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Risk Evaluation of Invasive Species Transport Across the U.S.-Canada Border in Washington State

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EXECUTIVE SUMMARY

Non-indigenous invasive species (NIS) create a multitude of undesired economic, social, and ecological effects. Financial costs include reduced revenue and property value, and prevention and control expenditures (Pimentel et al., 2000). Social impacts include reduction in preferred uses including cultural and recreational activities, as well as loss of valued aesthetic qualities and civic pride in the surrounding ecological landscape (Bureau of Land Management, 2006). Ecological impacts include changes in soil and water quality, alteration of habitats, and displacement of native species (Elton, 1958).

Despite increased public awareness of these potential impacts, new invasions are common as many NIS populations continue to proliferate and expand into new areas via human modes of transportation. NIS may be easily overlooked during inspections due to the small size of the plant fragments, eggs, or other types of propagules. Furthermore, incongruities in policies and procedures used by countries with shared borders can result in inconsistencies in regulating and controlling the trans-boundary transport of NIS. This is certainly the situation that exists between Canada and the United States. Differing levels of enforcement for NIS species of concern on either side of the border can therefore result in NIS control on one side, but not on the other. The uncontrolled site can then serve as a source of NIS to the other, controlled side of the border.

In this study the Relative Risk Model (RRM) developed by Wiegers et al (1998) was applied to conduct a landscape-scale risk assessment of human-mediated transport of NIS across the Washington State-British Columbia border. Modes of transportation that were examined included cars, trucks, trains, freight containers, freight and cargo tankers, ferries, and marine and freshwater recreational boats and commercial shipping vessels. These modes coupled with garden escapes from intentional plantings provide mechanisms for invasive plant and animal species introductions into the major habitat types in Washington. The project study area extended along the length of the Washington State and British Columbia (B.C.) Canada border and from the north end of Vancouver Island to the south end of Puget Sound. The Washington portion of the study area, designated as the NIS receiving body, was divided into seven assessment subregions based on county jurisdictions, the level at which terrestrial NIS are controlled. The B.C. portion, designated as the NIS source body was limited to the southern third of the province, including Vancouver Island (**Figure 1**).

The RRM is a modification of the Analysis Phase of the USEPA framework for ecological risk assessment (1998). The USEPA framework defines the Analysis phase as the characterization of exposure and effects and the relationship between them. The RRM method uses ranks and filter values to quantify this characterization process using sources of stressors, stressors, and habitats to quantify impacts to valued assessment endpoints. In this study the RRM method used is based on those of Colnar and Landis (2007) except two additional ranks were added: a transportation rank estimating the volume of each transport pathway; and an impact rank estimating magnitude of effects to endpoints by stressors.

The eight NIS stressors selected and used in this model, based on stakeholder input were: spotted knapweed (*Centaurea stoebe*), Scotch broom (*Cytisus scoparius*), purple loosestrife (*Lythrum salicaria*), Eurasian watermilfoil (*Myriophyllum spicatum*), zebra mussel (*Dreissena polymorpha)*, *Spartina* (*Spartina anglica*), European green crab (*Carcinus meanas*), and the colonial tunicate *Didemnum* sp A. All selected stressors are present in B.C. except for the zebra mussel, which was included as a prospective species based on stakeholder suggestion and its known economic, social, and/or ecological impacts in other areas of the country. Modes of transportation (transport pathways) that were selected as the primary means by which NIS would be transported to the study area from the source (B.C.) were commercial trucks, trains, garden escapes, freight containers, freight, freshwater boats and equipment, and marine boats, ballast, and equipment.

Habitats that were selected for inclusion in the risk assessment included the major natural habitat types of Washington State: forest, shrub steppe, grassland, lakes, rivers, wetlands, riparian, estuarine, intertidal and marine habitats, as well as agricultural and urban habitats created by human influenced land use practices. The assessment endpoints at risk were that were selected were: Douglas fir (*Pseudotsuga menziesii*), Taylor's Checkerspot butterfly (*Euphydryas editha taylori*), Great Blue Heron (*Ardea herodias*), Dungeness crab (*Cancer magister*), hay crops, cattle, water quality, and urban gardens and parks.

The RRM results indicated that the transport pathway with the highest risk was freshwater recreational boats, which had a higher relative risk score than the next three highest scores, freight, trucks, and ships, combined. Pathways with the lowest risk were containers, garden escapes, and trains. The heavy weight of the freshwater pathway was driven by the fact that all three high risk NIS stressors were freshwater species; zebra mussel, purple loosestrife (semi-aquatic) and Eurasian watermilfoil. The fact that all three freshwater NIS were ranked as high risk NIS due to their aggressiveness in out-competing native species heavily influenced the other risk scores (risk to endpoints, habitats, and subregions). For instance, subregions with higher amounts of freshwater habitats tended to have high risk scores also. The subregion of highest risk, the King-Snohomish-Pierce Tri-County region, has many freshwater boating locations; however, the risk score was also heavily influenced by the mere fact that as the urban hub of Washington, this subregion accommodates high volumes of all the various transportation modes, providing direct linkages (pathways) to other regions.

Monte Carlo uncertainty analysis revealed high uncertainty regarding mechanisms of NIS transport, as well as regarding the specific effects NIS had on the Great Blue Heron. Additionally, a high degree of model uncertainty came from geographic information systems (GIS) datasets which were used in this analysis. Further research, especially on mechanisms of transport, will aid future risk assessments of this type and improve natural resource manager’s abilities on both sides of the border to prevent NIS introductions in the most cost effective manner possible.

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INTRODUCTION

A non-indigenous invasive species (NIS) is defined as a species living beyond its natural range or natural zone of potential dispersion, including all domesticated, feral, and hybrid species, that has the potential to pose undesirable or detrimental impacts on humans, animals, or ecosystems (Elston, 1997; Invasive Plant Council of British Columbia, 2004). Impacts of NIS can be economic, ecological, or cultural. Economic impacts include lost revenue when NIS impede or destroy crops such as hay, wood products, or shellfish, decreased property values (British Columbia Ministry of Agriculture and Lands, 2006; Kevin Hupp, personal communication, 2006), and increased monitoring and control costs for regulated species (Pimentel et al., 2000). Ecological impacts include displacement of native species through competition or interference with trophic interactions and alteration of ecosystem processes such as erosion, accretion, and nutrient cycling (Mack et al., 2000; Mooney and Cleland, 2001; Simberloff, 1996). Cultural and social impacts include reduced aesthetics, civic pride, and enjoyment in the surrounding landscape and reduced recreational or cultural usage of the natural resources (Bureau of Land Management).

Incongruities exist between policies in British Columbia and Washington regarding NIS prevention and control. Regulated NIS species of concern vary on either side of the border (Regional Invasive Species Task Force, 2003). Therefore, a species may be strictly controlled on one side of the border but allowed to persist on the other side. This incongruity creates the potential for continuous introduction of NIS across the border. Alternatively, species that are regulated on both sides of the border may be inadvertently transported in freight, in personal belongings, or attached to vehicles, ships, or recreational equipment (Ruiz et al., 2000; Campbell and Kriesch, 2003).

Increasing efforts are being made to encourage and facilitate cooperation across international boundaries to prevent and control NIS. The creation of the "*Weeds Across Borders*" conference, which focuses on international NIS policy, and the Cross Borders Project, a local collaboration between weed management agencies in the Okanogan region of Washington and British Columbia, highlight this effort.

Risk assessments are commonly used in predicting the establishment and impacts of NIS. However, risk assessment procedures typically address only species on a small geographic scale and are often qualitative, not quantitative, in nature (Mantas, 2003; U.S. Department of Agriculture, 2004).

The Relative Risk Model (RRM) was developed to evaluate multiple, dissimilar stressors simultaneously and comparatively at landscape scales (Landis and Wiegers, 1997; Wiegers et al., 1998). Although originally designed to assess risk of chemical stressors in Port Valdez, AK, it has been adapted to accommodate biological stressors as well (Colnar and Landis, 2007; Landis *et al.*, 2005) and has been applied to many different study areas, including Cherry Point, WA (HartHayes and Landis, 2004; Landis et al., 2000; Markiewicz et al., 2001) the Willamette and McKenzie rivers in Oregon (Luxon and Landis, 2005), the lower Androscoggin watershed in Maine (Pfingst, 2006), and the Brazilian rain forest reserve (Moraes *et al.*, 2005).

The objectives of this study were to conduct an ecological risk assessment (ERA) to 1) evaluate the mechanisms and pathways by which certain NIS are introduced and transported across the United States and Canadian borders in Washington State, and 2) quantify and calculate the potential risks they pose to shared resources in the marine, aquatic, and terrestrial ecosystems across an integrated regional-scale landscape. The specific questions this study was to answer were:

- Which modes of transport pose the highest risk for NIS transport and establishment?
- Which NIS stressors pose the greatest risk?
- Which geographic locations are at highest risk from NIS transported by the various transportation modes?

- What endpoints are at highest risk from NIS stressors?
- What habitats are at greatest risk from NIS stressors?

This information could be helpful to decision-makers and resource managers in developing strategies to prevent and control NIS on both sides of the border.

METHODS

An ecological risk assessment (ERA) was conducted using the Relative Risk Model (RRM) developed by Wiegers et al. (1998) and adapted for use in assessing risks posed by invasive species (Chen, 2007; Colnar and Landis, 2007; Pfingst, 2006).

Problem Formulation

Study Area

The study area was defined as the east-west length of the Washington border with British Columbia, including approximately the lower third of British Columbia to the north and the upper two-thirds of Washington State (**Figure 1**) to the south. For the purposes of this study, Washington was considered the receiving area and divided into seven sub-regions along county borders, whereas B.C. was considered the source of NIS stressors and designated as one subregion that included Vancouver Island to the west.

Stakeholder Outreach and Input

Stakeholder input was solicited at the onset of the investigation to ensure that the project and results were meaningful to policy-makers and resource managers. Stakeholders were defined as decision-makers, managers, experts, and concerned citizens who had some stake in prevention, management, and/or control of invasive species in British Columbia or Washington State. Stakeholders in federal, state/provincial, county/regional district, and local/municipal occupations as well as Tribes/First Nations, experts (academics and professionals) and non-governmental organizations (NGOs) were contacted by e-mail, fax, or phone calls. The requested information was of three types: 1) terrestrial, freshwater, or marine invasive species of concern; 2) important flora, fauna, sensitive habitats or ecosystem functions that should be included in the ERA to protect from invasive species; and 3) any datasets, contacts, or other information that would help identify additional stressors or endpoints, or otherwise help to document stressors' transport, establishment, and effects on valued endpoints.

Over 150 stakeholders were contacted and 34% responded. Responses varied widely in content and detail. Many responses listed invasive species of concern; several listed other people to contact, but only a few named endpoints at risk. All responses were incorporated into the Problem Formulation Phase, evaluated, and either incorporated into the Conceptual Model or eliminated from further consideration.

Sources of Stressors

Sources of stressors usually have a high level of uncertainty associated with them because: 1) it is difficult and costly to identify, monitor, map and update sources of NIS populations and their spatial distributions; 2) regulatory agencies and governing bodies have varying resources to complete these tasks within the different jurisdictional areas, and may have varying levels of interest in doing so; and 3) NIS populations are often recorded in the field as GPS point locations, which do not describe the extent or density of the populations.

Potential source populations of NIS can be categorized into four major groupings: those within their native ranges, established populations in B.C., established populations in Washington, and populations outside the study area. In this study, source populations outside the study area were excluded. Moreover, while it is recognized that NIS could be transported from a number of sources (including sources within Washington), sources were restricted to known or estimated NIS populations in the British Columbia portion of the study area. The only exception was for the zebra mussel, which is not currently established in B.C. It was included in the assessment to determine its potential transport pathways into Washington State and the potential risks it could pose to the selected assessment endpoints. Data collected from Midwestern United States, specifically from the Great Lakes region, and from eastern Canada were used.

