THE EFFECT OF CLIMATE CHANGE ON INVASIVE SPECIES AND THEIR POTENTIAL IMPACTS IN WHITEHORSE

Submitted to

Yukon Invasive Species Council
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Submitted by:
INDUSTRIAL FORESTRY SERVICE LTD.
Contact: Amy Farella, B.I.T.
1595 Fifth Avenue
Prince George, BC, V2L 3L9
Phone: 250.564.4115 (ext 256) Fax: 250.563.9679
Email: afarella@industrialforestry.ca

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Table of contents

1.0 PHASE 1: LITERATURE REVIEW

1.1 Introduction

Land managers are increasingly compelled to respond to the threat and implications of non-native species invasions. Terrestrial non-native invasive species are considered to be the greatest threats to biodiversity save for the loss of habitat (Wilcove et al. 1998). The World Conservation Union lists several species found in Canada as part of the World's 100 Worst Invasive Species (2000), including: leafy spurge (*Euphorbia esula*), Japanese knotweed (*Polygonum cuspidatum*), purple loosestrife (*Lythrum salicaria*), rainbow trout (*Oncorhynchus mykiss*), European Starlings (*Sturnus vulgaris*), rats (*Rattus spp.*) and domestic cats (*Felis catus*) (Lowe, Browne and Boudjelas 2000).

Changes in climate may alter the impacts of invasive species on ecosystems and their components. The Yukon Invasive Species Council (YISC) is a non-profit organization with the mandate of preventing and managing the introduction and spread of invasive species in Yukon (YISC 2011). The YISC contracted Industrial Forestry Service Ltd. (IFS) to review relevant knowledge to determine how invasive species may interact with a changing Yukon climate. This review synthesizes key sources that identified known distributions, invasive characteristics, ecological preferences, pathways of introduction, consequences of invasion (ecological, economic, social), and mitigation options for priority non-native invasive species. We found little documentation of invasive species being directly influenced by climate change and none documenting interactions in environments comparable to Whitehorse. Air temperature and precipitation patterns have been modelled on a regional basis for the Whitehorse area and the resulting predictions give indications of how environmental conditions may change. Many environmental factors influence species presence in an ecosystem and in many cases it is difficult to know exactly how changed conditions will help or hinder the establishment of invasive species. The goal of this document is to provide resource managers with current information to aid the risk management decision-making in regards to invasive species. Information presented in this report attempts to summarize the current state of knowledge about invasive species and their behaviours in the focus area and neighbouring jurisdictions as well summarizing expected climate changes and possible interactions. Phase 1 summarizes findings of the literature review; Phase 2 compares and contrasts invasive plant risk analysis procedures developed in Alaska and British Columbia.

1.1.1 Background

Non-native invasive species are plants, animals or microorganisms, introduced by humans to novel ecosystems and have negative impacts on environment, economy or society (Government of Canada 2004a, 2004b). These invasive species have attributes that give them advantages over native organisms allowing them to flourish in their new environments (Government of Canada 2004a, 2004b; Valery et al. 2008). Species with invasive characteristics can be referred to as invasive, non-native, alien, introduced, or non-indigenous with similar intentions (Valery et al. 2008). Not all new-invaders result in perceptible impacts to the receiving environment, however, for the purposes of this review "invasive species" are organisms (i.e. plant, animal, fungus, or bacterium) that are not native to the focus area (Whitehorse, Yukon) and have had negative impacts on economy, environment, or social welfare in Yukon or other jurisdictions (Government of

Canada 2004a, 2004b; Hatfield and Pollard 2009; YISC 2010c). Invasive species are able to reproduce rapidly and aggressively colonize new areas where, if they establish sustaining populations, they cause considerable ecological changes (Canadian Council of Fisheries and Aquaculture Ministers 2004; Government of Canada 2004a, 2004b). Invasive species become predators, competitors, parasites, hybridizers and diseases in their new environments. They can alter the structure and the species composition of invaded ecosystems by suppressing or excluding native species, changing evolutionary or successional trajectories, and by out-competing native species for resources such as nutrients, water, or light (McNeely et al. 2001; Canadian Council of Fisheries and Aquaculture Ministers 2004; Government of Canada 2004a, 2004b; Hatfield and Pollard 2009). The environmental changes brought about by invasive species infestations are often challenging or impossible to reverse, resulting in permanent ecological damage (McNeely et al. 2001; Canadian Council of Fisheries and Aquaculture Ministers 2004; Government of Canada 2004a, 2004b). Invasive species are recognized globally as a major contributing factor to biodiversity loss and ecosystem change, both of which result in impacts to human society (McNeely et al. 2001; Canadian Council of Fisheries and Aquaculture Ministers 2004; Government of Canada 2004a, 2004b). Nationally, about one quarter of Canada's endangered species are negatively impacted by invasive species (Government of Canada 2004a, 2004b; Ministry of Water, Land and Air Protection 2004). Invasive species also become issues in international relations. The pests such as the Asian long-horned beetle (found in packing material from China) and the potato wart (found in exports from PEI to the USA) result in trade restrictions and special inspection-quarantine measures (Government of Canada 2004a). The tourism industry in Whitehorse could be negatively impacted if, at some time in the future, Canadian waterways are considered a source of invasive species like didymo (*Didymosphenia geminata*). Resource dependent communities such as rural and First Nation communities are disproportionately affected by invasive species through ecosystem alterations that impact economically important natural resources (Government of Canada 2004a).

Individual ecosystems have specific abiotic conditions and biotic components that act as barriers or filters countering potential invading species. Species adapted to similar conditions (ones with similar life histories) are more likely to be successful invaders (Fausch et al. 2001). Species enter new ecosystems through pathways e.g. in water currents or imported goods (Government of Canada 2004, USDA 2010). Pathways of introduction may not always be obvious because the pathway may not always be impacted by the invasive species. Invasive organisms can be transported in ballast water; however the impacts of their introduction do not directly affect the shipping industry (Government of Canada 2004a). Pathways can be classed as natural (e.g. normal distribution through wind or water currents), human assisted (e.g. associated with movement of goods or people), unintentional (e.g. accidentally introduced in contaminated ballast water or hay) or intentional (e.g. sanctioned stocking or biocontrol releases) (USDA 2010; DNR 2011). These different types of invasion pathways can be managed in order to exclude invasive species and prevent their introduction to new habitats (McNeely et al. 2001; Government of Canada 2004a). The risk of the introduction is dependent on the economic, cultural and ecological factors of the pathway (i.e. the demand for goods) and how and from where they are transported (Ministry of Water, Land and Air Protection 2004). Not all invasions are successful; success is a function of chance events and factors like the amount of competition in the receiving environment. The level of competition in a receiving environment can be changed by disturbance providing "windows of opportunity" for invasion (McNeely et al.

2001). Disturbances can reduce predation or create the required habitat niches needed for invasive species establishment; although, disturbance events may be less important for the establishment of invasive animals than it is for invasive plants. Establishment of invasive animals requires similar disturbance regimes in the receiving environment as in the native environment (Fausch et al. 2001; McNeely et al. 2001; Hatfield and Pollard 2009). Anthropogenic disturbances are increasing around the world potentially providing more opportunities for the successful establishment of invasive species, especially plants (McNeely et al. 2001).

Changing climate results in changes in atmospheric variables such as air temperature or precipitation amounts and timing. Changes in atmospheric variables also impact ecosystem components e.g. timing of flowering, flooding. Changes in atmospheric variables and ecosystem functioning could present opportunities for invasive species to become increasingly invasive or promote an established species to become invasive as species respond to the changed conditions (Dukes and Mooney 1999; Stachowicz et al. 2002).

1.2 Current State of Invasive Species in Yukon

The Yukon Territory has low numbers of introduced species: three terrestrial invertebrates, two freshwater fish, one freshwater alga, two mammals, four birds and approximately 150 plants. Adjacent jurisdictions of Alaska and British Columbia (BC) contain many invasive species not yet found in Yukon. These species may have the potential to become invasive in Yukon depending on local atmospheric conditions and ecosystem resilience (Hatfield and Pollard 2009). Yukon's relatively invader-free condition allows management efforts to be focused on invasive species that are well established elsewhere such as white sweetclover (*Melilotus officinale*).

The Yukon Invasive Species Council (YISC) was formed with the goal of preventing and managing the introduction and spread of invasive species in Yukon (YISC 2011). YISC is involved with public education and awareness, coordinating volunteer management efforts (i.e. community weed pulls), invasive species research, as well as prevention and early detection and rapid response (EDRR) activities (YISC 2010c, 2011). YISC has an open membership with representatives from municipal, territorial, federal, and First Nation governments, non-profit organizations, industry (including agriculture), and private citizens (YISC 2010c, 2011).

Currently, Yukon does not have specific legislation regarding invasive species management; however, re-vegetation requirements do exist for sites disturbed during natural resource extraction under the Yukon Quartz Mining Act (2003), the Placer Mining Act (2003) and under the Land Use Regulations (C. 17) of the Territorial Lands (Yukon) Act (2003). These regulations require vegetated areas disturbed by operational activities to be returned to a state that either allows re-vegetation by native plants or the site should be left in a state that closely resembles the pre-disturbance conditions. The Yukon Government has published two volumes (under its former title the Department of Renewable Resources) containing re-vegetation prescriptions *Guidelines for Reclamation/Revegetation in the Yukon* (Kennedy 1993; Hill et al. 1996), that have become the industry standard (A. Altherr pers. comm. 2011).

1.2.1 Current State of Invasive Species in Adjacent Jurisdictions

1.2.1.1 Alaska

There are 116 non-native animal species (amphibians, birds, fish, invertebrates, mammals, parasites, pathogens, and reptiles) and 312 non-native plant species that have been recorded in Alaska. Only 20 animal species, and a similarly small fraction of plant species, are deemed invasive (Carlson et al. 2008; McClory and Gotthardt 2008).

Invasive species are managed by the Department of Natural Resources to "maintain uninterrupted productivity of natural and agricultural resources" (Carlson et al. 2008). There is an extensive network of agencies managing invasive plants including state, federal, regional, private, non-profits and the general public (Carlson et al. 2008). Involved agencies include Alaska Pest Risk Assessment Committee (AKPRAC), Alaska Committee for Noxious and Invasive Plant Management (CNIPM), Alaska Invasive Species Working Group (AISWG), Alaska Pest Risk Assessment Committee (AKPRAC) and local Cooperative Weed Management Areas (CWMA). These agencies coordinate the management of statewide and local invasive species issues (Carlson et al. 2008, DNR. 2011).

1.2.1.2 British Columbia

Invasive species management in BC is organized by a variety of authorities depending on the risk level of the invader and the jurisdiction it is found in. The BC Inter-Ministry Invasive Species Working Group (IMISWG) is responsible for the implementation of the provincial invasive plant Early Detection and Rapid Response management plan. This plan outlines the coordinated management activities that would be triggered by the discovery of a new highly invasive plant in the province (BC IMISWG 2010). Regional invasive plant and/or invasive species committees have been developed across the province to promote and in some cases coordinate on the ground management activities of invasive species of concern to their region (IPCBC 2011a). The regional committees are aided by the Invasive Plant Council of BC (IPCBC) through provincial initiatives and coordination in the areas of public education activities and research funding (IPCBC 2011a). Along the BC-Yukon border there are two invasive plant management committees, the Northwest Invasive Plant Council (NWIPC) and the North East Invasive Plant Committee (NEIPC) (NEIPC 2010; NWIPC 2011). The NWIPC occupies the majority of the BC-Yukon border, extending from Alaska to the Rocky Mountains east of Watson Lake (the Stikine Region boundary, NWIPC 2011). NEIPC operates in the area that includes the Rocky Mountains east to the Alberta border (NEIPC 2010). The combined invasive plant lists of the two agencies totals approximately 70 species that are established, or could become established, in their operating areas. Prominent species of concern for Yukon have established populations in northern BC including *Centaurea stoebe*, *Euphorbia esula*, and *Cirsium arvense*. Both committees focus on preventing new species introductions and reducing or preventing the further spread of established invasive plant species that currently have a limited distribution in central and northern BC (see NEIPC 2010 and NWIPC 2011 for detailed management strategies and invasive plant ranking systems). There is no analogous system for managing invasive animal species in BC, and little modern published data exists except for non-native fish sightings (see Cliford and Guiguet 1958; Wind 2004; Hatfield and Pollard

2009; M. Herborg pers. comm. 2011). IPCBC recently announced its intention to transition to an invasive species council (IPCBC 2011b). This move will help address the lack of resources on invasive animal and aquatic species in BC and build on the efficiencies of the established IPBC invasive plant communication and management network.

A thorough summary of international, federal and provincial legislation pertaining to invasive plant management can be found in the IPCBC Legislative Guidebook to Invasive Plant Management in BC (2007) and the Proposed Action Plant for Invasive Alien Terrestrial Plants and Plant Pests Phase (Government of Canada 2004b). A similar synthesis of legislation for vertebrate species is not yet available.

1.3 Climate Change in Whitehorse

The Whitehorse Adaptation Project Team (2010) analyzed meteorological data gathered since the 1940's and concluded that climate change will have considerable implications for the community. Documented changes include increases in winter temperatures, earlier ice break-up, delayed freeze-up and an increased number of growing degree-days. In response, the project team drafted the Whitehorse Climate Change Adaptation Plan in order to help the community prepare for the impacts of changing climate. The plan models potential atmospheric changes that may result from climate change using Intergovernmental Panel on Climate Change (IPCC) scenarios (Whitehorse Adaptation Project Team 2010). These scenarios (called B1 and A1B) anticipate how various drivers (including demographic and socioeconomic developments) will result in climatic changes by 2030 and 2050 (IPCC 2000; Whitehorse Adaptation Project Team 2010). The A1B scenario describes changes in the context of very rapid economic growth, world population first increasing then declining and implementation of new, more efficient technologies. These conditions are combined with an anticipated reduction in regional differences in per capita income (IPCC 2000). The A1B scenario places equal emphasis on fossil and non-fossil energy use (IPCC 2000). The B1 scenario uses the same population peaks and declines as A1B combined with a rapid shift towards a service and information economy and the implementation of new resource-efficient technologies (IPCC 2000). The A1B scenario predicts medium-high increases in CO_2 concentrations whereas the B1 scenario predicts low increases. The purpose of the two different scenarios was to demonstrate the greatest range in potential climate shift (Whitehorse Adaptation Project Team 2010).

There is a general consensus among climate change models that resulting temperature increases will be more pronounced in the higher latitudes, temperature shifts will result in hydrological changes, and the impacts of increased CO_2 concentrations will vary across different ecosystems (IPCC 2001; Compass Resource Management Ltd. 2007; Burgiel and Muir 2010). However, predicting climate change is complex and is further complicated by natural variations and cycling of phenomena like the Pacific Decadal Oscillation (the periods of warm and cool phases of surface sea temperature over 50-60 years) and the El Niño Southern Oscillation (tropical air pressure patterns along the west coast, IPCC 2001; Compass Resource Management Ltd. 2007). These cycles interact with local topography and result in some of the uncertainties in climate modeling (Compass Resource Management Ltd. 2007).

Climate change can manifest its self in a variety of ways (e.g. more rain, more summer heat, more wind) and these changes interact with local conditions and biota resulting in inconsistent shifts in ecological conditions across the landscape (Soja et al. 2007; Johnstone et al. 2010b; S. Green pers. comm.). Ongoing research at the University of Northern BC suggests that the shifts in ecological conditions appear especially variable in Yukon (S. Green pers. comm.). Climate models developed for northern BC using interpolated conditions between climate stations (including temperature changes as a result of elevation differences) performed very poorly for Yukon. The modeled changes in temperature coupled with changes in elevation (lapse rates) did not show consistent trends in lapse rates. The model results for Yukon are a complex of positive, negative, no trend and inverted trend areas. This mosaic of response clusters may be an indicator of the complex local conditions interacting with changing climate to produce clusters with similar responses and adaptive capacity to changing climate. Continuing research is finding patterns of species associations within these response clusters however the specific variable to use to measure climate change response across the landscape seems to differ with individual response clusters (S. Green pers. comm.).

The climate change modeling for the Whitehorse area anticipates a warming of winter air temperature by 3.3-5.4°C and an increase in mean annual precipitation of 72 mm by 2050 (Whitehorse Adaptation Project Team 2010). These changes in temperature and precipitation are expected to lengthen the growing season from its current 150 days to 168 -175 days by 2050 (Whitehorse Adaptation Project Team 2010). The realized range of an organism is determined by its tolerance of environmental conditions; therefore, different environmental conditions resulting from climate change can alter species ranges and restructure ecosystems (Campbell and McAndrews 1993; McNeely et al*.* 2001). Changes in a species' range and abundance can result from alterations in physiological or abiotic factors, changes in the number or survival of offspring, and changes in interactions between species (McNeely et al*.* 2001). Potentially problematic species may be able to take advantage of new conditions created by environmental changes and establish in new ecosystems (Carlson and Shephard 2007; Bennett and Mulder 2009; HDR Alaska Inc. 2009; Johnstone et al. 2010b). Alternatively, the dryness of environments near Whitehorse combined with the extreme summer day length may constrain potential invaders (S. Green pers. comm.).

Models suggest that some forested environments may take hundreds of years to reach equilibrium after climatic change, as changes in observed plant communities tend to lag behind changes in environmental conditions. This lag time has been attributed to time required for soil development, species migration, or time needed for mature trees to die and be replaced by different species (Campbell and McAndrews 1993; Johnstone et al. 2010a, 2010b). The earth's climate periodically undergoes short (geologically speaking) periods of cooling and heating; these changes have influenced alterations of ecosystems and species assemblages (Campbell and McAndrews 1993; Johnstone et al. 2010a). In one southern Ontario mixed wood forest, species composition changed as a result of cooling climate and these changes continued in the forest for at least another 150 years after the cooling period had stopped (Campbell and McAndrews 1993). The continuing changes were characteristic of seral type of succession (Campbell and McAndrews 1993). In the forests of south central Yukon, Johnstone et al*.* (2010b) characterizes the shifting of white spruce (*Picea glauca*) forests to aspen (*Populus tremuloides*) forest as a response to climate change. She found that forests regenerating 7–10 years post-fire on dry-warm mircosites (e.g. south aspects, low elevation/latitude) were largely composed of alder (*Alnus* sp.) instead of the pre-fire white spruce forest. This contrasted with cooler, moister north aspect sites that were still dominated by white spruce after fire disturbance. Johnstone et al. (2010b) hypothesized that this shift in dominant species was due to the increased moisture stress experienced on warm sites favouring alder establishment and that shift in conditions was a result of changing climate. However, other research has found that white spruce establishment post-fire is dependant on several factors such as seed abundance and seedbed deterioration (Peters et al. 2005). White spruce is not adapted to fire dispersal like lodgepole pine (*Pinus contorta*) that produces serotinous cones. White spruce seeds are viable for one year only, making surviving seed sources critical for post-fire seedling recruitment (Coates et al. 1994; Peters et al. 2005). White spruce seed production is also cyclical with very abundant “mast” years being followed by several years (2-6 years in boreal forests) of very low seed production. Sites burned during non-mast years can show little or no white spruce regeneration because of a lack of seed sources and because the potential for a site to act as a seedbed for white spruce deteriorates very rapidly after fire (Peters et al. 2005). Alternatively, aspen respond very well to post fire conditions (warmer soils and opportunities for stem or root suckering) and increase in abundance (Oswald and Brown 1990; Coates et al. 1994). The increase in aspen abundance can actually limit white spruce recruitment through competitive interactions and through smothering seedlings in leaf litter. White spruce is shade tolerant and eventually will grow to dominate the aspen (Oswald and Brown 1990). In time, the abundance of aspen on post-burn white spruce sites in Johnstone et al. (2010b) may be described as seral succession instead of a reaction to changing climate.

