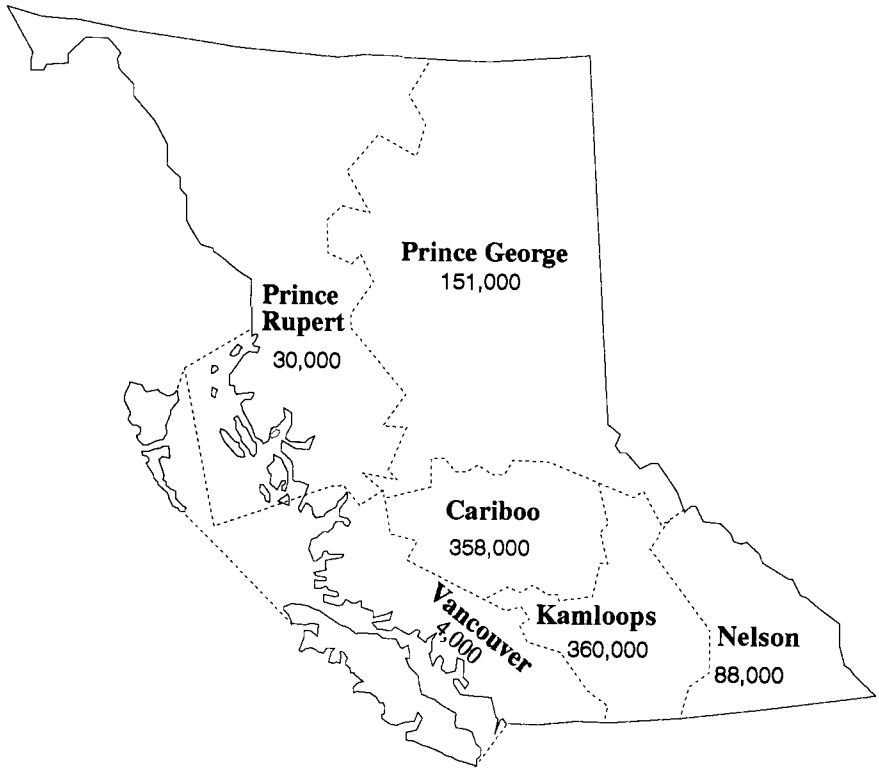

Fig. 1. Allocated animal unit months (AUMs) by forest region in British Columbia in 1990.

(Tisdale 1947; van Ryswyk et al. 1966; McLean and Marchand 1968). Climatically, the Bunchgrass Zone is characterized by hot dry summers and moderately cold winters. Annual precipitation may be less than 335 mm and is usually bimodally distributed in May–June and December–January (Van Ryswyk et al. 1966). Although grasslands only occupy about 1.3 million ha, these communities are important for late-fall, winter and early-spring grazing.

Bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. & Smith) is the dominant and most productive forage species in the Bunchgrass Zone (Tisdale 1947; Van Ryswyk et al. 1966; McLean and Marchand 1968). Associated species vary depending upon the site and past grazing history of the area but may include needle-and-thread (*Stipa comata* Trin. & Rupr.), Sandberg's bluegrass (*Poa sandbergii* Vasey), prairie Junegrass (*Koeleria cristata* Pers.), arrow-leaved balsamroot (*Balsamorhiza sagittata* (Pursh) Nutt.) and numerous other forbs (Tisdale 1947; McLean and Marchand 1968; Wikeem et al. 1989). On sandy soils, needle-and-thread, sand dropseed (*Sporobolus cryptandrus* (Torr.) Gray), red three awn (*Aristida longiseta* Steud.), and Indian ricegrass (*Oryzopsis hymenoides* (R. & S.) Ricker) may dominate (Lloyd et al. 1990). Important browse species for both cattle and wildlife include Saskatoon (*Amelanchier alnifolia* Nutt.), common chokecherry (*Prunus virginiana* L.), Wyeth buckwheat (*Eriogonum heracleoides* Nutt.), Douglas maple (*Acer glabrum* var. *douglasii* (Hook.) Dippel), and rose (*Rosa* spp.) throughout the zone. Bitterbrush (*Purshia tridentata* (Pursh) DC.) is also an important browse species in the Okanagan and East

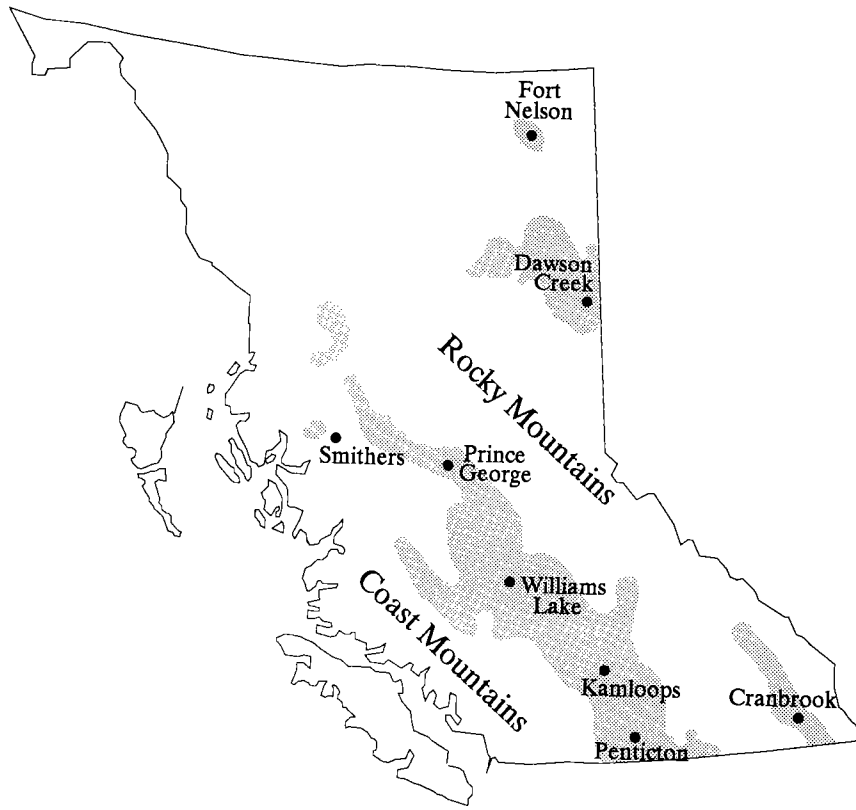

Fig. 2. Location and extent of the range resource in British Columbia.

Kootenay regions near Penticton and Cranbrook, respectively (Fig. 1). Big sagebrush (*Artemisia tridentata* Nutt.) and rabbitbrush (*Chrysothamnus nauseosus* (Pall.) Britt.), the dominant shrubs in this zone, have little grazing value for domestic livestock.

Ponderosa Pine Zone. This zone occupies nearly 800 000 ha between 49 and 51°N (Hope et al. 1991a). Occurring at between 335 and 900 m elevation, it is the warmest and driest forest zone in the province with annual precipitation at 280–550 mm. Ponderosa pine (*Pinus ponderosa* Dougl.), the climax dominant tree, generally forms open stands except when trees are immature (Tisdale 1950). On ranges in excellent condition, bluebunch wheatgrass is often associated with the same species present in the Bunchgrass Zone. Rough fescue (*Festuca scabrella* Torr.) and Idaho fescue (*Festuca idahoensis* Elmer) often replace bluebunch wheatgrass or co-dominate in the most southerly portions of the zone, and shrubs such as bitterbrush, Saskatoon, common chokecherry and rose contribute to understory cover, especially in the East Kootenay region. This zone provides early-spring and late-fall forage for livestock.

