University of Alberta

Biology and Control of Russian Thistle (*Salsola tragus* L.) in Bighorn Sheep (*Ovis canadensis* Shaw) Winter Ranges in Montane Grasslands of Jasper National Park, Alberta, Canada

by

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ABSTRACT

Russian thistle (*Salsola tragus* L.) invaded areas of native montane grassland important to winter survival of bighorn sheep (*Ovis canadensis* Shaw) were studied in Jasper National Park, Alberta, Canada. The biology of Russian thistle and its control in the Park were studied in the field and greenhouse. Russian thistle in grasslands were 9.1 cm tall with 37.5 seeds per plant, whereas larger plants in naturally disturbed habitats were 29.8 cm tall with 1562.4 seeds per plant. Plants travelled up to 4,180 m during dispersal. With soil seed contact, litter depth did not inhibit performance or survivability; without soil contact, thick litter reduced germination and plant performance. Russian thistle responded positively to increased greenhouse temperature and drier conditions. Seven control treatments involving herbicide, seeding mixes, hand pulling, and grazing exclusion were assessed. Grazing exclusion was the best field management option, increasing litter and biomass, while reducing Russian thistle density and biomass.

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See them tumbling down,
Pledging their love to the ground
Lonely but free I'll be found
Drifting along with the tumbling tumbleweeds.

Cares of the past are behind
Nowhere to go but I'll find
Just where the trail will wind
Drifting along with the tumbling tumbleweeds.

I know when night has gone
That a new world's born at dawn.

I'll keep rolling along
Deep in my heart is a song
Here on the range I belong
Drifting along with the tumbling tumbleweeds.

"Tumbling Tumbleweeds" composed by Bob Nolan in 1932 and recorded by the Sons of the Pioneers.

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CHAPTER I. BACKGROUND

1. INTRODUCTION

The International Union for Conservation of Nature (IUCN), currently recognizes the spread of invasive alien species as one of the greatest threats to the ecological and economic well being of the planet (McNeely et al. 2001). The impact of invasive alien species on native ecosystems, habitats, and species is severe and often irreversible. In Canada, alien species include at least 27% of all vascular plant species, 181 insect species that feed on woody plants, 55 freshwater fish species, 26 mammal species, 24 bird species, 4 amphibian species, 2 reptile species, and several fungi and mollusk species (Environment Canada 2004). Invasive alien species are often plants, which pose a heightened concern because they can alter structure, organization, or function of ecological systems (Olson 1999), resulting in reduced biodiversity, loss of habitat and food for native animals, and changes to natural ecological processes (e.g. plant community succession) (Parker et al. 1999, Booth et al. 2003, Radosevich et al. 2007). Some invaders reduce or eliminate species and communities that national parks or nature preserves were established to protect (U.S. Congress 1993).

Invasion by non native plant species is considered an ecological and economical threat to protected natural areas and adjacent surrounding lands in Canada (McPhee 2007). To protect and preserve examples of Canada's natural heritage policies, action plans must be developed to deal with invasive species in natural areas (White et al. 1993). The National Parks Act requires that national parks be managed for maintenance of ecological integrity (Mosquin 1997), which is considered the key focal point of policies and practices for Canada’s protected areas (Canadian Parks Council 2006). Restoration activities are expected to be consistent with recommendations in, ”An Invasive Alien Species Strategy for Canada” (Canadian Parks Council 2006). Environment Canada (2004) recommends that an ecosystem approach be used to manage invasive species through eradication, containment, and control.

In Jasper National Park, situated along the Rocky Mountains in western Alberta, 123 non native invasive plant species have been documented in several hundred infestations along transportation corridors and disturbed sites (McPhee 2007). The Jasper National Park Management Plan (Parks Canada 1997) recognizes that these non native species threaten the integrity of native plant species and communities. Their management is an integral component of the Park's objective to maintain or restore the integrity of Rocky Mountain ecosystems and preserve native biodiversity (McPhee 2007).

This study focused on one non native invasive species in Jasper National Park, Russian thistle (*Salsola tragus* L.). The Jasper National Park Integrated Pest Management Plan (McPhee 2007) included Russian thistle as one of the most noxious broadleaf species representing significant threats to native plant communities and ecological integrity in the park. Large areas of Russian thistle have been observed in native montane grassland communities used for winter grazing by bighorn sheep (*Ovis canadensis* Shaw) and other ungulates. There is concern these areas of invasion may be increasing in size, and appear to coincide with areas subject to sustained use by bighorn sheep, elk (*Cervus elaphus* Linnaeus), and deer (*Odocoileus* spp.). Overgrazing of critical winter range areas has diminished range condition, thus permitting Russian thistle to become established and compete with, or replace, already stressed native plant species and possibly reduce wildlife forage.

