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INVASIVE HAWKWEEDS (*HIERACIUM* SPP.) IN NORTHEASTERN BRITISH COLUMBIA

INVASIVE PLANT RISK ASSESSMENT AND LITERATURE SEARCH

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October 2006

Executive Summary

Northeastern British Columbia (BC) is a region recently invaded by hawkweeds (*Hieracium* spp.). A literature search, field inventory, and risk assessment were completed in 2006 to assess the impact and threat of invasive hawkweed species in northeastern BC. Four invasive hawkweeds were documented at six sites in northeastern BC during the field inventory including orange hawkweed (*H. aurantiacum*), tall hawkweed (*H. piloselloides*), meadow hawkweed (*H. caespitosum*), and an unidentified yellow hawkweed (*H. spp.*). There is a high probability that there are more species and more sites in the region as there are large areas within the region requiring inventory.

The distribution of and area infested by hawkweeds in northeastern BC is relatively small. However, the recent trend in the spread of these species appears to be increasing. According to the BC Ministry of Forests and Range Invasive Alien Plant Program (IAPP), there are extensive infestations of orange and numerous yellow hawkweed species in central and northwestern BC. Invasive hawkweeds in central BC are a serious threat to northeastern BC because of the proximity of these regions and their transportation linkages. Hawkweeds have caused extensive degradation of a wide variety of habitats in central and northwestern BC, and can degrade similar habitats in northeastern BC. Hawkweed sites at Monkman Park and Pink Mountain demonstrate that hawkweeds will establish, spread rapidly and seriously degrade various habitat types in northeastern BC.

Invasive hawkweeds have substantial impacts on soil factors and plant community composition and structure. Factors that predispose a site to hawkweed invasion include anthropogenic and natural disturbance, course soil texture, and low soil nutrient levels. Hawkweeds are successful invaders due to their reproduction strategies and their ability to quickly disperse over the landscape.

Management issues include formalizing treatment processes within BC Parks and identification of discrete species. Increased hawkweed inventory, and education of local stakeholders and residents can be used to prevent further establishment and spread of hawkweeds in northeastern BC. Hawkweeds can be managed using proper grazing management, rehabilitation of native or cultivated plant communities at hawkweed sites, and herbicides. There are no biological control agents currently approved for hawkweeds in North America; however, biocontrol may be available in the future.

Invasive hawkweeds in northeastern BC will affect agriculture (i.e. cattle and forage production), guide outfitters, recreation and tourism, and natural biodiversity. Invasive hawkweeds should be managed actively by stakeholder agencies in northeastern BC. This risk assessment describes major threats, and presents important obstacles and findings. Agencies, policy makers, and landowners can use this information to prevent the spread of invasive hawkweeds throughout the region.

Acknowledgements

We would like to thank the following people for reviewing and / or contributing to this document: Robert Drinkwater, Laura Blonski, and Andrew Pantel of the BC Ministry of Forests and Range; Linda Wilson of the University of Idaho; and Jill Copes of the New Invaders Weed Program. We would also like to thank Nancy Elliot of the BC Ministry of Forests and Range, who provided map production technical support.

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Introduction

Scope

The North East Invasive Plant Committee (NEIPC) is the invasive plant management body for northeastern British Columbia (BC). NEIPC has a broad-based membership including local and provincial government agents, invasive plant management contractors, concerned citizens, and private industry representatives. The main goal of NEIPC is to prevent further damage to northeastern BC ecosystems by invasive plants and to rehabilitate ecosystems degraded by invasive plants (North East Invasive Plant Committee, 2006). NEIPC encourages public reporting of invasive plants, and informs the public of invasive plant programs. Inventory information from NEIPC is contributed to and maintained in a regional database (i.e. BC Ministry of Forests and Range Invasive Alien Plant Program). Invasive plant risk assessment and preventing invasive plant establishment are important functions of NEIPC. This report provides a risk assessment of hawkweed (*Hieracium spp*.) in northeastern BC for NEIPC to employ as a management tool.

Background

Hawkweeds (*Hieracium* spp.) belong to Tribe Lactuceae of Family Asteraceae (Asteraceae includes species such as the common dandelion, *Taraxacum officinale*). The *Hieracium* genus is composed of three subgenera including *Chionoracium*, *Hieracium*, and *Pilosella*. Subgenus *Chionoracium* includes approximately 20 species native to North America. Subgenus *Hieracium* has species native and invasive to North America, while all species in subgenus *Pilosella* are invasive to North America (Wilson *et al.* 1997). Approximately fourteen native and fourteen invasive hawkweeds (*Hieracium* spp.) are in the Pacific North West (Wilson 2006).