Interior Douglas-Fir Zone. This zone is the most important forest zone for grazing in the southern interior, serving as late-spring, summer and early-fall range (Tisdale 1950; Tisdale and McLean 1957). Extending over 4.8 million ha, it occurs from 300 to 1400 m elevation between 49 and 52°30′N (Hope et al. 1991b). Annual precipitation averages 300 to 750 mm.

Depending on aspect and elevation, canopy closure in this zone varies from open stands to dense closure. Periodic fires have replaced Douglas-Fir, the climax dominant, with lodgepole pine (*Pinus contorta* (Moench) Voss) and aspen (*Populus tremuloides* Michx.) over extensive areas (Tisdale 1950; Tisdale and McLean 1957; McLean 1970). Large grassland communities, formerly classified as upper grassland (Tisdale 1947; McLean and Marchand 1968), occur within this zone because of edaphic and topographic conditions, combined with fire (Hope et al. 1991b).

Grassland associations within the Interior Douglas-Fir Zone, in excellent range condition, are often dominated by rough fescue, bluebunch wheatgrass or Idaho fescue. On northern grasslands in the Cariboo and Chilcotin Regions near Williams Lake (Fig. 2), Richardson's needlegrass (*Stipa richardsonii* Link) and sheep fescue (*Festuca ovina* L.) are often the climax dominants. Other important forages include Kentucky bluegrass (*Poa pratensis* L.), prairie Junegrass, yarrow (*Achillea millefolium* L.) and arrowleaf balsamroot, depending upon the site, past grazing history and the moisture regime. Columbia milkvetch (*Astragalus miser* Dougl.) often contributes to ground cover but is toxic to cattle (Majak et al. 1974). Saskatoon, Douglas maple, pasture sage (*Artemisia frigida* Willd.) and rose are common shrubs (Mitchell et al. 1981a,b).

In open stands of Douglas-fir at low elevation and on south slopes, bluebunch wheatgrass is usually the primary forage plant. Pinegrass (*Calamagrostis rubescens* Buckl.), however, is the principal herbaceous species over most of the Interior Douglas-Fir Zone and may comprise 40–80% of the ground cover under the forest canopy in this zone (Tisdale 1950; McLean 1967). Other associated species in the Douglas-Fir Zone include Richardson's needle-grass, northwestern sedge (*Carex concinnoides* Mack.), heart-leaf arnica (*Arnica cordifolia* Hook.), showy aster (*Aster conspicuus* Lindl.), creamy peavine (*Lathyrus ochroleucus* Hook.) and vetch (*Vicia* spp.) (Tisdale 1950; Tisdale and McLean 1957; Annas and Coupe 1979; Utzig et al. 1989; Anonymous 1989). Common shrubs in this zone include rose, whitetop spirea (*Spirea betulifolia* Pall.), soopolallie (*Shepherdia canadensis* (L.) Nutt.) and bearberry (*Arctostaphylos uva-ursi* (L.) Spreng).

Montane Spruce Zone. The Montane Spruce Zone occurs at middle elevations (1000 to 1700 m) from 49 to 53°N between the Interior Douglas-Fir Zone and Engelmann Spruce – Subalpine Fir Zone. Occupying nearly 1.4 million ha, this zone is characterized by a cool, continental climate. Mean annual precipitation in this zone ranges from 380 to 900 mm (Hope et al. 1991c). The Montane Spruce Zone is important summer range for beef cattle from June to September depending upon its geographic location.

Pinegrass is the principal forage species throughout the zone except on seeded clearcuts where agronomic forage species such as orchardgrass (*Dactylis glomerata* L.), alsike clover (*Trifolium hybridum* L.) and white clover (*Trifolium repens* L.) are most often seeded. Other associated native species on dry sites include bearberry, common juniper (*Juniperus communis* L.), false box (*Pachistima myrsinites* (Pursh) Raf.) and arctic lupine (*Lupinus arcticus* (Smith) Hitchc.). Heart-leaf arnica, common horsetail (*Equisetum arvense* L.), oak fern (*Gymnocarpium dryopteris* (L.) Newm.) and black gooseberry (*Ribes lacustre* (Pers.) Poir) are common on wetter sites (Lloyd et al. 1990).

Interior Cedar Hemlock Zone. This zone extends from 400- to 1500-m elevation from 49 to 54°15′N in the southern part of the province and from 54°45′ to 57°30′N in the north (Ketcheson et al. 1991). Commonly referred to as the interior wet belt, annual precipitation in this zone can exceed 1200 mm.

The Interior Cedar Hemlock Zone is used sparingly for grazing throughout the province but can be locally important near Kamloops, east of Williams Lake, and in the Nelson forest region between Cranbrook and Penticton (Fig. 2). Forest canopies and understory vegetation are often dense in the Interior Cedar Hemlock Zone, but forage production

potential is high when areas are logged. A wide range of species may be available depending upon the site association and management practices, but little has been documented regarding important forages in this zone. On native sites, pinegrass, sedges (*Carex* spp.) and fireweed (*Epilobium angustifolium* L.) combine with Saskatoon, blueberry (*Vaccinium* spp.), willows (*Salix* spp.) and numerous other forbs for cattle forage. This zone is used for cattle grazing in July and August but has been used for summer sheep grazing for silvicultural purposes in the Kamloops and Nelson forest regions.

Engelmann Spruce – Subalpine Fir Zone. This zone occupies the highest elevation (860 to 1860 m) of all forest types in British Columbia (Coupe et al. 1991). Although it extends over 12 million ha, grazing is limited to wetlands and forest openings (McLean et al. 1963) mainly in drier subzones. Clearcut logged areas in wetter subzones serve as transitional range for 10 to 15 yr and can be highly productive when seeded to agronomic forages.

Important forage species have been poorly documented for this zone, but pinegrass, sedges, heart-leaf arnica and some browse species such as huckleberry are common native forages (McLean et al. 1971; Anonymous 1989). Domestic species such as orchardgrass and clovers are important forages on seeded sites.

Although small in extent, two edaphic grassland associations in the Engelmann Spruce – Subalpine Fir Zones were classified by McLean (1970) as the *Artemisia tridentata* spp. *vaseyana* – *Calamagrostis rubescens* and the *Festuca idahoensis* – *Eriogonum heracleoides* types. In these associations, bluebunch wheatgrass, Idaho fescue, prairie Junegrass, Kentucky bluegrass, western needlegrass (*Stipa occidentalis* Thurb.) and Wyeth buckwheat are available for livestock grazing.

Alpine Tundra Zone. Depending upon the location, the Alpine Tundra Zone occupies elevations ranging from 1000 m in the northern part of the province to above 2300 m in the southeast (Pojar and Stewart 1991). Alpine grazing is locally important in the central and southern interior near Nelson, Kamloops, and Williams Lake. Common species available for grazing include sedges, fescues, alpine timothy (*Phleum alpinum* L.) and mixed forbs and shrubs (Selby 1980; McLean 1979; Annas and Coupe 1979).