Montane grasslands of the lower Athabasca Valley and surrounding hillsides near Jasper Lake, provide a unique critical winter range habitat for ungulate species, particularly bighorn sheep. This winter range is located on exposed slopes at lower elevations providing good predator visibility and escape terrain. Due to low precipitation and wind swept conditions the area retains little snow allowing easy access to winter forage. The Athabasca Valley is an important east-west corridor through the Rocky Mountains for rail, vehicle traffic, and pipelines. Non native plant species, including Russian thistle, brought in along these transportation corridors threaten winter range areas. Invasive plant species can alter native plant communities and reduce range condition (Olson 1999). Poor range health and reduced forage availability, combined with severe winter conditions, could theoretically reduce localized ungulate populations.

This research on Russian thistle will address the extent and character of infestations in the Athabasca Valley, mechanisms of invasion, the role of wildlife grazing on establishment, and management strategies. Research results will benefit protected areas and land managers throughout the province and beyond who are involved with ungulate grazing and invasive species.

2. RUSSIAN THISTLE

2.1 Plant Origin and History

Russian thistle, colloquially referred to as tumbleweed, is an annual forb native to Central and Southwest Asia and Southeast Europe; now widely naturalized in South Africa, Asia, Australia, Europe, and North and South America (Flora of North America 2009, USDA Agricultural Research Service 2009). Russian thistle is a member of the *Chenopodiaceae* (Goosefoot) family, and related to another invasive species in the Park, kochia (*Kochia scoparia* (L.) Schrad) (Brenzil 2004).

Russian thistle nomenclature is confusing and the plant has numerous scientific synonyms including *Salsola australis* R. Br., *Salsola iberica* (Sennen & Pau) Botsch, *Salsola kali* L. and *Salsola pestifer* A. Nelson (Howard 1992, Mosyakin 1996, USDA Forest Service 2006, Orloff et al. 2008). *Salsola tragus* L. is now accepted as the correct name (Flora of North America 2009, Integrated Taxonomic Information System 2009). The correct name was used by some botanists in the 19th century, but most North American botanists chose to use a European misapplication of the name (Mosyakin 1996). Numerous field books (including Moss 1994 Flora of Alberta), government publications, and reports in Alberta refer to the plant as *Salsola kali,* or other synonyms.

According to Flora of North America (2009), *Salsola tragus* is an extremely polymorphic species consisting of several subspecies; however many of them are simply morphological variants of limited or no taxonomic value (Flora of North America 2009). Plant specimens collected from Jasper National Park were taken to the University of Alberta herbarium for expert indentification, where the plant was confirmed as *Salsola tragus* L.

Russian thistle was first introduced to North America in 1873 by Russian immigrants as a contaminant in flax (*Linum* sp.) seed in South Dakota (Brenzil 2004, Orloff et al. 2008). After its introduction Russian thistle quickly spread across the continent by contaminated seed, threshing crews, railroad cars, and by its wind blown dispersal mechanism (Orloff et al. 2008). Russian thistle first arrived in Canada in 1889, east of Morden Manitoba (Evans 2002). It was such a large concern for farmers in Manitoba that it was largely responsible for the creation and enactment of Canada's first provincial noxious weed act in 1894 (Evans 2002). By 1895 several provinces and 16 states were infested with Russian thistle (Young and Evans 1972) and it was abundant in drier parts of southern Alberta and Saskatchewan by 1909 (Evans 2002).

Agricultural practices of the late 1800s and early 1900s and the plowing of native prairie facilitated the rapid dissemination of Russian thistle. Russian thistle is not aggressive enough to compete with established native vegetation, so like many weeds, it benefits from agricultural practices designed to reduce environmental stresses (e.g. irrigation and fertilization) (Young 1991). Russian thistle has apparently had a long relationship with agriculture; Young (1991) mentions archaeologists have found carbonized seeds in excavations of some of the world's oldest agricultural sites in southern Eurasia.