1.4 Climate Change Impacts on Invasive Species

Invasive species often tolerate a wide range of climatic conditions, allowing them to colonize a greater number of habitats and enhancing their ability to invade new ecosystems (Burgiel and Muir 2010). Changes in ecosystem conditions (such as temperatures, precipitation patterns, elevated CO_2 levels or increased nitrogen deposition) may have significant impacts on a native species (Burgiel and Muir 2010). Environments experiencing climate change impacts may be more susceptible to colonization by invasive species due to the ecosystem’s decreased suitability for native species and the altered interactions between ecosystem components (McNeely et al. 2001).

Native species in higher latitudes are expected to respond to climate changes by altering the timing of life cycle events including the end of hibernation or start of leaf out (Root and Hughes 2005). The timing of these phenological changes often depends on the amount of heat energy available over time (accumulated temperature). Differences in available heat may result in shifts in hatching, budding, or breeding. These changes in phenology can disrupt communities by the shifting of predator-prey and other competitive interactions. Organisms would be particularly at risk if the timing of their life cycle changes started to occur before food was available (Root and Hughes 2005; Compass Resource Management Ltd 2007). It may also be possible that climatic changes may favour native species by increasing their competitive ability allowing them to expand their range into new ecosystems. This range expansion of native species may increase the pool of potential invasive species (Burgiel and Muir 2010). For example, mountain pine beetle (*Dendroctonus ponderosae*) has been increasing its range in western Canada. This range expansion is linked to many factors including warmer winter temperatures and high winter survival rates (Burgiel and Muir 2010). Native species that become more competitive or invasive will result in complications when defining "invasive". Currently most regulations, funding and response mechanisms are designated for non-native (or "alien") invasive species (Root and Hughes 2005, Burgiel and Muir 2010).

Changes in the frequency and intensity of extreme weather events (e.g. windstorms, fire or floods) can also increase the success of invasive species by killing individual organisms and stressing others (Compass Resource Management Ltd 2007; Burgiel and Muir 2010). Removing individuals increases disturbance through emptying niches and exposing bare soil. Both conditions are conducive for the establishment of new species (McNeely et al. 2001). Stressed organisms are more susceptible to pests and diseases, which may create opportunities for invasive pests or parasites to establish (McNeely et al. 2001).

Warmer atmospheric conditions will allow the agriculture and horticulture industries to grow increasing number of species more competitively in higher latitudes and altitudes (McNeely et al. 2001). New species open up economic opportunities as well as increase opportunities for their associated pests to contaminate new areas (Kolar and Lodge 2000; McNeely et al. 2001; Burgiel and Muir 2010). Fast growing, non-native species may also be introduced for an expanding biofuel industry. Purposeful introductions of these potentially profitable species pose similar risks as unintended invasions and standardized risk analysis procedures should be conducted before any introductions are authorized (Kolar and Lodge 2000; McNeely et al. 2001; Government of Canada 2004a; Burgiel and Muir 2010).

1.5 Management Recommendations

Invasive species are managed to minimize the negative impacts they have on the environment, economy and society. For example, agricultural crops are protected against invasive species because infestations reduce crop yields, increase control costs (leading to increased economic and environmental costs) and because products contaminated with invasives may be worth less at market (Fraser Basin Council 2003). Severe, persistent infestations limit land use options and may reduce property values (Government of Canada 2004a). The federal invasive species management strategy has four key areas (Government of Canada 2004a):

1. Prevention of new invasions
2. Early detection of new invaders
3. Rapid response to new invaders
4. Management of established and spreading invaders (containment, eradication and control).

The combination of this framework with ecosystem-based, adaptive management principles aids decision-making and mitigation of the impacts of invasive species (Government of Canada 2004a; Burgiel and Muir 2010). Ecosystem-based, adaptive management activities preserve the inherent resiliency of ecosystems in turn ensuring ecosystem services for the future (Burgiel and Muir 2010).

All land managers and stakeholders have a role in regulating and managing invasive species as users of impacted systems and facilitators of unintentional introductions (Government of Canada 2004a). The bulk of management agency efforts meant to mitigate effects of climate change on invasive species have been spent on gathering knowledge of potential impacts (increasing capacity). While increased capacity is needed to predict and plan for climate changes, management strategies for invasive plants in changing climate conditions also need to be developed and tested (Compass Resource Management 2007).

1.5.1 Prevention

Preventing the introduction of potentially invasive species is by far the preferred management strategy, no invasive organisms become established and it is very cost effective (Fraser Basin Council 2003; Government of Canada 2004a; BC IMISWG 2010; DNR 2011). Prevention measures can include education, risk analysis, and pathway management through quarantine and inspection activities at critical points of entry (Government of Canada 2004a; Hatfield and Pollard 2009; DNR 2011). These management activities are less expensive than resource losses and management expenses for established infestations (Government of Canada 2004; BC IMISWG 2010; DNR 2011). The purposeful introduction of potentially detrimental species, such as sport fish or garden plants results from a difference in values, environmental or aesthetic. Prevention policies for these species will have political and economic impacts (by inhibiting a sport fishery or by banning sales) and successful prevention policy will need to acknowledge and make allowances for these different values (Hatfield and Pollard 2009). It can be challenging to raise public support and funding for prevention programs, as they deal with potential threats that may be difficult to quantify. Invasive species managers need to rigorously quantify the economic and ecological impacts and clearly communicate this information to the public to build the case for implementation of prevention activities (Government of Canada 2004a; Hatfield and Pollard 2009).

Public education is often employed as a preventative tool to increase public awareness that individual actions impact the establishment and spread of invasive species (Government of Canada 2004a). Educational initiatives target resource users such as boaters and describe how their actions i.e., the movement of boats between waterways, can move invasive aquatic organisms to new locations. Successful education initiatives require sustained effort and can utilize a large amount of resources (Hatfield and Pollard 2009). Regulations and legislation can act as preventative measures when they limit what is introduced to an area. They can accomplish this through proactive listing such as “prohibited” or “restricted” importation lists (BC Ministry of Water, Land and Air Protection 2004; DNR 2011). This method treats every non-native species as potentially invasive allowing managers to limit entry until evidence indicated it was advantageous to do so (McNeely et al. 2001). Prior to listing, a standardized, scientifically based risk assessment should be conducted (Ministry of Water, Land and Air Protection 2004; McNeely et al. 2001; BC IMISPWG 2010). A disadvantage of this method is that some species will incorrectly be considered detrimental until proven otherwise and regulations and legislations that may negatively affect trade are not likely to be endorsed by political and economic interests (Hatfield and Pollard 2009).

1.5.2 Pathways

The ways by which invasive species are introduced to new areas are termed “pathways”. Pathways include the movements of commodities such as hay, livestock and aquarium trade (Table 1); see discussion in “Background” and Table 2 (Government of Canada 2004a; USDA 2010; DNR 2011). Intentionally introduced invasive species (for horticulture, game species or aquaculture purposes) have the advantage of active transport by humans resulting in significant long distance spread to new areas (Canadian Council of Fisheries and Aquaculture Ministers 2004; Government of Canada 2004a; DNR 2011). Livestock and other imported animals become vectors for invasive species when they carry a disease or other invasive organism on their body or in their digestive tract (DNR 2011). Packaging materials, particularly wood packaging, act as pathways moving invasive insects like the Asian longhorned beetle (*Anoplophora glabripennis*) (Government of Canada 2004a). Pathway management effectively manages for many species at the same time instead of using separate strategies to manage individual species (Fraser Basin Council 2003; Government of Canada 2004a; Hatfield and Pollard 2009).

Table 1. Potential invasion pathways used by invasive species (Adapted from Government of Canada 2004a).

Invasive Species Type	Intentional Introductions	Unintentional Introductions
Aquatic	Live bait	Commercial shipping - ballast water, hull fouling
	Aquarium and pond trade	Recreation/commercial boating and plane floats
	Live food fish	Water diversions - canals, dams
	Authorized lake/stream stocking	Natural movement between water bodies
	Unauthorized stocking or movement	Garbage
Animals and Pests	Wildlife/pet trade	In animal products - meat, dairy, eggs, pet supplies
	Farming/ranching fur, game or livestock species (including apiculture)	Packing materials, soils, aggregates
	Research and development	Commercial transport - vehicles, containers
	Zoos, game preserves	Recreation/tourism - baggage, vehicles, equipment
		Natural movement across barriers and boundaries
Plants and Plant pests	Live plants - agriculture, horticulture	Food plants for humans or animals
	Seeds/grains - agriculture, horticulture	In soils, gravels
		Contaminants in seed/grains
		Contaminants in wood and other plant products
		In carriers - wildlife, livestock, horticulture supplies, garbage
		Natural movement across barriers and boundaries

Species that have a high probability of being introduced to a management area make good candidates for risk assessment. Managing pathways to prevent the introduction of invasive species works to prevent many species so a detailed risk assessment of each individual species may not be required. However risk assessments can help to focus control efforts among priority species. Risk assessment helps define the acceptable level of risk or level of damage if the priority species were to invade and establish populations (Hatfield and Pollard 2009). It utilizes a systematic decision making process to quantify the potential for harm from invasive species through hazard identification, risk estimation, risk management and risk communication (Government of Canada 2004a). Risk assessment should consider the environmental, economic, social (including human health) and cultural impacts that the introduction of an invasive species would have (Government of Canada 2004a). The risk of the introduction, establishment and spread of invasive alien species depends on a vast number of socio-economic, political, cultural and ecological factors including: pathways of introduction (e.g. the demand for goods and services and where they come from) and the adaptability of the invasive species to new ecosystems (Government of Canada 2004a). Risk assessments need to be based on the best knowledge currently available (Government of Canada 2004a).

1.5.3 Control and Containment

1.5.3.1 Early Detection Rapid Response

Immediate response to newly arrived invasive species is the second most efficient and effective management strategy. Waiting to take action until after a species has become widely established results in increased control costs and a diminished likelihood of eradication. Strategies to enable quick decision-making and effective communication concerning new invaders are termed Early Detection and Rapid Response (EDRR) (McNeely et al. 2001; Government of Canada 2004a; BC IMISWG 2010). EDRR programs has the following components: early detection network, surveillance strategy, plan of action (upon discovery of a new invader), clear roles and responsibilities (including partnerships), resources and long term commitment from involved parties. Implementation of EDRR in conjunction with key stakeholders and partners increases program stability and long-term success (BC IMISWG 2010). Public education is needed to inform the public about why EDRR strategies are needed and to build funding support before a new invader is discovered (Government of Canada 2004a; Hatfield and Pollard 2009; BC IMISWG 2010). The level of management response to a new invader is based on the results of a risk assessment. Species that would trigger the provincial EDRR strategy in BC include yellow star thistle (*Centaurea solstitialis*) and common crupina (*Crupina vulgaris*) as these species result in significant negative impacts in jurisdictions where they have become established (BC IMISWG 2010; NWIPC 2011). Canada Food Inspection Agency and Agriculture Canada are the federal agencies responsible for bio-security who inspect international shipments of goods and vehicles to prevent unintentional species introductions. These federal agencies do not have a presence in Yukon; the nearest office is located in southern BC, which may leave Whitehorse vulnerable to invasion through direct flights from Europe (Switzerland and Germany) or through international borders (Alaska) (Canadian Food Inspection Agency 2008).

1.5.3.2 Control

Actions are needed to contain and possibly eradicate invasive species once they are established beyond the EDRR level. Successful eradication or control programs are science-based, use the principles of integrated pest management and involve all relevant stakeholders (McNeely et al. 2001; Government of Canada 2004a). Eradication and control strategies should focus on actions that have “a high probability of success”, meaning actions that are practical, achievable and flexible to allow for future changes in priorities e.g. new species, new management options (Government of Canada 2004a). Management goals may include eradication, containment or suppression depending on the extent of the infestation, the potential damage caused and the resources available for management (Government of Canada 2004a; DNR 2011). Eradication of a few isolated populations (or individuals) may be feasible, however, if the invasive species becomes widely established, containment to a particular region or ecosystem may be the most realistic option (DNR 2011). Control efforts are not a permanent solution to invasive species issues. Control methods must be continuously applied, any break in activities entails further spread of the invasive organism or an increase in abundance resulting in an increase in impacts (Hatfield and Pollard 2009).

Acceptable injury thresholds should be determined in order to prioritize species or infestations for management action and to make best use of limited resources. For example, the Alaska Natural Heritage Program (AKNHP) scored invasive plant species for “invasiveness” and a threshold value of 59 or greater is considered invasive (see Alaskan risk ranking description in Carlson et al. 2008 and Appendix 1 for a listing of Alaskan rankings for priority species in Yukon, DNR 2011). Eradication, control and containment of less invasive species with widespread distributions are unlikely because of the large amount of resources it would require (DNR 2011). Public support of eradication methods is very important as management often involves public agencies and funds and contentious control measures can result in public complaints and program stoppages (DNR 2011). Management options involving pesticides are especially controversial and need to be clearly explained before starting a treatment program (Government of Canada 2004a).

1.6 Climate Change Impacts on Freshwater

Irrespective of climate change, globally freshwater taxa are considered very threatened. Twenty to 35% of the world’s freshwater fish species are classed as endangered, threatened or extinct (Ministry of Water, Land and Air Protection 2004). The isolated nature of freshwater systems results in greater potential to evolve locally unique life forms or endemic species (Ministry of Water, Land and Air Protection 2004). The impacts of climate change have the potential to greatly impact many freshwater species even if the magnitude of the climatic change is small (Ministry of Water, Land and Air Protection 2004). Warming air temperatures, as a result of climate change, are expected to increase evaporation, evapotranspiration, precipitation, and water temperatures, which would influence flows in lakes and streams (Kolar and Lodge 2000; Compass Resource Management Ltd. 2007; Rahel and Olden 2008). Warmer air temperatures will influence the rate of glacier retreat, alter frequency and intensity of climatic phenomena (e.g. El Niño), impact flooding regimes and decrease ice cover duration; all of which could result in changes in aquatic organism activity and distribution (Kolar and Lodge 2000; Chu et al. 2005; Rahel and Olden 2008; Goulding 2011). Some changes in aquatic conditions have been documented in Yukon or in neighbouring jurisdictions such as: increased air temperature, increased average annual temperature, increased precipitation, increased frequency of extreme events, increased water temperatures and change in stream flow (Compass Resource Management Ltd. 2007; HDR Alaska Inc. 2009; Whitehorse Adaptation Project Team 2010; Goulding 2011). Changes in atmospheric conditions can result in changes in ecosystem vegetation and these shifts in vegetation can moderate or exacerbate climate impacts on aquatic systems (Soja et al. 2007; Ball et al. 2010; Johnstone et al. 2010b). Changes in streamside vegetation can impact hydrology (through encroaching shrubs or increased runoff) and alter nutrient cycling in the system e.g. carbon and nitrogen (Ball et al 2010). The shift from coniferous trees to deciduous species allows greater light penetration and increased solar radiation to reach the soil and streams (Ball et al. 2010). Increased solar radiation can lead to increases in permafrost melting and make conditions suitable for invasive species by increasing the depth of the active soil layer and available light (Ball et al 2010;

Johnstone et al. 2010b). Changes in the hydrological cycle will be further complicated by increases in human population densities and water use demands (Kolar and Lodge 2000; Chu et al. 2005; Rahel and Olden 2008; Goulding 2011). The interconnected nature of water bodies complicates water management. Water bodies can cross jurisdiction boundaries (e.g. international boundaries) and this increases the challenges associated with actions in headwaters having down stream ramifications (Ministry of Water Land and Air Protection 2004).

Cold-water fish species (especially in small water bodies) are impacted by temperature increases as shown by reduced survival of organisms with narrow temperature range tolerances and increased primary production in the upper layers of water bodies (Kolar and Lodge 2000; Chu et al. 2005; Compass Resource Management Ltd. 2007; Rahel and Olden 2008). Modeling has predicted a reduction in the range of cold-water fish species like Arctic char (*Salvelinus alpinus*) up to 40% by 2020, and 63% by 2050. The dramatic range reduction would extirpate Arctic char from the western arctic (Chu et al. 2005). Changes in the conditions of water bodies can be offset by their size. Larger lakes have greater buffering capacity for temperature changes and may be able to maintain their temperature gradients despite some warming of surface layers. Such lakes may see increases in biodiversity as a result of warming surface layers and benefit from the resulting increased primary production (Compass Resource Management Ltd. 2007). In small lakes, warmer water temperatures will also lead to increases in primary production and the resulting increases in lake biological oxygen demand. Increases in oxygen demand in small or closed water bodies can produce anoxic (oxygen poor) conditions and reduce the amount of oxygenated habitat available (Kolar and Lodge 2000; Compass Resource Management Ltd. 2007; Rahel and Olden 2008).

To date much of the predicted impacts of climate change on aquatic systems has focused on salmon bearing systems. More knowledge is needed to clarify and quantify the influences of terrestrial vegetation, hydrology changes and changed climatic conditions on aquatic systems in order to enable more accurate predictions (Compass Resource Management 2007; Ball et al. 2010). Predictions are limited by a lack of inventory and species behavior information for native aquatic species for most northern jurisdictions. Aquatic resource management agencies need to make research and capacity building a priority in order to develop effective prevention and management strategies.

1.7 Freshwater Invasive Species

Invasive aquatic organisms enter new water bodies in a variety of ways, as hitch hikers on recreational or commercial boating, float plane floats, canoes, paddleboats, research boats as well as trailers, and fishing equipment (Canadian Council of Fisheries and Aquaculture Ministers 2004). Vehicles and equipment often move between water bodies and watersheds potentially making them important pathways of introduction for invasive species. Live bait used for recreational or commercial fishing is another potential source in the form of minnows, frogs, worms, leeches and insects (Canadian Council of Fisheries and Aquaculture Ministers 2004; Hatfield and Pollard 2009). These organisms have the potential to be invasive or to harbour invasive alien pathogens (Canadian Council of Fisheries and Aquaculture Ministers 2004). Aquatic organisms can be introduced through the aquarium and garden pond industry that may use organisms that may become invasive if they escape or are intentionally released into native ecosystems (Canadian Council of Fisheries and Aquaculture Ministers 2004; Government of Canada 2004a; Hatfield and Pollard 2009; DNR 2011). Currently the climate in Whitehorse is not conducive to the establishment of reproducing populations of typical pond fish (usually tropical or neo-tropical in origin) in local water bodies and conditions may not change sufficiently to allow establishment in the future. However, non-native aquatic organisms have the potential to transmit parasites and pathogens that may infect native organisms (Kolar and Lodge 2000; Canadian Council of Fisheries and Aquaculture Ministers 2004).

Many new fish populations have been started across Canada by unauthorized fish stocking (Canadian Council of Fisheries and Aquaculture Ministers 2004; Hatfield and Pollard 2009). These activities are generally well-intentioned efforts to promote recreational opportunities or commercial fishing stocks (Canadian Council of Fisheries and Aquaculture Ministers 2004; Hatfield and Pollard 2009). Public education is needed to inform the public of the potential unintended consequences of introduced species (e.g. limiting food resources causing tropic shifts, loss of biodiversity) while attempting to secure voluntary compliance with established legislation. Non-native fish species can also be introduced through international shipping, the bait trade, aquarium and pond trade, aquaculture, canals and dams increasing water body connectivity and through authorized stocking (Kolar and Lodge 2000; Canadian Council of Fisheries and Aquaculture Ministers 2004; Hatfield and Pollard 2009).