Forage Production in the Southern Interior

Forage production on Crown range varies widely depending on the biogeoclimatic zone, site, range-condition class, soil type, annual weather patterns and degree of forest canopy closure. On grasslands and low elevation forests, soil moisture is often a limiting condition, and annual weather patterns significantly affect forage availability.

In the lower grassland near Kamloops, forage production varied from 400 to 900 kg ha^{-1} on excellent-condition range (McLean and Marchand 1968). In the south Okanagan, Marchand (1964) reported that forage production at four sites near Penticton averaged 1000 kg ha^{-1}. No data are available for this zone for northern grasslands near Williams Lake.

McLean and Marchand (1968) reported average forage yields ranging from 250 to 500 kg ha^{-1} on poor and excellent range-condition sites in the middle grassland near Kamloops. Wikeem et al. (1989), however, found that forage yields over 2 yr were 1300 kg ha^{-1} on an excellent-condition site north of Kamloops.

Many grass species such as bluebunch wheatgrass, needle-and-thread, prairie Junegrass and crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.) can produce considerable fall regrowth in some years depending upon fall moisture and temperature conditions (Wikeem 1984; Van Ryswyk et al. 1989). Indeed, Wikeem (1984) reported that nearly 30% of the total annual production on grassland in the south Okanagan occurred as fall regrowth that enhanced both forage production and forage quality for livestock and wildlife.

Grassland phases within the Interior Douglas-Fir Zone, which occur on shallow soils and south slopes, are some of the most

productive areas for grazing in the province. Yields on excellent condition grassland dominated by rough fescue average more than 1100 kg ha^{-1} and can range from about 475 to 2700 kg ha^{-1}, depending upon annual weather patterns and sites (McLean and Marchand 1968). Yields on Becher Prairie, west of Williams Lake, equalled 660 kg ha^{-1} on sites dominated by bluebunch wheatgrass (Wikeem and Newman, unpubl. data). Successional stages induced by grazing also influence forage availability. McLean and Marchand (1968), for example, reported average forage yields of about 110, 280, 450 and 620 kg ha^{-1} for lower grasslands in poor, fair, good and excellent range condition, respectively. Similar reductions were reported for mid- and upper-grassland sites as well (McLean and Marchand 1968).

Many more factors affect the grazing value of forest range than grasslands. On forest range, both soil moisture and canopy cover, as well as their interactions, influence forage yield. At higher elevations, effective moisture becomes less limiting, but the density of forest canopy influences forage production profoundly. Indeed, production may be reduced by 60% when open stands are compared to stands with 80% canopy closure (Dodd et al. 1972).

McLean and Marchand (1968) suggested that forage yields in the Ponderosa Pine Zone near Kamloops averaged about 475 kg ha^{-1} and ranged from 200 to 1000 kg ha^{-1}. In the Similkameen Valley west of Penticton, McLean et al. (1971) found that forage production averaged nearly 800 kg ha^{-1} over 12 sites in climax Ponderosa Pine – Idaho fescue communities. Similarly, forage yields ranged from about 335 to 800 kg ha^{-1} over 10 yr at Skookumchuck Prairie north of Cranbrook (McLean and Smith 1973). Bluebunch wheatgrass can account for 25–65% of the total forage production on some sites in good or excellent range condition (Wikeem 1984).

Dry sites in the Interior Douglas-Fir Zone, where the understory is dominated by bluebunch wheatgrass or Idaho fescue, often have high forage-production capability. McLean and Smith (1973) reported 11-yr averages of 500 and 800 kg ha^{-1} for two open Douglas-fir sites in the Rocky Mountain Trench near Cranbrook. Similarly, forage yields from nine Douglas-fir – Idaho fescue sites in the Similkameen averaged about 900 kg ha^{-1}, compared to five Douglas fir – bluebunch wheatgrass sites, which yielded 450 kg ha^{-1} (McLean et al. 1970).

Where pinegrass is the principal herbaceous species, it can provide 50–65% of the available forage for livestock (Tisdale 1950). McLean (1979) observed that forage production averages about 273 kg ha^{-1} in this zone where the tree canopy closure is minimal but yields can be as high as 675 kg ha^{-1} (McLean et al. 1971). Tisdale (1950) reported a range of herbage yields from about 100 to 725 kg ha^{-1} in the Interior Douglas-Fir Zone near Kamloops. Few data are available for the Cariboo forest region (Fig. 1), but carrying capacities in this zone are estimated at 2–6 ha AUM^{-1} for pinegrass communities and from 3 to 6 ha AUM^{-1} in forested bluebunch wheatgrass communities (Anon. 1989).

Limited forage-production data are available for the Montane Spruce and Engelmann Spruce – Subalpine Fir Zones, especially under forest canopy. Forage yields average about 540 kg ha^{-1} and can range from 300 to 675 kg ha^{-1} on unseeded clearcuts dominated by pinegrass (Clark and McLean 1978; Youwe et al. 1991). McLean et al. (1971) remarked that a reasonable average for the Engelmann Spruce – Subalpine Fir Zone in the Ashnola area, west of Penticton, is about 370 kg ha^{-1}. Forage production in localized edaphic grasslands and sedge meadows may be as high as 1800 kg ha^{-1} (McLean et al. 1971) and 1000 kg ha^{-1} (McLean et al. 1963), respectively. Both the Montane Spruce and Engelmann Spruce – Subalpine Fir Zones are used mostly for summer cattle grazing in July and August although edaphic grasslands in the Similkameen may be used as spring and fall range (McLean et al. 1971). Some experimental summer sheep grazing also occurs in the Engelmann Spruce – Subalpine Fir Zone in the Clearwater forest district north of Kamloops.

Few data document forage production in the Alpine Tundra. In the Ashnola area near Penticton (Fig. 2.), herbage yields in plant communities dominated by oatgrass (*Danthonia* spp.) and sedges averaged 1768 kg ha^{-1} and yields on sedge meadow were 1380 kg ha^{-1} (Brink et al. 1972). Similar values were reported on Nevis Mountain near Fort Nelson (Brink et al. 1972) and in alpine areas near Kamloops (Mitchell et al. 1981a,b).

Forage Seeding and Fertilization

On depleted grassland sites, forage production can be enhanced 2 to 10 times with range seeding depending on the site, the plant community structure and weather (McLean and Bawtree 1971a; McLean and Wikeem 1983). Several agronomic species have been recommended for seeding in the Bunchgrass Zone, but on the driest sites (<250 mm precipitation) crested wheatgrass (Summit, Nordan and Fairway varieties) and Whitmar beardless wheatgrass have survived best (McLean et al. 1979). Approximately 45 000 ha have been seeded in the Bunchgrass Zone with specialized equipment that tills, seeds and packs the soil in one pass. Fall is generally the best time to seed crested wheatgrass on dry grasslands (McLean and Wikeem 1983).