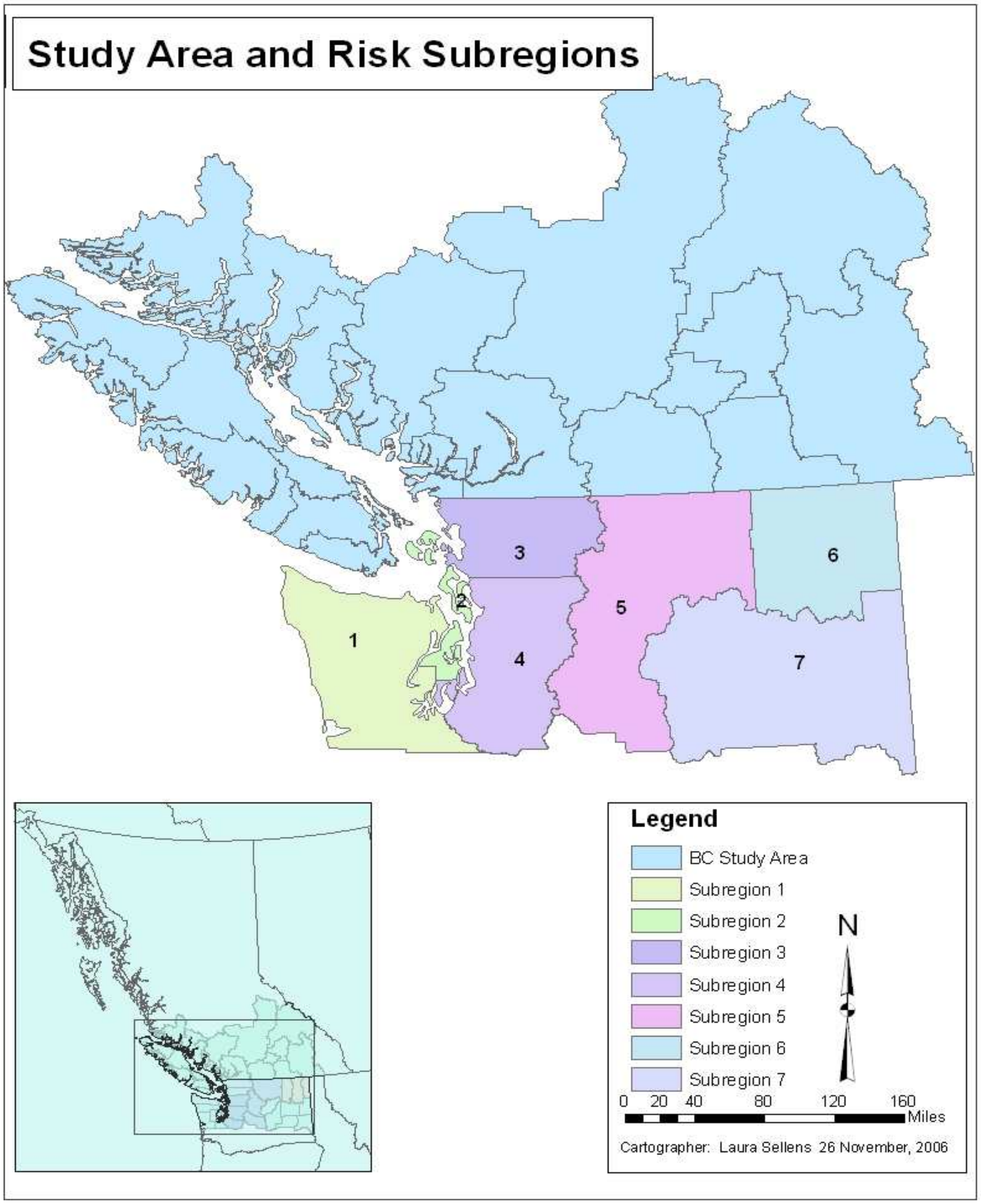

Figure 1. Study area and risk subregions.

Stressors (NIS)

Stressors were selected from the compiled list of species suggested by the stakeholders based on the level of concern (the number of times they were suggested), or for which there were available data. Stressor selection was also guided by including those NIS that could serve as a representative of a specific group of NIS that utilized or resided in a specific habitat type identified in the study area. The final eight NIS stressors that were selected for inclusion in the Conceptual Model and risk assessment were: spotted knapweed (*Centaurea stoebe*), Scotch broom (*Cytisus scoparius*), purple loosestrife (*Lythrum salicaria*), Eurasian watermilfoil (*Myriophyllum spicatum*), zebra mussel (*Dreissena polymorpha)*, *Spartina* (*Spartina anglica*), European green crab (*Carcinus meanas*), and the colonial tunicate *Didemnum* sp A. All these stressors are present in B.C. except for the zebra mussel, as stated above, which was included as a prospective species due to its well-documented economic, social, and/or ecological impacts in other areas of the country.

It should also be noted that Washington stakeholders specifically recommended *Spartina alterniflora* for inclusion in the ERA analysis, since it is a problematic species in the state; however there are only confirmed populations of *Spartina anglica* present in B.C., not *Spartina alterniflora* (Community Mapping Network, 2007). Since B.C. is the source area in this assessment, *S. angelica* was selected for inclusion. A description of each stressor follows.

Spotted Knapweed

Spotted knapweed (*Centaurea stoebe* L., also known as C. *biebersteinii* DC and *C. maculosa* Lam.) is a short lived perennial native to Eastern Europe and Asia (Wilson et al., 2003). It is highly adapted to disturbance (Roche et al., 1986) and has slight allelopathic qualities which may contribute to its success as an invader (Bais et al., 2002; Bais et al., 2003). Spotted knapweed is associated with open, fairly dry habitats including rangelands (Roche et al., 1986), grasslands (Duncan 2001) open forests, sagebrush and along (Zouhar, 2001) railroads and roadsides (Meier and Weaver (1997). Historical specimen collections indicate that spotted knapweed may have been first introduced to Victoria, B.C. in 1893 as a contaminant of alfalfa seeds shipped from Asia Minor or Germany (Maddox, 1982). However, it is suspected of having been transported in ship ballast water as well (Roche and Talbott, 1986). Although it was originally introduced on the west side of the Cascade Mountains, rapid infestation on the east side may have predominantly come from Montana, where it is very widely established (Roche et al., 1986). As of 2000, it is estimated to have infested 50,000 acres in B.C. and 500,000 acres in Washington (Duncan, 2001).

Potential mechanisms of transporting spotted knapweed include trucks, trains, the surfaces of their associated shipping containers, and within freight shipments such as contaminated hay or seed, live cattle, and gravel or fill dirt (Kevin Hupp, personal communication, 2006; USDA Forest Service, 2006).

Impacts of spotted knapweed infestations include displacement of native vegetation, crop, or forage vegetation of economic value, reduced quality of livestock forage and, consequently, loss of beef production (B.C. Ministry of Agriculture and Lands, 2006). Specifically it can reduce the production, quality, and sale price of hay crops, reduce forage for and production of cattle livestock, displace native vegetation for the Taylor's Checkerspot butterfly, and reduce aesthetic quality and increase weed control cost in gardens and parks, including non-urban parks such as National Forests. As a result spotted knapweed is estimated to result in an annual economic loss of $400,000 CD from reduced hay production (B.C. Ministry of Agriculture and Lands, 2006).

Spotted knapweed is listed as a priority invasive plant in B.C. (B.C. Ministry of Agriculture and Lands, 2006) and is regulated in Washington as a Class B noxious weed, which means it is designated for control in areas where it is not already widely established (Washington State Noxious Weed Control Board, 2006). It is listed on the Pacific Northwest

Economic Region's Priority Threat List as a priority invasive species in B.C. (Regional Invasive Species Task Force, 2003). The plant can be controlled by pulling it out by its roots, reducing areas of exposed bare soil, using biological control agents, or by herbicide applications (B.C. Ministry of Agriculture and Lands, 2006).

Scotch Broom

Scotch broom (*Cytisus scoparius* L. Link) is a perennial shrub that can form dense stands along roadsides, in grasslands, open forests rangeland, and (Prasad 2002) riparian areas (Parker, 2000; Zouhar, 2005). Scotch broom was initially introduced in 1850 by intentional planting in a garden (Pojar and MacKinnon 1994). It has more recently been planted along roadsides and railroad rights-of-way as a groundcover (Bill McArthur, personal communication, 2007; Zouhar, 2005). Today, it is still considered by some to be a desirable garden shrub despite its weedy characteristics, and is available for purchase primarily through online vendors (Anonymous, 2006). Scotch broom is widely established, mainly on west side of Cascades, from B.C. to California (Pojar and MacKinnon, 1994).

Impacts of Scotch broom include displacement and crowding of native vegetation, especially to the unique flora of Pacific Northwest prairie ecosystems e.g., Garry Oaks (Meyers et al., 2004; Pojar and MacKinnon, 1994; Zouhar, 2005). It also has the potential to change soil chemistry by fixing nitrogen in areas that do not normally have nitrogen fixing plants (Zouhar, 2005). Specific impacts to assessment endpoints include displacing native flora, including those plants species critical for Taylor's Checkerspot survival (Parker et al., 1997; Murray and Jones, 2002; Vaughan and Black, 2002), reduced aesthetic quality and increasing weed control costs in gardens and parks, and crowding saplings in recently planted forest stands (Bill McArthur, personal communication, 2007; Prasad, 2002)

Scotch broom is regulated under RCW Chapter 17.10 and WAC Chapter 16-752 in Washington as a Class B noxious weed (Washington State Noxious Weed Control Board, 2006). It is listed on the Pacific Northwest Economic Region's Priority Threat List as a priority invasive species in B.C. (Regional Invasive Species Task Force, 2003). It can be controlled by pulling, cutting, burning, mulching, insect biocontrol, or herbicide application (Prasad, 2002).

Purple Loosestrife

Purple loosestrife (*Lythrum salicaria* L.) is a perennial forb that grows to 2 meters tall in roadside ditches, river banks, wetlands, brackish and freshwater marshes, wet meadows and sloughs at low elevations (Lindgren, 2003; Pojar and MacKinnon, 1994). It can spread by seed, rhizomes, or vegetative propagules (Thompson et al., 1987). It is unknown when it was originally introduced to New England, but it was most likely first introduced via ship ballast, with continual inoculations from the same source (Thompson et al., 1987). Purple loosestrife was well established in northeast coastal wetlands by the 1830's, spread rapidly across the North American continent (Thompson et al., 1987), and is now widely distributed across Washington (Washington State Noxious Weed Control Board 2006) and in southern B.C. (Klinkenberg, 2006).

Transport pathways include trucks, trains (Sharon Sorby, personal communication, 2006), freight i.e., in wildflower seed mixes or as illegal horticultural imports via online commerce, freshwater boats and garden escapes (Thompson et al., 1987).

General impacts of purple loosestrife include domination and infill of wet habitats, restriction of water flow and degradation of waterfowl habitat (Blossey et al., 2001; Schooler et al., 2006; Thomspon et al., 1987). Pimentel et al. (2000) estimate the costs to control it in the U.S. to be $45 million annually. Specific effects include displacement of native species in gardens and parks, changes in trophic interactions of the Great Blue Heron, ecosystem function through reduction of water flow in aquatic habitats, and water quality by altering decomposition rates and nutrient cycling.

Purple loosestrife is regulated under RCW Chapters 17.10 and 17.26 and WAC Chapters 16-752 and 16-752-400 as a Class B noxious weed, (Washington State Noxious Weed Control Board 2006). It is listed on the Pacific Northwest Economic Region's Priority Threat List as a priority invasive species in both B.C. and Washington (Regional Invasive Species Task Force, 2003). The preferred method of control of this species is insect biocontrol since this plant is usually situated near water resources where herbicide application is restricted or discouraged (Sharon Sorby, personal communication, 2006).

Eurasian Watermilfoil

Eurasian watermilfoil (*Myriophyllum spicatum* L.) is an aquatic perennial plant that grows from seeds, rhizomes and plant fragments in lakes, sloughs, slow streams and rivers (Pojar and MacKinnon, 1994). The date of its original introduction from Eurasia is unknown, but the earliest specimen from Washington was collected in 1965 (Washington Department of Ecology, 2006). It is present in many water bodies on both sides of the Cascades in B.C. and Washington (Klinkenberg, 2006; Washington Department of Ecology, 2006).