Today in North America, Russian thistle occurs from British Columbia east to Labrador and south through the United States to northern Mexico (Howard 1992). It is common throughout southern and central portions of the Prairie Provinces and absent in northern Alberta (Leeson et al. 2005). Northern occurrences are rare, although Crompton and Basett (1984) found Russian thistle as far north as 55° latitude. An isolated population of Russian thistle occurs in the Peace River region near Taylor, British Columbia (Latitude: 56° 09' 08" N) (British Columbia Ministry of Agriculture, Food and Fisheries 2002). Recently Russian thistle has been observed north of Fort McMurray, Alberta, (Latitude: 57° 01' 01" N) on oil sands mining areas (Brown pers. comm. 2009).

In Jasper National Park Russian thistle is common on dry exposed or disturbed sites in the lower Athabasca Valley. It was documented near Windy Point as early as 1946 (Pfeiffer 1948). In 1980, Russian thistle was considered common on open sand dune ridges in the Jasper Lake area (Sharp 1980). In 1993 the amount of Russian thistle in open southeast facing slopes adjacent to Jasper Lake had diminished the value of the grasslands for wildlife (Biota Consultants 1993). By the early 1990s the Jasper Warden Service considered Russian thistle a serious concern due to its ability to invade and dominate overgrazed rangeland (Weerstra and Weerstra 2007).

2.1 Plant Characteristics

Russian thistle is an annual, well adapted to hot dry conditions. It can develop a deep widely branched taproot 1 m or more in length (British Columbia Ministry of Agriculture, Food and Fisheries 2002). Mature plants are 0.1 to 1.3 m in height (Morisawa 1999, British Columbia Ministry of Agriculture, Food and Fisheries 2002) and are rounded and bushy with numerous slender ascending stems (Orloff et al. 2008). In late fall and early winter, the base of the stem becomes brittle and breaks off at soil level (Orloff et al. 2008) allowing the plant to tumble in the wind, hence the name ‘tumbleweed’. A specialized layer of cells in the stem allows the plant to break cleanly away from the roots; destruction of these cells coincides with seed maturity (Young 1991). The plant disperses seeds as it rolls along the ground. Seed production can vary depending on conditions (Halvorson and Guertin 2003), with a single plant producing up to 200,000 seeds (Young and Evans 1972). New infestations commonly appear as a trail of seedlings across fields (USDA Forest Service 2006).

Russian thistle only reproduces by seed. It is indeterminate, with flowering and seed production continuing until temperatures drop below -3.9 ℃ (Morisawa 1999). Individual small winged seeds are retained in the leaf axils. The seed contains no endosperm, but is comprised of a spirally coiled, fully differentiated seedling, which facilitates the seed in rapidly taking advantage of short periods of favorable conditions (Young et al. 1995). Seed germination is based primarily on an internal time clock rather than external factors, with seeds able to germinate under very specific temperature conditions in the fall (Young and Evans 1972). Over winter, temperature restrictions disappear and in spring seeds germinate under a wide range of seed bed temperatures (Howard 1992). Spring germination can occur if daytime temperatures are above freezing; however seedlings are very susceptible to frost (Morisawa 1999).

Seeds are short lived and seed viability in the soil deceases greatly within two years. Young et al. (1995) report that under irrigated conditions 99% of seeds germinated in the first year or died before germinating. Seed germination and viability vary depending on environmental factors. Brenzil (2004) found that for seeds planted in the fall, 31% germinated the following spring, 0.5% germinated the second year and 0.04% germinated the third year. The soft porous nature of the seed may allow it to germinate rapidly, contributing to its lack of longevity (Young et al. 1995).

Russian thistle is a shade intolerant, initial colonizer in primary and secondary succession (Howard 1992). It is well adapted to cultivated dryland agriculture and is found on disturbed sites, including overgrazed rangelands (Morisawa 1999, British Columbia Ministry of Agriculture, Food and Fisheries 2002, Whitson et al. 2006). Russian thistle grows along roads, railroad tracks, fields, and disturbed sites. It can invade many different disturbed plant communities, and colonize barren desert areas that cannot support other flora (Howard 1992). Young et al. (1995) considered Russian thistle one of the most efficient plants in the world at producing plant dry matter per unit of water used. Russian thistle is considered one of the most common and troublesome invasive weed species in the drier regions of the United States (Whitson et al. 2006). It grows well on uncompacted, well drained soil with a sunny exposure (British Columbia Ministry of Agriculture, Food and Fisheries 2002), does not perform well in moist environments (Brenzil 2004), and cannot tolerate saturated soils for extended periods of time (British Columbia Ministry of Agriculture, Food and Fisheries 2002).