Forage production on low elevation grassland can also be improved with nitrogen (N) fertilization, although this range improvement technique is not used frequently in British Columbia. Most research on BC grasslands has focused primarily on application rates, site-specific response and residual effects of N fertilizers (Mason and Miltimore 1959; Mason and Miltimore 1964; Kilcher et al. 1965; Hubbard and Mason 1967; Mason and Miltimore 1969; Mason and Miltimore 1972; Wikeem et al. 1989).

Van Ryswyk et al. (1993) evaluated dry-matter yield responses to N fertilization from 34 field trials on grassland and forest range in British Columbia, according to vegetation, soil and range-condition class. Low elevation grasslands in the Bunchgrass Zone, dominated by bluebunch wheatgrass on Brown/Dark Brown Chernozemic soils, gave the least response in the first harvest year after N application. Average forage yields from the application of 200 kg N ha^{-1} equalled 795, 394 and 95 kg ha^{-1} for excellent, good and poor condition classes, respectively. Averaged responses on crested wheatgrass were 105 kg ha^{-1} (84% increase over control) on Brown Chernozemic soils and 668 kg ha^{-1} (107% increase over control) on Dark Brown/Black Chernozems. Compared to other nutrients, N deficiencies appear to be the most limiting for plant growth on grassland. Indeed, applications of phosphate and potash have consistently produced no response beyond that produced by the application of N alone on most grassland. Carry-over effects on low-elevation grasslands can occur for up to 10 yr or longer (Van Ryswyk et al., 1993).

Seeding clearcuts to agronomic forages is a common range improvement practice in British Columbia. Since 1960, more than 50 000 ha of harvested forestland have been seeded, mostly by fixed-wing aircraft or helicopter. The objectives for forage seeding on forestland generally are to: (1) provide quality forage for livestock, (2) improve soil fertility, (3) decrease erosion, (4) prevent weed invasion, and (5) reduce fire hazards (McLean and Bawtree 1971b). Most seeding has been done in the Ponderosa Pine, Douglas-Fir and Montane Spruce zones, although seeding can be effective in other forest zones.

Numerous species such as orchardgrass, smooth brome (*Bromus inermis* Leys.), Kentucky bluegrass, creeping red fescue (*Festuca rubra* L.), crested wheatgrass, rambler alfalfa (*Medicago sativa* L.) and clovers have been recommended for seeding on forestland to meet site specific conditions. Although more than 21 seeding mixes have been recommended for seeding clearcuts, landings and roadsides, little research has been done in British Columbia to evaluate the ability of individual species or mixes to meet livestock or forest management objectives (Nordstrom 1984).

Forage production is usually enhanced when clearcuts are seeded. For example,

forage yields on unseeded clearcuts in the Montane Spruce Zone averaged 41% less (538 kg ha^{-1}) compared to sites that were logged and seeded to orchardgrass, timothy, smooth brome, crested wheatgrass and clovers (913 kg ha^{-1}) at 4.5 kg ha^{-1} (Clark and McLean 1978). Moreover, the seeded areas consistently produced more forage than the unseeded area over 4 yr.

Forage-seeding rates influence both the rate at which the forage stand develops and the standing crop. Youwe et al. (1991) seeded three Montane Spruce cutblocks to orchardgrass, timothy, alsike clover and Dutch white clover at 3 and 12 kg ha^{-1}. In the first year after seeding, forage production equalled 300 kg ha^{-1} on areas seeded at each rate and on the unseeded controls. By the second year after seeding, however, forage production on the lower seed rate was nearly double (525 kg ha^{-1}) the unseeded control, and total forage yields on the areas seeded at 12 kg averaged almost 1500 kg -ha^{-1} (Youwe et al. 1991).

Forage production can be further increased with N fertilization (Freyman and Van Ryswyk 1969). Indeed, Wikeem et al. (1993) found that increasing N rates from 100 to 400 kg N ha^{-1} at 100-kg increments increased forage yields to more than 400% of control on two lodgepole pine sites in the south Cariboo. Moreover, an addition of 55 kg ha^{-1} sulfur to N further increased forage production on both sites by 50% compared to N alone. On forestlands, N was generally depleted after 3 yr (Wikeem et al., 1993).

Plant Communities and Forage Production in the Central Interior and North

Very little information is published on the ecology and management of native vegetation or community pastures used for beef production in the central interior and northern regions of British Columbia, even though these areas provide nearly 20% of AUM provincially. Except for the nearly 170 000 ha of community pastures and 880 000 ha of wetlands and meadows, most of the area is forested in various stages of succession.

The most important biogeoclimatic zones for grazing are the Sub-Boreal Spruce, and Sub-Boreal Pine–Spruce Zones in the central interior near Prince George and Smithers, and the Boreal White and Black Spruce Zone east of the Rocky Mountains in the Peace River region (Fig. 2). The Spruce Willow Birch Zone is locally important east of the Rocky Mountains, mainly for guide outfitter horses. Most of the region is characterized by long cold winters and mild summers (McLean and Pringle 1979). Generally, the grazing period extends only 4-5 mo depending on the location and annual weather conditions.

Extending from 51°30′ to 59°N, the Sub-Boreal Spruce Zone is important in the Cariboo, Prince Rupert and Prince George forest regions at elevations ranging from 490 to 1250 m. The climate is continental, characterized by seasonal extremes, with precipitation ranging from 440 to 900 mm (Meidinger et al. 1991). Hybrid white spruce (*Picea engelmannii* × glauca) and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) are the climax dominant trees, but lodgepole pine and trembling aspen dominate seral stands.

Most grazing in the Sub-Boreal Spruce Zone near Smithers occurs on open south facing edaphic grasslands (Pojar et al. 1984). Mesic subzones with dense overstory have some range value as well (Willoughby 1986). Common forage species include western needlegrass, prairie Junegrass, timber oatgrass (*Danthonia intermedia* Vasey), American vetch (*Vicia americana* Mulh.) and Saskatoon (Willoughby 1986). In south-facing edaphic grassland communities, Kentucky bluegrass, slender wheatgrass (*Agropyron trachycaulum* (Link)), stiff needlegrass, blue wildrye (*Elymus glaucus* Buckl.), California brome (*Bromus carinatus* H. & A.) and common dandelion (*Taraxicum officinale* Weber) are forage plants for livestock.

Few data are available on forage production potential throughout most of the Sub-Boreal Spruce Zone. Forage production can range from 300 to 600 kg ha^{-1} under the canopy of spruce and pine, but yields can exceed 3000 kg ha^{-1} on edaphic-grassland sites (Willoughby 1986). Much of

the Sub-Boreal Spruce Zone is used for late-spring, summer and early-fall range from May to August.

Lying in the rain shadow of the Coast Mountains, the Sub-Boreal Pine Spruce Zone occupies the gently rolling landscape from the Fraser and Nechako plateaus at elevations ranging from 850 to 1500 m (Steen and Demarchi 1991). The mean annual precipitation ranges from 335–580 mm with more than half falling as snow (Steen and Demarchi 1991). Lodgepole pine is the dominant tree over large areas of this zone occasionally accompanied by white spruce and trembling aspen. Understory vegetation is generally low growing and varies widely among site associations but may include pinegrass, sheep fescue, rough-leaved ricegrass (*Oryzopsis asperifolia* Michx.), heart-leaf arnica, peavine, prickly rose (*Rosa acicularis* Lindl.) and willows (*Salix* spp).