Eurasian watermilfoil was sold for many years as an aquarium plant and may have been initially introduced to the environment when improperly disposed. It has also been intentionally planted in the past; however its main mechanism of transport currently is on boat trailers. The distribution of Eurasian watermilfoil in Washington State is closely correlated with the Interstate highway system, indicating that propagules are transported by boats and boats trailers and find suitable habitats along roadways where they rapidly become established (Washington Department of Ecology, 2006). Even dried fragments can remain viable and spread in new areas if they become rehydrated (Okanogan Noxious Weed Control Board). Modes of transportation are via recreational freshwater boats, in freight as packing materials, inadvertent hitchhikers with other aquatic horticulture plants, or illegal purchase online (Maki and Galatowitsch, 2003).

The impacts of Eurasian watermilfoil include changes in water quality, restricting recreation, restricting water flow in dams and irrigation systems, displacing native biota or impacting their food sources (Washington Department of Ecology, 2006). Specific effects include changes in native plant populations in urban gardens and parks, trophic interactions with Great Blue Heron and its prey, and ecosystem function by affecting water quality.

The costs of control of Eurasian watermilfoil in Washington are estimated at $1 million annually (Washington Department of Ecology, 2006). It is regulated under RCW Chapters 17.10 and 17.26 and WAC Chapters 16-752 and 16-752-400 as a Class B noxious weed (Washington State Noxious Weed Control Board 2006). It is listed on the Pacific Northwest Economic Region's Priority Threat List as a priority invasive species in B.C. (Regional Invasive Species Task Force, 2003). It can be controlled by herbicide, underwater mowing or rotovation, biocontrol, and shading (Sharon Sorby, personal communication, 2006).

Zebra Mussel

The zebra mussel, *Dreissena polymorpha* (Pallas, 1771) is a small mussel with a concave or flat bottom, averaging 2.3-2.5 cm long with varying patterns of stripes or solid albino, brown or black (Claudi and Mackie, 1994). It aggressively establishes in freshwater systems, especially impoundment areas with moderate pH, (Allen and Ramcharan, 2001), and adequate calcium (Benson and Raikow, 2006). Zebra mussel was first introduced in the late 1980's to the Great Lakes from the Black Sea through ballast water of a marine cargo ship (Benson and Raikow, 2006.). Zebra mussels are currently well established and widespread throughout the Great Lakes and Midwest region in Canada and the United States. The nearest known established population to Washington is in South Dakota (Benson and Raikow, 2006), however, monitoring programs in California and Washington have identified zebra mussels attached to boats on trailers several times (Benson and Raikow, 2006; Washington Department of Fish and

Wildlife, 1999). At present, the dominant mode of human-mediated transport of zebra mussel is on boats and trailers. Studies indicate it can stay alive for several days out of water under the right temperature and humidity conditions. It is also possible for it to be shipped undetected in water garden plants, fish or in their packing materials (Washington Department of Fish and Wildlife, 1999).

General impacts include fouling, clogging and of water pipes, changing water quality, ruining boats by clogging engine cooling systems, altering trophic interactions among native species and altering habitats (Benson and Raikow, 2006). Economic costs to U.S. industry and businesses are estimated at $100 million annually (Pimentel et al., 2000). Specific effects include changes in distribution or abundance of native species in gardens and parks; trophic interactions for Great Blue Heron; ecosystem function through alteration of water quality; and habitat suitability through ecosystem engineering.

The zebra mussel is considered an aquatic nuisance species in Washington and is regulated as such under RCW Chapter 77.12.875 and WAC Chapters 232-12-016, 232-12-01701 and 232-12-271. It is listed on the Pacific Northwest Economic Region's Priority Threat List as a priority invasive species in Washington but not B.C. (Regional Invasive Species Task Force, 2003).

Spartina

Spartina, *Spartina anglica* (C.E. Hubbard) is one of several non-indigenous species. *S. alterniflora*, *S. densiflora*, *S. patens* are generally referred to collectively as *Spartina* due to their similarities in morphology and impact. *S. anglica* is a hybrid between *S. alterniflora* and *S. marina* (Thompson, 1991). It is a perennial grass that grows to almost 2 meters tall and spreads by seed, rhizomes, and colonization of plant fragment. It grows in clumps of increasing size on tidal mudflats (Whatcom County Noxious Weed Control Board). *Spartina anglica* was introduced to Washington intentionally for erosion control (Hacker et al., 2001). It is currently found in several sites around the Fraser River Delta and a few areas farther north in the Strait of Georgia (Community Mapping Network, 2007). As of 2000, *S. anglica* was established at 76 sites in the Puget Sound (Hacker et al., 2001).

Modes of transport for *S. anglica* include marine ships, including their ballast water, and inclusion in freight as packing material or as an unnoticed hitchhiker. Shipments that could include *Spartina* are live or fresh marine species such as fish, bait, or aquaculture products.

Potential impacts include sediment accretion (Thompson 1991) and associated changes in physical structure of the environment, alteration of trophic interactions and primary production, and reduction in habitat used by shellfish (Hacker et al., 2001) and shorebirds (Western Aquatic Plant Management Society, 2004). Specific effects include changes in native populations in gardens and parks, habitat suitability for native species in gardens and parks, trophic interactions for Great Blue Heron and Dungeness crab, ecosystem function through ecosystem engineering (e.g., changing gradient, channelization, and infill of mudflats), and water quality by changing water flow.

All four (nonindigenous) *Spartina* species are regulated under RCW Chapters 17.10 and 17.26 and WAC Chapters 16-752 and 16-752-500 through 16-752-525. It is listed on the Pacific Northwest Economic Region's Priority Threat List as a priority invasive species in Washington but not B.C. (Regional Invasive Species Task Force, 2003). Manual removal, excavation, burial and herbicide are all used currently to control *Spartina* in Washington, whereas B.C. only uses mechanical methods. Control efforts have been successful in reducing the abundance of *Spartina* from the Fraser River Delta, Willapa Bay, Gray's Harbor, and Puget Sound (Ducks Unlimited Canada, 2006; Murphy et al. 2007). The Fraser Delta *Spartina* program cost $134,877CD in 2005 for monitoring and control (Ducks Unlimited Canada, 2006), and the Washington costs in 2006 were $1,518,320 (Murphy et al. 2007).

European Green Crab

The European green crab, *Carcinus meanas* (Linnaeus, 1758) is a medium sized crab with maximum carapace width of four inches. It can be identified not by its color, which can vary from green to yellow to red depending on its life stage, but by its characteristic five spines on either side of the eyes (Washington Department of Fish and Wildlife, 2002). They inhabit the nearshore intertidal and subtidal areas, as well as estuaries (Jamieson et al., 2002). Although it arrived on the east coast in the early 1800's, the first documented introduction on the west coast was in 1989 in San Francisco Bay. It is thought to have been transported from the east coast via ballast water or in packing materials of live marine species. From San Francisco, the European green crab has traveled via currents up the west coast to Washington and B.C. (Jamieson et al., 2002; Washington Department of Fish and Wildlife, 2002).

Transportation vectors for green crabs include marine shipping and its associated ballast water and as hitchhikers in freight such as live seafood or bait.

General impacts are predation on or displacement of native or commercially important species (Lohrer and Whitlatch, 2002; Walton et al., 2002). In Washington and B.C. there is particular concern that it will negatively impact the multimillion dollar commercial shellfish industry. The European green crab out-competes Dungeness crab for prey in similar size classes (P. Sean McDonald, personal communication, 2006). Specific effects include changes in distribution or abundance of Dungeness crab, other native species found in gardens and parks, and trophic interactions of Dungeness crab and Great Blue Heron.

The European green crab is regulated under RCW Chapter 77.12.875 and WAC Chapters 232-12-016, 232-12-01701 and 232-12-271. It is listed on the Pacific Northwest Economic Region's Priority Threat List as a priority invasive species in Washington but not B.C. (Regional Invasive Species Task Force, 2003). It is controlled by manual removal (Washington Department of Fish and Wildlife, 2002).

Colonial Tunicates *Didemnum sp*. A

Colonial tunicates (*Didemnum* sp. A) are taxonomically indistinct species. *Didemnum* sp. A is so called because taxonomists have not yet discerned whether the species found in Washington and B.C. is the same as other similar invasive colonial tunicates found around the globe including New England, northern Europe, New Zealand, and Japan, or a different species that has become established. It is a tan, yellow to pinkish sea squirt that grows in colonies which form dense lobed mats or ropes. *Didemnum* spreads through release of larvae into the water column and by colony fragmentation (Bullard et al., 2007; Cohen, 2005). It grows on hard natural or artificial substrates in marine habitats to depths of 65m (Cohen, 2005). It has been observed in the low intertidal zone as well (Bullard et al., 2007). *Didemnum* was first collected on the West Coast in 1993 at San Francisco Bay and spread to areas of Puget Sound and the Strait of Georgia by 2004 (Cohen, 2005).

Didemnum is thought to have been introduced by ballast water, hull fouling, or in shellfish stock (Cohen, 2005). Transport mechanisms include marine ships and as freight e.g., as seafood and/or packing materials.

General impacts include smothering of native and commercially important species, blocking or obstructing water distribution and filtration systems, and altering habitats by covering surfaces (Bullard et al., 2007; Dijkstra et al., 2007; Osman and Whitlatch, 2007). *Didemnum* is unpalatable to many creatures, possibly because its external surface is acidic or it may produce chemical deterrents (Bullard et al., 2007).

Potential impacts to endpoints include changes in native species populations in (marine) gardens and parks, trophic interactions for Dungeness crab and Great Blue Heron by smothering or displacing prey, habitat suitability through covering of surfaces, and water quality by restricting filtration.

Didemnum sp. A is regulated under RCW Chapter 77.12.875 and WAC Chapters 232-12-016, and 232-12-271. A similar species in New Zealand, *D. vexillium* was successfully controlled underwater by chlorine treatments in an enclosed space and by being smothered with sand. On land, pressure washing has also been effective (Coutts and Forrest, 2007). In Edmonds, Washington control of *Didemnum* sp. A was achieved with chlorine treatments (Lambert, 2005).

Modes of Transportation - Transport Pathways

Many vectors for the transport of NIS exist. The Invasive Species Advisory Committee Invasive Species Pathways Team compiled an exhaustive list of transport pathways, which they grouped into three categories: 1) transportation related pathways, 2) "living" industry pathways, and 3) miscellaneous pathways (Campbell and Kriesch, 2003). Transportation pathways include commercial, personal, and military transport as freight, food, equipment, and pets via land air, or water. Pathways may also include attachment on the outer surface of vehicles or containers e.g., hull fouling or as inadvertent component of ballast water and packing materials (Campbell and Kriesch, 2003).

"Living" industry pathways include shipments of live food (e.g., seafood, plant foods, and livestock), aquaculture, pets, aquarium species, bait, non-pet animals such as organisms for research and the associated potential for hitchhikers in these shipments (Campbell and Kriesch, 2003).

Other miscellaneous pathways include anthropogenic waterways such as canals and locks, minimally processed animal and plant products such as forestry products (logs, firewood, wood chips), hay, or hides, ecosystem disturbances that facilitate NIS introductions such as logging, land clearing, development, and habitat restoration activities, and natural dispersal by wind, water, or animals (Campbell and Kriesch, 2003).

The focus of this study was on transportation related pathways. The modes of transportation by which human activities specifically encourage NIS widespread distribution (excluding air) were first categorized into five groups: 1) terrestrial; 2) aquatic; 3) freight-related; 4) intentional releases; and 5) disturbance-related. The specific modes of transportation utilized in each category were then described in detail as follows:

1) Terrestrial modes are:
    a. vehicles and trains used for personal, recreational, commercial, governmental, and agricultural uses; and
    b. humans themselves, including clothing, personal equipment, baggage, and pets.

2) Aquatic modes related to marine and freshwater environments are:
    a. boats, including ballast water, holds, internal and external surfaces and equipment; and
    b. man-made waterways, including locks, dams, canals, and pipes.

3) Freight-related modes are:
    a. freight containers and stowaways,
    b. packing materials, and
    c. freight itself (for example, invasive nursery plants).

4) Intentional releases are varied; examples include:
    a. garden escapes and biocontrol releases.

5) Disturbance-related modes include:
    a. road, rail, and utility rights-of-way.

After evaluating each of the categories and modes of transportation the following modes were selected for inclusion in the final Conceptual Model and risk assessment: commercial trucks, trains, garden escapes, freight containers, freight, freshwater recreational boats and equipment, marine boats, ballast, and equipment. Gardens escapes were included as an example of an intentional introduction with unintended effects.