Invasive hawkweeds were introduced to North America from Europe beginning in the late 1700s (Wilson 2006). Species that escape their native habitat, accidentally or intentionally, establish populations and become dominant or disruptive to existing plant communities are termed “invasive”. For example, orange hawkweed (*H. aurantiacum)* was introduced from Europe to Vermont as an ornamental (Wilson and Callihan 1999). Invasive hawkweeds have quickly spread throughout much of northwestern United States and Canada (Wilson and Callihan 1999). Internationally, hawkweeds have invaded grasslands and various conservation areas in New Zealand (Lamoureaux *et al.* 2003; McIntosh and Allen 1993; McIntosh *et al.* 1995; Rose *et al.* 1995). Invasive hawkweeds establish and spread quickly because they outcompete native vegetation for available nutrients and moisture. Invasive hawkweeds have an advantageous reproductive strategy relative to their native counterparts in that they are able to reproduce sexually as well as asexually via vegetative propagation and apomixis (i.e. seed production without pollen).

Northeastern BC, including the Peace and Fort Nelson Forest Districts, is an area recently invaded by hawkweed (see Figure 1). The first invasive hawkweed site was documented

in this region around 1999 (Copes 2005), whereas it was identified as a significant management issue in central and northwestern BC as early as 1994 (North West Invasive Plant Council 1994). Four documented invasive hawkweed species are present in northeastern BC infesting a combined area estimated to be about 60,071 m^2. This is a relatively small total area infested compared to central and northwestern BC. However, the potential exists for invasive hawkweeds to spread within the region and to encroach from central and northwestern BC, and other provinces into northeastern BC. Central and northwestern BC encompasses Mackenzie, Prince George, Vanderhoof, Nadina, Skeena-Stikine and Kalum Forest Districts. Hawkweeds in adjacent provinces were not investigated as part of this risk assessment and require further research (see **Recommendations)**.

Hawkweeds are widespread in central and northwestern BC, therefore, inventory and management of hawkweeds in that area may not be an effective expenditure of resources. Prior to 2006, most invasive hawkweeds were not inventoried or were rarely inventoried to the species level in northwestern, central and northeastern BC (i.e. yellow hawkweeds were often identified as *H. spp.*). The BC Ministry of Forests and Range publication titled "A Key to the Identification of Invasive and Native Hawkweeds (*Hieracium* spp.) in the Pacific Northwest" by Linda Wilson provides invasive plant managers with a tool for identification of invasive and native hawkweeds. As this tool only became recently available, the complete spectrum of hawkweed species within central and northwestern BC is unknown.

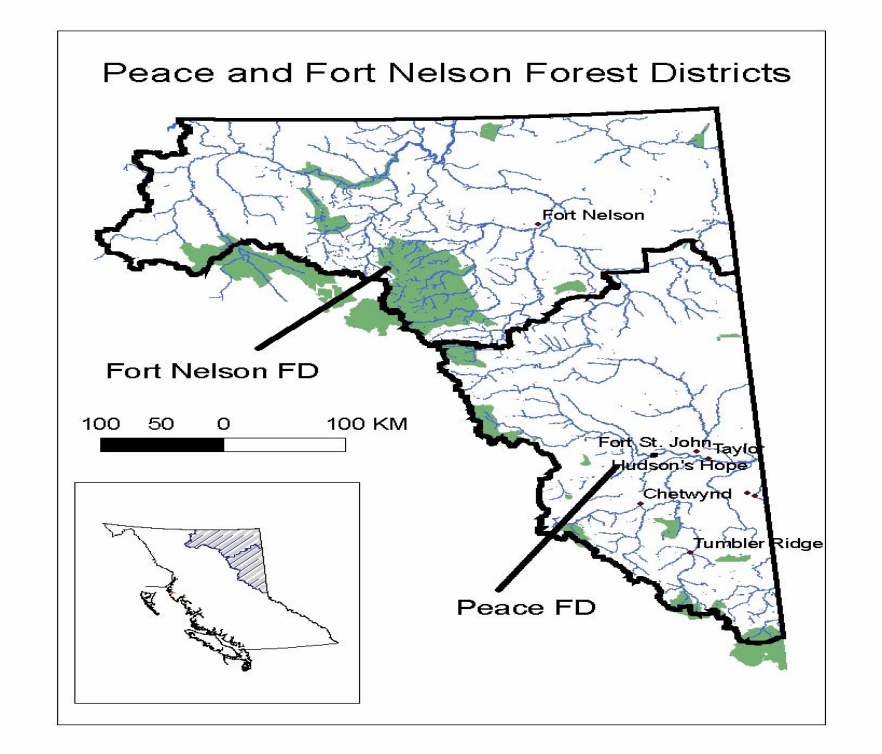

Figure 1 – Northeastern British Columbia including Peace and Fort Nelson Forest Districts (FD) (Map contributed by Nancy Elliot).