Generally the Sub-Boreal Pine Spruce Zone has low capability for grazing and a short grazing season from May to September. Carrying capacity under forest canopies ranges from 2 to 8 ha AUM^{-1} depending upon the site (Anon. 1989). Extensive wetlands throughout the area, however, are used for hay production and for grazing (Van Ryswyk and Bawtree 1977; Annas and Coupe 1979; Steen and Demarchi 1991). On native-sedge meadows forage production can range from 560 to 6000 kg ha^{-1} (Heyes 1979; Van Ryswyk and Bawtree 1977; McLean 1979). With proper water control, complete fertilization with N, phosphorus and potassium and seeding to reed canary grass (*Phalaris arundinacea* L.), yields can exceed 7700 kg ha^{-1} on low-elevation sites (Anon. 1993). Similarly, carrying capacity can be enhanced greatly in some subzones after logging, particularly if they are seeded to agronomic forages.

Most of the Boreal White and Black Spruce Zone occurs east of the Rocky Mountains as an extension of the Great Plains from 54°N to the Yukon and Northwest Territory borders (DeLong et al. 1991). Occupying elevations from 230 to 1300 m; annual precipitation varies from 330 to 570 mm, and temperatures may be above 10°C for only 2–4 mo (DeLong et al. 1991). Common tree species throughout the zone include white spruce, trembling aspen, lodgepole pine, black spruce (*Picea mariana* (Mill.) B.S.P.), paper birch (Betula papyrifera Marsh.) and Alaska paper birch (*B. neoalaskana* Sarg.). Most of the forest remains in some stage of succession as a result of frequent fires.

Perhaps as much as 50% of the range resource in the Peace River area occurs in seral aspen communities (DeLong 1988). A variety of grasses, herbs and shrubs such as bluejoint (*Calamagrostis canadensis* ((Michx.) Beauv.) fuzzy-spiked wildrye (*Elymus innovatus* Beal), slender wheatgrass, creamy peavine, vetch, rose, Saskatoon, red-osier dogwood (*Cornus stolonifera* Michx.) and willows provide excellent forage and browse (McLean 1979).

Forage yields are variable depending upon the site association and extent of canopy closure, but few data are available. McLean and Pringle (1979) reported that young trembling aspen stands are often less productive than mature stands, and the forage production can vary from 400 to 1000 kg ha^{-1}. This zone is used for cattle grazing from mid-May to mid-September.

Livestock Production

Relatively few studies have been undertaken evaluating beef production on most range types in British Columbia because of the high cost and time required. Those studies that have been done, however, reveal that both average daily gains (ADG) and beef production ha^{-1} vary among sites, seasons, length of the grazing period, abundance and quality of available forage and livestock class (Nordstrom 1984).

On grasslands grazed in both spring and fall, Quinton et al. (1985) reported that both cow and calf gains were greatest on upper grasslands in the Interior Douglas-Fir Zone and progressively increased from the lower grasslands to upper grasslands in both spring and fall (Table 1). Grazing periods on these grasslands generally correspond to plant phenology during the initial growth cycle

Table 1. Average daily gain (kg ± SE) of cows and calves on grassland in southern British Columbia

Season	Grassland community		
	Lower	Middle	Upper
	Cows		
Spring	0.32±0.19	0.57±0.08	0.92±0.09
Fall	0.17±0.23	0.40±0.10	0.54±0.09
	Calves		
Spring	0.85±0.03	0.96±0.04	0.99±0.03
Fall	0.66±0.09	0.70±0.02	0.78±0.03

in spring and regrowth in fall. Both cows and calves gained better on all grassland types in spring compared to fall in response to better forage-quality conditions (Quinton et al. 1985).

Most work in the Interior Douglas-Fir Zone has focused on steers and heifers. Consistently, ADG for both classes of livestock averaged from 0.80 to 0.90 kg d^{-1} from open lodgepole pine–pinegrass and open aspen–pinegrass to closed lodgepole pine–pinegrass communities over the grazing season (Tisdale 1950; McLean 1967; McLean 1972). Grazing seasons varied from 70 to 103 d (McLean 1967; McLean 1972). The time of turnout and removal of stock in fall influences the seasonal ADG. Indeed, the highest weight gains for steers on pinegrass range generally occured in June (1.47 kg d^{-1}), but by September and October ADG only averaged from 0.34 to 0.40 kg d^{-1}.

Van Ryswyk et al. (1973) evaluated the effects of fertilization on forage and beef production on sedge meadows in the Interior Douglas-Fir Zone near Kamloops. Fertilization increased dry-matter yield of native sedges, which increased beef production ha^{-1} for yearling steers from 89 to 214 kg ha^{-1} over the grazing season. Average daily gains on fertilized pastures (0.24 kg d^{-1}), however, were similar to those on the unfertilized areas (0.22 kg d^{-1}). These values are considerably lower than yearling steer and heifer weight gains (0.64 kg d^{-1}) collected on sedge meadows over 7 yr in the Montane Spruce Zone near Kamloops (McLean et al. 1963).

Considerably more data are available for animal production in the Montane Spruce Zone. Average daily gains of cows ranged from 0.13 to 1.7 kg d^{-1} (Clark and McLean 1978; Quinton 1987; Quinton et al. 1991) on seeded clearcuts. Part of the explanation for such a wide difference in gain is the length of the grazing season which varied from 103 to 28 d in the two trials, respectively. As in the Interior Douglas-Fir Zone, weight gains decline over the grazing season from July (0.55 kg d^{-1}) to September when cows may lose weight (0.21 kg d^{-1}) (Quinton 1987). Few studies have documented the effects of grazing systems on animal production. Quinton (1987), however, reported that calf gains over 5 yr were different ($P < 0.05$) when cattle were grazed on a continuous-grazing system (0.92 kg d^{-1}) compared with rotational grazing (0.83 kg d^{-1}).

Community Pastures

Community pastures in British Columbia are located in the Peace River block and the central plateau region around Prince George. Conceived in the 1950s, community pastures were blocks of land reserved primarily to supply forage for domestic livestock (Campbell and Bawtree 1991). All of the 17 community pastures, comprising nearly 170 000 ha, were derived by clearing forestland. Following clearing, these areas are either seeded to agronomic forages or left to succession with native species. Up to 30 or more livestock producers may together use a single pasture.

Virtually no data are available quantifying forage production on community pastures. Indeed, in conducting an assessment of selected community pastures, Campbell and Bawtree (1991) could only infer forage production on the basis on hay yields in the region. They estimated that production could range from 2200 to 6600 kg ha^{-1} and average 3300 kg ha^{-1}. A 5-yr grazing study at Sunset Community Pasture near Dawson Creek revealed that carrying capacity ranged from 0.13 to 0.17 ha AUM^{-1} (Broca 1982).