Russian thistle exploits disturbed sites and exposed soil. However, it competes poorly with established vegetation and lacks the aggressiveness to overtake dense native populations (Young 1991). Rutledge and McLendon (1996) suggest both intra-specific and inter-specific competition can reduce set seed. During drought conditions or if competing vegetation is removed, Russian thistle will dominate (Morisawa 1999). With a C4 metabolic pathway, Russian thistle has increased germination at higher temperatures, and higher water use efficiency compared to C3 species (Crompton and Basett 1984). However, under cool conditions the attributes of C4 plants become less advantageous and they often cannot compete with native and crop C3 species (Brenzil 2004).

Russian thistle is a pioneering annual that invades disturbed sites during early successional stages but may only remain in the system for two to seven years (Lodhi 1979, Howard 1992). Even as a monoculture, it becomes stunted after colonization of a disturbed area (Lodhi 1979, Schmidt and Reeves 1989). Lodhi (1979) found that Russian thistle contained allelopathic phytotoxins and claimed the plant litter was autotoxic. However, Schmidt and Reeves (1989) later refuted Lodhi's finding, suggesting the poor growth following initial colonization was not due to phytotoxins from the litter of previous Russian thistle plants. Russian thistle does not likely have an allelopathic effect on surrounding plants as evidenced by Russian thistle material having no effect on growth of *Agropyron smithii* Rydb. (Schmidt and Reeves 1989).

Russian thistle is a non mycorrhizal species (Schmidt and Reeves 1984). On sites with vesicular arbuscular mycorrhizal (VAM) fungi in the soil, Russian thistle roots were readily invaded by the fungi to the detriment of the plant (Allen and Allen 1988, Allen et al. 1989). VAM hyphae attempted to invade the roots of Russian thistle, but were rejected causing browning and death of root segments. At the seedling stage, the VAM invasion resulted in reduced growth and survival; inoculation in field trials reduced Russian thistle density up to 30%. Halvorson and Guertin (2003) suggested as mycorrhizal fungi build up in the soil following a disturbance, Russian thistle populations decline and the fungi will be available to create associations with compatible species for the next successional stage.

Although Russian thistle is generally an undesirable species, it has nutritional value for domestic animals and wildlife. It is consumed by a number of animals including bison, cattle, elk, deer, prairie dogs, pronghorn, and sheep; the seeds are eaten by birds and small mammals (Howard 1992). Russian thistle contains more protein and carbohydrates than clover (*Trifolium* spp.) (Long 1941), and although not as palatable, it has as much mineral salt and 65% as much protein as alfalfa (*Medicago sativa* L.) (Howard 1992). During prolonged drought periods in the late 1930s, farmers in Canada and the United States harvested Russian thistle for hay and silage when agricultural crops failed (Young 1991, Evans 2002). Due to its efficient use of water, there has been interest in using Russian thistle as a forage crop in semiarid regions (Howard 1992).

2.2 Management and Control

Russian thistle must be managed by preventing seed production and depleting the soil seed bank. The British Columbia Ministry of Agriculture, Food and Fisheries (2002) recommends preventing establishment of new infestations by minimizing disturbance and seed dissemination, eliminating seed production, and maintaining healthy native plant communities.

Numerous attempts to find an effective biological control agent have been unsuccessful. A leaf mining moth (*Coleophora klimeschiella* Toll) and a stem boring moth (*Coleophora parthenica* Meyrick) were approved and released in California but were not effective at reducing Russian thistle populations (California Department of Food and Agriculture 2008). Currently a blister mite (*Aceria salsolae* de Lillo & Sobhian) from the Mediterranean Basin, a stem boring caterpillar, and two weevils are under investigation (Orloff et al. 2008).

The British Columbia Ministry of Agriculture, Food and Fisheries (2002) suggest mowing or pulling young plants can manage Russian thistle, if repeated over several years. Mowing is effective on very young plants; however older plants will recover by axial branching below the cut (California Department of Food and Agriculture 2008). Hand pulling of large plants is difficult and may cause injury from the spines (USDA Forest Service 2006). Loosening the soil during cultural control practices must be avoided because loose soil is necessary for Russian thistle germination and is likely to aggravate the situation (Orloff et al. 2008).

Planting competitive desirable species can prevent Russian thistle establishment in many non-crop environments (Orloff et al. 2008). Reestablishment of native plant species can reduce Russian thistle infestations (Rutledge and McLendon 1996). The British Columbia Ministry of Agriculture, Food and Fisheries (2002) recommends seeding disturbed areas to perennial grass.