Habitats

Vegetative habitats were identified in the study area using USGS North America Land Cover GIS data and depicted as a data layer on a map of the study area. Similar vegetative cover types such as open and closed shrub steppe, varieties of grasslands, and varieties of forests were grouped to obtain five main habitat types:

1) Shrub steppe;
2) Agriculture and crop/vegetation mosaic;
3) Grassland and savanna;
4) Urban and built-up; and
5) Water bodies.

A snow, ice, and barren vegetation grouping is also depicted on the map but was not included in the final Conceptual Model as a habitat type. Marine and freshwater habitats (rivers, riparian zones, wetlands, estuaries, and near-shore and inter-tidal marine zones) were added to the final vegetative layer for a complete representation of pertinent habitats identified in the study area. The habitat categories selected for inclusion in the Conceptual Model and final risk assessment represent the major natural habitat types of Washington State: forest, shrub steppe, grassland, lakes, rivers, wetlands, riparian, estuarine, intertidal and marine habitats. Agricultural and urban land uses were also included in the Model and ERA because they comprise major areas of land in Washington State and are distinctly different from less managed habitats.

Endpoints

Endpoints were defined in this study as species, land uses, and environmental qualities that reflect economic, cultural, social, or ecological values to be protected. In soliciting stakeholder input very few endpoints were recommended for inclusion in the risk assessment. As a result a list of potential endpoints that inhabited and/or utilized each of the selected habitats in the study area was compiled. The endpoints were then categorized into groups based on relevance and relationship to economic, cultural, social, or ecological values as follows:

1) Economic Values (major resource-based industries of Washington and British Columbia)
    a. Agriculture hay crops,
    b. Cattle (dairy) livestock,
    c. Forestry products, and
    d. Shellfish

2) Ecological Values (and Services)
    a. Water quality

3) Social values (for example, threatened and endangered species, aesthetic values) were:

a. Sage grouse (listed as threatened by the Washington Department of Fish and Wildlife (1998) and as a species of special concern by the US Fish and Wildlife Service (2005),
b. Taylor's Checkerspot butterfly (candidate for federal listing as endangered (2002),
c. Puget Sound Chinook (listed as threatened 1999),
d. Great blue heron
e. Lingcod, and
f. Urban gardens and parks

A series of interviews were then conducted with NIS managers, as well as a review of natural resource management agencies' and non-governmental organizations' websites to obtain their input on these proposed endpoints. Using that process the stakeholders were able to define more clearly their values and recommend specific endpoints to include in the assessment that would help them address their decision-making needs and management goals. For example, the Garry Oak habitat is a sensitive ecosystem of concern in both B.C. and Washington and was recommended by several stakeholders for inclusion in the assessment. In reviewing the list of valued species found only in the Garry Oak ecosystem the Taylor's Checkerspot butterfly (*Euphydryas editha taylori*) was identified as potentially at risk from NIS establishment, as well as a candidate for federal listing as endangered. It therefore could serve as a representative (indicator) species of a unique and valued habitat type present in Washington State, as well as of ecological importance to the stakeholders.

Applying the same methodology the eight endpoints selected for inclusion in the final Conceptual Model and risk assessment were hay crops, cattle livestock, the Taylor's Checkerspot butterfly (*Euphydryas editha taylori*), urban gardens and parks, Douglas fir (*Pseudotsuga menziesii* (Mirbel) Franco), Great Blue Heron (*Ardea herodias* Linnaeus, 1758), water quality, and Dungeness crab (*Cancer magister* Dana, 1852). A description of each is as follows:

Hay crops and cattle are in the top ten agricultural commodities of Washington State, with 2005 revenues of $366 million for hay and $601 million for cattle. Hay crops are primarily grown on the east side of the Cascades, however some hay farming occurs of the west side as well. Likewise cattle production occurs on both sides of the Cascades but predominates on the east side (Washington State Department of Agriculture, 2006).

Taylor's Checkerspot butterfly (*Euphydryas editha taylori*) is a small butterfly endemic to the Garry Oak savannah ecosystem of southwestern B.C., Washington, and northern Oregon. Its forage and refuge is specific to several floral species that are specific to this ecosystem, which has been extensively developed, leaving tiny fragments of suitable habitat for the remaining Taylor's Checkerspot butterfly. The current population is found in three areas of South Puget Sound (namely, Fort Lewis Air Force Base), in the Willamette Valley of Oregon, and possibly one small patch in San Juan County. It is extinct in B.C. This minimal distribution has led to a petition on its behalf for emergency listing as a protected species under the Endangered Species Act (Vaughan and Black, 2002).

Gardens and parks, including municipal, county, state, and national parks in terrestrial, aquatic and marine habitats, are culturally, ecologically, and economically important in Washington. The Washington landscape is an icon of the Pacific Northwest and source of civic pride. Urban gardens and parks provide refugia for native flora and fauna, and therefore are an important repository for biodiversity, highly valued by stakeholders. In addition to the intrinsic value of native residents, gardens and parks are the locations where important ecosystem functions are carried out, such as water and nutrient cycling, and highly prized destination locations for recreation. Approximately $400 million was spent on travel (a proxy for tourism) by visiting Canadians in 2006, whereas total travel spending in Washington was estimated at $13.8 billion (Washington State Department of Community, Trade and Economic Development, 2006).

Douglas fir (*Pseudotsuga menziesii*) is a large, long-lived tree that can grow to 70m tall. It is native to Washington and B.C. (Pojar and MacKinnon, 1994). It is a dominant forest species west of the Cascades, but is also present in Ponderosa pine forests east of the Cascades. Douglas fir is an important species in Washington forestry (Bill McArthur, personal communication, 2007).

The Great Blue Heron (GBH) (*Ardea herodias*) is a common but charismatic bird, perhaps because it is large and easily identified by its slate-grey color, 1.5m wingspan and characteristic long neck, legs and beak. In March 2003, the Seattle City Council made the GBH the Official Bird of Seattle. It can be found in or near estuaries, rivers, lakes, mature forests, wetlands, meadows, or mudflats. The diet of the GBH can come from a variety of sources; fish amphibians, reptiles, invertebrates, small birds and small mammals. In the winter, voles are an especially important food source. In Washington it is most common in the nearshore areas of Puget Sound, but may be found year-round across the state in major wet areas such as river drainages (Seattle Audubon Society, 2006).

Water quality includes physical, chemical, and biological parameters in freshwater and marine environments. Clarity, nutrient content, dissolved oxygen, and flow are the characteristics most likely to be altered by the NIS stressors selected for inclusion in the Conceptual Model and risk assessment, which in turn can have undesired effects on the selected endpoints. Water quality is also important for biogeochemical processes, native biota, human health, commerce, and recreation. Inclusion of water quality as an endpoint also serves as a reminder that endpoints are not necessarily biotic; endpoints are whatever stakeholders care about.

Dungeness crab *Cancer magister)* is large crab of significant economic importance. The 1999-2000 season produced revenues of $34.8 million for Washington (Hansen, 2001). It is included in the assessment as a representative shellfish for both its economic importance, as well as its cultural importance to First Nations and Tribes (Northwest Indian Fisheries Commission). Dungeness crab use estuarine as juveniles and shift to marine habitats as adults (Rooper et al. 2001). They also forage in intertidal habitats as subadults (Holsman et al., 2006; Rooper et al. 2001).

Effects

For the purposes of this preliminary risk assessment, only direct measurable effects caused by the various NIS were selected for inclusion in the ERA to facilitate comparisons of the relative risks posed by the NIS stressors to the endpoints. The broad-based categories of effects selected were quantifiable changes in:

1) Size or distribution of endpoint populations;
2) Trophic interactions as represented by declines in forage or prey populations;
3) Habitat quantity and/or quality for endpoint species;
4) Ecosystem function as represented by changes in water or soil quality, and
5) NIS source populations, establishment of new populations.

These broad categories were used to reflect stakeholder concerns, increase comparability of risks between dissimilar stressors, and to put the results into a "big picture" context that may be of use to decision-makers and resource managers.

Specific impacts of these effects include loss of revenue from crops, livestock, wood products, shellfish, and visitation of gardens and parks; decreased property values, reduced cultural value, civic pride, and aesthetic enjoyment of the landscape, altered ecosystems and habitats, increased cost to control the NIS of concern, and increased magnitude of these impacts as more source populations become established (Elston, 1997; Kevin Hupp, personal communication, 2006).

Conceptual Model

The final step in the Problem Formulation Phase of the ERA is to create a Conceptual Model that provides a schematic diagram showing the potential linkages between identified sources of stressors, stressors, habitats, and endpoints in relation to potential exposure and effects pathways. The Conceptual Model helps to consolidate data and information from a variety of sources, as well as provide a means to evaluate whether there is a probability of risk to the valued endpoint(s). For conditions of risk to exist (**Figure 2**), a source must release a stressor that is carried via an exposure pathway to a suitable habitat where an endpoint also occurs, and then affect the endpoint in some way.

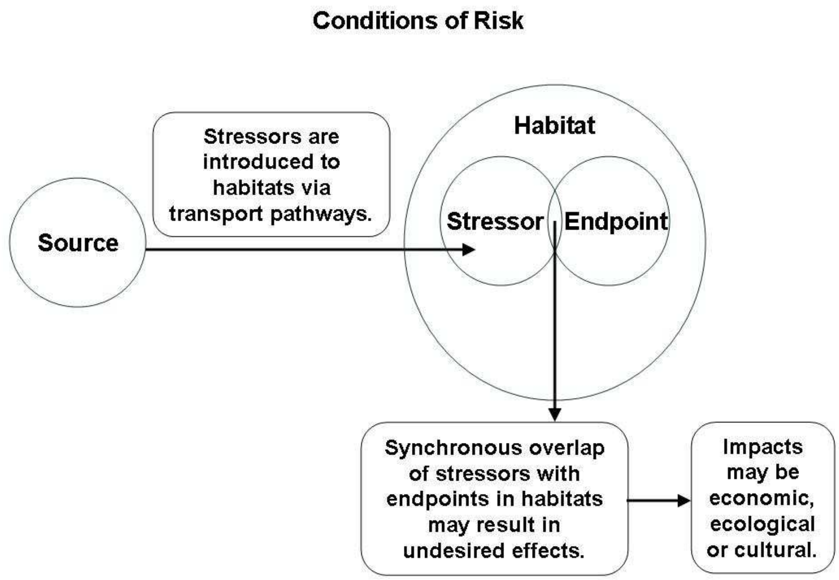

Figure 2. The conditions of risk.

Using these criteria, the data and information gathered during the review of the scientific literature, from interviews and surveys of stakeholders, and by conducting site visits to verify the data were compiled into an initial Conceptual Model. The initial lists of sources of NIS stressors, specific NIS stressors, modes of transportation, habitats, and endpoints in the diagram were comprehensive and detailed. Through further research and stakeholder input several of the sources, stressors, habitats, modes of transportation, and endpoints were redefined or eliminated from the model (**Figure 3**). To make the final Conceptual Model easier to read it was divided into eight separate sub-models, one for each final Conceptual Model (**Figure 3**) to make it less confusing, however they were depicted in each of the NIS stressor-specific Conceptual Models (**Figures 4-11**). The red lines in the final Model, as well as in the sub-models indicate the compounding nature of biological invasions as a new source is created by each successive establishment of NIS (**Figures 4-11**).