Average daily gain of cows and calves on the Sunset Community Pasture was similar to

those on seeded forest range in the Montane Spruce Zone. Indeed, Broca (1982) reported that 5-yr mean ADGs for cows and calves were 0.55 and 0.99 kg d^{-1}, respectively, over a 136-d grazing period on fields within the community pasture, seeded to smooth brome, creeping red fescue, timothy and alsike clover. On unseeded fields, cow and calf ADGs were 0.19 and 0.95 kg ha^{-1}, respectively, for a 121-d grazing period. Beef production per hectare was substantially higher for both cows and calves on the tame (106 and 200 kg ha^{-1}) compared with the native (3.4 and 28.9 kg ha^{-1}) fields. Broca (1982) concluded that these differences likely resulted from increased forage production on the seeded pastures, since average forage quality on the seeded and native pastures was similar.

Past and present management of community pastures has been extensive, using ecological principles of range management developed for native grasslands. Considerable opportunity exists for improved management of these resources by adopting a more intensive, agronomic approach to pasture management, such as rotational grazing systems, fertilization and improved forage-species selection for seeding (Campbell and Bawtree 1991). Presently, there is insufficient demand for additional forage in the northern and central interior to warrant further investment in the pastures. Moreover, more research needs to be undertaken to clarify the biological and economic opportunities for community pastures.

Challenges for Management of Range Resource

More than 20 noxious-weed species are distributed over an estimated 100 000 ha of forest and grassland in British Columbia. Much of this area encompasses the most valuable range in the province for spring and fall grazing for both cattle and wildlife. Moreover, virtually all of the 1.1 million ha of grassland and open forest may be susceptible to invasion by knapweed (*Centaurea* spp.) (Harris and Cranston 1979). Other species, such as houndstongue (*Cynoglossum officinale* L.), can occur under forest canopy in the Ponderosa Pine and Douglas-Fir zones.

Few studies have been done to determine the effects of these weeds on forage production and species composition, but forage yields can be at least 50% lower on areas infested with diffuse knapweed (*Centaurea diffusa* Lam.) (Myers and Berube 1983). Indeed, Watson and Renney (1974) found a significant ($P < 0.05$) inverse correlation between forage production and knapweed yields.

Herbicides have been effective in local control of some species, but biological control is considered the only viable long-term solution to controlling most weed species. Biological control agents are presently available for diffuse knapweed and spotted knapweed (*Centaurea maculosa* Lam.), leafy spurge (*Euphorbia esula* L.), Canada thistle (*Cirsium arvense* (L.) Scop.), bull thistle (*Cirsium vulgare* (Savi) Tenore) and nodding thistle (*Carduus nutans* L.). Efficacy of the agents has not been determined yet, but initial results are encouraging.

Resource overlaps occur on virtually all the areas grazed by livestock on crown land in British Columbia. The integration of forage and livestock management on crown land with other recognized values, such as timber, wildlife, watershed quality and capacity, and recreation, will continue to challenge resource managers in British Columbia. In the past, the interactions with timber and wild ungulates were of principal concern, but greater emphasis will be placed on environmental issues and conservation in the future.

There continues to be concern over the impacts of cattle grazing on forest regeneration in British Columbia. Under poor management, livestock can adversely affect forest regeneration by trampling and browsing seedlings (Nordstrom 1984). Most commonly, cattle damage trees through incidental trampling, but these scars cover generally about 25% of the stem circumference and are located near the base of the seedling (Newman et al. 1991). Occasionally, scars may be larger, but they rarely girdle the tree seedling completely. Newman et al. (1991) reported that cattle rarely browsed lodgepole pine seedlings (<2%) when other forage species

were available. Studies in British Columbia indicate that tree seedling mortality by cattle can range from negligible to 56% depending on the site and cattle management (Clark and McLean 1978; McLean and Clark 1980; Newman et al. 1991). Other factors, however, such as poor planting stock, site conditions, the planting process and rodents also contribute to seedling damage and mortality. Indeed, Newman et al. (1991) reported that 18% of lodgepole pine seedlings were damaged before cattle were introduced onto three plantations near Kamloops, and 77% of all trees in one pasture were damaged by voles. Some trees were completely girdled and defoliated by voles. McLean and Clark (1980) concluded that cattle can be compatible with conifer regeneration if the numbers of cattle and length of the grazing period are strictly controlled.

Wildlife are prevalent over most of the range area used for livestock grazing. In the last 30 yr, there have been conflicts between cattle and California bighorn sheep (*Ovis canadensis* californiana) in the Ashnola region (Pitt and Allaye Chan 1985), elk (*Cervus canadensis*) in the East Kootenay area (Pitt 1982) and with mule deer (*Odocoileus hemionus hemionus*) near Kamloops (Willms et al. 1975; Willms and McLean 1978; Willms et al. 1980). All these conflicts have focused on dietary overlap and forage allocation. Although these disputes commonly occur, generally they can be mitigated through cooperation based on knowledge of the issues (McLean 1979).

Management of livestock and pastures on crown range in British Columbia may be more complex than in other regions of Canada because of the diversity of vegetation and because of the extensive overlap of range use with other resource interests. Over the next decade, there will be much greater emphasis on integrated use. Public demand for energy, fibre, food, water, recreation and minerals will need to be balanced with environmental issues such as biodiversity and conservation. Consequently, principals of livestock and forage management need to be modified to produce optimal returns to the livestock industry within an integrated-use framework.

Agriculture Canada. 1989. Development of the agri-food sector in British Columbia. Appendix commodity profile. Forages. Agriculture Canada, New Westminster, BC. 36 pp.

Annas, R. M. and Coupe, R. 1979. Biogeoclimatic zones and subzones of the Cariboo Forest Region. BC Ministry of Forests. 103 pp.

Anonymous. 1989. A field guide for the identification and interpretation of ecosystems of the Cariboo Forest Region. Ministry of Forests and Lands, Williams Lake, BC. 176 pp.

Anonymous. 1993. Forage production on poorly drained soils in the southern interior of British Columbia. Cariboo Poorly Drained Soils Dev. Exten. Comm., British Columbia Ministry of Agriculture Food and Fisheries, Victoria, BC.

BC Ministry of Forests. 1992. Annual Report 1990–1991. British Columbia Ministry of Forests, Victoria, BC. 79 pp.

Brink, V. C., Luckhurst, A. and Morrison D. 1972. Productivity estimates from alpine tundra in British Columbia. Can. J. Plant Sci. **52**: 321–323.

Broca, S. A. 1982. Weight gains in beef cattle in the south Peace River area of British Columbia. B.Sc. thesis. University of British Columbia, Vancouver, BC. 56 pp.

Campbell, C. W. and Bawtree, A. H. 1991. Community pasture assessment for Integrated Resources Branch, British Columbia Ministry of Forests. BC Ministry of Forests, Victoria, BC. 137 pp.

Clark, M. and McLean A. 1978. Compatibility of grass seeding and coniferous regeneration of clearcuts in the south central interior of British Columbia. BC Ministry of Forests, Research Note 83, Victoria, BC. 25 pp.

Coupe, R., Stewart, A. C. and Wikeem, B. M. 1991. Engelmann Spruce – Subalpine Fir Zone. Pages 223–236 *in* D. Meidinger and J. Pojar, eds. Ecosystems of British Columbia, BC Ministry of Forests, Special Report Series 6, Victoria, BC.

DeLong, C. 1988. A field guide for identification and interpretation of seral aspen ecosystems of the BWBSc1, Prince George Forest Region. BC Ministry of Forests, Land Management Report 16, Victoria, BC. 36 pp.