In agricultural crop and non-crop areas herbicides can control immature Russian thistle plants to prevent seed production. Pre-emergent herbicides are applied to the soil prior to seed germination; if applied in fall they can provide season long control (California Department of Food and Agriculture 2008). According to Orloff et al. (2008) the most effective pre-emergent herbicides are atrazine (Aatrex), bromacil (Hyvar), chlorsulfuron (Telar), hexazinone (Velpar), imazpyr (Arsenal), napropamide (Devrinol), simazine (Princep), and sulfometuron (Oust). Post-emergent herbicides must be applied directly to plants in early growth stages, preferably early seedling stages before the plant hardens and produces spiny branches (Orloff et al. 2008). Post-emergent herbicides typically do not provide long term control due to repeated flushes of seed germination following application (USDA Forest Service 2006, California Department of Food and Agriculture 2008). Russian thistle is not readily controlled by any post-emergent herbicide once in the spiny stage (Orloff et al. 2008). Effective post-emergent herbicides are dicamba (2,4-D, Banvel, Vanquish), glufosinate (Finale, Liberty, Rely), glyphosate (Roundup), and paraquat (Gramoxone) (Orloff et al. 2008).

Russian thistle is prone to developing herbicide resistance (Brenzil 2004, California Department of Food and Agriculture 2008, Orloff et al. 2008), particularly to Group 2 herbicides (Brenzil 2004, Saskatchewan Ministry of Agriculture 2008) which are inhibitors of the enzyme acetolactate synthase (Hall et al. 1999). Herbicide resistant biotypes of Russian thistle have evolved in only a few years following treatment with chlorsulfuron (Telar) or sulfometuron (Oust) (Orloff et al. 2008). Herbicide resistance has been documented in California, Idaho, Montana, North Dakota, Oregon, Washington (California Department of Food and Agriculture 2008, Saskatchewan Ministry of Agriculture 2008), and Saskatchewan (Brenzil 2004, Saskatchewan Ministry of Agriculture 2008). In Alberta, two populations are resistant to sulfonylureas (Beckie pers. comm.). Repeated use of a single herbicide, or of herbicides with the same mode of action, should be avoided to prevent herbicide resistant populations (Orloff et al. 2008). Using a combination of management strategies and rotating herbicide modes of action will reduce the chances of developing herbicide resistance.

3. STUDY AREA

3.1 Location

The study area is located in Jasper National Park, in west central Alberta in the Rocky Mountains, approximately 350 km west of the city of Edmonton. The Continental Divide makes up the west boundary of the park and is the border between Alberta and British Columbia. Jasper National Park is 10,878 km^2 in size (Parks Canada 2005). The park is comprised of three primary ecoregions, montane, subalpine, and alpine. Of the three ecoregions, the montane ecoregion is the smallest in size but contains the richest diversity of flora and fauna, and provides important winter range for most of the large mammal species in Jasper National Park (Decker and Bradford 2001). A large proportion of human development in the park occurs in the montane ecoregion, including roads, railway, pipelines, and the town of Jasper.

The study area was located in the montane grassland hillsides and valley bottom in the lower Athabasca Valley from 12 Mile Bridge on Highway 16 to Brule Lake near the east gate (Figure 1-1). The area was selected with Parks Canada staff based on presence of Russian thistle and heavy grazing of winter ranges by bighorn sheep (McPhee pers. comm. 2008, Westhaver pers. comm. 2008).

3.2 Climate

Variations in Jasper National Park climate are due to a combination of elevation, rainshadow effect, and latitude. The climate of Jasper National Park is characterized by long cold winters and short cool summers, with occasional hot spells (Parks Canada 2005). The climate of the montane ecoregion is the warmest and driest of the three ecoregions in the park, with the greatest temperature fluctuations (Holland and Coen 1983a). The daily average temperature from the Environment Canada Jasper Weather Station in January is -9.8 °C; the daily average temperature in July is 1 5 °C. Moisture reserves in the upper soil horizons are often depleted by early July and it is not uncommon to have prolonged periods of soil water stress later in the summer (Stringer 1973). Average annual precipitation at the Environment Canada Jasper Weather Station is 399 mm, with summer precipitation greater than winter precipitation. In winter, warm Pacific air masses raise temperatures and result in the montane ecoregion being intermittently snow free (Holland and Coen 1983a). Holland and Coen (1983a) suggest winds in the montane ecoregion are more frequent and a little stronger than those in other areas because the valleys, such as the Athabasca Valley, are oriented parallel to prevailing westerly winds.