Several levels of legislation exist to limit the introduction and spread of invasive aquatic organisms. The federal Fisheries Act (1985) regulates the possession and movement of live fish. Authorization is required from federal and territorial fisheries management agencies before any introductions or transfers could be made (Environment Yukon 2010). Territorial, provincial and state governments (Yukon, BC, Alaska) have also implemented freshwater fishing live bait bans. Several US states are implementing legislation to limit the spread of aquatic invasives organisms through fishing gear restrictions. Maryland has recently implemented a ban on felt soled waders to help curb the spread of organisms like didymo (Maryland Department of Natural Resources 2011). Alaska has banned felt soled waders in the southeast part of the state and has plans for a statewide ban by 2012 (Dunker 2009; Maryland Department of Natural Resources 2011). Currently there are no regulations in Canada designed to limit the spread of invasive species through the movement of aquatic vehicles and equipment (Canadian Council of Fisheries and Aquaculture Ministers 2004). The effectiveness of regulations depends on compliance; therefore the public needs to be aware that the regulations exist, which may require education campaigns (Hatfield and Pollard 2009).

Currently little published information exists for potential or existing aquatic invasive species in Yukon. The long travel distance to Yukon impedes the introduction of some aquatic invasive species and cold-water temperatures and winter ice cover can limit the establishment of non-native species that arrive in the area.

1.7.1 Invasive Aquatic Species in Whitehorse

Yukon is home to two non-native fish species and two translocated species; three spine sticklebacks (*Gasterosteus aculeatus*), goldfish (*Carassius auratus*), rainbow trout (*Oncorhynchus mykiss*) and Arctic char. Three spine sticklebacks were introduced with a shipment rainbow trout stocked during the 1970's into Long Lake and Gloria Lake II, both pothole lakes (A. von Finster pers. comm.; von Finster 2003, note reported sites as Long Lake and Gladys Lake II; Environment Yukon 2008, note first stocking reported as 1982 and stickleback presence not mentioned; Government of Yukon 2010a). Goldfish have been introduced to a pond at the Takhini Hot Springs near Whitehorse. The Yukon Government conducted a variety of control efforts (netting, predation, piscicide treatment) to prevent possible spread into the Takhini River. The pond once again has a population of goldfish who may have survived control efforts or have been reintroduced (A. von Finster pers. comm. 2011; von Finster 2003; Government of Yukon 2010a).

Rainbow trout naturally occur in the Kathleen, Dezadeash and Aishihik systems but they have been introduced outside that range through stocking programs. Rainbow trout have been recorded in McIntyre Creek since the 1950's after they escaped from a stocked location the Upper Yukon River drainage system and have colonized nearby areas of the Yukon River (von Finster 2003; Environment Yukon 2008; YISC 2010c). Rainbow trout have been observed in the Whitehorse Rapids Fishway in the Yukon River, although individuals have not yet been caught above the fishway (A. von Finster pers. comm. 2011; Government of Yukon 2010a). A reproducing population has established in the Yukon River tributary of Croucher Creek located within Whitehorse. Rainbow trout have formed a reproducing population in the McLean lakes near Whitehorse. The effects of the rainbow trout on the native fish populations have not been quantified and there are concerns that they may compete with juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and Arctic grayling (*Thymellus arcticus*) (Government of Yukon 2010a). Little information is available on introduced rainbow trout distribution and abundance in Yukon however the species slowly be increasing its range. Invasion success of rainbow trout has been linked to synchronizing fry emergence with low probability of flooding (Fausch et al. 2001). Changes in flood timing and duration will impact further rainbow trout invasion success and the interactions between this and native species (Fausch et al. 2001; Rahel and Olden 2008). The native range of Arctic char is confined to two lakes on the North Slope; this range has been expanded to many pothole lakes through stocking efforts (Government of Yukon 2010a). Arctic char have escaped several times from hatchery facilities near Whitehorse and are now found in McIntyre and Porter creeks.

Other potentially invasive species have been noted in Yukon including didymo and zebra mussels (*Dreissena polymorpha*). Didymo is a single celled, freshwater alga that forms long chains of cells that coalesce into whitish - brownish mats on the bottom of stream and riverbeds. Didymo has been found in the Yukon and Kathleen rivers (YISC Undated). The hypothesized native range includes cold, nutrient poor, circumpolar streams in Europe, Asia and North America. This species appears to be expanding its range as didymo is increasing being found in warmer, lower latitude streams (Bothwell and Spaulding 2008; Bothwell et al. 2009). Didymo was noted in BC for the first time in 1866 and water quality records for Vancouver Island, BC for the early 1980's mention didymo as a very minor component of the algal community. The first reported "out-break" of didymo in Canada occurred in 1989 in the Heber River on Vancouver Island (Bothwell et al. 2009). Since 1989, many large blooms of didymo have been recorded across Canada and the northern US as well as New Zealand, often in prime fly fishing rivers. This "explosion" of didymo blooms may potentially be a result of an invasive strain of didymo although this has not been confirmed yet. Didymo in New Zealand is very genetically similar to didymo in North America and experts believe didymo was introduced to New Zealand on the felt-soled waders of fly fisherman from North America.

The pore size of felt waders allow for transportation of didymo and other introduced parasite such as whirling disease (*Myxobolus cerebralis*). The expansion and invasive habits of didymo over the last 20 years have resulted in concerns for benthic communities and local fish populations. Nuisance out-breaks appear to decline after a period of time (approximately 7 years) except in reaches with stable flows and substrates i.e., controlled flows with bedrock substrates (Bothwell and Spaulding 2008; Bothwell et al. 2009). Impacts of didymo blooms will vary with the extent, depth of coverage and duration of the bloom. In streams where didymo may be native no negative impacts have been observed on native salmon populations (Bothwell and Spaulding 2008). Negative impacts have been recorded on species that spend their entire lives in inland waters such as brown trout (*Salmo trutta*) and have resulted in shifts in invertebrate and algal communities (Bothwell and Spaulding 2008; Bothwell et al. 2009). Water chemistry can indicate potential area more susceptible to didymo blooms. Didymo requires a minimum concentration of 2 mg/L of calcium and 2.5 mg/L of sulphur. Gradients in calcium and sulphur concentrations have been linked to broad scale distributions of didymo in Norway (Bothwell and Spaulding 2008). Increased water nutrient levels (including eutrophication) can result in increased didymo growth but do not cause nuisance blooms (Bothwell et al. 2009). Prevention of didymo transmission between water bodies requires gear to be free of hitchhiking organisms, achieved by thoroughly drying or disinfecting all gear. Zebra mussels are not known in Yukon waters however; twice “in the past few years” they have been found on recreational boats at the Alaska Yukon border. US Custom officials recognized the invaders would not allow the boats into the State. Allegedly, three boats that were turned back during one incedent returned to Whitehorse and had their vessels professionally cleaned before returning to the border and successfully crossing. The second incident involved two boats contaminated with zebra mussels. After the vessels were refused entry they did not attempt to cross the border again (Environment Yukon 2010). Zebra mussels are freshwater bivalves that rapidly colonize hard surfaces. Zebra mussel invasions have been implicated in native species decline and in the loss of local populations (Ricciardi et al. 1993; Ricciardi 2004). Colonization can clog water intakes, colonize beaches, boats, and docks and reduce plankton availability negatively impacting zooplankton and altering water quality (IPCBC 2010).

1.7.2 Invasive Aquatic Species in Adjacent Jurisdictions

Freshwater ecosystems in BC are threatened by impacts from invasive plants species such as purple loosestrife (*Lythrum salicaria*), didymo, and Eurasian water-milfoil (*Myriophyllum spicatum*) and a variety of introduced fish species (Ministry of Water, Land and Air Protection 2004).

Three invasive aquatic plant species have extensive infestations in northern BC: knotweeds (*Polygonum* spp.), Himalayan balsam (*Impatiens glandulifera*) and marsh plume thistle (*Cirsium palustre*). Knotweeds are known outside of cultivation near communities along the Highway 16 corridor from the Hazeltons to Haida Gwaii and are apparent in gardens in the Prince George area (NWIPC 2011). Record keeping for Himalayan balsam infestations in northern BC began relatively recently in 2006, since that time nearly 100 new sites have been inventoried from Prince George to Prince Rupert and from to Stewart to Ft. St. James (NWIPC 2011). Most Himalayan balsam infestations are associated with historic yard waste dumping and subsequent establishment and spread (NWIPC 2011). Marsh plume thistle distribution is concentrated around Prince Rupert and the Robson Valley between Prince George and McBride. The Robson Valley infestations have progressed southward to Quesnel and northward towards McLeod Lake. Marsh plume thistle was recorded as establishing as far north as the community Groundbirch in the Peace River Regional District. Two other species of aquatic invasive plants have established in northern BC but have limited distributions. Yellow flag iris (*Iris pseudacorus*) has only been recorded Haida Gwaii and Hartley Bay Inlet on the BC mainland and purple loosestrife had established at one site near Houston. This purple loosestrife site is considered eradicated as a wood pellet production plant was built on top of the infestation circa 2008 and no plants have been reported on the site since (Ministry of Forests, Lands and Natural Resource Operations 2011b). Purple loosestrife has also been introduced to areas in Anchorage, Alaska and efforts to eradicate are ongoing (AKEPIC 2011). Historical records exist for didymo presence in the Bulkley River system in the Skeena Region (BC Ministry of Environment Undated). Didymo was added to the IAPP database in 2011, previously no formal monitoring system for this species existed (M. Herborg pers. comm. 2011; Ministry of Forests, Lands and Natural Resource Operations 2011c).

BC is home to at least 15 non-native freshwater fish species, of which only three species were introduced legally. The remaining 12 species are the result of illegal introductions and species movements from the USA (Wind 2004). The greatest densities of non-native fish are found in the southern half of BC (Wind 2004; Hatfield and Pollard 2009). Non-native fish impact native populations by altering competitive and predatory interactions, physically displacing resident individuals from their preferred habitat, diluting the local gene pool (i.e., hybridization), and by introducing new diseases or parasites (Wind 2004; Hatfield and Pollard 2009). A list of non-native fish species introduced into the northern regions of BC is shown in Table 2, this list does not include species native to parts of BC that have been introduced outside their range to other areas of the province (i.e. rainbow trout).

Table 2. Non-native fish stocked or introduced to BC, adapted from Wind 2004, and Hatfield and Pollard 2009.

Previously stocked species		
Common name	***Scientific name***	***Ministry of Environment Region***
Brook trout	*Salvelinus fontinalis*	Skeena and Omineca
Illegally stocked species		
Common name	***Scientific name***	***Ministry of Environment Region***
Brook trout fry	*Salvelinus fontinalis*	Peace
Bullhead	*Ameriurus* sp.	Skeena and Omineca
Fathead minnow	*Pimephales pomelas*	Omineca
Goldfish	*Carassius auratus*	Omineca
Yellow perch	*Perca flavescens*	Peace
Aquaculture Escapees		
Common name	***Scientific name***	***Ministry of Environment Region***
Atlantic salmon	*Salmo salar*	Skeena

Brook trout (*Salvelinus frontinalis*) is a popular recreational species that threatens native salmonids by competing for similar habitats and food sources. Brook trout also readily hybridizes with native Dolly Varden (*Salvelinus malma malma*) and Bull trout (*Salvelinus confluentus*) (McPhail 2008; Hatfield and Pollard 2009). Westslope cutthroat trout (*Oncorhynchus clarkii*) is native to Kootenay drainage system (southern interior BC) and this subspecies has been introduced to lakes in the Peace River system (McPhail 2008). Rainbow trout is native to all parts of BC except the Yukon, Liard and upper Kootenay rivers but popular recreational species has been translocated through the provincial stocking program to all regions of the province. Modern stocking releases use triploid or triploid all female stock to help reduce genetic concerns (Hatfield and Pollard 2009). The impacts of climate change on aquatic systems are likely going to be quite variable (see section 1.6) resulting in an array of impacts on non-native fish species. Changes in water temperature alter fish growth, survival, distribution and timing of life events. Climate change may impact other water body characteristics including turbidity, ice cover, pH, flow levels and timing as well as streamside, algal and invertebrate populations. This complex situation was simplified by Chu et al. (2008) who modeled warm water (flathead minnow and bullhead), cool water (yellow perch) and cold water (salmonids) fish species presence in relation to air temperature and ground water contribution for southern Ontario. Future fish distribution, in the context of changing climate, for warm water and cold water fish species could be predicted by air temperature and ground water inputs. However, cool water fish distribution was not explained by these two variables (Chu et al. 2008). Climate change may result in more frequent cool water conditions in the Yukon and this may facilitate establishment of cool water species however, establishment is highly dependent on species introduction and water body connectivity.

Freshwater ecosystems in Alaska have been invaded by a variety of invasive species: knotweeds, Himalayan balsam, loosestrife (*Lythrum* sp.), American white water-lily (*Nymphaea odorata* ssp. *odorata*) and didymo and fish species see Table 3 (Fay 2002; Carlson et al. 2008; McClory and Gotthardt 2008). The comprehensive Alaska Aquatic Nuisance Species management Plan, administered by the Alaska Department of Fish and Game, was developed to minimize the impacts of these species through coordinated management efforts (Fay 2002). The invasive plant risk ranking exercise performed by Carlson et al. (2008) describes the freshwater plant Eurasian water-milfoil as the species with the highest invasiveness rank, 90 out of a possible 97 points. This plant has not been recorded in Alaska although the closely related native spiked water-milfoil (*M. sibiricum*) has been recorded in all three broad ecogeographic regions (south coastal, interior boreal, arctic alpine) used to describe potential habitat regions in the ranking system (Carlson et al. 2008).

Table 3. Non-native fish stocked or introduced to Alaska (adapted from Fay 2002; McClory and Gotthardt 2008).

Stocked Species	
Common name	***Scientific name***
Brook trout	*Salvelinus fontinalis*
Invasive Fish Species	
Common name	***Scientific name***
Alaska blackfish	*Dallia pectoralis*
American shad	*Alosa sapidissima*
Arctic char*	*Salvelinus alpinus*
Arctic grayling*	*Thymellus arcticus*
Coho salmon*	*Onocrhynchus kisutch*
Rainbow trout*	*Onocrhynchus mykiss*
Three spine stickleback	*Gasterosteus aculeatus*
Western mosquito fish	*Gambusia affinis*
Aquaculture Escapees	
Common name	***Scientific name***
Atlantic salmon	*Salmo salar*

*Native species translocated to other parts of Alaska

Two non-native amphibian species have been recorded in Alaska, the Pacific chorus frog (*Pseudacris regilla*) and the red-legged frog (*Rana aurora*). The native roughskin newt (*Taricha granulosa*) has been translocated outside its native range in Alaska. The Pacific chorus frog is expanding in wetlands in southeast Alaska. Its natural dispersal range is likely limited unless human assisted (McClory and Gotthardt 2008). The red-legged frog was introduced from Washington to Chichagof Island in 1982, this expanding into nearby wetlands (Alaska Department of Fish and Game 2011).

1.8 Invasive Insects

Canada is home to 416 species of non-native insects; the majority (82%) originated from Europe. BC has a relatively high rate of occurrence of non-native insects (25%) compared to prairie and northern areas (2% combined) (Langor et al. 2009). This high rate of incidence is a result of the high volume of trade entering BC from other countries. The greatest diversity of non-native species in BC is concentrated in the south. This abundance of non-native insects coincides with the greatest diversity of woody plant species (Kolar and Lodge 2000; Langor et al. 2009). Globally, woody plant genera e.g. *Picea, Pinus*, *Malus, Prunus, Salix, Betula*, *Populus* and *Quercus* have wide distributions and high abundance; they also have the greatest diversity of pests. It is expected that more invasive insect species will move into central and northern BC as a result of range expansion (Langor et al. 2009). Non-native invasive insect species recorded in northern BC include larch sawfly (*Pristiphora erichsonii*), birch leafminer (*Fenusa pusilla*), ambermarked leafminer (*Profenusa thomsoni*) and striped alder sawfly (*Hemichroa crocea*), (Table 4). The Government of Canada (2010a) reports that larch sawfly has been recorded in the Yukon Territory. There have been repeated introductions of gypsy moth (*Lymantria dispar*) into southern BC during the past 100 years. Eradication programs have prevented this species from establishing reproducing populations in the province (Ministry of Forests Lands and Natural Resource Operations 2011a).

There are several invasive insect pests recorded in Alaska (Table 4). The larch sawfly has recently expanded its range from Anchorage to Fairbanks and it is being actively controlled by the forest service. The larch sawfly is found throughout the range of larch in Alaska. Two other pests of woody species have been detected in Alaska; birch leafminer is found in the Anchorage, Fairbanks and Kenai Peninsula areas and one male gypsy moth was found in Fairbanks in 2006 (McClory and Gotthardt 2008).

Table 4. Invasive pests found in Yukon, Alaska or BC, information adapted from Ministry of Forests and Canadian Forest Service 2001 and Government of Canada 2010a.

Scientific Name	*Pristiphora erichsonii*
Common Name(s)	Larch sawfly
Native range	Europe
Hosts	European larch, subalpine larch, tamarack, western larch
Diet and feeding behavior	Phytophagous / Phyllophagous / Free-living defoliator
Detection	Slits on new shoots were females have deposited eggs, look for larvae crawling on branches.
Impacts	Defoliation, repeated, severe infestation may cause tree death. Egg laying in young shoots results in shoot death and crown deformation.
Present in Yukon	Yes
Distribution in Adjacent Jurisdictions	Present in Alaska and BC. In Canada it was reported in Fort Nelson in 1952 and then in northwestern Alberta in 1996-1999 (Government of Canada 2010a).
Management strategies	Control on ornamentals or isolated trees shake infested branches and destroy larvae that fall to the ground.
Scientific Name	*Fenusa pusilla*
Common Name(s)	Birch leafminer
Native range	Europe
Hosts	White and paper birches and rarely feeds on black, yellow, or river birches.
Diet and feeding behavior	Phytophagous / Phyllophagous / Miner

Detection	Grey-green patches on leaf surface that form around egg masses. Damage visible early summer.
Impacts	Foliage damage, severe infestations weaken the host tree but rarely cause tree death.
Present in Yukon	Unknown
Distribution in Adjacent Jurisdictions	Canada: First reported in Edmonton in 1970. Found throughout BC. Alaska: Anchorage and Fairbanks (Holsten 2003).
Management strategies	Keep ornamentals healthy, water roots in the fall, applying a suitable fertilizer in spring and water during dry periods.

Scientific Name	*Profenusa thomsoni*
Common Name(s)	Amber-marked birch leafminer
Native range	Europe
Hosts	White, paper and yellow birches.
Diet and feeding behavior	Phytophagous / Phyllophagous / Miner
Detection	Small, light-coloured patches on upper leaf surface in July. Leaves turn brown later in the summer.
Impacts	Foliage damage, severe infestations weaken the host tree but rarely cause tree death.
Present in Yukon	Unknown.
Distribution in Adjacent Jurisdictions	Found throughout BC.
Management strategies	Control on ornamentals or isolated trees shake infested branches and destroy larvae that fall to the ground.