DeLong, C., Annas, R. M. and Stewart, A. C. 1991. Boreal White and Black Spruce Zone. Pages 237–250 *in* D. Meidinger and J. Pojar, eds. Ecosystems of British Columbia. BC Ministry of Forests, Special Report Series 6, Victoria, BC.

Demarchi, D. A. 1991. Sub-Boreal Pine – Spruce Zone. Pages 195–208 *in* D. Meidinger and J. Pojar, eds. Ecosystems of British Columbia. BC Ministry of Forests, Special Report Series 6, Victoria, BC.

Dodd, C. J. H., McLean, A. and Brink, V. C. 1972. Grazing values as related to tree-crown covers. Can. J. For. Res. **2**: 185–189.

Freyman, S. and Van Ryswyk, A. L. 1969. Effect of fertilizer on pinegrass in southern British Columbia. J. Range Manage. **6**: 390–395.

Harris, P. and Cranston, R. 1979. An economic evaluation of control methods for diffuse and spotted knapweed in western Canada. Can. J. Plant Sci. **59**: 375–382.

Heyes, G. E. 1979. The effect of clipping date and height on forage yields, nutritive quality and stored food reserves of a Chilcotin wetland meadow. M.Sc. thesis. University of British Columbia, Vancouver, BC.

Hope, G. D., Lloyd, D. A., Mitchell, W. R., Erickson, W. R., Harper, W. L. and Wikeem, B. M. 1991a. Ponderosa Pine Zone. Pages 139–151 *in* D. Meidinger and J. Pojar, eds. Ecosystems of British Columbia. BC Ministry of Forests, Special Report Series 6, Victoria, BC.

Hope, G. D., Mitchell, W. R., Lloyd, D. A., Erickson, W. R., Harper, W. L. and Wikeem, B. M. 1991b. Interior Douglas-fir Zone. Pages 153–166 *in* D. Meidinger and J. Pojar, eds. Ecosystems of British Columbia. BC Ministry of Forests, Special Report Series 6, Victoria, BC.

Hope, G. D., Mitchell, W. R., Lloyd, W. R., Harper, W. L. and Wikeem, B. M. 1991c. Montane Spruce Zone. Pages 183–194 *in* D. Meidinger and J. Pojar, eds. Ecosystems of British Columbia. BC Ministry of Forests, Special Report Series 6, Victoria, BC.

Hubbard, W. A. and Mason, J. L. 1967. Residual effects of ammonium nitrate and ammonium phosphate on some native ranges of British Columbia. J. Range Manage. **20**: 1–5.

Ketcheson, M. V., Braumandl, T. F., Meidinger, D., Utzig, G., Demarchi, D. A. and Wikeem, B. M. 1991. Interior Cedar – Hemlock Zone. Pages 167–181 *in* D. Meidinger and J. Pojar, eds. Ecosystems of British Columbia. BC Ministry of Forests, Special Report Series 6, Victoria, BC.

Kilcher, M. R., Smoliak, S., Hubbard, W. A., Johnston, A., Gross, A. T. H. and McCurdy, E. V. 1965. Effects of inorganic nitrogen and phosphorus fertilizers on selected sites of native grassland in western Canada. Can. J. Plant Sci. **45**: 229–237.

Lloyd, D., Angove, K., Hope, G. and Thompson, C. 1990. A guide to site identification and interpretation for the Kamloops forest region. BC Ministry of Forests, Land Management Report 23, Victoria, BC. 399 pp.

Majak, W., McLean, A., Pringle, T.P. and Van Ryswyk, A.L. 1974. Fluctuations in miserotoxin concentration of timber milkvetch on rangelands in British Columbia. J. Range Manage. **27**: 363–366.

Marchand, L. S. 1964. An ecological study of sagebrush in interior British Columbia. M.S.F. thesis, University of Idaho, Moscow, Idaho, U.S.A.

Mason, J. L. and Miltimore. J. E. 1959. Increase in yield and protein content of native bluebunch wheatgrass from nitrogen fertilization. Can. J. Plant Sci. **39**: 501–504.

Mason, J. L. and Miltimore, J. E. 1964. Effect of nitrogen content of beardless wheatgrass on yield response to nitrogen fertilization. J. Range Manage. **17**: 145–147.

Mason, J. L. and Miltimore, J. E. 1969. Yield increases from nitrogen on native range in southern British Columbia. J. Range Manage. **22**: 128–131.

Mason, J. L. and Miltimore, J. E. 1972. Ten year yield response of beardless wheatgrass from a single nitrogen application. J. Range Manage. **25**: 269–272.

McLean, A. 1967. Beef production on lodgepole pine-pinegrass range in southern British Columbia. J. Range Manage. **20**: 214–216.

McLean, A. 1970. Plant communities of the Similkameen Valley, British Columbia, and their relationships to soils. Ecol. Monogr. **40**: 403–424.

McLean, A. 1972. Beef production on lodgepole pine–pinegrass range in the Cariboo region of British Columbia. J. Range Manage.**25**: 10–11.

McLean, A. 1979. Grazing forests and clearcuts. West. Wildlands **5**: 134–135.

McLean, A. and Bawtree, A. 1971a. Seeding grassland ranges in the interior of British Columbia. Agriculture Canada, Ottawa, ON., Publ. 1444.

McLean, A. and Bawtree, A. 1971b.. Seeding forest rangelands in British Columbia. Agriculture Canada, Ottawa, ON., Publ. 1463.

McLean, A. and Clark, M. B. 1980. Grass, trees, and cattle, on clearcut-logged areas. J. Range Manage. **33**: 213–217.

McLean, A. and Marchand, L. 1968. Grassland ranges in the southern interior of British Columbia. Agriculture Canada, Ottawa, ON, Publ. 1319.

McLean, A. and Pringle, W. L. 1979. Range Plant Communities. Pages 37–53 *in* A. McLean, ed. Range management handbook for British Columbia. Agriculture Canada, Kamloops, BC.

McLean, A. and Smith, J.H.G. 1973. Effects of climate on forage yields and tree-ring widths in British Columbia. J. Range Manage. **26**: 416–419.

McLean, A. and Wikeem, S. J. 1983. Effects of time of seeding on emergence and long-term survival of crested wheatgrass in British Columbia. J. Range Manage. **36**: 694–700.

McLean, A., Nicholson, H. H. and Van Ryswyk, A. L. 1963. Growth, productivity and chemical composition of a sub-alpine meadow in interior British Columbia. J. Range Manage. **16**: 235–240.

McLean, A., Lord, T. M. and A. J. Green. 1970. Utilization of the major plant communities in the Similkameen Valley, British Columbia. J. Range Manage. **23:** 346–357.

McLean, A., Lord, J. M. and Green, A. G. 1971. Utilization of the major plant communities in the Similkameen Valley, British Columbia. J. Range Manage. **24**: 346–351.

McLean, A., Waldern, D. E. and Bawtree, A. 1979. Seeding British Columbia rangelands. Canada Agriculture (Spring) **24**(2): 19–20

Meidinger, D., Pojar, J. and Harper. W. L. 1991. Sub-Boreal Spruce Zone. Pages 209–221 *in* D. Meidinger and J. Pojar, eds. Ecosystems of British Columbia. BC Ministry of Forests, Special Report Series 6, Victoria, BC.