A literature search for information pertaining to invasive hawkweeds present in northeastern BC was done in summer 2006. Information about some species in northeastern BC was not available and as a result is supplemented by information about closely related invasive species within the *Hieracium* genus. The literature review was augmented by field observations made by Honey Giroday and Veronica Baker during a hawkweed inventory of northeastern BC. Giroday and Baker gathered information from personal interviews with various invasive plant experts and invasive plant management contractors. Hawkweed sites inventoried previous to 2006 were monitored by Giroday and Baker during the field inventory. A highway survey for new hawkweed sites was completed on Highways 29, 97, and 52. Inventory information was collected from a local invasive plant management contractor, Jill Copes of the New Invaders Weed Program. All inventory information was entered into the BC Ministry of Forests and Range Invasive Alien Plant Program (IAPP). Inventory data and literature collected was used to conduct a risk assessment following the format of the "Invasive Species Assessment Protocol" (Nature Serve 2004) and "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" (California Exotic Pest Plant Council and Southwest Vegetation Management Association 2003). Ecological and economic impacts, invasive potential, and management methods are addressed in this risk assessment.

Area of Concern

Northeastern BC, including the Peace and Fort Nelson Forest Districts, are topographically separated from central BC by the Rocky Mountains along their western

edge. Northeastern BC is an extension of the Alberta plateau into BC (BC Ministry of Forests 1991). The northeastern portion of the Peace Forest District is relatively flat or undulate and is bordered to the south and west by the Rocky Mountains. The Fort Nelson Forest District is undulate in the south and bordered by the Rocky Mountains to the north and west. Major transportation corridors connect the area with surrounding provinces. Highway 97 connects central BC to northeastern BC, where it becomes the Alaska Highway at Dawson Creek. The Alaska Highway is a world renowned travel route and tourist destination connecting northeastern BC to Alaska via the Yukon Territory. Northeastern BC is connected to Alberta via Highway 49, and to the Northwest Territories via Highway 77.

Northeastern BC is ecologically different from central BC due to the dominance of grasslands and jack pine forests in the Peace Forest District and muskeg-spruce forests in the Fort Nelson Forest District (Baker and Giroday field notes 2006). Northeastern BC is primarily dominated by Boreal White and Black Spruce (BWBS) between 230m and 1300 metres (BC Ministry of Forests 1991). At higher elevations, Engelmann Spruce-Subalpine Fir (ESSF), Spruce-Willow-Birch (SWB) and Alpine Tundra (AT) dominate. Forest fires are frequent in the BWBS of northeastern BC and maintain forests in a mosaic of successional stages. Agriculture is an important industry in the region and prime agricultural land exists in the BWBS around Dawson Creek and Fort St. John (BC Ministry of Forests 1991). Oil and gas exploration and extraction is a common and growing activity throughout the area, as are other industrial activities such as logging and mining (e.g. coal extraction). Recreation is also a significant industry in northeastern BC.

Hawkweed Species Present in Northeastern British Columbia

Northeastern BC currently has four documented invasive hawkweeds: orange hawkweed (*H. aurantiacum*), tall hawkweed (*H. piloselloides*), meadow hawkweed (*H. caespitosum*) and an unidentified yellow hawkweed (*H. spp.*).

Orange hawkweed is a perennial herb with stolons (BC Ministry of Environment, Lands and Parks, and Ministry of Forests 1998). It has a short, erect, unbranching stem growing to be 0.3 to 1.2 metres tall. The leaves are oblanceolate and approximately 4 to 25 centimetres (cm) long and 1.2 to 4.5 cm wide. The leaves are sparsely or moderately hairy or the upper side is glabrous (BC Ministry of Environment, Lands and Parks, and Ministry of Forests 1998). The upper leaf surface has simple hairs while the lower surface has simple and stellate hairs (Wilson 2006). The margins of the leaves are entire to wavy-toothed (BC Ministry of Environment, Lands and Parks, and Ministry of Forests 1998). Stems have no leaves or few if present. The stem is bristly-hairy at the base becoming glabrous towards the upper portion. Flower heads of orange hawkweed have orange strap shaped flowers that are arranged in a round or flat-topped inflorescence. Involucres are 6 to 11 mm tall, and are linear-lanceolate, scarcely graduated, greenish or blackish, and glabrous. Achenes are narrowed at the base, 2.5 to 3 mm long and several-ribbed. Pappus hairs are white to brownish bristles (BC Ministry of Environment, Lands and Parks, and Ministry of Forests 1998).

Tall hawkweed is an invasive hawkweed that lacks stolons (Wilson 2006). The stem is erect, not stiff, and unbranching growing to 40 to 90 cm tall. Basal leaves are narrowly elliptical and glabrous or with few simple and stellate hairs. On the lower leaf surface there are few simple or stellate hairs along the midvein. Leaf margins are entire to wavy-toothed. Flowers are yellow and strap-shaped. There are usually eleven to twenty heads in an open, round-topped cluster (Wilson 2006).