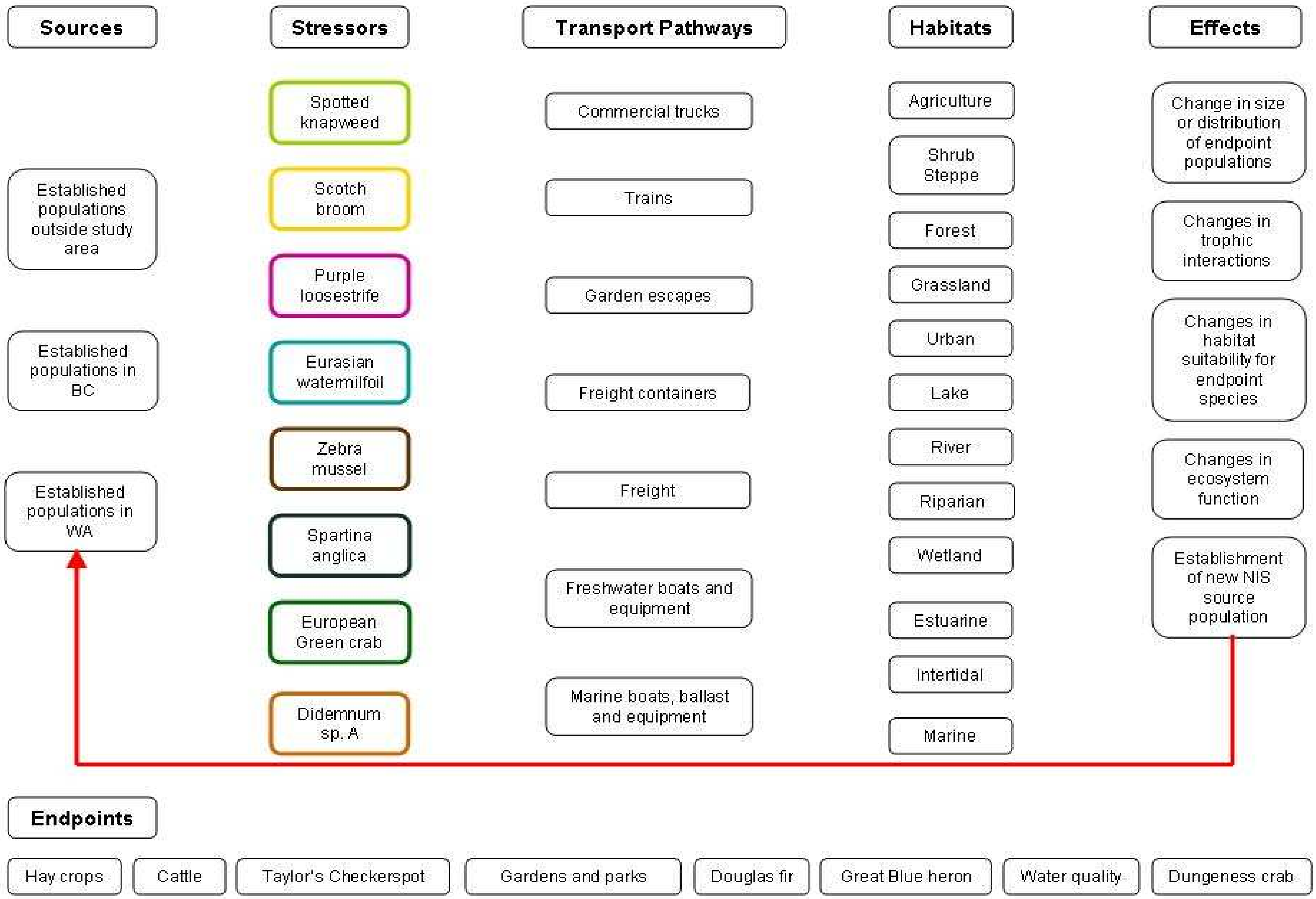

Figure 3. Final Conceptual Model listing components selected for inclusion in the risk assessment. Lines showing linkages between components are not shown.

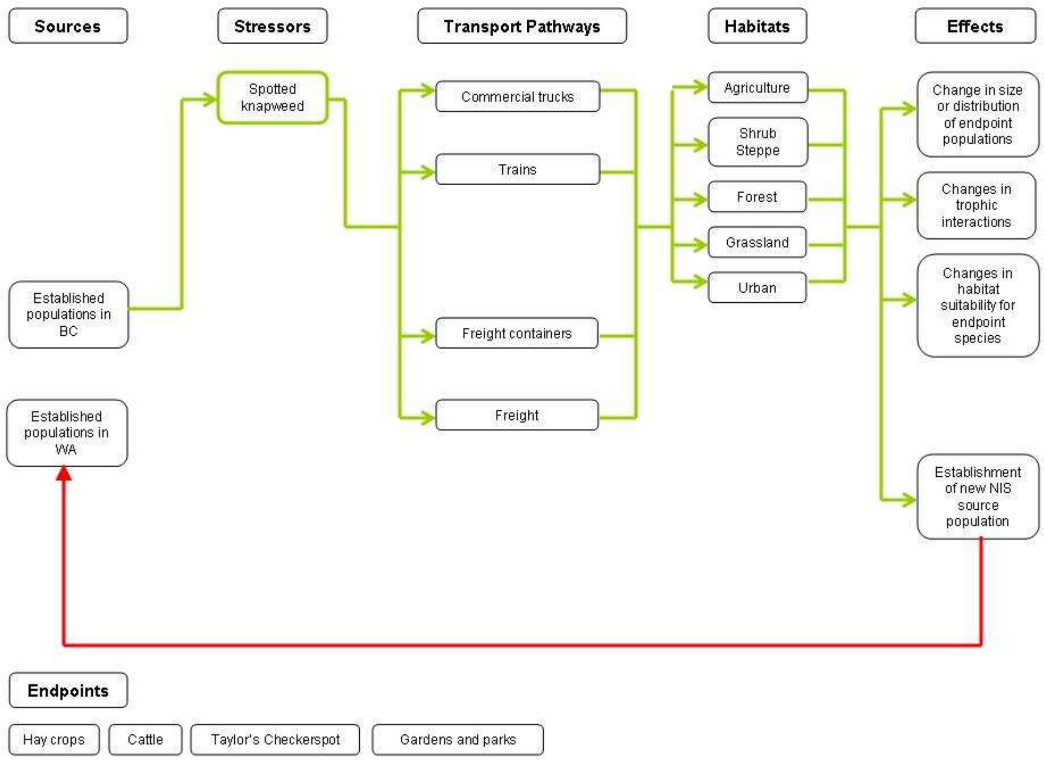

Figure 4. Conceptual Model for spotted knapweed. Lines indicate complete pathways, i.e., potential risk to endpoints listed at bottom of figure.

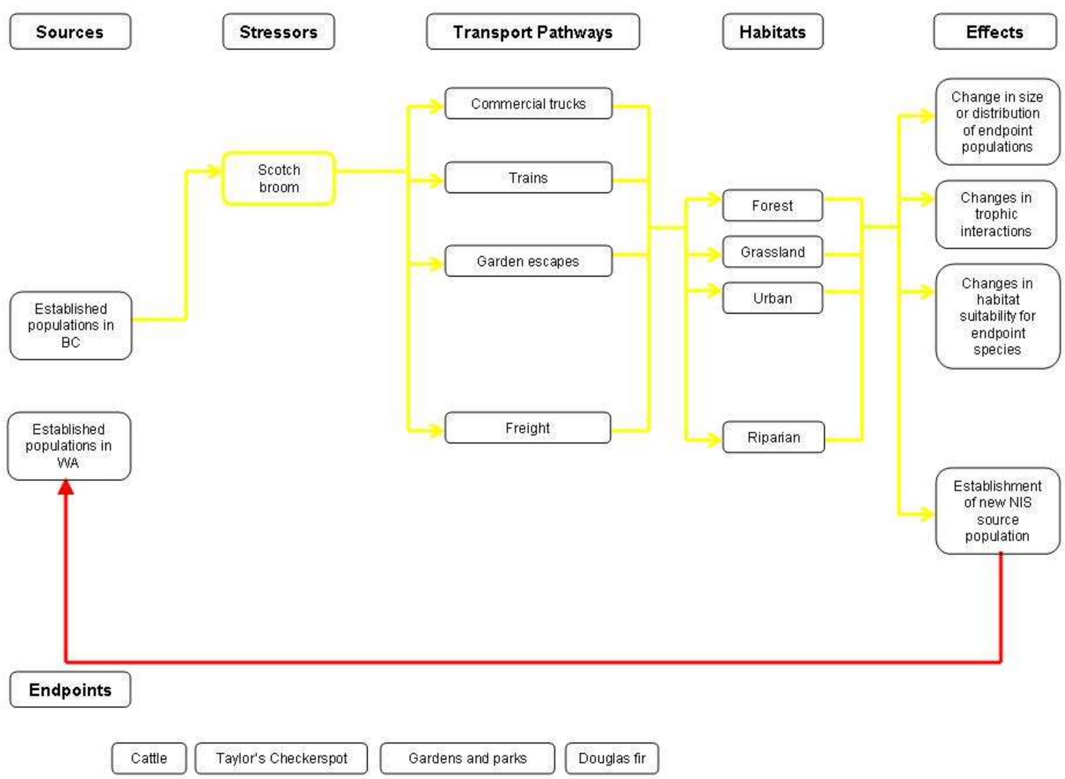

Figure 5. Conceptual Model for Scotch broom.

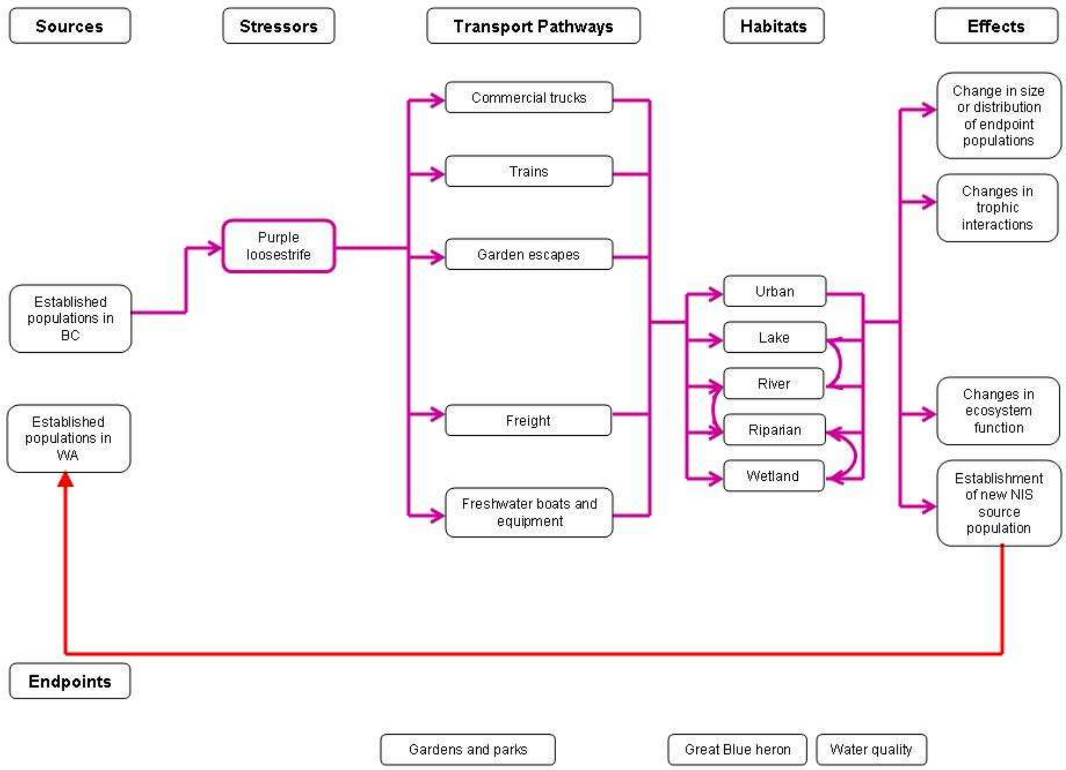

Figure 6. Conceptual Model for purple loosestrife.