Scientific Name	*Hemichroa crocea*
Common Name(s)	Striped alder sawfly
Native range	Europe
Hosts	Red alder, occasionally paper birch also found on willow.
Diet and feeding behavior	Phytophagous / Phyllophagous / Free-living defoliator
Detection	Skeleton-like leaves, yellowish sawfly larvae with black heads and dark brown dorsal stripe and patches. Larvae eat holes through the leaf from the underside, eating everything except large veins.

Impacts	Periodically causes heavy defoliation (BC coast). Damage can result in reduced growth of attacked trees.
Present in Yukon	Yes
Distribution in Adjacent Jurisdictions	BC: Throughout B.C. but most common on the coast. Alaska: Present
Management strategies	Unknown

Scientific Name	*Lymantria dispar*
Common Name(s)	Gypsy moth
Native range	Europe, Asia
Hosts	Alder, birch, cherry, dogwood, Douglas-fir, hazelnut, hemlock, juniper, larch, maple, oak, pine, poplars, some cedars, some true firs, willow and many ornamentals.
Diet and feeding behavior	Phytophagous / Phyllophagous / Free-living defoliator
Detection	Caterpillar stage feeds on developing leaves in the spring. Larvae chew small holes in the surface of the leaves. Older larvae consume entire leaves. Mid-summer spongy egg masses covered with tan coloured can be found on tree trunks and branches or in debris near defoliated trees.
Impacts	BC: Throughout B.C. but most common on the coast. Alaska: Present
Present in Yukon	No
Distribution in Adjacent Jurisdictions	Alaska: First individual recorded in Fairbanks in 2006. BC: Series of introductions since 1911 generally confined to Vancouver Island and the Lower mainland.
Management strategies	In BC annual surveys, pheromone-bait traps, egg surveys, and when needed aerial and ground applications of Btk (*Bacillus thuringiensis* var. 'Kurstaki').

1.9 Invasive Birds and Mammals

1.9.1 Invasive Birds and Mammals in Whitehorse

There are no mammal or bird species that are considered invasive in Yukon. The species introduced to Yukon with the highest global invasiveness ranking is the feral cat (it is ranked 38th). It is ranked so highly because of its impacts on prey populations (Global Invasive Species Database 2011a). Potentially invasive animal species found in Yukon include the feral horse (*Equus caballus*), Rock Pigeon (*Columba livia*), House Sparrow (*Passer domesticus*), European Starling (*Sturnus vulgaris*) and Eurasian Collared-dove (*Streptopelia decaocto*), see Table 5 (YISC 2010c). All invasive animals have low population numbers and are not anticipated to have considerable negative impacts on native species. The garden earthworm has been noted in Yukon; however, its distribution does not appear to be expanding (YISC 2010c). Elk (*Cervus elaphus*) have been introduced to southern Yukon several times since the 1950's, and several self-sustaining populations persist. Elk are considered an exotic species in Yukon however they are not considered to cause detrimental impacts to the environment, economy or society and so are not considered an invasive species (Yukon Elk Management Planning Team 2008).

Table 5. Invasive characteristics of bird species introduced to Yukon.

Scientific Name	*Passer domesticus*
Common Name(s)	House Sparrow
Native Range	Europe, Africa, Asia (GISD 2011b).
Identification	Non-migratory, small songbird. Males: brown/back, black streaks, grey crown with red sides, red nape, black chin, white throat, upper breast and cheeks. Females/juveniles: Grey/brown crown, light brown eye stripe, grey/brown throat, no streaks on breast and belly (GISD 2011b).
Habitat	Urban, agricultural or disturbed areas and wetlands (GISD 2011b).
Impacts	Aggressive, displace native species through competition. May evict native birds from their nests. Agricultural pest – feeds on grain, young fruit and vegetables (GISD 2011b).
Present in Yukon	Yes, first reported in Whitehorse in the 1990's, now over-wintering population is roughly several dozen birds. Nesting observations were first made in the late 2000's (P. Sinclair per. comm. 2011). Not known to be established in any other community (C. Eckert per. comm. 2011).
Distribution in Adjacent Jurisdictions	Alaska: Yes, BC: Yes, especially prevalent on the coast. Provincially it's considered to have an "insignificant" impact on biodiversity (Murray and Pinkham 2002).
Management Strategies	Limit access to nesting sites and remove nests from nest boxes (Murray and Pinkham 2002).
Scientific Name	*Sturnus vulgaris*
Common Name(s)	European Starling
Native Range	Europe, Southwest Asia and Northern Africa (GISD 2011c).
Identification	Small iridescent black bird. May have white flecks on breast (GISD 2011c).
Habitat	Urban, agricultural, grassland, forested, coastal and disturbed areas (GISD 2011c).
Impacts	Flocks damage agricultural crops. Compete with native species for food. Prefer ground invertebrates (GISD 2011c).

Present in Yukon	Yes, a small population (fewer than 10 individuals) has been recorded yearly since the 1970's. Confirmed breeding pairs occur roughly once a decade (P. Sinclair pers. comm.). The population is migratory. Nesting pairs arrive in late April or early May then leave in September/ October. Over wintering individuals don't survive (C. Eckert per. comm. 2011).
Distribution in Adjacent Jurisdictions	Alaska: Yes, BC: Yes, provincially it is considered to have moderate impacts on native biodiversity (Ministry of Water, Land and Air Protection 2004).
Management Strategies	Limit access to nesting sites and remove nests from nest boxes (Murray and Pinkham 2002).
Scientific Name	*Streptopelia decaocto*
Common Name(s)	Eurasian Collared-dove
Native Range	Europe, Africa, Asia (GISD 2011d).
Identification	Males/females: medium-sized gray dove, black collar, squared tail, black bill, red eyes and legs (GISD 2011d).
Habitat	Urban, agricultural, grassland, riparian and disturbed areas (GISD 2011d).
Impacts	Competes with other bird species, feeds on grain products, is a carrier of West Nile virus (GISD 2011d).
Present in Yukon	Yes (YISC 2010c).
Distribution in Adjacent Jurisdictions	Alaska: Yes, BC: Yes, (Ministry of Water, Land and Air Protection 2004).
Management Strategies	Regulated hunting, southeastern US (GISD 2011d).

1.9.2 Invasive Birds and Mammals in Adjacent Jurisdictions

Fourteen non-native bird species and 21 non-native mammals have been recorded in Alaska (McClory and Gotthardt 2008). Roughly half of these species are considered invasive by the Global Invasive Species Database (2011) and are listed in Table 6 (McClory and Gotthardt 2008). Elk were introduced to southern Alaska to develop sport-hunting opportunities and populations are expanding on some islands (Schrader and Hennon 2005; McClory and Gotthardt 2008). Elk diet and habitat requirements overlap with Sitka black-tailed deer (*Odocoileus hemionus*). This overlap in requirements raises concerns about detrimental competition between the two species. Raccoons (*Procyon lotor*) and European rabbits (*Oryctolagus cuniculus*) have not established large populations and are not suspected of causing environmental damage (Schrader and Hennon 2005). Rats are suspected of causing the most ecological damage of all invasive animals introduced to Alaska. The negative impacts of rat predation on island populations of ground-nesting birds in other parts of the world has motivated the state to run rat trapping programs on some marine islands (Schrader and Hennon 2005; Alaska Department of Fish and Game 2011). Non-native mammal species in BC are not tracked like invasive plant species or introduced fish species (M. Herborg pers. comm. 2011). For general discussion of species present in the province see Cliford and Guiguet (1958) or Klinkenberg (2010).

Table 6. Non-native species recorded in Alaska, adapted from McClory and Gotthardt 2008.

Introduced Birds in Alaska	
Common name	***Scientific name***
Chukar	*Alectoris chukar*
Eurasian Collared Dove*	*Streptopelia decaocto*
European Starling*	*Sturnus vulgaris*
House Finch	*Carpodacus mexicanus*
House Sparrow	*Passer domesticus*
Rock Dove	*Columba livia*
Introduced Mammals in Alaska	
Common name	***Scientific name***
Black rat	*Rattus rattus*
Brown or Norway rat*	*Rattus norvegicus*
Canadian beaver	*Castor canadensis*
Domestic dog	*Canis familiaris*
Domestic cat	*Felis catus*
Domestic cattle**	*Bos taurus*
Domestic ferret	*Mustela putorius furo*
Elk	*Cervus canadensis*
European rabbit	*Oryctolagus cuniculus*
House mouse	*Mus musculus*
Raccoon	*Procyon lotor*
Red fox	*Vulpes vulpes*
Reindeer	*Rangifer tarandus asiaticus*
Wild boar	*Sus scrofa*

*Well established in urban areas (Schrader and Hennon 2005).

**Listed as Scottish cattle in McClory and Gotthardt 2008.

1.10 Invasive Plants

Approximately one-quarter of plant species in Canada originated from Europe and Asia; however, only 120 to 160 of these species are considered invasive. Invasive plants establish quickly through mechanisms such as prolific seed production, aggressive rooting structures, or broad ecological tolerances (Fraser Basin Council 2003). The response of individual species to climate change is challenging to anticipate because of the numerous complex interactions between plants and the environment. Experimental increases in air temperature have been implicated in short-term increases in vegetative growth of native herbaceous alpine species. The response is different for native high arctic herbaceous species; increases in air temperature trigger short-term increases in reproductive output. The positive responses in growth and reproductive effort are not sustained for more than a couple of years, possibly due to nutrient or water limitations (Arft et al. 1999). The herbaceous, weedy annual lamb's quarters (*Chenopodium album*) responded to increased CO_2 concentrations with increased vegetative growth until growth was limited by water and nutrient availability (Hobbs and Mooney 2005). Increased CO_2 concentrations are predicted to stimulate growth in leguminous, shrubs such as white sweetclover. Increased growth would increase nitrogen fixation increases and may result in increased invasiveness. The same increases in CO_2 concentrations may make C4 grass species less competitive (Duke 2000).

1.10.1 Invasive Plants in Whitehorse

Twenty highly invasive plant species found in Yukon (Government of Yukon 2010b). This is an enviable number as many more invasive plant species found in the neighbouring jurisdictions of Alaska and BC (Cody 2000; YISC 2010c; Bennett and Mulder 2009; NEIPC 2010; YISC 2010c; DNR 2011; NWIPC 2011). Eleven of these invasive species, and five other potential invaders present in neighbouring jurisdictions are listed in Table 7. Detailed identification, habitat, impact and control information for each species is included in Appendix 1. In Yukon, the majority of known infestations are associated with anthropogenic disturbances and urban areas (Line et al. 2008; Bennett and Mulder 2009). This pattern of distribution may change as the number of invasive plant species increases. The number of invasive plant species is anticipated to increase due to species range expansion and increased trade and movement of people (Carlson and Shephard 2007; HDR Alaska 2009). More invaders will increase the likelihood that highly detrimental species such as knotweed will become established (Carlson and Shephard 2007; Bennett and Mulder 2009; NWIPC 2011).

Table 7. Priority invasive plant species discussed in this report

Priority invasive species established in Yukon
Common tansy (*Tanacetum vulgare*)
Creeping thistle (*Cirsium arvense*)
Dalmatian toadflax (*Linaria dalmatica*) and Great butter-and eggs (*Linaria vulgaris*)
Hawkweeds (*Hieracium* spp.)
Leafy spurge (*Euphorbia esula*)
Oxeye daisy (*Leucanthemum vulgare*)
Perennial sow-thistle (*Sonchus arvensis*)
Spotted knapweed (*Centaurea stoebe*) and other knapweeds
Smooth brome (*Bromus inermis*)
Sweetclover (*Melilotus officinale*)
Priority invasive species established in adjacent jurisdictions
Garlic mustard (*Alliaria petiolata*)
Knotweeds (*Polygonum* spp.)
Himalayan balsam (*Impatiens glandulifera*)
Plumeless thistle (*Carduus acanthoides*)
Purple loosestrife (*Lythrum salicaria*)

Invasive knotweeds were ranked as the most invasive species out of the priority species discussed in this report. Knotweed (ranked as a complex of species) scored an invasiveness ranking of 87 out of 100 (Carlton et al. 2008). Spotted knapweed (*Centaurea stoebe*) followed closely behind with a score of 86 out of 100 (Carlton et al. 2008). Both species are considered highly invasive by NWIPC and NEIPC (NEIPC 2010; NWIPC 2011). The species with the lowest invasiveness rankings were common tansy (*Tanacetum vulgare*), 56 out of 98, plumeless thistle (*Carduus acanthoides*) 61 out of

100, and ox-eye daisy (*Leucanthemum vulgare*) 61 out of 100 (Carlton et al. 2008). Conversely, common tansy is considered an Extremely Invasive species by NWIPC (NWIPC 2011). Invasive plant managers consistently report common tansy as the species with the greatest number of new sites (NWIPC 2009). Many new common tansy sites have been large, especially in the Prince George area where three new common tansy sites were inventoried in 2008, all with areas greater than 1 hectare (A. Eastham per. comm. 2011).

1.10.2 Invasive Plants in Adjacent Jurisdictions

The proximity of Alaska and BC to international trade routes, their larger populations and increased landscape disturbance results in increased invasive plant diversity (Kolar and Lodge 2000; Government of Canada 2004a; Burgiel and Muir 2010). Alaska tracks 196 species of terrestrial and aquatic plants and BC tracks 174 (EDDMapS 2011; Ministry of Forests, Lands and Natural Resource Operations 2011b). The number of invasive species under observation is much larger than the number of species designated as noxious in legislation, 29 species in Alaska, and 49 in BC (BC Weed Control Act 1985; State of Alaska prohibited and restricted noxious weeds 2003).

Approximately 70 invasive plant species are found in northern BC, including species with severe detrimental impacts in southern areas of the province, e.g., knapweeds and knotweeds (NEIPC 2010; NWIPC 2011). Population numbers of these highly detrimental species are currently low even though a large amount suitable habitat is available. Control efforts for these highly detrimental species focus on eradication of localized populations and preventing further spread from southern areas. Infestations of a few highly detrimental species such as marsh plume thistle and field scabious (*Knautia arvensis*) are restricted to northern and central areas of the province. Control efforts for these species are focused on regional containment and eradication of satellite populations (NWIPC 2011). Marsh plume thistle, field scabious and common tansy have special management areas (“containment lines”) where efforts are focused on containing the species to a well-defined, densely infested area (NWIPC 2011). Containment agreements also exist between NEIPC and NWIPC. The boundary between the committees at the Pine Pass severs as the northern containment boundary for orange hawkweed (*Hieracium aurantiacum*) and ox-eye daisy.

The majority of Alaska’s invasive plant infestations are associated with anthropogenic disturbances (i.e. roadways). Some species have begun to infest undisturbed ecosystems: white sweetclover, spotted knapweed, invasive hawkweeds (e.g. *Hieracium aurantiacum*), Himalayan balsam and invasive knotweeds (Carlson et al. 2008).

Potential invasive plant ranges as a result of climate change may help direct detection and conservation efforts (HDR Alaska Inc. 2009). HRD Alaska Inc. developed a coarse scale model using weather data from Fairbanks, Anchorage and Juneau to model invasive plant ranges in Alaska, eastern Siberia and western Yukon (including the Whitehorse area). Climate change was modeled using low and high emission scenarios and it was combined with global records for invasive species range. The resulting maps highlight changes in species’ potential range (expansions and contractions) under different climate change scenarios. Life history or species adaptive capabilities were not quantified during the modeling. The factors that limited invasive species establishment were summer precipitation, winter precipitation and the minimum winter temperature (HDR Alaska Inc. 2009).

1.11 Summary

Invasive, non-native plants, animals, fungi, and bacteria are defined by their negative impacts on the economy, environment, and social welfare (McNeely et al 2001; Government of Canada 2004a). They alter the structure and functioning of disturbed and (for some species) intact ecosystems by successfully competing with native species for resources such as water, light or nutrients. Human induced disturbances can offer “windows of opportunity” for increased recruitment of invasive species (especially invasive plants). Management agencies are increasing efforts to prevent and control invasive species establishment through coordinated management strategies. The number of invasive species in Yukon is expected to increase through species range expansion and through the increased movement of goods and people. The exact impacts of climate change on the introduction and spread of invasive organisms is difficult to pinpoint. The presence of invasive species in neighbouring jurisdictions is a good indication of potential invaders. Established invasive species have adapted to the long, dry growing seasons in the Whitehorse area. The establishment of highly invasive species such as knotweeds and spotted knapweed is increasingly likely. Invasive species have complex relationships with changing climate and changing ecosystems. Invasive species like didymo and rainbow trout are already present in Yukon and are positioned to take advantage of increased solar radiation and changes in stream flow to expand their distribution. The abundance and distribution of invasive species increases over time and the responses of native organisms and ecosystems to changing ecological conditions will affect the success of future invasions.

Invasive species are managed to minimize their negative impacts on the environment, economy and society. Invasive species management has four key areas (Government of Canada 2004a):

1. Prevention of new invasions
2. Early detection of new invaders
3. Rapid response to new invaders
4. Management of established and spreading invaders (containment, eradication and control).

This framework should be combined with ecosystem-based, adaptive management to facilitate decision-making and mitigation of the impacts of invasive species (Government of Canada 2004a; Burgiel and Muir 2010). All land managers and the general public has a role in regulating and managing invasive species (Government of Canada 2004a).

1. **Prevention** – Is efficient and cost effective. Prevention measures can include education, risk analysis, and pathway management through quarantine and inspection activities at critical points of entry. Purposeful introduction of species results from a difference in values. Successful prevention policies will need to acknowledge and make allowances for these different values. Invasive species managers need to rigorously quantify the economic and ecological impacts of invasive species and clearly communicate this information to the public to build support for prevention programs.

2. **Early detection** of new invaders is key to implementing an efficient and cost effective management strategy. Delayed action increases control costs and diminishes the likelihood of eradication of the invader. Early detection of a new invader relies on an informed network of spotters and a communication plan to notify agencies, partners and stakeholders of new incursions.

3. **Rapid response** - Once a new invader has been identified a coordinated plan of action should be implemented. The roles and responsibilities of involved agencies, partners and stakeholders should be clearly defined before the action plan is implemented. Early Detection and Rapid Response (EDRR) plans should be executed in conjunction with involved agencies, stakeholders, and partners to increase program stability and long-term success. Public education is needed to inform the public about EDRR strategies and why they are needed in order to build the required funding and support before a new invader is discovered.

4. **Management** actions are needed to contain and eradicate invasive species once they become established beyond the EDRR level. The magnitude of management action is determined by risk assessments and injury thresholds that prioritize species and infestations for action. Successful management programs use the principles of integrated pest management and involve all relevant stakeholders. Management programs should focus on practical, achievable actions that have a high probability of success while still maintaining flexibility to allow for changes in future priorities. Management strategies can include eradication, containment or suppression of the invading. The management strategy used depends on the invading species, the extent of the infestation, the potential for damage and resources available for management. Public support for management strategies is needed as control efforts often involve public agencies and funding. Management options involving pesticides are especially controversial and need to be clearly explained before starting a treatment program. Control efforts are not a permanent solution to invasive species. Invasive species management requires continuous effort; breaks in management result in further spread, increases in abundance and intensifying detrimental impacts.