Meadow hawkweed is a perennial herb with a short, stout rhizome and long, leafy stolons (BC Ministry of Sustainable Resource Management and Ministry of Forests 1998). Stems are erect and solitary with glandular, simple, and stellate hairs. Basal leaves are oblanceolate to spoon-shaped, and entire or minutely toothed (BC Ministry of Sustainable Resource Management and Ministry of Forests 1998). The upper leaf surface has long, simple hairs (Wilson 2006). The lower leaf surface has moderately dense stellate and long simple hairs. Heads are approximately twenty to fifty in a compact flat-topped cluster. Flowers are strap-shaped and yellow (BC Ministry of Sustainable Resource Management and Ministry of Forests 1998). Phyllaries are sparsely covered with numerous stellate, glandular and simple hairs (Wilson 2006). Plants are 20 to 70 cm tall (Wilson 2006).

Information regarding tall and meadow hawkweed phenology was not found in the literature. Tall, meadow, and orange hawkweed are closely related and have similar morphology. As a result, phenology of orange hawkweed is likely applicable to tall and meadow hawkweed given the absence of more specific information.

Orange hawkweed forms rosettes in spring and early summer, and spreads primarily by stolons (BC Ministry of Agriculture, Food and Fisheries 2002). Seedlings will flower in June-July and quickly produce seed by early August (BC Ministry of Agriculture, Food, and Fisheries 2002). Orange hawkweed in northern BC has a short flowering time of usually two to three weeks (Baker and Giroday field notes 2006). Plants overwinter and regrow the next spring (BC Ministry of Agriculture, Food, and Fisheries 2002).

Hawkweeds are predominantly found in open fields, mountain meadows, and forest clearings at mid to high elevations (Wilson 2006). Hawkweeds can infest permanent pastures, cleared timber units, abandoned farmland, and other disturbed habitats (Wilson 2006). Hawkweeds have been documented between 450 and approximately 1,500 m with the largest infestations occurring at 1,000 m (Wilson *et al*. 1997). Orange hawkweed can be found on sites with a maximum slope gradient of 41% that typically face southeast (Klinkenberg 2004). Although invasive hawkweeds are usually not found in dry habitats such as shrub-steppe grasslands (Wilson 2006), orange hawkweed can be found on xeric to subhydric sites (Klinkenberg 2004). Orange hawkweed is usually found on submesic to mesic sites with a medium soil nutrient regime (Klinkenberg 2004). Meadow hawkweed typically grows in deep forest soils low in organic matter, while tall hawkweed grows in shallow, coarse-textured soil, particularly along roadsides and in outwash areas (L.M. Wilson, personal communication, August 2006). Orange hawkweed has been observed in Sub-Boreal Spruce (SBS), ESSF, Interior Cedar-Hemlock (ICH),

Interior Douglas-Fir (IDF), Sub-Boreal Pine-Spruce (SBPS), and SWB BEC zones (Klinkenberg 2004). However, it is probable that orange hawkweed and other hawkweeds in northeastern BC are not limited to these BEC zones.

Hawkweed Species Threatening Northeastern British Columbia

According to the BC Ministry of Forests and Range Invasive Alien Plant Program (IAPP), queendevil hawkweed (*H. praealtum*), meadow hawkweed (*H. caespitosum*), and kingdevil hawkweed (*H. floribundum*) are currently present in central BC. Central BC is a primary access corridor to northeastern BC. These species have the potential to move into northeastern BC from central BC along Highway 97. Hawkweeds in adjacent provinces and territories, including Alberta, and Yukon and Northwest Territories, were not investigated as part of this risk assessment. Further research is required to assess the spread of invasive hawkweeds from these regions into northeastern BC (see **Recommendations)**.

Current Distribution, Area Infested and Trend

According to current inventory information from IAPP and the New Invaders Control Program, there are relatively small, though widely distributed hawkweed sites in northeastern BC (see Figure 2). All known hawkweed sites in the region, with the exception of a site in Monkman Provincial Park, are managed annually by members of the NEIPC. Four orange hawkweed sites are currently documented in northeastern BC. Three orange hawkweed sites are in the Peace Forest District and are close to or along the Alaska Highway. A site at Tower Lake, north of Dawson Creek, does not appear to have survived cultivation (IAPP site number not available; assigned 999999). Hawkweeds at the Cecil Lake (IAPP site number: 222009) site, north of Fort St. John, have spread into the surrounding area to about 2,000 m^2 (Copes 2005). A site near Pink Mountain (205220), south of Fort Nelson, has orange hawkweed and an unidentified yellow hawkweed. Hawkweeds on this site have approximately 80 to 90% coverage, are along the roadside, in a hunting camp, and have spread onto a gas pipeline rights-of-way (R. Drinkwater, personal communication, August 2006). The orange hawkweed site in the Fort Nelson Forest District is along the Alaska Highway near Steamboat (205303), north of Fort Nelson.

In 2004 Jill Copes found tall hawkweed and meadow hawkweed at the Kinuseo Falls Campground in Monkman Provincial Park, south of Tumbler Ridge (2005). Further inventory of Monkman Park including Murray River Road, the main access route for the park, revealed that hawkweeds have spread from the campground north along the road to approximately the 14 km mark (222007). Also, hawkweeds are along the Bulley Creek Forest Service Road within Monkman Provincial Park. This site requires the attention of BC Parks and expedient treatment to minimize spread (see **Recommendations**). An unidentified yellow hawkweed was documented on Highway 29 in 2004 (220295). Baker and Giroday (field notes 2006) found new hawkweed sites of the periphery of northeastern BC, in the McKenzie Forest District along Highway 97. These sites

included tall hawkweed infestations at Powder King Ski Hill and the Azouzetta Lake lookout.