Mitchell, W. R., Green, G. E., Lloyd, D., Russell, F., Erickson, W. and Walkem, D. 1981a. Identification and interpretation of ecosystems of the western Kamloops forest region. Vol. I: Very dry climatic region. BC Ministry of Forests, Land Management Handbook 2, Victoria, BC.

Mitchell, W. R., Green, G. E., Lloyd, D., Russell, F., Erickson, W. and Walkem. D. 1981b. Identification and interpretation of ecosystems of the western Kamloops forest region. Vol. II: Dry and subcontinental climatic regions. BC Ministry of Forests, Land Management Handbook 2, Victoria, BC.

Myers, J. H. and Berube, D. E. 1983. Diffuse knapweed invasion into rangeland in the dry interior of British Columbia. Can. J. Plant Sci. **63**: 981–987.

Newman, R. F., Wikeem, B. M., Pitt, M.D., Quinton, D. and Youwe, P. 1991. Tree seedling damage on grazed clearcuts. British Columbia Ministry of Agriculture, Fisheries and Food, Victoria, BC, Factsheet 91–29.

Nicholson, A., Hamilton, E., Harper, W. L. and Wikeem, B. M. 1991. Bunchgrass Zone. Pages 125–138 *in* D. Meidinger and J. Pojar, eds. Ecosystems of British Columbia, BC Ministry of Forests, Special Report Series 6, Victoria, BC.

Nordstrom, L. O. 1984. The ecology and management of forest range in British Columbia: a review and analysis. BC Ministry of Forests, Land Management Report 19, Victoria, BC. 91 pp.

Pitt, M. D. 1982. East Kootenay problem analysis: the interaction among grass, trees, elk and cattle. BC Ministry of Forests. Victoria, BC. 65 pp.

Pitt, M. D. and Allaye Chan, A. 1985. The interactions between cattle and California bighorn sheep on the Ashnola mountain range. British Columbia Ministry of Agriculture and Food, Project 271319, Victoria, BC. 165 pp.

Pojar, J. and Stewart, A. C. 1991. Alpine Tundra Zone. Pages 260–274 *in* D. Meidinger and J. Pojar, eds. Ecosystems of British Columbia. BC Ministry of Forests, Special Report Series 6, Victoria, BC.

Pojar, J., Trowbridge, R. and Coates, D. 1984. Ecosystem classification and interpretation of the sub-boreal spruce zone, Prince Rupert Forest Region, British Columbia. BC Ministry of Forests, Land Management Report 17, Victoria, BC. 319 pp.

Quinton, D. A. 1987. Beef cattle nutrition and performance on seeded clearcuts in southern interior British Columbia. Can. J. Anim. Sci. **67**: 919–928.

Quinton, D. A., Stroesser, L. and Douwes, H. 1985. Weight gains and nutrition of cattle grazing on grasslands of central interior British Columbia, Canada. Pages 1180–1181 *in* Proc. 15th Int. Grassl. Congr., Kyoto, Japan.

Quinton, D. A., Newman, R., Wikeem, B., Pitt, M. and Youwe, P. 1991. Beef production on seeded clearcuts in southern interior British Columbia. Forest Resource Development Agreement Research Memo 188, Victoria, BC, 2 pp.

Selby, C. J. 1980. Alpine and subalpine vegetation in the southern Chilcotin Mountain rangelands of British Columbia. M.Sc. thesis. University of British Columbia, Vancouver, BC.

Steen, O. and Tisdale, E. W. 1947. The grasslands of the southern interior of British Columbia. Ecology **28**: 346–365.

Tisdale, E. W. 1950. Grazing of forest lands in interior British Columbia. J. For. **48**: 856–860.

Tisdale, E. W. and McLean, A. 1957. The Douglas-fir zone of southern interior British Columbia. Ecol. Monogr. **27**: 247–266.

Utzig, G. F., Comeau, P. G., Macdonald, D. L., Ketcheson, M. V., Braumandl, T. G., Warner, A. R. and Still, G. W. 1989. A field guide for identification and interpretation of ecosystems in the Nelson Forest Region. 2nd ed. BC Ministry of Forests, Victoria, BC. 83 pp.

Van Ryswyk, A. and Bawtree, A. 1977. Management and improvement of meadows on organic soils of interior British Columbia. B.C. Dept. Agri. Field Crops Branch, Victoria, BC. 11 pp.

Van Ryswyk, A. L., McLean, A. and Marchand. L. S. 1966. The climate, native vegetation and soils of some grasslands at different elevations in British Columbia. Can. J. Plant Sci. **46**: 35–50.

Van Ryswyk, A. L., Hubbard, W. A. and Miltimore, J. E. 1973. Beef production potential and chemical composition of fertilized and unfertilized sedge hays grown on an organic soil of interior British Columbia. Can. J. Anim. Sci. **53**: 181–186.

Van Ryswyk, A. L., Broersma, K., Hall, J. W. and Bawtree, A. H. 1989. Dry matter yield of nitrogen fertilized crested wheatgrass on three chernozems (Mollisols). Can. J. Plant Sci. **69**: 933–937.

Van Ryswyk, A.L ., Wikeem, B., Newman, R. and Broersma, K. (1993). Nitrogen fertilization of grass and forested lands of southern-interior British Columbia, Canada: assessment of yield response. Proc. 4th nt. Rangel. Congr., Montpellier, France. (In press).

Watson, A. K. and Renney, A. J. 1974. The biology of Canadian weeds. 6. Centaurea diffusa and C. maculosa. Can. J. Plant Sci. **54**: 687–701.

Willoughby, M. 1986. The forage growth cycle and range communities of the Poplar Lake range unit, northcentral British Columbia. M.Sc. thesis. University of Alberta, Edmonton, AB.

Wikeem, B. M. 1984. Forage selection by California bighorn sheep and the effects of grazing on an Artemisia–Agropyron community in southern British Columbia. Ph.D. thesis, University of British Columbia, Vancouver, BC.

Wikeem, B. M., Newman, R. F. and Van Ryswyk, A. L. 1989. Effects of fertilization date and litter removal on grassland forage production. J. Range Manage. **42**: 412–415.

Wikeem, B. M., Newman, R. F. and Van Ryswyk, A. L. 1993. Forage response to N,P, and S fertilization on clearcut lodgepole pine sites J. Range Manage. **46**: 272–280.

Willms, W. and McLean, A. 1978. Spring forage selection by tame mule deer on big sagebrush range, British Columbia. J. Range Manage. **31**: 192–199.

Willms, W., McLean, A., Ritcey, R. and Low, D. J. 1975. The diets of cattle and deer on rangeland. Canada Agriculture (Fall) **20**(4): 21–23.

Willms, W., McLean, A., Tucker, R. and Ritcey, R. 1980. Deer and cattle diets on summer range in British Columbia. J. Range Manage. **33**: 55–59.

Youwe, P., Wikeem, B. M., Newman, R. F., Quinton, D. and Pitt, M. D. 1991. The effects of aerial seeding on forage stand development on montane spruce clearcuts. Forest Resource Development Agreement Research Memo 184, Victoria, BC, 4 pp.

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