Invasive species pose significant threats to Yukon’s natural environment; as climate changes these impacts may alter in severity and direction. Invasive species are having considerable impacts on ecosystems, biodiversity, and human health in adjacent jurisdictions and as time passes impacts and management costs are mounting. In order to address the threats posed by invasive species Yukon should continue developing a comprehensive management strategy including components of identification, prevention, control, research, regulatory approaches, public education and awareness, and continued coordination with neighbouring jurisdictions. The management strategy should be developed while considering potential climate changes and their implications for invasive species.

2.0 PHASE 2: SPECIES RISK ANALYSIS

2.1 Introduction

2.1.1 Background

Only a small percentage of invasive species introductions result in negative impacts in the receiving environment and the relative risk posed by deleterious species is variable. Risk assessment is a repeatable, logical process for researching, evaluating and communicating information about the relative threat of invasive species (GISP 2001; Government of Canada 2004b; IPPC 2007). The objective of assessing risk is to predict the likelihood of invasion and to determine the relative invasiveness rank for known or suspected invasive species (GISP 2001). Risk assessment is a fundamental part of prevention, rapid response and invasive species treatment programs (Government of Canada 2004a; IPPC 2007). Assessing the likelihood of successful invasion usually involves developing a series of questions to consider the impacts of invasive species on environmental, economic, and cultural factors. This process involves reviewing scientific literature, expert opinion as well qualitative and quantitative data analysis (GISP 2001; IPPC 2007). This integrated approach increases confidence in the analysis process and provides a knowledge base for informing management decisions (Government of Canada 2004a). The results of the risk assessment process can also be used to garner public support for funding invasive species exclusion and eradication programs (GISP 2001; IPPC 2007). Risk assessments can be conducted for specific species, vectors or pathways of introduction and should include risk communication (conveying the results of the assessment process to the public and legislators) as well as risk management (prevention or control strategies and action plans) (GISP 2001; Government of Canada 2004b; IPPC 2007). This review discusses species risk assessment processes.

Risk assessments help set management priorities by identifying species with the greatest potential for negative impacts. Identifying risks allows managers to allocate management efforts and funds more efficiently. This is especially valuable when there are multiple threats that require management. Characteristics traditionally evaluated in species risk analysis include: a measure of invasiveness, potential for introduction, likelihood of establishment, rate of spread, and potential economic and environmental impacts (GISP 2001; Carlson et al. 2008). Assessing the risk posed by new invaders has additional challenges because on impacts of species introduction are not always well understood for new environments (Government of Canada 2004a; IPPC 2007).

Studies have attempted to identify a specific set of characteristics that would define an invasive species however; the only predictive characteristic that is reliably correlated with species invasiveness is demonstrated invasiveness in other jurisdictions. Identifying analogous climates and habitats in the management area is generally helpful for predicting potential spread after species establishment but it does not guarantee the habitat is at risk. Invasive species behave less predictably outside their native range and have been found expanding into novel habitat types (GISP 2001; Carlson et al. 2008).

Invasive species risk assessment can be conducted before or after its detection in the management area (GISP 2001, Canadian Council of Fisheries and Aquaculture Ministers 2004). No mater when it is applied, an ideal risk assessment process analyzes a few easily obtainable characteristics that provide a measure of invasive potential while disregarding trivial information and resulting in an accurate invasion prediction at a reasonable cost. Effective risk assessments clearly differentiate between levels of risk posed by each species, are well documented, open to public review, and have had their validity verified (GISP 2001).

2.2 Risk Assessment Examples

There are many international examples of invasive species risk assessment processes however; few well-documented examples exist for jurisdictions adjacent to Yukon. Risk assessment processes in these areas are focused on invasive plants. The process for assessing the risks posed by other invasive organisms would follow the same general procedure as that outlined for invasive plants (or see Millsap et al. 1990; Fields and Gotthardt 2009).

2.3 International Standards

The International Plant Protection Convention (IPPC) is a plant health agreement established in 1952, with the objective of protecting native and cultivated plants by preventing the introduction and spread of invasive species. The core activities of the IPPC are coordinated by the Food and Agriculture Organization of the United Nations (IPPC 2011). The IPPC has developed international standards for assessing risk posed by invasive species. This process determines relative invasiveness, the need for regulation, and appropriate control measures. The process focuses on plant species proposed for intentional import, however; it can be adapted for use with unintentionally introduced organisms (IPPC 2004, 2007, 2010, 2011).

Standard components of IPPC species risk analysis includes:

1. Species identification, species taxonomy is identified to the appropriate level impacting its invasiveness.
2. Species presence or absence in the management area.
3. Confirmation of legislative or regulatory status in the management area.
4. Intended use of the species (for intentional introductions) – risk will vary depending on type of use managed vs. unmanaged landscapes, outdoor vs. indoor. For unintentional introductions potential or current use of the species is considered.
5. Habitat compatibility or suitability throughout the management area. Assess biological potential and consider potential adaptations.
6. Probability of introduction, both intended and unintentional. Assess reproductive and dispersal ability.
7. Behaviour in other jurisdictions (is it invasive elsewhere).
8. Probability of spread or dispersal.
9. Assessment of economic consequences.
10. Impacts on host species.
11. Management options, this includes effective control options and cultural considerations that may limit potential control options.
12. Quantify the degree of uncertainty in the risk assessment process.

2.4 Risk Assessment Examples from Adjacent Jurisdictions

Ranking systems developed for use in the neighbouring jurisdictions of Alaska and BC incorporate many of the elements of IPPC species risk analysis. Both systems use a series of questions to identify the relative risks posed by the introduction of non-native, invasive plant species. Input requirements and methods of scoring relative risk differ between the two systems and result in the systems being suited to different situations.

2.4.1 Alaska

2.4.1.1 Background

The state of Alaska is relatively free of invasive species compared to the continental states. Specialists from various state and federal land management agencies developed an invasiveness ranking system for non-native plants, in order to support efforts to prevent and minimize the impacts of invasive plant species and preserve natural areas (Carlson et al. 2008). This Alaskan Invasiveness Ranking System was intended to be "robust, repeatable and transparent", to evaluate the likelihood of species establishment in natural ecosystems in Alaska while recognizing impacts to local ecology and communities. The tool informs land managers of the relative threat posed by invasive species and when it is combined with species distribution information it can be used to prioritize control activities. The Alaskan Invasiveness Ranking System is based on six components:

1. Pre-screening to evaluate the probability a species can establish in the state based on the worldwide distribution of the potential invader. To facilitate the analysis the state was classified into three ecoregions, Pacific maritime, Interior-boreal, and Arctic-alpine.
2. Quantification of impacts of species introduction will focus on "natural" ecosystems instead economic impacts or agricultural or disturbed landscapes.
3. Flexibility to evaluate species already established and others that may arrive.
4. Evaluation process produces relative invasiveness scores instead of classes of invasiveness.
5. Flexibility in the evaluation process to calculate scores for species with abundant documentation as well as species lacking of invasiveness information.
6. Conclusions must be reasonable and be in accordance with current scientific understanding.

Four existing risk ranking systems were considered while developing the Alaskan invasiveness evaluation:

1. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands, California Exotic Pest Plant Council (Warner et al. 2003)
2. Ranking Invasive Exotic Plant species in Virginia, Virginia Department of Conservation and Recreation (Heffernan et al. 2001)
3. Southwest Exotic Species Ranking System, National Park Service (Hiebert and Stubbendieck 1993)
4. Weed Risk Assessment System, Australian Quarantine and Inspection Service (Pheloung et al. 1999)

These examples were used to inform analysis questions (and the scoring values assigned to them) and to evaluate the invasiveness rank of a species. Each existing analysis system is tailored to the goals of the developing management agency resulting in different invasiveness ranks for the same species. The specificity of ranking systems also resulted in none of the systems being a best fit for Alaskan management goals. Certain systems placed a greater emphasis on agricultural pests, or required extensive distribution records, which were not available for Alaska. None of the previously developed ranking systems scored known invasive species or species with broad distributions in their native habitats higher than other potential invasive species. Unknown or ambiguous information resulted in lower risk ranking scores, which may not accurately reflect their invasive potential. Ranking results were often categorical (extreme, high, medium, low) which can mask differences in invasiveness between species. The existing systems did not screen for habitat/biological compatibility within the management areas. To address these issues the Alaskan Invasiveness Ranking System borrowed features from the existing systems and added habitat suitability screening, numerical scoring, and procedures for handling missing information (Carlson et al. 2008).

2.4.1.2 Ranking Process

Plant species are evaluated in the Alaskan Invasiveness Ranking System by scoring a species based on answers to questions concerning habitat/climate suitability, ecological impacts, biological characteristics, distribution and dispersal ability and control options (ease and feasibility). The evaluation pre-screens species for climate compatibility. If the species has been collected in Alaska, or if it has been found in other areas of the world with similar climates the species continues in the risk ranking process (Carlson et al. 2008). The risk analysis consists of 21 questions. The response to each question determines its contribution to the species overall invasiveness score. Individual questions range from 0 to 10 points each; a response of "No perceivable impact" would score 0 whereas "has the potential to cause significant alterations" would score 7 and "Likely to cause major alterations" would score 10 points. The questions are grouped into four sections: ecological impacts (worth 40 points), biological characteristics and dispersal (25), distribution (25), and feasibility of control (10). Answers are based information collected from literature and expert opinion. The highest possible total score is 100 points; however any question that cannot be answered due to insufficient data has its maximum total removed from the total score. The removal of a 10-point question would result in that species being scored out of 90 instead of 100. Relative not absolute scores are used to compare species. Draft versions of the Ranking System were validated by expert review.

2.4.2 British Columbia

2.4.2.1 Background

Few detailed risk assessments have been conducted for invasive species in BC (Atwood and Young 2010). A committee of invasive plant managers and representatives from provincial ministries developed the BC Invasive Plant Core Ranking Process to aid land managers in prioritizing plant species for management. The committee, in conjunction with project staff, produced a streamlined risk assessment tool for managers who have a working knowledge of invasive plant biology, distribution and their impacts within their management area (L. Atwood pers. comm. 2011). The Core Ranking Process calculates the relative rank of an invasive plant species based on its ability to dominate and persist, susceptibility of the management area, ecological impacts and the extent of infestation within the management area (Atwood and Young 2010). The Core Ranking Process can also identify new invaders or ones with very limited distributions that are not yet linked to an Early Detection Rapid Response (EDRR) protocol by scoring those species higher (more invasive) in ecological impacts and management potential (Ministry of Forests, Lands and Natural Resource Operations 2011d).

The Core Ranking process was influenced by several existing ranking systems including:

1. Ranking Invasive Exotic Plant species in Virginia, Virginia Department of Conservation and Recreation (Heffernan et al. 2001)
2. Weed Risk Assessment System, Australian Quarantine and Inspection Service (Pheloung et al. 1999)
3. An Invasive Species Assessment Protocol Version 1, NatureServe (Morse et al. 2004)
4. General Decision Process for Managing Invasive Plant Species in Garry Oak and Associated Ecosystems, Garry Oak Ecosystem Recovery Team (2007)

These systems similarly scored potential species impacts very high. Species management and biology questions were frequently scored highly, however; the exact scoring system was different for each process. Draft versions of the Core Ranking Processes were reviewed by the development committee and tested for functionality by regional invasive plant committees (L. Atwood pers. comm. 2011).

2.4.2.2 Ranking Process

Plant species are evaluated in the BC Invasive Plant Core Ranking Process by ranking a species based on species' impact, management potential, ecology and biology. The interactive-online analysis process consists of 19 questions and up to five species can be analyzed at one time. Terminology, potential answers, scoring rational as well as potential sources of data required to answer the question are provided. Each question is weighted and the chosen response determines a question's contribution to the overall invasiveness score (Ministry of Forests, Lands and Natural Resource Operations 2011d). The relative weight of each answer is not easily discernable to the Core Ranking Process user. The scores for each analysis category as well as the cumulative score for each species are automatically calculated. The highest relative score corresponds to the highest priority species for management in the analyzed area (L. Atwood pers. comm. 2011; Ministry of Forests, Lands and Natural Resource Operations 2011d).

The Core Ranking Process has two analysis scale options, Large Management Areas (the entire province or areas larger than a regional district) and Local Management Area (a regional district to a specific site) (Ministry of Forests, Lands and Natural Resource Operations 2011d). The Large Management Areas option evaluates susceptible environments by examining the number of invaded and the number of susceptible Biogeoclimatic Ecosystem Classification (BEC) subzones (Ministry of Forests, Lands and Natural Resource Operations 2011d). The BEC system defines ecological zones using vegetation, soils, and climate variables as well as classifying ecosystems based on the potential climax vegetation. It is commonly used in forestry and conservation management in BC (Ministry of Forests, Lands and Natural Resource Operations 2011e). This land classification system is similar, although units are not directly transferable, to Yukon Ecoregions (Smith et al. 2004). Alternatively, the Local Management Areas option evaluates susceptible environments by examining the number of invaded and the number of susceptible habitat types such as wet meadows, riparian, and coniferous forests (Ministry of Forests, Lands and Natural Resource Operations 2011d).

2.4.2.3 Modeling Future Distribution

Atwood and Young (2010) evaluated risks posed by invasive plants to parks in BC using the BC Core Ranking Process as a component of a larger risk analysis. This larger risk assessment process also included determining susceptibility of BEC units, identification of priority ecosystems for protection, development of regional maps, development of a management decision support process, public messaging requirements for parks, and modeling future distributions of invasive plants in the context of climate change. In order to predict future invasive plant distribution species climate envelopes (conservative estimates of habitable climates, including BC distribution data) and predicted climate change scenarios were modeled for the entire province. A review was conducted of models and approaches for simulating future invasive species distribution. Atwood and Young (2010) found for large management areas (regional and larger scales) an ensemble of models (ex. BIOMOD) offered many advantages. The additional analysis provides a good example of expanded products that can be produced after an initial risk assessment is completed.

2.5 Comparison of Alaskan and BC Risk Assessment Tools

International Plant Protection Convention standards for invasive species risk assessment require 12 analysis components (see section 2.3). Table 8 represents how each system satisfies the standard components as well as additional assessed components.

Table 8. Questions used in the Alaskan invasiveness ranking system and the BC Invasive Plant Core Ranking Process that fulfill and exceed the IPPC standard risk analysis component requirements. For full assessment question details see Carlson et al. 2008 and Ministry of Forests, Lands and Natural Resource Operations 2011d.

	IPPC Standard Risk Assessment Component	Alaskan invasiveness ranking system Component Description	Assessment Question	BC Invasive Plant Core Ranking Process	Assessment Question
1	Species identification, species taxonomy to the appropriate level impacting its invasiveness.	Generally species or subspecies level is considered (when management area is entire state). Conspecific species modeled as one species. Other recognized invasive species in genus are noted, "Other invasive species in the genus".	Before pre-screening process and Biological Characteristics and Dispersal #8	Level is flexible, user decides on level before commencing assessment process	Done before commencing assessment process.
2	Species presence or absence in the management area.	Presence in any Alaskan Ecoregion is noted. Presence does not influence final rank. Species not found in Alaska are model and those with matching climates proceed in the assessment process.	Pre-screening matching climate process	"What proportion of susceptible habitat types contains the invasive plant?" and "In the majority of habitats that contain the invasive plant, the species distribution is?"	#5, #6
3	Confirmation of legislative or regulatory status in the management area.	Noted under "Extent of the species U.S. range and/or occurrence of formal state or provincial listing"	Ecological Amplitude and Distribution #5	"Is the species included in provincial legislation?"	#14
4	Potential or current use of the species.	Animal and insect use is considered under "Impact on Higher Trophic Levels". Anthropogenic use is considered under "Spread by Humans", "Highly domesticated or a weed of agriculture" and "Role of anthropogenic and natural disturbance in establishment"	Ecological Impact #4, Biological characteristics and Dispersal #3 and Ecological Amplitude and Distribution #1 and #3	Does not specifically quantify use. Negative impacts of use are documented with questions such as "Does the species affect human health or safety?"	#12, 13
5	a) Habitat compatibility or suitability throughout management area.	Pre-screening climate matching process describes what Ecoregions it has been collected in, what zones are susceptible and how similar international collection sites are with Alaskan Ecoregions. Specific habitats are noted under "Aquatic, wetland or riparian species"	Pre-screening matching climate process, Biological Characteristics and Dispersal #9, and Ecological Amplitude and Distribution #1 and #3	"Are habitat types in the management area susceptible to invasion?", "What proportion of susceptible habitat types contains the invasive plant?"	#4, #5
	b) Assess biological potential.	Reproduction, dispersal, competition, growth requirements detailed under Biological Characteristics and Dispersal also "Seed banks" and "Vegetative regeneration" under Feasibility of Control.	Biological Characteristics and Dispersal all questions, and Feasibility of Control #1 and #2	All Biology questions, competitive ability and spread potential noted under Ecology.	#1-#3, #6-#10

	IPPC Standard Risk Assessment Component	Alaskan invasiveness ranking system Component Description	Assessment Question	BC Invasive Plant Core Ranking Process	Assessment Question
	c) Consider potential adaptations.	None	None	None	None
6	a) Probability of introduction, both intended and unintentional.	"Long disturbance dispersal" notes movement by animals. Anthropogenic movements are noted under "Spread by humans" and "Highly domesticated or a weed of agriculture".	Biological Characteristics and Dispersal #2 and #3. Ecological Amplitude and Distribution #1	No questions specifically dealing with introduction. "Long distance dispersal is typical, because species has features that aid movement" and "Is the species present in neighbouring jurisdictions (i.e. adjacent BC government region or regional district or province or state)?"	#3, #17
	b) Assess reproductive and dispersal ability.	Detailed under "Mode of Reproduction" and "Long-distance dispersal" as well as "Seed banks" and "Vegetative regeneration" under Feasibility of Control.	Biological Characteristics and Dispersal all questions, and Feasibility of Control #1 and #2.	All Biology questions and Ecology question "In the majority of habitats that contains the invasive plant, the species distribution is"?	#1-#3, #6
7	Behaviour in other jurisdictions (is it invasive elsewhere).	Legal status noted under "Extent of the species U.S. range and/or occurrence of formal state or provincial listing". Note native and introduced range under "Current Global Distribution"	Ecological Amplitude and Distribution #5	Noted under three Management Potential questions, "Does the species occur on neighbouring jurisdictions lists of highly invasive species?", "Is the species present in neighbouring jurisdictions (i.e. adjacent BC government region or regional district or province or state)?", "Has the species been successfully managed in another jurisdiction (i.e. adjacent BC government region or regional district, province, state)?"	#15, #17, #18
8	Probability of spread or dispersal.	Detailed Biological Characteristics and Dispersal as well as "Highly domesticated or a weed of agriculture", "Role of anthropogenic and natural disturbance in establishment" and "Seed bank"	Biological Characteristics and Dispersal all questions, Ecological Amplitude and Distribution #1 and #3, and Feasibility of Control #1	All Biology and Ecology questions, also "Alter soil or water chemistry (e.g. fixes nitrogen, reduces dissolved oxygen, plant is allelopathic, etc)".	#1-#10, #11b
9	Assessment of economic consequences.	None	None	None	None

	IPPC Standard Risk Assessment Component	Alaskan invasiveness ranking system Component Description	Assessment Question	BC Invasive Plant Core Ranking Process	Assessment Question
10	Impacts on host or neighbouring species.	"Allelopathic", "Competitive Ability", "Thicket-forming /Smothering growth form" and "Known level of impact in natural areas"	Biological Characteristics and Dispersal #4 - #6, Ecological Amplitude and Distribution #2	Ecology several questions concerning competition and dominance and Species Impact questions "Alter soil or water chemistry (e.g. fixes nitrogen, reduces dissolved oxygen, plant is allelopathic, etc)?", and "Change the structure of the natural community (e.g. creates a new layer or eliminates an existing layer)?"	#7-#9, #11b,d
11	Management options, this includes effective control options and cultural considerations that may limit potential control options.	"Level of effort required"	Feasibility of Control #3.	Management Potential questions note legislative requirements, new invaders, presence in neighbouring jurisdictions, management success in other jurisdictions and predicted level of effort for eradication.	#14-#19
12	Quantify the degree of uncertainty in the risk assessment process.	Uncertainty in species information is recorded as "U" score for any question in the assessment. The question is then dropped from the assessment total score.	No specific question. Unknown species information can be noted in any question.	Uncertainty in species information can be recorded from some Ecology, Species Impact and Management Potential questions. Uncertainty in Ecology and Species Impact questions result in higher scores/risk ranking. Uncertainty in Management Potential results in a lower score/risk ranking.	No specific question. Uncertain species information can be noted in some Ecology, Species Impact and Management Potential questions.
	Additional Components of the Alaskan or BC Invasive Plant Risk Assessment Processes				
	Ecological impact ecosystem processes	Impact on Ecosystem Possesses	Ecological Impact #1	None	None
	Physical impact on community structure	Impact on Natural Community Structure	Ecological Impact #2	"Alter waterways (e.g. increase sedimentation or reduce the amount of open water)?" and "Excludes use by animals/humans, or forms an impassable barrier in recreation areas etc.?"	#11a, c
	Ecological impact community composition	Ecological impact on community composition	Ecological Impact #3	None	None

The Alaskan invasiveness ranking system analyzes three additional risk components; impacts on ecosystem processes, physical impacts on community structure, and impacts on community composition. The BC Core Ranking Process quantifies some physical impacts of invasive species but it does not quantify impacts on ecosystem processes or community structure. Differences between the two risk analysis processes are outlined in Table 9.