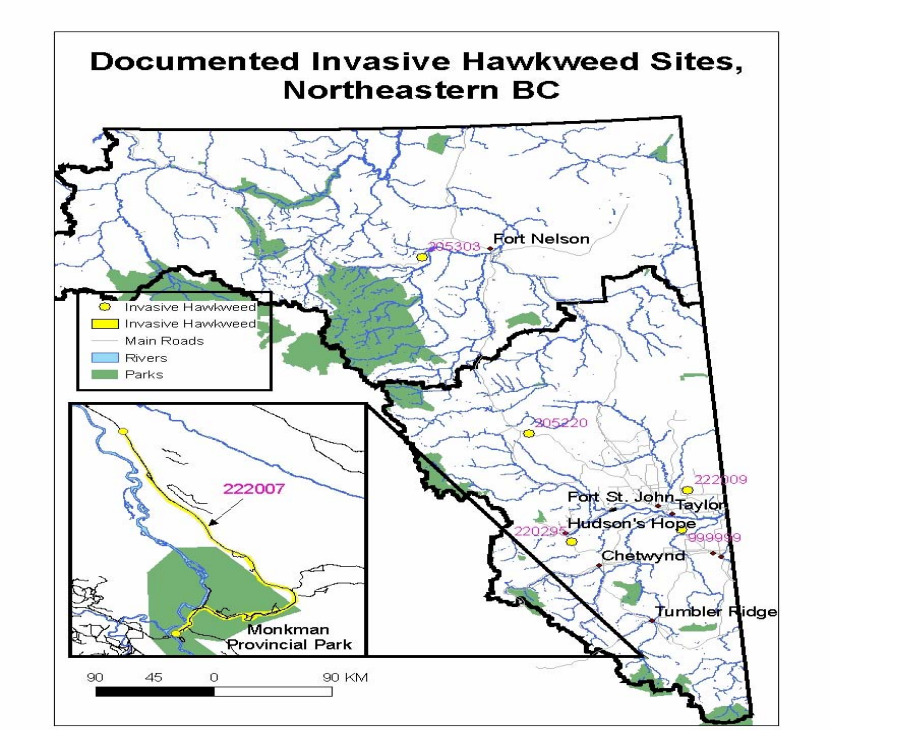

Figure 2 – Documented hawkweed sites in Northeastern British Columbia (Map contributed by Nancy Elliot).

Yellow-flowered hawkweeds and orange hawkweed infest approximately 60,060 m^2 and 11 m^2, respectively in northeastern BC. It is probable that this is an underestimate of the current infestation because there are some uninventoried areas in the region. Further detailed inventory for hawkweed is required in northeastern BC (see **Recommendations**). The New Invaders Weed Control Program 2005 report provided information used to assess recent trends in hawkweed spread. Copes (2005) found yellow hawkweed (1 site, greater than 4,000 m^2) and orange hawkweed (1 site, 2,000 m^2) in 1999 and 2003 respectively. In 2001 another orange hawkweed site was found and in 2004 another yellow hawkweed site was found. Recent trends in spread of hawkweeds in northeastern BC appear to be increasing, albeit slowly due to continued management of known hawkweed sites. Continued spread of hawkweeds is likely due, in large part, to human transport of propagules from existing sites in northeastern BC and sites outside the region.

Ecological Impacts

Soil

Invasive hawkweed species have substantial impacts on ecosystem attributes. For example, long term site and soil characteristics can be modified by hawkweed infestation.

Soil factors affected include soil pH, nutrients, moisture, organic material, and mycorrhizal fungi.

Numerous invasive hawkweed species form dense mats due to stoloniferous reproduction. Mouse-ear hawkweed (*H. pilosella*) mats often have "haloes" or areas of bare mineral soil surrounding plant patches. Boswell and Espie (1998) found that *H. pilosella* affected the soil in these halo zones and soil directly beneath the patch. The soil adjacent to mouse-ear hawkweed patches was drier than soil under the patch, and depleted in phosphorous and basic cations. Boswell and Espie (1998) suggest that mouse-ear hawkweed exploits the halo area surrounding plant patches for moisture and nutrient uptake. Some invasive hawkweeds are known to sequester mycorrhizal fungi (i.e. obligate soil micro-organisms that extract mineral elements and water from soil in exchange for sugars from their host plant) to the detriment of other plants (L.M. Wilson, personal communication, August 2006). Mouse-ear hawkweed also increases soil acidity (Boswell and Espie 1998, and McIntosh *et al.* 1995) and soluble aluminium content directly beneath plant patches (Boswell and Espie 1998). Increased soluble aluminium in the soil can inhibit growth of native species (Boswell and Espie 1998). McIntosh *et al.* (1995), and McIntosh and Allen (1993) suggest that the higher soil acidity under hawkweed patches relative to surrounding soil is caused by organic material accumulation. Organic material accumulation results from greater dry matter production under perennial hawkweeds relative to annual species (McIntosh *et al.* 1995). These alterations to soil factors have negative short and long term impacts on the site and native plant communities. Hawkweeds compete with native species for limited nutrient and moisture reserves. This affects the ability of a site to sustain native plant species and marginalizes the ability of the site to recover from a hawkweed infestation.