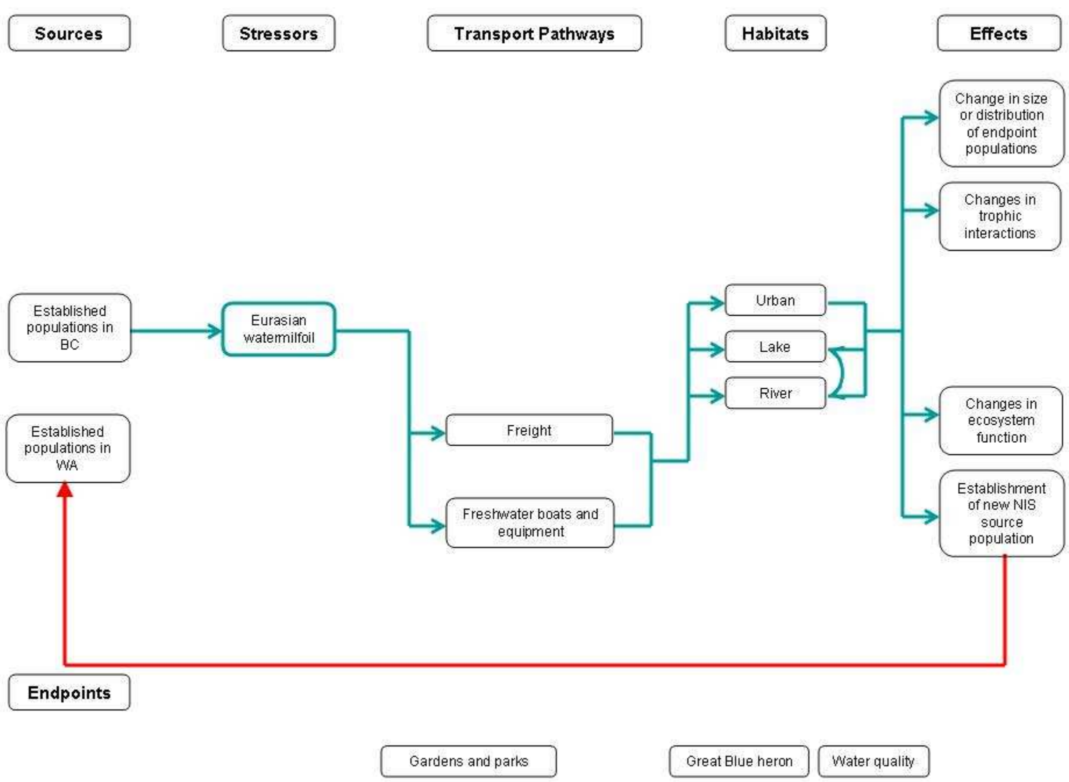

Figure 7. Conceptual Model for Eurasian watermilfoil.

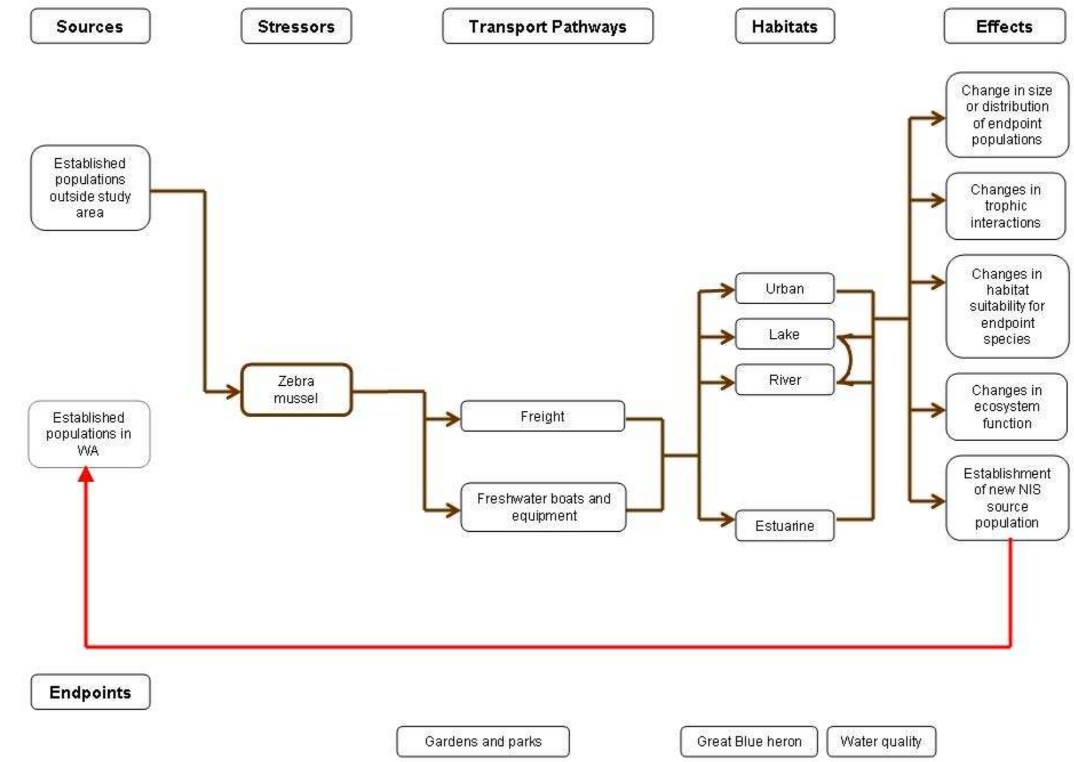

Figure 8. Conceptual Model for zebra mussel.

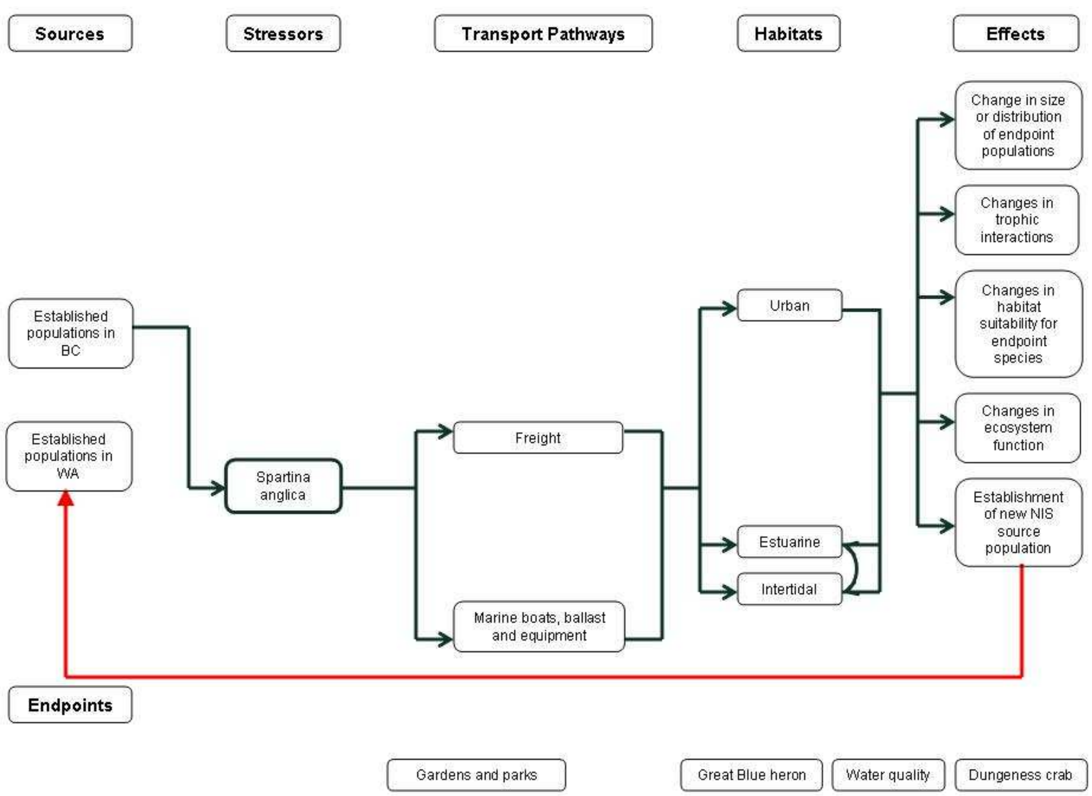

Figure 9. Conceptual Model for Spartina.

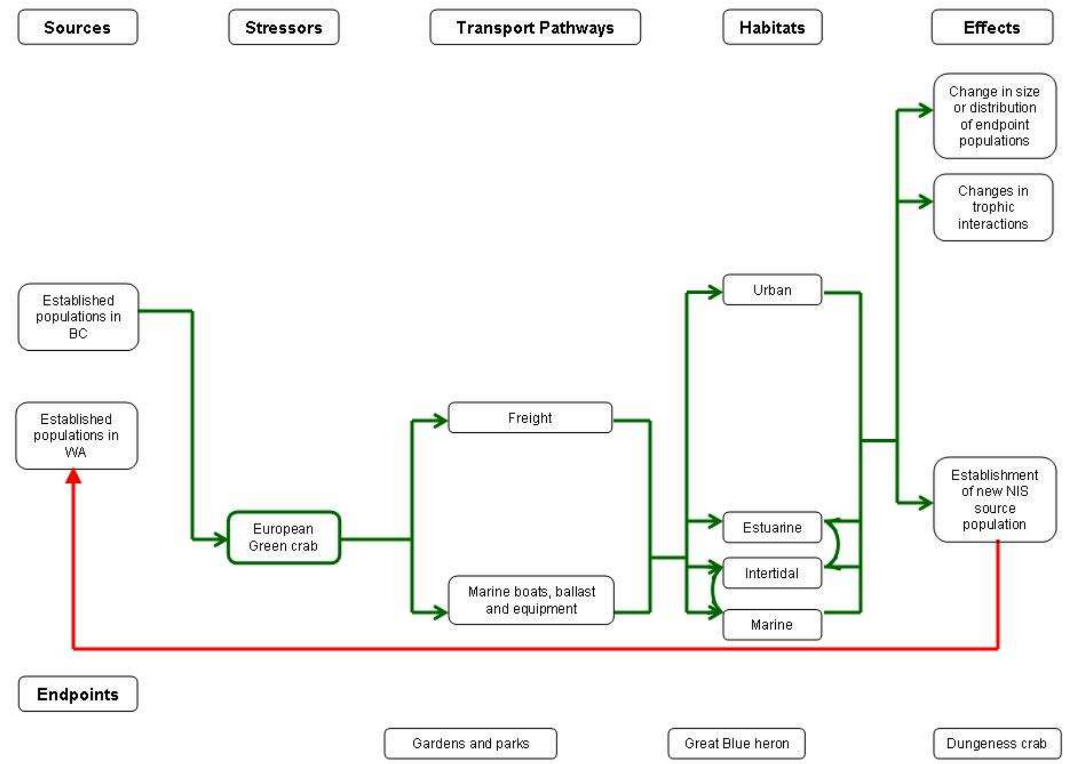

Figure 10. Conceptual Model for European green crab.

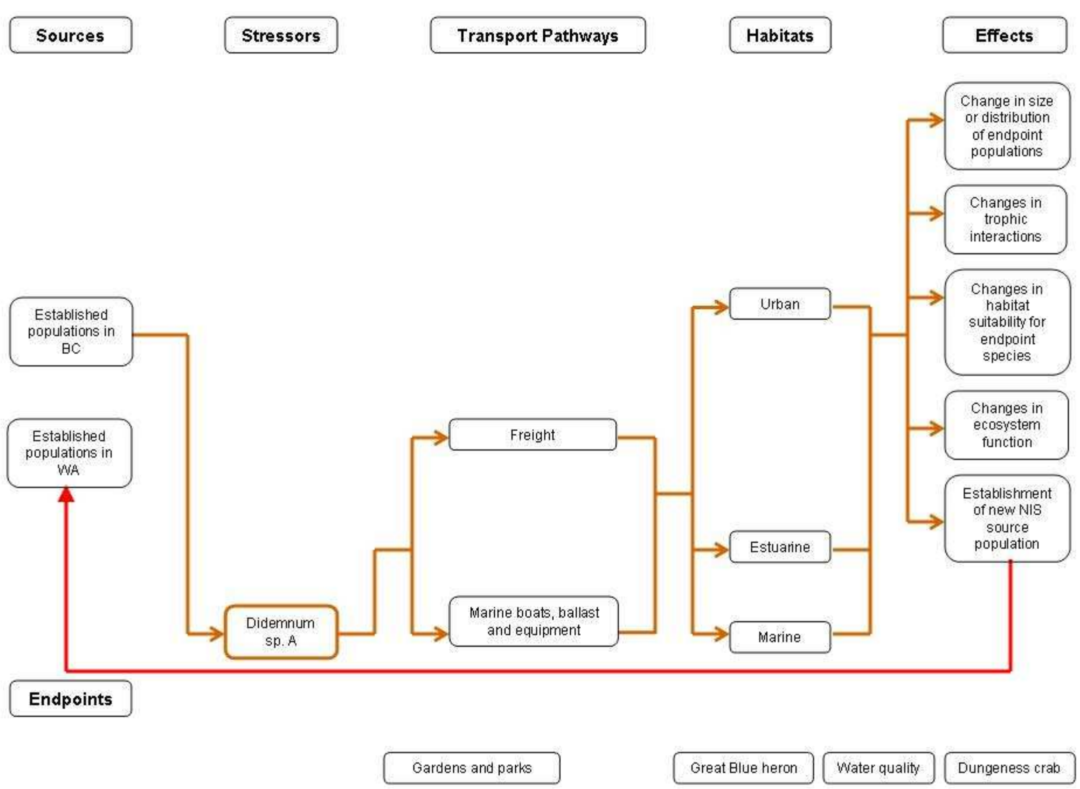

Figure 11. Conceptual Model for the tunicate, *Didemnum* sp. A.