Table 9. Differences between the Alaskan invasiveness ranking and the BC Invasive Plant Core Ranking Process systems.

Alaskan invasiveness ranking system	BC Invasive Plant Core Ranking Process
Carlson et al. (2008) outlines steps and scoring procedures.	Available as an online form. User only sees questions and allowable responses. Scoring system used for each analysis question not easily discernable. Online format ensures a standard assessment process is widely accessible.
Responses to risk analysis questions depend on available information. Assigning scores to responses requires additional consideration.	Discrete answers. All acceptable responses are selected from a multiple choice list.
Responses to risk analysis questions are documented throughout the analysis process.	Justification for responses to risk analysis questions would need to be recorded in a separate document. Information cannot be saved in the online form.
Only one management area scale considered.	Two scales of analysis available depending on the size of the management area (local or regional).
Climate matching analysis pre-screening performed for each species before the rest of the risk analysis.	Climate matching analysis not performed as part of the Core Ranking Process but can be performed as an additional analysis.
Designed to use all currently available, pertinent species information.	Designed to require less information, an understanding of species biology and behaviour in management area is still necessary.
Analyzes additional impacts on ecosystem processes, community structure, and community composition.	Analyzes additional physical impacts on ecosystem processes.

The relative ranks produced by both the Alaskan and BC ranking systems for highly invasive species were similar despite differences the analysis process and management areas (see Table 10).

Table 10. Relative ranks for the highest scored invasive plant species produced by the Alaskan invasiveness ranking system (for the entire state) and the BC Core Ranking Process for BC parks within three Ministry of Environment Regions. Only species found in the management area were included in the table. (Adapted from Atwood and Young 2010).

Alaskan invasiveness ranking	BC Core Ranking Process Rank		
	Region 6 Skeena	Region 7a Omineca	Region 7b Peace
knotweeds	knotweeds	orange hawkweed	purple loosestrife
spotted knapweed	orange hawkweed	spotted knapweed	leafy spurge
purple loosestrife	spotted knapweed	yellow hawkweed	diffuse knapweed
reed canary grass	marsh plume thistle	diffuse knapweed	common tansy
Himalayan balsam	diffuse knapweed	perennial sow thistle	spotted knapweed

2.6 Conclusions

There are many similarities between the Alaskan Invasiveness Ranking System and the BC Core Ranking Process. Both systems include all the risk ranking components recommended by the IPPC with the exception of economic impact analysis. These risk-analysis processes placed emphasis on managing for environmental concerns rather than economic ones. Economic analysis can be a very effective communication tool with policy makers and managers who may want to conduct a supplemental economic risk analysis (Canadian Council of Fisheries and Aquaculture Ministers 2004). The ranking systems are similar in that they both use literature reviews and expert opinion to inform the analysis responses, they both recommend expert review to validate results and the results of both processes can be considered a “snapshot” of the invasive plant issue. The relative invasiveness ranks produced by the Alaskan Invasiveness Ranking System and the BC Core Ranking Process are not directly transferable to other management areas (as ranks are partly based on management goals and species distribution in the management area) however the results suggest that both processes are equally able to distinguish highly invasive species. The Alaskan and BC ranking systems are based in part upon known species distributions and current plant knowledge. Risk rankings will need to be updated periodically to include advances in invasive species knowledge and management practices. Invasiveness risk rankings will require updating as species distributions and management agency goals change.

The chief difference between the Alaskan Invasiveness Ranking System and the BC Core Ranking Process is the Alaskan system was designed to catalog all available species information whereas the BC Core Ranking Process was designed to be more simply implemented. The online, multiple choice format of the Core Ranking Process facilitates quick species ranking with less data required than the Alaskan system. The different analysis scale options available in the BC Core Ranking Process are an attempt to clarify issues around habitat suitability at the landscape and regional scales. The process of tallying suitable pre-defined eco-regions should be transferable regardless of the landscape classification systems used. The Alaskan Invasiveness Ranking System develops a more through understanding of species biology and potential impacts but the process is more labour intensive. However, the climate matching pre-screening adds efficiency by preventing species without suitable habitats in the management area from being analyzed. Both risk analysis systems offer practical solutions to the problem of prioritizing invasive species for management the most appropriate procedure will depend on available information, documentation requirements and project scale.

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4.0 Appendix 1

Table 11. Invasive plant descriptions, species of concern to Whitehorse, Yukon Territory.

The tables combine available data and invasiveness ranking scores for Alaska, northwestern BC and Yukon. General descriptions of species distribution were available for northern BC from NEIPC (2010) and NWIPC (2011). General distribution descriptions were not always available for Alaska. Specific site information for both jurisdictions can be found at EDDMaps (2011) and IAPP (2011). For more detailed discussion on individual species including plant ranking and management strategies in Alaska see Carlson et al*.* 2008; DNR 2011; NWIPC 2011 or Province of BC 2002.

Scientific Name	*Cirsium arvense*
Common Name(s)	Creeping thistle, Canada thistle
Native Range	Europe, Asia, Africa (Shephard et al. 2007; IPCBC 2008e).
Life Cycle	Perennial (Cody 2000; IPCBC 2008e; Shephard et al. 2007).
Identification	Flower heads: white to purple, approx. 1 cm in diameter, borne on clusters of 1-5 at branch tips (Shephard et al. 2007; IPCBC 2008e) have a sweet vanilla scent. Flower bracts are spineless (IPCBC 2008e). Stems: erect, ridged, branching. Young plants appear as basal rosettes that bolt in late summer (Shephard et al. 2007). Mature plants 0.3-2.0 m tall (IPCBC 2008e). Deep, spreading roots (Cody 2000). Leaves: 5-17 cm long, oblong, alternate, sessile and clasping with wooly hairs on underside (Shephard et al. 2007; IPCBC. 2008e). Wavy, spiny leaf margins (IPCBC 2008e). Fruits: One-seeded, pale yellow to light brown straight or slightly curved (IPCBC 2008e).
Habitat	Adapted to a wide range of elevations and conditions including roadsides, railway right of ways, lawns, gardens, cultivated and fallow fields, margins of forests, meadows, wetlands, waste places and among native plant communities (Cody 2000; Shephard et al. 2007; IPCBC 2008e). Best adapted to rich, heavy loam, clay loam, and sandy loam soils. Relatively shade intolerant. Tolerates saline, wet, or dry soils (IPCBC 2008e).
Impacts	Crowds out forage grasses in pastures and rangelands, reducing yields and productivity, forms dense stands (IPCBC. 2008e; NWIPC 2011). Spreads rapidly, up to 5.5 m per season (IPCBC 2008e).
Reproduction	Disagreement in the literature: *Produces up to 40,000 wind-dispersed seeds per plant. Seeds may remain viable in the soil for up to 20 years* (YISC 2010c) and *develops seed sparingly, 1,000 to 1,500 seeds per flowering shoot, seeds may remain dormant for up to 3 years, mature seeds germinate most readily in mid-spring, seed viability may be low* (IPCBC 2008e). Reproduces by seed and vegetatively through creeping, horizontal roots, root fragments can start new infestations (IPCBC. 2008e, YISC 2010c). Plants are dioecious (males and females on separate plants) and grow in patches that are one clone and sex (Shephard et al. 2007; IPCBC. 2008e).
Alaska invasive ranking	79
NWIPC invasive category	2
Yukon Distribution	Found in Yukon, one site recorded near Haines Junction in 1995 (Cody 2000). This species is not considered to be a big problem yet (YISC 2010c).

Distribution in BC	Starting to appear in the Dease Lake. There are patches at Riley Creek on the Golden Bear/ Muddy Lake road near Telegraph Creek. North of Meziadin Junction (Hwy 37) all sites are scheduled for inventory and treatment (NWIPC 2011).
Introduction Pathways	Dispersed primarily by wind, seeds can also be dispersed by water, animals, clothing, equipment, and vehicles (IPCBC 2008e).
Control Options	Mowing and cutting has limited long-term effects and is used to limit seed production (NWIPC 2011). Repeated mowing or tillage will help reduce plant energy reserves (IPCBC. 2008e). Pulling and cutting can encourage vegetative spread. Seeds continue to mature after pulling or cutting, plants should be left in clear plastic bags to decompose in the sun before disposal (YISC 2010c, NWIPC 2011). Cattle can graze plants before flower heads are formed; afterwards very high nutrient levels make the thistle unpalatable and potentially toxic (NWIPC 2009).
Herbicide recommendations *(Herbicide treatments are most effective when carried out as part of an Integrated Pest Management Program)*	2,4-D is effective when used early in the season on new germinants, and will suppress mature plants with repeated treatments. Picloram and glyphosate give good control in the fall after the first hard frost. Spring applications of aminopyralid or clopyralid give good control and suppression of top growth. Applications of metsulfuron-methyl give good control up to the early bud stage (NWIPC 2011).
Biocontrol	*Larinus planus* has over wintered at a site in the Kispiox Valley but has not established a population. Numerous releases of the stem gall fly, *Urophora cardui*, have been also been made. Over wintering has occurred near Moricetown but it has not established. Advice to NWIPC from Dr. Peter Harris (DOA) is: “The Canada thistle rust should do well in your area and may already be present. It is very harmful to the thistle but its spread is rather poor. I think that the root crown weevil may help vector it and the presence of the rust certainly improves weevil survival. Thus it might be worth trying both together. I should let the weevil feed on some rusted plants early in the spring and then release it on some healthy plants.” Doctor Harris also suggests that the seed head weevil *Rhinocyllus conicus* may also help spread the rust (NWIPC 2011).
Similar native species	*Cirsium foliosum* is found in the wetlands of Whitehorse (Cody 2000).
Similar invasive species	Bull thistle *(C. vulgare)*, plumeless thistle (*Carduus acanthoides*), marsh thistle (*C. palustre*). *Cirsium arvense* lacks of spines on the main stem, has small flowers, and is less than 2 m tall (IPCBC 2008e).

Scientific Name	*Centaurea stoebe* (formerly *C. biebersteinii, C. maculosa)*
Common Name(s)	Spotted knapweed
Native Range	Eurasia, likely contaminant in seed (YISC 2010b)
Life Cycle	Biennial or short-lived perennial (IPCBC 2008a; YISC 2010b; YISC 2010c).
Identification	Flowerheads: pink-purplish flowers, rarely white flowers resemble thistles (YISC 2010b; YISC 2010c). Flowers found individually, at the ends of branches. Black-tipped flower head bracts give plants a spotted appearance (Shephard et al. 2007; IPCBC 2008a). Stems: branching above middle with gray hairs all over (YISC 2010c, YISC 2010b). Mature plants up to 1.5 m tall with a stout taproot (Shephard et al. 2007; YISC 2010b). Leaves: rosette leaves deeply lobed grey-green leaves (Shephard et al. 2007; IPCBC 2008a; YISC 2010b). Stem leaves slightly lobed to linear, leaf size decreases towards the tip of the stem (IPCBC 2008a; YISC 2010b). Fruit: brownish with tuffs at end for wind dispersal, very hard seed coat viable for at least 5-10 years (IPCBC 2008a; YISC 2010c).
Habitat	Found in grasslands, open forests, roadsides and right-of-ways (IPCBC 2008a). Prefers dry, well-drained or disturbed sites and readily invades farm fields (YISC 2010b; YISC 2010c). Spotted knapweed is more shade intolerant and prefers moister habitats than diffuse knapweed. Spotted knapweed can still be problematic in disturbed forested areas (IPCBC 2008a).
Impacts	Forms dense stands that dominate sites, infestations increase runoff and erosion leading to increases in sedimentation of water bodies (IPCBC 2008a; YISC 2010b). Dead standing stems can increase fire risk (IPCBC 2008a). Spotted knapweed has allelopathic properties that can alter soil chemistry, and prevent the growth of neighbouring plants (IPCBC 2008a; YISC 2010b; YISC 2010c).
Reproduction	Reproduces only by seed (IPCBC 2008a). It produces up to 20,000 seeds per plant and one third of these seeds remain viable in the soil after 8 years (IPCBC 2008a; YISC 2010c). Seeds may be viable for up to 15 years (IPCBC 2008a).
Alaska invasive ranking	86
NWIPC invasive category	1
Yukon Distribution	Alaska Highway (SW Teslin) and Klondike Hwy (near BC/Yukon border), suspected in Whitehorse. Recorded in Haines Junction (Cody 2000). The small patch has removed (YISC 2010c). Plants have been seen near Yukon/BC border south of Carcross and near the Morley River southeast of Teslin (YISC 2010c).
Distribution in BC	One old site at Pine tree Lake, 80 km north of Dease Lake (58^{o}53" north). A few hundred sites have been inventoried and treated along the Hwy 16 corridor. All spotted knapweed sites are managed using Integrated Pest Management principles (NWIPC 2011).
Introduction Pathways	Seeds are usually dispersed near the parent plant (Shephard et al. 2007, IPCBC. 2008a). Seeds can be spread in hay, on and in animals, and on vehicles (Shephard et al. 2007; IPCBC 2008a; YISC 2010c).
Control Options	Pulling, cutting or mowing is most effective when conducted prior to seed set. Seeds will mature on pulled plants so stems should be bent or crimped. Flowering plants must be bagged and removed. The root system should be removed to prevent re-sprouting. Follow-up treatments will be required to deplete the large seed bank (IPCBC 2008a; YISC 2010b).

Herbicide recommendations *(Herbicide treatments are most effective when carried out as part of an Integrated Pest Management Program)*	Effective herbicides include: picloram, dicamba, 2,4-D, clopyralid, aminopyralid and glyphosate. Picloram has been determined to be most effective; however it has residual effects (NWIPC 2011).
Biocontrol	Three seed head feeding agents *Urophora affinis*, *U. quadrifasciata* and *Metzneria paucipunctella* were released near Terrace in 1992 and 1997 and have established. The root feeding moth *Agapeta zoegana* and the root-mining weevil *Cyphocleonus achates* were released in 1995 and have not been detected since 1997. *Cyphocleonus achates* was re-released in 1998. The site has since been reduced and it is unlikely biocontrol agents are persisting (NWIPC 2011).
Similar native species	None
Similar invasive species	Black knapweed, *Centaurea nigra* (NWIPC Category 1), Brown knapweed, *Centaurea jacea* (NWIPC Category 1), Greater knapweed, *Centaurea scabiosa* (NWIPC Category 1), Diffuse knapweed, *Centaurea diffusa* (NWIPC Category 2), Mountain Bluet *Centaurea montana* (NWIPC Category 2), Blue buttons or cornflower, *Centaurea cyanus* (NWIPC Category 4) (NWIPC 2011).

Scientific Name	*Leucanthemum vulgare* formerly *Chrysanthemum leucanthemum*; *Chrysanthemum ircutianum*
Common Name(s)	Oxeye daisy
Native Range	Eurasia (YISC 2010a).
Life Cycle	Perennial (IPCBC 2008c; YISC 2010a)
Identification	Flowers: Single, terminal flower heads with white ray and yellow disc flowers. Flower heads approximately 5 cm in diameter. White ray flowers /petal tips are notched (IPCBC 2008c).
	Stems: Single to a few erect stems. Sometimes branched, 0.2 to 0.8 m tall (IPCBC 2008c). Leaves: Basal leaves are stalked, spoon-shaped, and 4-15 cm long. Stem leaves alternate, smooth and glossy, leaves become smaller towards flowers and clasp the stem (IPCBC 2008c; YISC 2010a). Leave have the unpleasant odour of creosote when bruised (YISC 2010c).
	Roots: Creeping rhizomes (YISC 2010a).
	Fruits: Ribbed black achenes (IPCBC 2008c). One plant can produce 500 to 26,000 seeds per plant (IPCBC 2008c; YISC 2010a). Seeds are viable for at least 2-3 years (YISC 2010a).
Habitat	Poor, dry soils on disturbed roadsides, gardens, waste areas, grasslands, forested areas, farm pastures and hayfields (IPCBC 2008c; YISC 2010c).
Impacts	Unpalatable due to its unpleasant taste, decreases forage for livestock and wildlife (IPCBC 2008c; YISC 2010c). Decrease local plant biodiversity, and may decrease ground cover and increase the amount of exposed soil (IPCBC 2008c).
Reproduction	By seed and underground rhizomes (IPCBC 2008c).
Alaska invasive ranking	61
NWIPC invasive category	2
Yukon Distribution	Dawson, Watson Lake, Haines Junction, Whitehorse, Mount Lorne and along the Haines Highway at Dezadeash Lake and the Alaska Highway at Morley and Rancheria rivers and Johnson's Crossing (YISC 2010a). Recorded along the Haines Highway (Cody 2000).
Distribution in BC	Large portions of the Cassiar area are still relatively free from oxeye daisy, especially Mount Edziza and Spatsizi and should be protected. It has spread up the Klappan River along Ealue Lake road to the trailheads into Spatsizi. One large area of the SBS aspen parklands that is lightly infested from Owen Lake through to Nadina. NEIPC has established a containment line at the Pine Pass (NWIPC/NEIPC boundary) (NWIPC 2011).
Introduction Pathways	Garden centers and wildflower seed mixes (YISC 2010c). Most seeds are dropped close to the parent plant. Seeds may be spread by flowing water (IPCBC 2008c).
Control Options	Trials indicated that sulfur-containing fertilizers such as ammonium sulfate (21-0-0-24) might have an effect on oxeye daisy. Several farms have noticed a dramatic reduction (NWIPC 2011). Pulling, cutting or mowing (or grazing by sheep or goats) is most effective when conducted prior to seed set. Flowering plants must be bagged and removed or left to decompose in clear plastic bags in the sun as pulled plants will produce seed after being pulled (YISC 2010a). The root system should be removed to prevent re-sprouting. Follow-up treatments are needed to deplete the large seed bank (IPCBC 2008c; YISC 2010a). Shade can reduce oxeye daisy biomass (IPCBC 2008c).