Plant Community

Hawkweeds have physical and chemical characteristics that affect community composition and structure. Some invasive hawkweed species have vigorous stolon growth and colonies expand quickly resulting in as many as 3,500 plants per square meter (Wilson and Callihan 1999). Hawkweeds that form dense mats impede seed germination and establishment of other species (Kloppel *et al.* 2003). Hawkweeds are reported to exhibit allelopathic effects on adjacent native vegetation by releasing toxic root exudates into the soil (Wilson and Callihan, 1999). Pienieng (1988) found that umbelliferone, a known root growth inhibitor in mouse-ear hawkweed, restricted growth of several clover species. Invasive hawkweeds potentially have a competitive advantage over other plants as they have high aluminium tolerance. As well, hawkweeds intensively utilize soil moisture, phosphate, and base cations from the halo region (Boswell and Espie 1998). Soil moisture is a limiting factor for plant growth in dry sub-humid environments. Reduction in soil moisture and available cations, high aluminium content and increased acidity of soils under and adjacent to hawkweed patches impedes establishment and survival of native plants. These combined effects also cause greater soil exposure in

areas surrounding hawkweed patches. Rose *et al.* (1995) suggest hawkweeds invade only small gaps of exposed soil on vegetated sites. Researchers suggest that hawkweed's ability to expand into established vegetation may reflect a heightened ability to capitalize on nutrients from beyond patch margins (Rose *et al.* 1995). The combined impacts of hawkweeds on plant communities allow hawkweeds to dominate a site by displacing native plants. As a result, they have the ability to undermine native biodiversity.

Higher Trophic Levels and Individual Native Plants

The impact of invasive hawkweeds on specific plant species or higher trophic levels in northeastern BC was not documented during the recent inventory (Baker and Giroday field notes, 2006). Information about the impacts of hawkweeds on specific plant species or higher trophic levels was also not found in the literature. Although impacts of hawkweeds on individual native species were not observed in the field or found during literature research; previous research emphasizes hawkweeds have potential negative impacts on the entire plant community (Wilson and Callihan 1999, Kloppel *et al.* 2003, Pienieng 1988, Boswell and Espie 1998).

Genetic Integrity

In general, there is little opportunity for invasive hawkweeds to hybridize with native hawkweeds (Wilson and Callihan 1999). Native hawkweeds are diploid while invasive hawkweeds are usually polyploid. Under normal conditions, native and invasive hawkweeds will not hybridize because of the difference in number of chromosomes. In addition, invasive hawkweeds are usually apomictic (i.e. produce seeds without pollination) while native hawkweeds always reproduce sexually (Wilson and Callihan 1999). L. Wilson and her collaborators are currently investigating the genetic relationships and possible hybridization among invasive hawkweeds (L.M. Wilson, personal communication, August 2006). The potential for impact of invasive hawkweeds on the genetic integrity of native species requires further investigation.

Economic Impacts

In the United States, expansion of hawkweed's range is estimated to be about 16% per year (Wilson and Callihan 1999) and cost stakeholders an estimated $58 million (US dollars) per year to control (Duncan 2005). Hawkweeds are expected to impact vital industries in northeastern BC, including agriculture. Agricultural activities, such as seed, forage, and cattle production, are affected invasive plants. For example, timothy seed production is affected by invasive plants because weeds reduce seed yield through competition in the field and dockage at the time of sale (Government of Alberta 2004).

Invasive hawkweeds can degrade primary range types used for cattle and wildlife forage. This degradation can negatively affect guide outfitters and cattle producers by limiting amounts of high quality forage available to cattle and wildlife. Forage quality and palatability of invasive hawkweeds are being investigated by L. Wilson. Information

from her research will provide insight into the impact of invasive hawkweeds on forage production.

Invasive Potential

Establishment via Anthropogenic and Natural Disturbances

Generally, invasive hawkweeds establish following anthropogenic and natural disturbances. MacQuarrie and Lacroix (2003) surveyed invasive plants in an upland hardwood Acadian forest on Prince Edward Island. Common hawkweed (*H. lachenalii*) was the only species found inside of the forest but not outside of the forest. They suggest that anthropogenic site disturbance of the forest allowed invasive species to establish in that area (MacQuarrie and Lacroix 2003). Disturbance from recreation and industrial activity facilitated hawkweed spread and establishment in Monkman Provincial Park, a park in northeastern BC (Baker and Giroday field notes 2006). Hawkweeds spread along roadsides, into parking lots and campground pads; areas of high and continued disturbance in the park (Baker and Giroday field notes 2006). Northeastern BC has numerous industries that cause large scale disturbances (e.g. mining, oil and gas extraction, and logging). As a result, hawkweeds will continue to establish and spread quickly in this area if unmanaged.