Analysis Phase

Relative Risk Model (RRM)

Risk calculation using the RRM approach consists of ranking the importance of sources, transport pathways, habitats and the impacts to endpoints in the Conceptual Model to calculate the risk of dissimilar stressors relative to each other. Ranks also enable the quantification of risk contributed by each source, transport pathway, habitat, and impact relative to the final risk score determined for each subregion in the study area. Ranks are determined based on criteria selected for the type of data used (**Table 1**) and can have values of 0, 2, 4, or 6, where 0 indicates no risk and 6 indicates high risk (Landis, 2005). Ranks can also be assigned based on probability to cause an impact to occur and based on a scale of 0, 1, 2, 3, 4, or 5 where 0 indicates no probability whereas 5 indicates a likely probability to cause an impact to occur (Landis et al., 2000).

Table 1. Specific criteria for ranks in the Relative Risk Model and underlying assumptions in ranking scheme.

Component	Criteria for ranking	Values	Assumptions
Source rank	Presence/absence of source in B.C.	0, 6	All source populations will release viable stressors. Hypothetical source for zebra mussel.
Transportation rank	Volume of each type of transportation in each subregion	0, 2, 4, 6	
Habitat rank	Area of each type of habitat in each subregion	0, 2, 4, 6	
Impact rank	Magnitude of impacts each stressor has on each endpoint	0, 2, 4, 6	If a stressor affects an endpoint in more than one way the magnitude of effect will be greater.

These rankings are weighted, or filtered, using a series of yes/no questions, called exposure filters and effect filters. The questions are designed to quantify the likelihood of a) exposure of the stressor to the endpoints in a habitat and b) the stressor causing the impacts to the endpoint that were listed in the Conceptual model. Filters modify the risk estimates according to the amount of overlap that exists between the ranked components. Filter questions are designed based on factors that could limit or facilitate exposure of the stressors to the endpoints and the effects they could impose (**Table 2**). Filters are assigned values of 0, 0.5 or 1, depending on the answer (no, maybe/depends, yes) to the question based on scientific data, observations, site visits, stakeholder input, and professional knowledge (Landis, 2005).

Data Sources

Due to the timeframe, scale, and limited funding of this project it was not possible to conduct data generating field surveys or experiments, but rather to rely on pre-existing available data. As a result, data availability, quality, and specificity varied widely for each component used in the risk assessment and affected the uncertainty associated with each risk calculation. Source ranks were determined by presence or absence of source populations of the eight NIS stressors in B.C., with the exception of the zebra mussel that was designated as being in B.C. though in reality it was not present there, so it could be used in the model. Presence of the sources was confirmed by the most recent distribution map or documentation available. Spotted knapweed, Scotch broom, purple loosestrife, and Eurasian watermilfoil distribution maps were obtained from E-Flora BC (Klinkenberg, 2006). The distribution map for *Spartina anglica* was provided by the Spartina Research Drift Card mapping website (Community Mapping Network, 2007). The European green crab presence was confirmed in the Report of the Commissioner of the Environment and Sustainable Development (Office of the Auditor General of Canada, 2002). The distribution map for *Didemnum* was prepared by the Woods Hole Science Center (U.S. Geological Survey, 2007). As a result of the NIS populations being mapped differently by different agencies with regard to extent, density, and number of individuals, it was not possible to rank source populations by size using the two-point scale used in other invasive species risk assessments using the RRM.

Table 2. Specific criteria for filters in the Relative Risk Model and underlying assumptions.

Component	Yes/no questions	Values	Assumptions
Exposure filter A	Is the stressor carried by the transport pathway?	0, 0.5, 1	
Exposure filter B	Is the habitat within transport distance?	0, 0.5, 1	Due to the short distance between B.C. and Washington state propagules will still be viable upon arrival.
Exposure filter C	Does the transport pathway pass through the habitat?	0, 0.5, 1	
Exposure filter D	Is the habitat suitable for the stressor?	0, 0.5, 1	Major habitats are similar in B.C. and Washington, so NIS from B.C. should be well suited to Washington habitats and become established.
Exposure filter E	Are prevention methods effective against transport?	0, 0.5, 1	NIS are continually introduced to Washington, therefore prevention methods allow transport.
Exposure filter F	Are control methods effective against establishment?	0, 0.5, 1	
Effect filter 1	Does the endpoint use the habitat?	0, 0.5, 1	
Effect filter 2	Do the stressor and endpoint co-occur temporally?	0, 0.5, 1	
Effect filter 3	Does the stressor affect the endpoint?	0, 0.5, 1	

Transportation ranks estimated the volume of traffic crossing the border by each transport pathway using the two-point scale. There are several very detailed traffic surveys describing vehicle crossing data (Canadian Council of Motor Transport Administrators, 2002; U.S. Department of Transportation Federal Highway Administration, 2006; Whatcom Council of Governments, 2001; U.S. Department of Transportation, Research and Innovative Technology Administration), however, each one was found to be lacking specificity in some regard. The most notable data gaps in these datasets were specific destinations and routes of travel. Since one of the goals of the project is to analyze the risks associated with travel routes in specific locations, these data gaps rendered several of the datasets unusable. Data on cross-border transportation of railroad, freshwater boating and marine shipping were likewise absent.

Therefore, traffic volumes were estimated in each subregion using available Washington State data with the assumption that transportation volume of each pathway type from B.C. would be proportional to total transportation volume of each pathway type in Washington.

The transportation ranks for truck, railroad, freshwater boats, marine shipping, and garden escape pathways were ranked by subregion using GIS analysis. Truck volume ranks were obtained from the Washington State Freight and Goods Transportation System dataset for State highways (Washington State Department of Transportation Workbench, 2006). Truck volumes for short road segments were reported in this dataset. Railroad volume ranks came from Washington State Department of Transportation's Railroads Active in Washington State dataset (Washington State Department of Transportation GIS Implementation Team, 1996). Freight volume was not reported in this dataset, so railroad freight volume was estimated using length of active track operated by Class 1 railroads (BNSF and Union Pacific), which also have active tracks extending into B.C. Class 1 railroads outperform smaller railroads with respect to freight volume, as well as revenue and were considered to be a reasonable proxy.

Freshwater boat volume ranks came from the Motorized Boat Launch and Public Moorage Facilities in Washington State dataset (Washington State Interagency Committee for Outdoor Recreation, 2003) with the assumption that freshwater boating traffic is proportional to the number of public boat launches. Marine shipping volume ranks came from the U.S. waterborne container trade by U.S. custom ports, 1997-2005 dataset (U.S. Department of Transportation, 2006) with the assumption that marine shipping volume is proportional to the revenues generated by marine shipping. Freight ranks were derived from averaging the trucking, railroad, and marine shipping ranks and ranking those averages. Container ranks, which were only used for calculating risk for terrestrial pathways, were derived in the same way as freight ranks, but using only the trucking and railroad ranks. Garden escape ranks were came from the 2000 Census Urbanized Areas, Washington State dataset (Washington State Office of Financial Management, 2002) with the assumption that garden escapes were proportional to the number of gardens in a subregion, which are proportional to the amount of urbanized area within the subregion.

The habitat ranks for agriculture, shrub steppe, forest, grassland, lake and riparian habitats were derived from the Washington GAP Project dataset (Cassidy, 1997). Habitats were extracted from the dataset using the descriptions of "primary habitat type" included in the dataset. Since the endpoint related to agriculture (hay crops) is only found in hay fields, polygons with other descriptions (orchards, row crops, etc) were excluded from the agricultural dataset. The forest habitat rank was limited to recently logged, disturbed, or reforested young forest in areas where Douglas fir was likely to be a dominant species. The exclusion of mature Douglas fir forests was important because Scotch broom, the stressor able to impact the Douglas fir endpoint, can only impact young saplings by crowding and shading. It does not impact older forests.

Urban, wetland, river, estuary, intertidal, and marine habitat ranks were derived from datasets other than the GAP dataset that were either more specific, more recent, or included habitats not found in the GAP dataset. Urban ranks were obtained from the 2000 Census Urbanized Areas of Washington State dataset (Washington State Office of Financial Management, 2002). Wetland and estuary habitat ranks were derived from the National Wetland Inventory dataset (U.S. Fish and Wildlife Service, 2006). Freshwater wetlands were extracted from this dataset, but excluded riverine and lake wetlands. Similarly estuarine wetlands data were also extracted, but excluded freshwater wetlands. River habitat ranks were assigned based on data from the Washington Department of Ecology Major Rivers of Washington Plus dataset (2003). Area of river habitat was not provided in the dataset so length of river segments in each subregion was used as a proxy. Intertidal habitat was ranked by subregion based on the amount of shoreline within the subregion (National Oceanic and Atmospheric Administration Special Projects Office, 1994). Marine habitat ranks were derived from the Bathymetry and Elevation of Puget Sound dataset (Finlayson et al. 2000). Area of subtidal habitat from 0-65m depth was used to assign these ranks because the stressor *Didemnum* has not been found below that depth and 65m is inclusive of the depth range at which the marine endpoint Dungeness crab is found (40m).

Exposure Filters

Exposure filter 1: the ability for the transport pathway to carry the stressor was determined by documented studies of the transport pathway when available, or by accounts of previous introductions and by analysis of propagule qualities such as size, fragmentation, stickiness, weight, and mechanism of seed dispersal.

Exposure filter 2: the viable transport distance for stressors, was assumed to be adequate given the short distance between B.C. and the subregions in the study area, as well as the short turn around time of modern shipping.

Exposure filter 3: the intersection between the transport pathway and the habitats was assessed per subregion by overlaying the transport pathways with the habitats in GIS. Large areas of overlap were given filter values of 1, minor areas of overlap were given filter values of 0.5, and areas of no overlap had filter values of zero.

Exposure filter 4: habitat suitability for the stressor was determined by life histories of the specific NIS stressor. The major habitat types of Washington are largely similar to those of B.C. so it was considered likely that stressors coming from B.C. into Washington would be well suited to habitats found there. Furthermore, most of the stressors in the study already occur in Washington, proving habitat suitability.

Exposure filter 5: prevention methods were assumed to be ineffective, since there are constant introductions of NIS to Washington on an annual basis. All the stressors in the Conceptual Model are regulated in Washington State against introduction. However, the influx of vehicles is so large and propagules of NIS are so small and challenging to identify, that inspection for NIS is like trying to "needle in a haystack". Moreover, public pressure to keep wait times down at border crossings probably limits the likelihood of thorough inspections. Finally, the shift in authority at the border from the U.S. Department of Agriculture to the Department of Homeland Security has likely affected the priorities of inspectors and possibly the degree of understanding about NIS issues, as well as the ability of inspectors to identify regulated species (Doyle, 2006).

Exposure filter 6: control methods were assessed using recent, local accounts of control measures and their associated success. In Washington, none of the stressors included in the assessment have been entirely eradicated once established, so all filter values were either 0.5 or 1. In cases where stressors have been limited in their spread, or where major portions of their distributions have been controlled, filter values of 0.5 were assigned. In cases where control efforts have not reduced stressor populations, filter values of 1 were assigned.

Effect Filters

Effect filter 1: habitat use by the endpoint was determined by current distribution maps of biotic endpoints in Washington and by NIS life history information. An estimate of rangeland available for livestock was derived from the ICBEMP range allotments dataset for Washington (Interior Columbia Basin Ecosystem Management Project, 1995). Location of gardens and parks was determined from the Washington State Department of Natural Resources major public lands dataset (Washington State Department of Natural Resources, 2005).