Herbicide recommendations *(Herbicide treatments are most effective when carried out as part of an Integrated Pest Management Program)*	Clopyralid effectively controls oxeye daisy and should be applied when shoots are young and growing. Metsulfuron methyl and picloram/2,4-D provides effective control. 2,4-D applied alone only provides short-term control unless it is combined with picloram. BC Ministry of Agriculture field trials demonstrated excellent to very good control with aminopyralid, picloram, picloram plus 2,4-D, or dicamba (IPCBC 2008c).
Biocontrol	None available.
Similar native species	Seashore chamomile (*Tripleurospermum maritimum)* found on the Arctic coast (YISC 2010a).
Similar invasive species	Shasta daisy *(Leucanthemum maximum & L. x superbum)* a related, larger species and has undivided leaves (YISC 2010c). Scentless chamomile (*Tripleurospermum perforata*) has smaller flowerheads (2–3 cm diameter) and divided feathery-like leaves (IPCBC 2008c; YISC 2010a).

Scientific Name	*Tanacetum vulgare*
Common Name(s)	Common tansy
Native Range	Eurasia (IPCBC 2008d).
Life Cycle	Perennial (YISC 2010c)
Identification	Flowers: flat-topped heads of bright yellow, button-like flowers, there are no ray flowers, 20-200 flower heads per plant (Shephard et al. 2007; IPCBC 2008d; YISC 2010c). Flower heads 0.5-1 cm wide (Cody 2000). Stems: In clusters, giving off a strong odor when crushed (Shephard et al. 2007; IPCBC 2008d). Up to 1.8 m tall, mature stems are purplish-red with obvious glands giving a dotted appearance (IPCBC 2008d). Have creeping rhizomes (Shephard et al. 2007; IPCBC 2008d). Leaves: Dark green, fern-like with divided leaves with serrated leaflets, 10-20 cm long and 4–8 cm wide (Shephard et al. 2007; IPCBC 2008d). Seeds: 1 mm long achenes dotted with glands and 5-angled (IPCBC 2008d). One plant can produce 50,000 seeds per year, and seeds remain viable in the soil for up to 25 years (YISC 2010c).
Habitat	Disturbed roadsides, gardens, waste areas, grasslands, beaches and riverbanks (Shephard et al. 2007; IPCBC 2008d; YISC 2010c).
Impacts	It is mildly toxic to humans and livestock (alkaloids and other compounds) (YISC 2010c, NWIPC 2011). Unpalatable due to its unpleasant taste, decreases forage for livestock and wildlife (Shephard et al. 2007; IPCBC 2008d; YISC 2010c). Dairy cattle feeding on common tansy produce off tasting milk (IPCBC 2008d).
Reproduction	By seed and root fragments (Shephard et al. 2007; IPCBC 2008d; YISC 2010c).
Alaska invasive ranking	56 (out of 98)
NWIPC invasive category	1
Yukon Distribution	Scattered locations in communities around Yukon (YISC 2010c). Recorded south of Haines Junction along the Haines Highway in 1995 (Cody 2000).
Distribution in Adjacent Jurisdictions	Alaska: In Haines it is invading beach meadows (YISC 2010c). BC: Numerous single plants and patches along hwy 37 from Kitwanga to north of Dease Lake. Also a few patches between Telegraph Creek to Glenora and in the Atlin area (NWIPC 2011).
Introduction Pathways	Garden escapee, contaminated soil, and transported on vehicles and equipment (IPCBC 2008d; YISC 2010c).
Control Options	Not controlled by single mowing events, plants respond with increased vegetative growth (IPCBC 2008d; NWIPC 2011). A combination of mowing and herbicide treatment of re-growth is effective. Treatments need to be repeated over several years. Wear gloves and protective clothing when pulling to prevent skin irritation (IPCBC 2008d). Flowering plants need to be bagged and removed or left to decompose in the sun because pulled plants will produce seed (YISC 2010c; NWIPC 2011). The root system needs to be removed to prevent re-sprouting. Follow-up treatments are required to deplete the large seed bank (IPCBC 2008d, YISC 2010c).

Herbicide recommendations *(Herbicide treatments are most effective when carried out as part of an Integrated Pest Management Program)*	Picloram, picloram/2,4 D, metsulfuron methyl, and aminopyralid (IPCBC 2008d).
Biocontrol	None available.
Similar native species	*Tanacetum bipinnatum*, fewer, larger flower heads 1-2 cm wide. Leaves moderately hairy.
Similar invasive species	None.

Scientific Name	*Melilotus officinale.* white sweetclover was formerly *Melilotus alba.*
Common Name(s)	White or yellow sweetclover
Native Range	Eurasia (Spellman 2008).
Life Cycle	Biennial, functions as an annual in Yukon (Bennett and Mulder 2009).
Identification	Flowers: sweet smelling, small white or yellow in tapering spike-shaped clusters at the end of branches (Shephard et al. 2007). Stems: Upright growth habit from taproot, many branched stems (Shephard et al. 2007). Grows 200+ cm tall (Spellman 2008). Leaves: toothed, oblong to lance shaped, compound with three leaflets (Shephard et al. 2007). Seeds: one plant is capable of producing over 300,000 seeds per year and 80% of seeds are viable after 30 years (YISC 2010c). Seeds can float (Spellman 2008).
Habitat	Plants are tolerant of extremely cold temperatures and poor soil conditions (low nutrients and soil moisture). Prefers disturbed, sunny sites (Spellman 2008). Invades roadsides, cleared right-of-ways, gravel pits and stream banks (Nolen and Ross 2008; Spellman 2008).
Impacts	Problematic along roadsides, the tall plants block sightlines for animals and drivers (YISC 2010c). Roadside infestations have acted as a source for plants to invade recently burned areas (Bennett and Mulder 2009). As a legume it has the ability to fix atmospheric nitrogen into the soil and change conditions (Nolen and Ross 2008; DNR 2011). Invades stream banks where it displaces native vegetation causing problems for wildlife and river recreation (Spellman 2008).
Reproduction	By seed (Shephard et al. 2007)
Alaska invasive ranking	White sweetclover (formerly *M. alba*) 81; yellow sweetclover (formerly *M. officinale*) 69.
NWIPC invasive category	Not categorized by NWIPC.
Yukon Distribution	Gravel bars in Yukon River north of Whitehorse (Nolen and Ross 2008). Continuous patches along the highways near Watson Lake, Teslin, Whitehorse, Haines Junction, Carmacks, Faro, Mayo and Dawson. Extensive east and north of Carmacks and east and west of Teslin. Sporadic plants along majority of the Alaska Hwy southeast of Whitehorse and on the Klondike Hwy between Whitehorse and Dawson. Infestations along the hwy appear to coincide with recent maintenance disturbance (Nolen and Ross 2008).
Distribution in Adjacent Jurisdictions	Alaska: several river floodplains where it reduces the survival of establishing native plants (DNR 2011). Common along portions of the Healy, Stikine, Matanuska, and Nenana rivers (Spellman 2008). BC: Not inventoried.
Introduction Pathways	Agricultural practices (Spellman 2008; Bennett and Mulder 2009). Escaped from cultivation in Whitehorse in 1943 (Bennett and Mulder 2009).
Control Options	Reduce the size of cleared right-of-ways; allow native vegetation to in-fill (Nolen and Ross 2008). Top burning kills first-year plants; second-year plants can resprout and produced viable seed. Cutting at 2.5 or 10 cm does not prevent re-growth and seed production of first-year plants and second-year plant density and seed production was reduced by cutting at 2.5 cm but not at 10 cm (Conn and Seefeldt 2009).

Herbicide recommendations *(Herbicide treatments are most effective when carried out as part of an Integrated Pest Management Program)*	Established plant biomass is reduced by triclopyr and 2,4-D at recommended rates and chlorsulfuron at recommended 1/2, and 1/4 rates Conn and Seefeldt 2009.
Biocontrol	A native sweetclover weevil (*Sitona cylindricollis*) is found on the prairies but has not been recorded in Yukon although the closely related *Sitona aquilonius* has been collected in Yukon on Alpine and Northern sweetvetch, *Hedysarum alpinum* and *H. boreale* ssp. *mackenziei* (Anderson 1997).
Similar native species	None
Similar invasive species	Leaf arrangement is similar to other clover species. This species is taller and its stems and roots are stouter than other species (Shephard et al. 2007).

Scientific Name	*Sonchus arvensis*
Common Name(s)	Perennial sow-thistle
Native Range	Europe (Province of BC 2002).
Life Cycle	Perennial forb (Province of BC 2002).
Identification	Flower: Small, yellow, dandelion-like flower heads (up to 20) on glandular stalks grouped. Flower head bracts often covered with sticky hairs, flowers all summer long (Shephard et al. 2007; Province of BC 2002).
	Stems: single stem, up to 0.4–2.0 m tall, erect and branched near the top, exudes a milky juice when cut (Province of BC 2002). Deep vertical root and fleshy, spreading, horizontal roots (Shephard et al. 2007; Province of BC 2002).
	Leaves: alternate with weakly prickled margins and variable shapes. Lower leaves stalked, upper leaves sessile and clasping (Province of BC 2002). Early leaves of basal rosette are dandelion-like (Shephard et al. 2007; Province of BC 2002).
	Fruits: wind-blown seeds, 3 000-14 000 per plant (YISC 2010c). Dark brown, 2.5–3.5 mm long, ribbed and have a parachute-like pappus. Seeds short-lived and viability decreases nearly by half within 2 years (Province of BC 2002).
Habitat	Undisturbed and disturbed sites, roadsides, farm fields (YISC 2010c). Dry to moderately dry sites and riparian areas. Allelopathic chemicals from roots and decaying dead plants inhibit germination of other species (Province of BC 2002).
Impacts	Aggressive, reduces crop yields. It is an alternate host for several viral diseases (Province of BC 2002).
Reproduction	By seed and vegetatively from roots (Province of BC 2002).
Alaska invasive ranking	73 - *S. arvensis* had a high score in biological characteristics and dispersal ability but a relatively low score for ecological impacts. Species like *S. arvensis* chronically present in agricultural and disturbed habitats. Ability to establish and spread and the degree of ecological impacts are not necessarily positively correlated (DNR 2011).
NWIPC invasive category	3
Yukon Distribution	Established in the Whitehorse area and north, Carmacks, Johnson's Crossing, the Destruction Bay area, and at the Kotaneelee gas plant (YISC 2010c).
Distribution in BC	Wide distribution particularity along roadsides. The extents of the infestation have not been determined. Found at kilometer 66 on the Telegraph Creek Road and at Warm Bay in Atlin (NWIPC 2011).
Introduction Pathways	Wind dispersal, birds (Province of BC 2002).
Control Options	Hand pull and cultivate before the extensive root system is established. Intensive cultivation (every 3–4 weeks) over an extended period can exhaust root energy reserves. Intermittent tillage will spread root fragments and result in more individuals. Mowing prior to flowering can prevent seed production. Frequent mowing is needed because of the plant's long flowering period (Province of BC 2002).

Herbicide recommendations *(Herbicide treatments are most effective when carried out as part of an Integrated Pest Management Program)*	Relatively resistant to herbicides, high rates are needed to impact the extensive root system. Clopyralid, dicamba, 2,4-D, picloram, and glyphosate have been effective when plants are at the pre-bud or bud stage. Sow thistle's waxy leaves require a solution with good wetting ability (Province of BC 2002).
Biocontrol	Two approved for use in BC, none with established populations in northern BC (NWIPC 2011).
Similar native species	None
Similar invasive species	Annual sow thistle (*S. oleraceus*) does not have the extensive root system and its flower heads are smaller. Prickly lettuce (*Lactuca serriola*) has smaller flowers and its leaves are prickly on the underside midrib (Province of BC 2002).

Scientific Name	*Euphorbia esula*
Common Name(s)	Leafy spurge
Native Range	Eurasia (Province of BC 2002).
Life Cycle	Long-lived perennial forb (Province of BC 2002).
Identification	Flowers: small yellowish green flowers (YISC 2010c; Province of BC 2002). Flowers are arranged in many small clusters with hart-shaped, paired bracts underneath (Province of BC 2002). Stems: mature plants are 20–90 cm tall. Extensive underground rhizomatous root system. Plant parts exude milky latex that can cause skin irritation and blindness (Province of BC 2002). Leaves: linear, alternate, 2–6 cm long (Province of BC 2002). Fruits: Seeds are oblong, grayish to purple, contained in a 3-celled capsule. They can remain viable in the soil 5–8 years but most seeds will germinate in the first 2 years (Province of BC 2002).
Habitat	Low- to mid-elevations, dry roadsides, fields, grasslands, open forests, and disturbed habitats. Very dry to very wet sites but best adapted to semi-arid areas with coarse-textured soils (Province of BC 2002).
Impacts	Forms dense monocultures. Produces allelopathic chemicals that limit establishment of other species. Invades rangeland, reduces its productivity for livestock and wildlife (Province of BC 2002).
Reproduction	Primarily vegetatively from roots but also by seed (Province of BC 2002).
Alaska invasive ranking (18)	84
NWIPC invasive category (2)	1
Yukon Distribution	Once patch in the Dawson area (YISC 2010c).
Distribution in BC	Scattered patches throughout the NWIPC operating area, none reported near Yukon border.
Introduction Pathways	Garden escapee (YISC 2010c). Seeds float on water and can be transported by animals (Province of BC 2002).
Control Options	Tillage, mowing, and pulling are not very effective control methods because of the extensive root system and the potential for fragments to resprout (Province of BC 2002).
Herbicide recommendations *(Herbicide treatments are most effective when carried out as part of an Integrated Pest Management Program)*	Picloram has been successful on small infestations. Spring applications of picloram and 2,4-D are effective when applied before flowers emerge. Annual applications of dicamba and 2,4-D are effective. Glyphosate can be effective when applied at one-month intervals (Province of BC 2002).
Biocontrol	A flea beetle, *Aphthona cyparissiae*, was released near Houston, BC and further monitoring of the release indicated that the beetle established. The infestation has since decreased and the beetle is no longer present (NWIPC 2011).
Similar native species	None
Similar invasive species	Six introduced species of spurge occur in BC (Province of BC 2002).

Scientific Name	*Impatiens glandulifera*
Common Name(s)	Policeman's helmet or Himalayan balsam
Native Range	Asia (BC Ministry of Agriculture 2011).
Life Cycle	Annual (NWIPC 2011, BC Ministry of Agriculture 2011).
Identification	Flowers: pink-purple to white, irregular shaped, up to 3 cm in length, with five petals (Shephard et al. 2007).
	Stems: hexagonally angled, hollow, thick, reddish-green, many-branched, stems grow up to 3 m tall, with large swollen nodes and glands at the nodes (Shephard et al. 2007; BC Ministry of Agriculture 2011). Shallow roots (NWIPC 2011).
	Leaves: lanceolate to ovate, up to 15 cm long, with a stout petiole and finely serrated margins. Lower leaves opposite, upper leaves whorled with three leaves per node (Shephard et al. 2007, BC Ministry of Agriculture 2011).
	Fruits: Seeds produced in pods, up to 800 (BC Ministry of Agriculture 2011) to 2500 (NWIPC 2011) seeds produced per plant. Seeds are viable for 18 months (+/-). Mature seedpods eject seeds up to 6 m from parent plant (BC Ministry of Agriculture 2011).
Habitat	Prefers riparian area with moist, rich soils and in full sun to light shade (BC Ministry of Agriculture 2011).
Impacts	Dense stems clog streams and wetlands and prolific seed production results in aggressive spread (Shephard et al. 2007).
Reproduction	Only by seed, seeds are even known to have germinated under water (BC Ministry of Agriculture 2011).
Alaska invasive ranking	80 (out of 92)
NWIPC invasive category	1
Yukon Distribution	Unknown.
Distribution in BC	Escaping from gardens, 90+ sites inventoried across the NWIPC operating area since 2006.
Introduction Pathways	Plants near watercourses can eject seeds into the water where they can be transported long distances. Ditch infestations are spread quickly by mowing operations (BC Ministry of Agriculture 2011). Garden escapee (Shephard et al. 2007).
Control Options	Hand pulling. Immediately re-vegetate. Repeated mowing can prevent seed production and has eliminated sites in 2-3 years in the UK (NWIPC 2011).
Herbicide recommendations *(Herbicide treatments are most effective when carried out as part of an Integrated Pest Management Program)*	Herbicide treatment should be timed before flowering otherwise seed production still occurs (NWIPC 2011).
Biocontrol	None
Similar native species	None
Similar invasive species	None

Scientific Name	*Alliaria petiolata*
Common Name(s)	Garlic mustard
Native Range	Europe, Scandinavia to Himalayas (Haber 2002).
Life Cycle	Biennial (Haber 2002; Shephard et al. 2007).
Identification	Flowers: small, white, 4 petals and produced in the second year. Looks like other mustards (Haber 2002; Shephard et al. 2007).
	Leaves: triangular, toothed leaves with a strong garlic smell. Forms dense mats of over wintering rosettes. Has a white taproot with a horseradish-like taste (Haber 2002). First year rosettes have dark green, kidney shaped leaves, 5 cm long with distinct leaf veins and scalloped edges. Second year plants have branched stems to 1 m tall with alternate triangular leaves, decreasing in size toward the top of the plant (Shephard et al. 2007).
	Fruits: Eight to 10 shiny, black, cylindrical seeds per pod (Shephard et al. 2007).
Habitat	Full sun to shade, especially floodplains and forests with alkaline soils (Shephard et al. 2007; Haber 2002).
Impacts	Dominates forest understory. Reduces forage for grazing wildlife (Shephard et al. 2007). When grazed by dairy cows, it gives the milk a strong odour. Gives poultry flesh an unpleasant taste (Haber 2002).
Reproduction	By seed (Shephard et al. 2007).
Alaska invasive ranking	63 (out of 90)
NWIPC invasive category	Not ranked by NWIPC.
Yukon Distribution	Unknown.
Distribution in Adjacent Jurisdictions	BC: earliest BC record is in a Victoria garden in 1948 (Haber 2002). No plants have been recorded in the NWIPC operating area. Alaska: Two infestations in Juneau and both are managed by the Juneau CWMA and the Tongass National Forest (DNR 2011).
Introduction Pathways	Garden escapee (Haber 2002).
Control Options	Hand pull or mow before seed set. Repeat treatments for 2 to 5 years to deplete the seed bank (Polster 2009).
Herbicide recommendations *(Herbicide treatments are most effective when carried out as part of an Integrated Pest Management Program)*	None found.
Biocontrol	None found.
Similar native species	None found.
Similar invasive species	There are many weedy species of mustard (Royer and Dickinson 1999). *Alliaria petiolata* has a distinct leaf shape and odour (Shephard et al. 2007).