Natural disturbance, such as fire, blow down, and grazing, is also important for the establishment of hawkweeds (Rose *et al.* 1995). Although disturbance is a key factor in establishment of hawkweeds, invasive hawkweed species spread into relatively undisturbed areas due to their ability to compete with native vegetation (Wilson and Callihan 1999, Kloppel *et al.* 2003, Pienieng 1988, Boswell and Espie 1998).

Innate Reproductive Potential

Hawkweeds are successful invaders largely due to their various reproductive strategies. These include sexual and asexual reproduction, high seed production and viability, rapid generation time and high germinability (Wilson 2006). Invasive hawkweeds can reproduce asexually, via stolons, rhizomes, and adventitious root buds (Wilson and Callihan 1999). Invasive hawkweeds can also reproduce asexually by apomixis (i.e. seed production without pollination) and will sometimes produce seeds sexually by pollination (Wilson and Callihan 1999). Hawkweeds can produce a large number of seeds. For example, the flowering stem of orange hawkweed can produce several hundred seeds (BC Ministry of Agriculture, Food and Fisheries 2002). Hawkweed seeds remain viable in the soil for a prolonged period (Wilson and Callihan 1999). For example, meadow hawkweed and orange hawkweed can remain viable in the soil for seven years (Panebianco and Willemsen 1976, and Wilson and Callihan 1999). Hawkweed also has a rapid generation time of 63 days. (Wilson 2006). These reproductive strategies ensure rapid population expansion and establishment.

Dispersal

Several hawkweed sites were found approximately 250 kilometres apart during the northeastern BC inventory (Baker and Giroday field notes 2006). The BC Ministry of Agriculture, Foods, and Fisheries (2002) suggests that hawkweeds are spread primarily by recreationists, and movement of hay. Recreationists and industrial equipment movement is a primary vector of spread in northeastern BC (Baker and Giroday field notes 2006). Hawkweeds are also popular ornamentals and are spread intentionally and accidentally by humans (Wilson 2006).

Hawkweeds disperse via natural means as well. Hawkweed seeds are ribbed and usually have barbs that cling to fur and feathers facilitating transport by wildlife (L.M. Wilson, personal communication, August 2006). Also, hawkweed seed heads are consumed by livestock and wildlife, which can assist with transport of seeds. Pappus hairs of mature seeds allow for airborne transport. As invasive hawkweeds with stolons reproduce vegetatively, the transport of stolons, rhizomes, and root buds may contribute to dispersal (L.M. Wilson, personal communication, August 2006). The rapid spread and adverse impacts of hawkweed in the Pacific Northwest over the past 15 years demonstrates this species ability to spread easily and successfully into new habitats.

Management of Hawkweed

Hawkweeds are managed using proper grazing management, rehabilitation of native or cultivated plant communities at hawkweed sites, and herbicides. Minimizing disturbance and propagule dispersal, eliminating seed production on a site by removing heads, and maintaining healthy plant communities are some ways to prevent establishment of new hawkweed infestations (BC Ministry of Agriculture, Foods, and Fisheries 2002). Over-grazing can allow hawkweeds to establish (Lamoureaux *et al.* 2003). For example, mouse-ear hawkweed is well adapted to grazing by having a prostrate growth habit and establishes readily in areas with grazing caused disturbance. Lamoureaux *et al.* (2003) suggest soil fertilization and removal of grazers to allow re-colonization of a site by native species.

Hawkweeds can invade areas low in available nutrients because they sequester nitrogen which limits nutrients available for other plants. Soil fertility management may also improve the ability of native species to compete with hawkweeds (Lamoureaux *et al.* 2003 and Wilson 2006). Hawkweed management needs to focus on improving the plant community to favour grasses and native forbs (Wilson 2006). A combination of fertilization and herbicide treatment should be used to rehabilitate a hawkweed site (Wilson and Callihan 1999). Herbicides are relatively effective in controlling hawkweeds; however, hawkweed re-establishes on a site if the plant community is not healthy. Selective herbicides such as phenoxy-type herbicides are effective in the treatment of hawkweeds (Wilson and Callihan 1999).

Currently the BC Ministry of Forests and Range along with the Idaho Department of Agriculture, the Montana Noxious Weed Trust Fund, and the US Bureau of Land

Management are the primary sponsors of the Biological Control Program in the Invasive Hawkweed Consortium (Wilson 2006). The goal of the program is to find suitable biological control agents that will contribute to stemming the spread of hawkweed populations. For example, a gall wasp, *Aulacidea subterminalis*, a biological control agent for mouse-ear hawkweed, is currently used in New Zealand. Plants with galls showed a reduction in stolon length of 75%, reducing the ability of mouse-ear hawkweed to reproduce vegetatively.