3.3 Landscape, Topography and Soils

The Athabasca River flows northward through the study area, widening and slowing to create Jasper Lake and again directly outside of the park to create Brule Lake. Both lakes are very shallow, and large portions are seasonally dry, revealing sandy lake bottoms during periods of low flow. Strong winds mobilize sand and silt from the exposed lake bed and deposit it in the surrounding area. Dune formations are located along both Jasper Lake and Brule Lake.

In the study area the Athabasca Valley is oriented in a northeast direction with large open grasslands located along hillsides on the west side of the valley, particularly from Windy Point at the base of Roche de Smet to Benson Ridge at the east edge of the park. On the east side of the valley open grasslands are located primarily on south facing slopes in areas such as Cinquefoil Mountain, Syncline Ridge, and Edna's Knoll.

In the Athabasca Valley, studies were focused in two specific ecosections, the Devona (DV) Ecosection and the Talbot (TA) Ecosection. In the Jasper Lake area, Russian thistle was primarily associated with DV1 Ecosites and TA2 Ecosites (Figure 1-2). The following ecosite information was derived from the Ecological (Biophysical) Land Classification of Banff and Jasper National Parks (Holland and Coen 1983b).

The DV1 Ecosite occurs on the Athabasca Valley floor, adjacent to Jasper Lake. It is associated with ridged dune landforms (maximum depth 25 m) of calcareous, medium textured eolian material. Soils are rapidly drained, extremely calcareous Orthic Regosols. Wind erosion and deposition is ongoing. Soil texture is very fine sandy loam to silt loam.

The TA2 Ecosite occurs on lower slopes of the Athabasca Valley from Jacques Creek to Jasper's east gate. The ecosite is typified by veneers of calcareous, medium textured eolian materials overlaying morainal till and bedrock. Eolian deposits are a result of strong winds transporting material from the Athabasca River floodplain and shores of Jasper Lake. As a result of the deposition of wind blown material, soils associated with this ecosite are rapidly to well drained, extremely calcareous Orthic and Cumulic Regosols. In localized protected areas, Orthic Eutric Bunisols may occur in minor amounts.

3.4 Vegetation

The montane ecoregion in the study area is characterized by three vegetation communities: closed forest communities dominated by Douglas fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) and white spruce (*Picea glauca* (Moench) Voss); deciduous forest occurring on fluvial fans, terraces and floodplains; and open grasslands occurring on dry exposed slopes (TeraWestland 2005). This study focuses primarily on vegetation and site conditions associated with open grassland communities.

In the DV1 Ecosite, vegetation on drier sites on exposed dunes is dominated by creeping juniper (*Juniperus horizontalis* Moench), northern wheatgrass (*Agropyron dasystachyum* (Hook.) Scribn), and rush like sedge (*Carex scirpoidea* Michx.) (L6 vegetation type). Thickets of white spruce are found in moist depressions (Holland and Coen 1983b). Occasionally, communities of june grass (*Koeleria macarantha* (Ledeb.) J.a. Schultes), fringed sage (*Artemisia frigida* Willd.), and wild blue flax (*Linum lewisii* Pursh) (H6 vegetation type) are found.

The TA2 Ecosite encompasses the majority of grassland in the valley. It is dominated by june grass, fringed sage, and wild blue flax (H6 vegetation type); and shrubby cinquefoil (*Dasiphora floribunda* (Pursh) Kartesz, comb. nov. ined.), bearberry (*Arctostaphylos uva-ursi* (L.) Spreng), and northern bedstraw (*Galium boreale* L.) (L1 vegetation type) (Holland and Coen 1983b). The H6 vegetation type occurs mainly on south and east facing erosional scarps between Jasper Lake and Jasper's east gate (Holland and Coen 1983b). The L1 vegetation type is typical of steep south exposures. Although limited in presence, gullies and northerly aspects are characterized by white spruce, juniper, and bearberry (O17 vegetation type).

According to the range plant community types for the montane subregion of Alberta (Willoughby et al. 2005) the climax community associated with south facing slopes in the study area is a fringed sage / june grass (A1) community type. The prominent species in this community (june grass, northern wheatgrass, fringed sage, pussy toes (*Antennaria* spp.), and bearberry) are typical of xerophytic and Mixed Prairie type grasslands throughout Western Canada (Willoughby et. al 2005). Grazing likley had a strong role in the development of