Scientific Name	*Lythrum salicaria*
Common Name(s)	Purple loosestrife
Native Range	Eurasia (Province of BC 2002).
Life Cycle	Perennial forb or woody "half shrub" (Province of BC 2002).
Identification	Flowers: showy, purple with yellow center, 5–7 petals arranged in long vertical racemes (Shephard et al. 2007; Province of BC 2002). Stems: erect, 0.5–2.0 m tall, four-sided (sometimes 5, Shephard et al. 2007). Annual stems from perennial rootstock. Plants become taller and bushier through time. Rootstock made of rhizomes and a taproot (Shephard et al. 2007;Province of BC 2002). Leaves: simple, entire, opposite or whorled (Province of BC 2002). Fruits: small, oval seeds in capsules. One plant can produce 300,000 seeds per flowering stalk. Seeds can remain viable for 20 years (Province of BC 2002).
Habitat	Riparian and wet areas at low- to mid-elevation. Tolerates up to 50% shade and standing water. Grows in calcareous and acidic soils. Moisture is required for growth and reproduction, but well-established plants can persist on dry sites for many years (Province of BC 2002).
Impacts	Form dense stands that can impede water flow in waterways and reduce biodiversity (Shephard et al. 2007; Province of BC 2002). In systems with cattails (*Typha latifolia*), it is favoured by variable water levels and drawdown improves seedling establishment. Cattails compete with *L. salicaria* where water levels are constant and deep (Province of BC 2002). *L. salicaria* can hybridize with horticultural varieties (Shephard et al. 2007).
Reproduction	Seed and vegetatively from rhizomes (Province of BC 2002).
Alaska invasive ranking	83
NWIPC invasive category	1
Yukon Distribution	Unknown.
Distribution in BC	One site near Houston, considered eradicated (NWIPC 2011).
Introduction Pathways	Seeds transported by water, animals and humans. Seeds drop from capsules when air temperature cools in the fall (Province of BC 2002).
Control Options	Handpull small infestations before plants set seed. Remove the entire root system to avoid resprouting (Province of BC 2002).
Herbicide recommendations *(Herbicide treatments are most effective when carried out as part of an Integrated Pest Management Program)*	Herbicide use in wet areas is often restricted. Glyphosate, triclopyr, and 2,4-D have been used successfully to manage this plant in the US on suitable sites (Province of BC 2002).
Biocontrol	Three agents are approved for use in BC but none have been released in the NWIPC operating area (NWIPC 2011).
Similar native species	Sometimes confused with fireweed (*Epilobium angustifolium*), which has flowers with 4 petals and a round stem (Shephard et al. 2007; Province of BC 2002). In Alaska *L. salicaria* blooms in the fall after *Epilobium* (Shephard et al. 2007).
Similar invasive species	Sweet rocket or dames' violet (*Hesperis matronalis* (Province of BC 2002).

Scientific Name	*Carduus acanthoides*
Common Name(s)	Plumeless thistle
Native Range	Eurasia (Province of BC. 2002).
Life Cycle	Winter annual or biennial forb (Province of BC. 2002).
Identification	Flowers: large terminal, purple-pink disc florets (2-5 cm across) arranged in groups of 1 to 5 with several rows of spiny floral bracts (Province of BC. 2002). Stems: erect stems 0.3 to 1.2 m tall, branching above middle with spines. Thick, fleshy taproot (Province of BC. 2002). Leaves: lobed, spiny basal rosette leaves 10 to 20 cm long. Stem leaves alternate, sessile, hairy underneath, clasping and continuous along the stem (Royer and Dickinson 1999). Fruits: achenes with bristles (Province of BC. 2002).
Habitat	Mid-elevations pastures, fields, disturbed habitats and roadsides (Province of BC. 2002).
Impacts	Unpalatable to livestock, dense infestations can reduce forage availability. It has invaded restored grasslands and is very aggressive due to abundant seed formation (Province of BC. 2002).
Reproduction	Seed, up to 9,000 seeds produced per plant. High rate of germination under favourable conditions (90 to 95%). Seeds remain viable for 10 years (Royer and Dickinson 1999).
Alaska invasive ranking	61
NWIPC invasive category	2
Yukon Distribution	Unknown.
Distribution in BC	No known sites in the NWIPC operating area (NWIPC 2011).
Introduction Pathways	Wind dispersal (Royer and Dickinson 1999).
Control Options	Handpull rosettes and cut flowerheads to prevent seed production. Mechanical removals need to be repeated to deplete seed bank (Province of BC. 2002).
Herbicide recommendations *(Herbicide treatments are most effective when carried out as part of an Integrated Pest Management Program)*	Picloram, dicamba, 2,4-D, metsulfuron-methyl and glyphosphate have successfully managed infestations. Spring or fall application to rosettes before bolting is recommended. Metsulfuron-methyl should be applied to bolting plants (Province of BC. 2002).
Biocontrol	Several agents are used to manage sites in southern BC (NWIPC 2011).
Similar native species	Native thistles are generally blue-green in colour and have hairy upper and lower leaves. The leaves of native thistles do not clasp the stem from node to node (Province of BC. 2002).
Similar invasive species	Nodding thistle (*C. nutans*), *C. acanthoides* rosette leaves are deeply serrated almost to midrib (Province of BC. 2002).

Scientific Name	*Polygonium sp. (Fallopia* sp.)
Common Name(s)	Knotweeds (Japanese *P. cuspidatum*, Himalayan *P. polystachyum*, Giant *P. sachalinense,* Bohemian *P. x bohemicum*)
Native Range	Asia (Wilson 2007).
Life Cycle	Perennial (Wilson 2007, IPCBC 2008f).
Identification	Flowers: small, white/green axial flowers in showy branched plumes along the stem (IPCBC 2008f; Shephard et al. 2007). Stems: hollow, upright, bamboo-like, reddish-green with red. Stems 1-5 m tall. Older rootstocks have many stems. Rootstock is made up a dense mat of rhizomes (IPCBC 2008f; Shephard et al. 2007). Leaves: heart to oval shape except *P. Polystachyum* - leaves are elongated and tapered. Leaves 8-10 cm wide and 15 cm long on all species except *P. sachalinense* -leaves are twice as large as other species. Leaf arrangement zigzags along stems of on *P. cuspidatum* (IPCBC 2008f; Shephard et al. 2007). Fruits: *P. cuspidatum* plants are all female so they do not produce seed. *P. x bohemicum* is a hybrid of *P. cuspidatum* and *P. sachalinense* and perfect and female plants occur in BC and other parts of the Pacific and Inland Northwest. Perfect *P. x bohemicum* flowers produce pollen, and can fertilize *P. cuspidatum* allowing seed production. *P. polystachyum* and *P. sachalinense* have perfect flowers allowing seed production (Wilson 2007).
Habitat	Prefer moist and disturbed habitats (canals, ditches streams, lakes and beaches). Intolerant of shade. Grows in a variety of soil types including loams, silts and sand with pH up to 7 (IPCBC 2008f, Wilson 2007).
Impacts	Dense stands shade out other plant species and reduce or eliminate access to water bodies for wildlife or recreational activities. Infestations reduce sight lines along roads. Infestations Increase soil erosion potential because rhizomes do not hold soil together well (IPCBC 2008f).
Reproduction	Rapid vegetative spread. Rhizomes can extend horizontally 20 m and 3 m deep. Small fragments (1 cm/ 0.7 g) can resprout. Fragments resprout in soil or water (IPCBC 2008f).
Alaska invasive ranking	87 (out of 91) *P. cuspidatum, P. sachalinense, P.* X *bohemicum* ranked as one species
NWIPC invasive category	1
Yukon Distribution	Unknown.
Distribution in Adjacent Jurisdictions	BC: *P. cuspidatum* and *P. polystachyum* are found on Haida Gwaii. *P. cuspidatum* in Hazelton, *Polygonium* species in Hartley Bay, Prince Rupert and Terrace (NWIPC 2011). *P. Cuspidatum* is present as a garden ornamental in Prince George (Andrea Eastham, NWIPC Coordinator pers. comm. 2011). Alaska: *Polygonum cuspidatum* was perceived to be one of the most invasive to natural habitats in Alaska, *P. x bohemicum* and *P. sachalinense* are more widespread in the south-east (DNR 2011).
Introduction Pathways	Along waterways, plant parts are transported downstream. (NWIPC 2011). Primarily from fragments that are dispersed by human activities (e.g. mowing) or by water (IPCBC 2008f).

Control Options	Difficult because of its extremely vigorous rhizomes. Light exclusion, continuous pulling and for those infestations close to the ocean treatment with salt water, have proven successful if the efforts are integrated and continuous over a long period of time (NWIPC 2011).
Herbicide recommendations *(Herbicide treatments are most effective when carried out as part of an Integrated Pest Management Program)*	Effective herbicides include: imazapyr, glyphosate, and triclopyr. Stem injections/cut surface treatments are most effective in the summer or fall, while foliar applications are most effective at the late bud stage (IPCBC 2008f).
Biocontrol	None available although research initiated by CABI in 2007 (IPCBC 2008f).
Similar native species	None.
Similar invasive species	None.

Scientific Name	*Linaria vulgaris* and *L. dalmatica*
Common Name(s)	Common toadflax, butter-and-eggs, yellow toadflax, Dalmatian toadflax
Native Range	Europe (Province of BC 2002).
Life Cycle	Both species are perennial forbs (Province of BC 2002).
Identification	Flowers: snapdragon-like, bright yellow with white centers, arranged in long terminal racemes (Province of BC 2002, YISC 2010c). *L. dalmatica* has larger, showier flowers (Province of BC 2002).
	Stems: *L. dalmatica* 0.6-1.2 m tall, single or multiple stems. *L. vulgaris*. 0.1 to 0.8 m tall. Extensive underground rhizomes (YISC 2010c), and long taproot (1 m) (Province of BC 2002).
	Leaves: *L. vulgaris* are lance-shaped, pale, narrow, alternate, slightly waxy or Lower leaves appear opposite. *L. dalmatica* has crowded, waxy, heart-shaped, clasping, alternate leaves. First year plants form a rosette (Province of BC 2002).
	Fruits: Oval to round, angular and slightly winged capsules. *L. dalmatica* up to 500,000 seeds produced per plant. Seeds are viable for up to 10 years. *L. vulgaris* can produce 30, 000 seeds per plant. Seeds are viable for up to 10 years (Province of BC 2002).
Habitat	Low- to mid-elevation roadsides, disturbed areas, gardens, cultivated fields, grasslands and open forests. Tolerant of low temperatures and coarse soils (Province of BC 2002).
Impacts	Both species are mildly toxic to livestock (*L. dalmatica* contains glucoside, quinoline alkaloid and peganine) and both lower the forage value of pastures. Both species are persistent, aggressive and can form dense populations. Plants compete with native vegetation, altering the species composition (Province of BC 2002).
Reproduction	By seed and vegetatively from roots (Province of BC 2002).
Alaska invasive ranking	*L. dalmatica* 58, *L. vulgaris* 69
NWIPC invasive category	*L. dalmatica* 2, *L. vulgaris* 3
Yukon Distribution	*L. vulgaris* is common in Yukon gardens and it is spreading onto roadsides. *L. dalmatica* one patch has been reported near Rancheria (YISC 2010c).
Distribution in BC	Both species have a wide distribution along Hwy 16 (NWIPC 2011).
Introduction Pathways	By wind and animals. Deer, elk, and birds eat seed heads (Province of BC 2002).
Control Options	Cutting reduces seed production. Sheep grazing can suppress infestations and reduce seed production if done before seed set (Province of BC 2002). Hand pulling has eliminated some sites (Province of BC 2002; NWIPC 2011). Frequent tilling can be effective on cropland. It requires 2 years of treatment with 8–10 cultivations in year 1 and 4–5 cultivations in year 2. Follow-up treatments with seeding appropriate perennial species to compete (Province of BC 2002).

Herbicide recommendations *(Herbicide treatments are most effective when carried out as part of an Integrated Pest Management Program)*	*Linaria dalmatica*, fall applications of picloram and picloram mixed with 2,4-D are effective on some sites (Province of BC 2002). *L. vulgaris* is difficult to manage with herbicides. Apply herbicides during flowering when carbohydrate reserves in the root are at their lowest. Picloram, dicamba, and picloram with 2,4-D have all offered control in some situations (Province of BC 2002).
Biocontrol	*Linaria dalmatica, Mecinus janthinus* a stem mining weevil was released at Lanfear Hill in Terrace and Burns Lake in 1998, Vanderhoof in 2003, and Prince George in 2006 and 2007. *Mecinus janthinus* has established in Terrace and Prince George. All the common toadflax sites monitored in the NWIPC operating area have agents feeding on the flower parts (NWIPC 2011).
Similar native species	None.
Similar invasive species	*Linaria vulgaris* is similar but has more linear leaves and generally is smaller, and *L. dalmatica* has clasping, hart-shaped leaves (Province of BC 2002).

Scientific Name	*Hieracium sp.*
Common Name(s)	Invasive hawkweeds (Orange, meadow)
Native Range	Eurasia (Province of BC 2002)
Life Cycle	Perennial (IPCBC 2008b).
Identification	Flowers: Bright orange, orange-red, or yellow ray flowers with one to many flower heads in terminal clusters (IPCBC 2008b). Stems: Orange hawkweed stems are usually single 0.3 to 1.2, unbranched, leafless, and covered in black hairs and contain a milky fluid. Yellow hawkweeds have stems with short, stiff hairs (IPCBC 2008b). Leaves: Orange has basal rosettes, leaves 4-20cm long, with hairs on both upper and lower surfaces. Yellow has no leaves or greatly reduced stem leaves (IPCBC 2008b). Seeds: Dark ribbed achenes, 2 mm long (IPCBC 2008b).
Habitat	Prefers well-drained, coarse-textured soils. Invades natural openings, disturbed sites, roadsides, pastures, and clearings (IPCBC 2008b).
Impacts	Forms dense mats of rosettes and out-competes forage plants in hay fields and pastures. Will replace herbaceous native vegetation in undisturbed areas threatening biodiversity (Shephard et al. 2007; IPCBC 2008b).
Reproduction	Through aboveground runners (stolons), rhizomes, seed, and for some species buds on the roots. Established populations expand via stolons (IPCBC 2008b).
Alaska invasive ranking	79 -*H. aurantiacum* and *H. caespitosum* (tested as one species), 42 (out of 82) *H. umbellatum*
NWIPC invasive category	Category 1 species, however control treatments are only conducted on sites with a high opportunity of control or where infestations are threatening special interests.
Yukon Distribution	*H. caespitosum* along the Alaska Highway west of Watson Lake. *H. umbellatum* in the southeast region is expanding into roadsides along the Alaska Highway. Observed as far west as Whitehorse (Bennett and Mulder 2009).
Distribution in BC	Currently there are 8 invasive hawkweed species in BC (IPCBC 2008b). The hawkweed complex is extensively distributed across the NWIPC operating area. NEIPC has established a containment boundary for hawkweeds in the Pine Pass (NEIPC/NWIPC boundary) to prevent their spread into their region (NWIPC 2011).
Introduction Pathways	Mainly by intentional (e.g. mowing and wildflower seed mixes) and accidental activities. Also by wind, animals, and in contaminated hay and soil (IPCBC 2008b).
Control Options	Mowing and digging are not recommended as disturbance encourages vegetative growth. Trials have show that some infestations can be controlled with applications of ammonium sulfate, 21-0-0-25, in the spring, or fall or before a wet period if an established stand of grass is present.
Herbicide recommendations *(Herbicide treatments are most effective when carried out as part of an Integrated Pest Management Program)*	Actively growing plants can be effectively controlled with clopyralid, picloram, picloram plus 2,4-D, aminopyralid, or aminopyralid plus 2,4-D. Clopyralid and glyphosate suppress orange hawkweed for short periods (IPCBC 2008b). Timing rate trials conducted in 1997, near Quick BC, on what is believed to be yellow hawkweed (*H. almatia)*. Results indicated that all herbicide treatments tested effectively control yellow hawkweed (NWIPC 2011).
Biocontrol	None available although research is ongoing (NWIPC 2011).

Similar native species	Alaska: Both native and non-native species of hawkweed have been observed. Native Alaskan hawkweeds do not have stolons, have branched stems with many leaves and are typically found in high-elevation meadows (Shephard et al. 2007). BC: 13 native hawkweed species have been recorded, 12 species have yellow flowers. Hawkweeds are readily hybridizing in BC. Native yellow species have leaves up the length of their stems and some species have glabrous leaves (IPCBC 2008b).
Similar invasive species	NA.

Scientific Name	*Bromus inermis*
Common Name(s)	Smooth brome
Native Range	Southern Europe (Polster 2009).
Life Cycle	Perennial cool season grass (Polster 2009).
Identification	Flowers: Open, nodding panicle, 5 to 20 cm long, 1- 4 branches per node. Each branch has several purplish-brown spikelets 1.5 to 3 cm long. Spikelets contain 7 to 10 flowers (Royer and Dickinson 1999).
	Stems: Grass, seedling covered in fine, silky hairs and has a pink stem base. Sod forming rhizomatous root system, reaching up to 1.2 m long (Polster 2009). Roots and shoots produced at each node on rhizomes (Royer and Dickinson 1999).
	Leaves: Flat blades, 15 to 40 cm long, 5 to 15 mm wide, almost hairless. Sheaths are closed, ligules are present and are 1 to 2 mm long (Royer and Dickinson 1999).
	Seeds: Disagreement in literature *Produces 156 to 10,808 seeds per plant* (Polster 2009) and *produces 200 seeds per plant* (Royer and Dickinson 1999). Seeds are viable for 2 to 10 years (Polster 2009). Seeds are pale-yellow to dark brown, 10 mm long and 2 mm wide, with a short awn (less than 3 mm) (Royer and Dickinson 1999).
Habitat	Roadways, waterways, fallow fields, waste places, openings in spruce, ponderosa pine or lodgepole forests and meadow communities. Prefers clay or loamy soils, tolerates sandy soils. Has a pH range of 6.0 to 7.5. High mortality rate on organic soils. Tolerant to intermittent flooding (max 45 days) and saline conditions. Cold and drought resistant and shade intolerant (Polster 2009). Widely used as a forage crop and also used in reclamation (Pavlick and Anderton 2007)
Impacts	Invades native grasslands and forms dense sod mats potentially excluding other species (Polster 2009). Acts as an alternate host for some vial diseases of barley, brome and oats (Royer and Dickinson 1999).
Reproduction	Single seed (caryopsis or grain), 7 to 10 seeds per spikelet (Royer and Dickinson 1999).
Alaska invasive ranking	62
NWIPC invasive category	Not categorized as invasive by NWIPC.
Yukon Distribution	Wide distribution. Northern extent Eagle Plains on the Dempster Highway (Cody 2000).
Distribution in Adjacent Jurisdictions	Common in hayfields and roadsides throughout most of North America (Royer and Dickinson 1999).
Introduction Pathways	Wind and animal dispersal. Transported by ants and seeds may pass through the digestive tracts of birds (Polster 2009). Agriculture escapee, persisting after cultivation (Royer and Dickinson 1999).
Control Options	Mow or graze before flowering in hot weather. Treatment will need to be repeated multiple times. Prescribed burning in fall or in early spring reduces stem density and favours warm season grasses (Polster 2009).

Herbicide recommendations *(Herbicide treatments are most effective when carried out as part of an Integrated Pest Management Program)*	None found.
Biocontrol	None found.
Similar native species	The native species *Bromus pumpellianus* however *B. inermis* typically has glabrous lemmas, nodes and leaves (Pavlick and Anderton 2007).
Similar invasive species	Panicle of smooth brome is more open and less dense than *B. tectorum* whose panicle is also drooping and purplish and its leaves are covered in soft white hairs (Royer and Dickinson 1999).

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