Recommendations

The NEIPC has an opportunity to contain a group of highly invasive plants before they spread from a few, small established sites. Proactive control of hawkweed will minimize the expenditure required. Treatment of small invasive plant sites is less expensive than treating large sites that have been established for numerous years. Aggressive management of invasive hawkweeds in northeastern BC should be the primary goal of NEIPC. To achieve this goal, NEIPC should treat known sites at least twice during the field season with the goal of reducing the number or area of sites by 50% in the next three years. Inventory for and monitoring of hawkweed sites should also be increased for early detection and rapid response to control isolated and disjunct populations. Education of stakeholders and the public about this group of plants will ensure increased early detection of and rapid response to new hawkweed sites, as well as continued treatment of known sites. NEIPC should set a goal of assisting in or coordinating three to four education program tours that address invasive hawkweeds. Continued proactive management will be required to control hawkweeds effectively and inexpensively.

During 2006 inventory for invasive hawkweeds it was apparent that there are areas that require further inventory. These include areas that were not inventoried by Baker and Giroday due to time constraints, and to which hawkweed could spread.

- Forest Service Roads in the Tumbler Ridge area (e.g. Wolverine Forest Service Road).
- Provincial parks and conservation areas in the Tumbler Ridge area (e.g. Hole in the Wall and Wapiti Provincial Park).
- Highways 77 (north of Fort Nelson), 49 (Dawson Creek to the Alberta border), and 2 (Dawson Creek to Tumbler Ridge).

Inventory of community pastures and range tenures should continue as well.

Hawkweeds in adjacent provinces and territories, including Alberta, and the Yukon and Northwest Territories, were not investigated as part of this risk assessment. The presence of hawkweeds in these areas will affect hawkweed management in northeastern BC. If present, hawkweed will spread from these regions along transportation linkages into northeastern BC. In this case, NEIPC should actively monitor these linkages for hawkweed. If hawkweed is not currently in these provinces or territories, it is likely that hawkweed will spread into them from northeastern BC. Prevention of invasive

hawkweed spread into uninfested provinces depends on making invasive plant management agencies in these regions aware of hawkweed. These agencies should be contacted by the NEIPC, informed of hawkweeds in northeastern BC, and gleaned of information about the presence or absence of hawkweeds in their area. NEIPC's hawkweed management strategy should be updated with information from these agencies.

Invasive hawkweeds in Monkman Provincial Park need to be controlled to prevent spread of hawkweed into the surrounding area by recreationists and industrial activities. Monkman Park may present a management difficulty because effective treatment of large sites within the park requires the use of herbicide, which is generally not used in provincial parks. The process for allowing herbicide treatment within provincial parks has not been formalized by BC Parks, the government agency that manages provincial parks and conservation areas in BC. However, the North East Invasive Plant Committee should work with BC Parks to find a suitable treatment method and strategy for this area.

Hawksbeard (*Crepis tectorum*) is an invasive plant that is widespread in northeastern BC. Hawksbeard is not managed actively by the NEIPC because it is a much less aggressive plant, and it is an ephemeral weed (i.e. it does not persist in the long term). It is a species that is similar to yellow-flowered hawkweeds and blooms at approximately the same time. Inventory and management of invasive hawkweeds will be difficult in areas where hawksbeard and hawkweed ranges overlap. Contractors and personnel managing hawkweed in these areas will need well developed plant identification skills. The use of L. Wilson's new hawkweed key and providing training to contractors / personnel in its use will allow for accurate identification of hawkweeds.

Differentiating between invasive hawkweed species is difficult due to high variability of characteristics within species. Identification of invasive hawkweeds by personnel, contractors and the public will require the key and possibly invasive plant expertise. Accurate and timely identification is an integral part of effective early detection of species in the area and rapid response to invasive plant reports. An invasive plant identification hierarchy should be developed by the NEIPC with the support of it members. Local individuals responsible for initial identification will need to be appointed. Specimens that cannot be identified at this level would be sent to appointed regional experts for identification. A document produced with this information will formalize and simplify plant specimen identification in northeastern BC.

Conclusion

Invasive hawkweeds in northeastern BC will negatively affect industries, such as agriculture, and natural ecosystems if unmanaged. Hawkweeds out compete native vegetation for soil nutrient and moisture reserves, and spread relatively quickly due to their successful reproductive strategies. Based on what has occurred on similar habitats in central BC, invasive hawkweed will spread rapidly in northeastern BC without management. This rapid spread will be facilitated by anthropogenic disturbance and propagule transport. The total area infested is currently small which gives agencies the

opportunity to control hawkweed before it spreads throughout northeastern BC. Collaboration across jurisdictional boundaries and proactive management are the best methods to eradicate invasive hawkweeds in northeastern BC.

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