Effect filter 2: temporal overlap was determined based on life history strategies of stressors and biotic endpoints. The only NIS stressor that actively moves to occupy different habitats is the European green crab, however the endpoints it interacts with, Dungeness crab and Great Blue Heron, are also mobile and occupy overlapping ranges of habitats.

Effect filter 3: stressor effects on endpoints were well documented for some species, hypothesized for others, or totally absent in the case of the Great Blue Heron. Documentation of endpoints or the habitats they use being affected by NIS was common, but it was less often that the particular NIS species were listed, perhaps because many habitats contain several NIS that produce high risk scores due to their combined cumulative effect in the risk calculation. In the scientific literature few studies unequivocally proved the effect of NIS species on the endpoints selected for use in the Conceptual Model. In the absence of documentation or as a supplement to it, expert opinions were obtained from professionals with knowledge of the endpoint in question.

Risk Characterization Phase

Risk Calculations

Each pathway connecting source, stressor, mode of transport, habitat, subregion, endpoint, and effect was calculated individually using the ranks and filters described above. Applicable ranks and filters were multiplied to estimate the risk for each possible combination. At this stage, incomplete pathways in the Conceptual Model dropped out of the overall calculation because one or more zeros in the calculation resulted in no risk score for that particular combination. The remaining combinations with risk scores were summed by adding the stressor, mode of transport, habitat, subregion, and endpoint scores together for that complete or partially complete exposure/effect pathway. Calculating each combination individually allowed easy verification of each calculation, identified the relative importance of each combination to the overall risk estimate, and isolated combinations of particular interest for further study.

Uncertainty Analysis

Since a preliminary risk assessment relies on existing data it was expected that data gaps would exist. Data gaps and the assumptions made necessary by them introduce uncertainty into the model. Uncertainty was measured by using Monte Carlo uncertainty analysis. The data used in every component in the model were evaluated in terms of low, medium, or high uncertainty according to set criteria (**Table 3**). Probability distributions were created for ranks (**Table 4**) and filters (**Table 5**) that describe the likelihood that an assigned value is correct, and if incorrect what values are likely to be correct. For example, if a habitat rank was assigned a value of 4 in the RRM matrix and had medium associated uncertainty (because one assumption was made in valuating the rank), there was expected to be a 80% chance the true value was a 4, a 10% chance it was a 2, and 10% chance it was a 6. Low uncertainty was assigned to values that used site specific data with no data gaps or assumptions. Therefore, probability distributions were not assigned to values with low uncertainty since the chance that the assigned rank or filter value is correct was close to 100%.

Table 3. Criteria used to designate uncertainty levels in Monte Carlo uncertainty analysis.

Uncertainty Level	Criteria
Low	1. Data are site specific
Medium	1. Data are not site specific
	2. One assumption made
High	1. No data
	2. More than one assumption made
	3. Two medium criteria

Once probability distributions were assigned to every rank or filter with associated uncertainty, the model was recalculated using Crystal Ball® simulation software (Decisioneering, Inc., 2000), a macro program used in conjunction with Microsoft® Excel spreadsheets. The software recalculates the risk scores using random combinations of values from the probability distributions. The simulation was set to undergo 3,000 trials, as in Colnar and Landis (2006). The result of the Monte Carlo simulation is a distribution indicating the overall uncertainty of the risk calculation, and a range of values the overall risk estimate could have given the associated uncertainty.

Table 4. Probability distributions for possible rank values at given uncertainty levels.

Assigned Rank	Uncertainty Level	Probability Distribution of Possible Ranks 0	2	4	6
0	Low	100	0	0	0
	Medium	80	10	10	0
	High	60	20	20	0
2	Low	0	100	0	0
	Medium	0	80	10	10
	High	0	60	20	20
4	Low	0	0	100	0
	Medium	0	10	80	10
	High	0	20	60	20
6	Low	0	0	0	100
	Medium	0	10	10	80
	High	0	20	20	60

Table 5. Probability distributions for possible filter values at given uncertainty levels.

Assigned Filter	Uncertainty Level	Probability Distribution of Possible Filters		
		0	0.5	1
0	Low	100	0	0
	Medium	80	10	10
	High	60	20	20
0.5	Low	0	100	0
	Medium	10	80	10
	High	20	60	20
1	Low	0	0	100
	Medium	10	10	80
	High	20	20	60

Sensitivity Analysis

One of the objectives of the assessment is to identify important data gaps, so that future research can address those gaps according to their importance, thereby reducing uncertainty in future assessments. This is done with Sensitivity Analysis. Sensitivity Analysis is another output function of the Crystal Ball® software. After quantifying the overall uncertainty in the risk calculations, the software computes the importance of each uncertain term. The result is a chart showing the percentage of uncertainty each term contributes to overall model uncertainty.

RESULTS

Risk Scores

The mode of transportation with the highest risk score was freshwater recreational boats. The score for freshwater boats was almost three times higher than the next three highest pathways, freight, marine ships, and trucks, combined (**Figure 12**). Scores for trains, garden escapes, and containers were much lower, indicating little associated risk to those transport pathways. The highest risk stressors (**Figure 13**) were zebra mussel, Eurasian watermilfoil, and purple loosestrife. The only stressor with medium risk was Scotch broom. The remaining stressors, spotted knapweed, *S. anglica*, European Green crab, and *Didemnum* sp. A were all low risk.

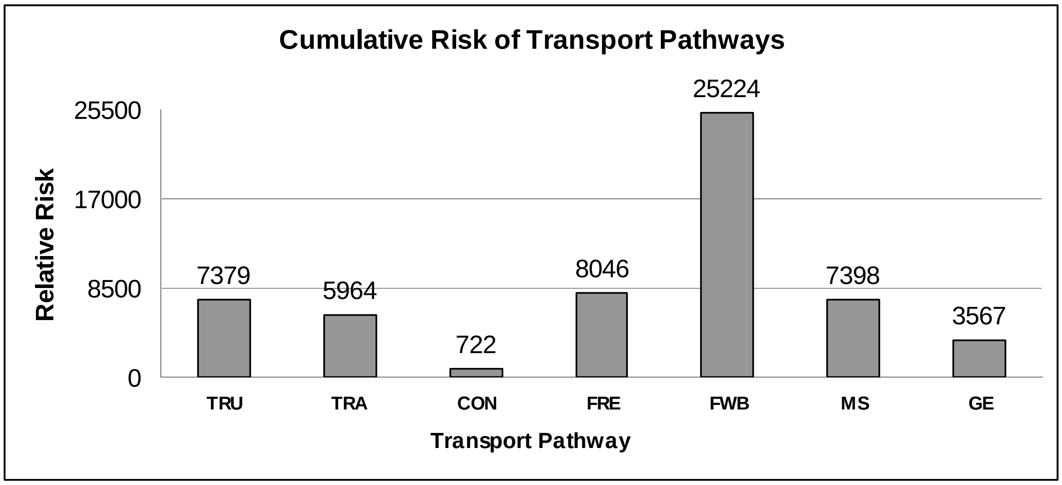

Figure 12. Relative risk scores for transport pathways. Gridlines approximate thresholds for high, medium, and low risk. Abbreviations: TRU, trucks; TRA, trains; CON, containers; FRE, freight; FWB , freshwater boats; MS, marine ships; GE, garden escapes.

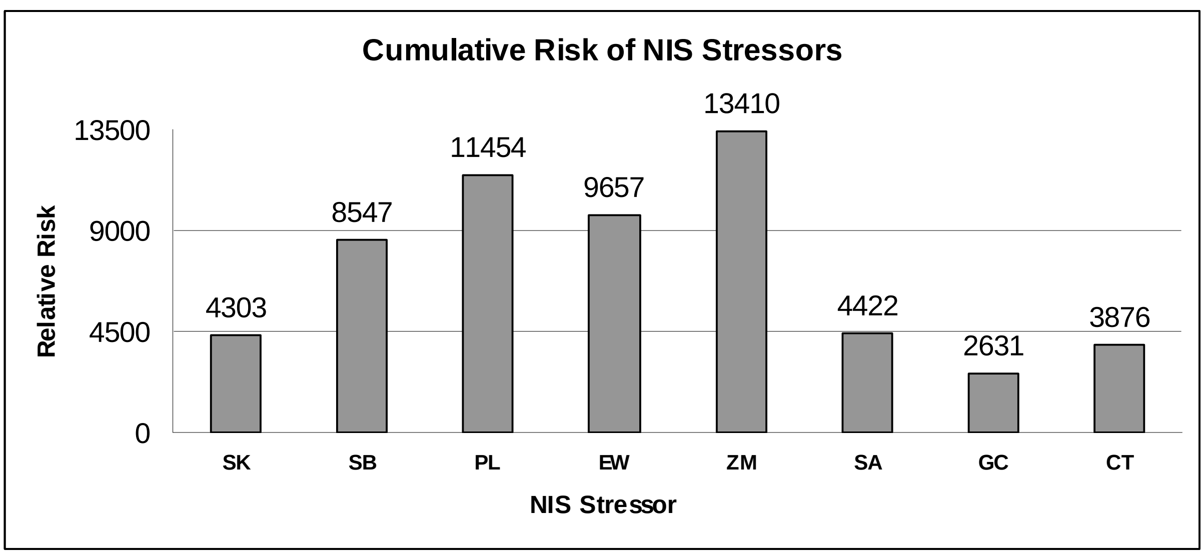

Figure 13. Relative risk scores of stressors. Gridlines approximate thresholds for high, medium, and low risk. Abbreviations: SK, spotted knapweed; SB, Scotch broom; PL, purple loosestrife; EW, Eurasian watermilfoil; ZM, zebra mussel; SA, *Spartina anglica*; GC, European green crab; CT, *Didemnum* sp. A.

Geographically, the subregion with the highest relative risk (**Figure 14**) was Subregion 4 the King-Snohomish-Pierce Tri-county region. Subregions with medium overall risk scores were Subregion 1, the Olympic Peninsula, Subregion 5, the Okanogan, and Subregion 7, the Spokane and the Palouse. Subregions with low overall risk scores were Subregion 2, the San Juan Islands and Kitsap County, Subregion 3, Whatcom and Skagit counties, and Subregion 6, Northeast Washington. The risk from stressors by subregion indicate that the terrestrial and freshwater species contributed some risk to every subregion, whereas marine species only contributed risk to regions with marine shoreline as expected (**Figure 15**). Moreover, stressors contributed risk to subregions unequally; e.g., spotted knapweed which constituted a much higher risk in Subregion 5 than in Subregion 2.

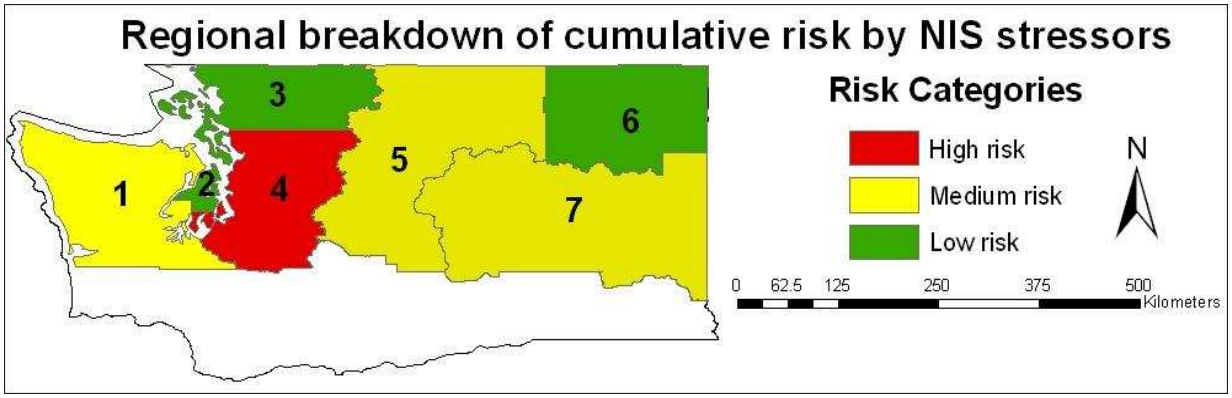

Figure 14. Relative risk in subregions. Categories of high, medium and low were derived using Jenks optimization of cumulative risk scores, which uses natural breaks in the data.

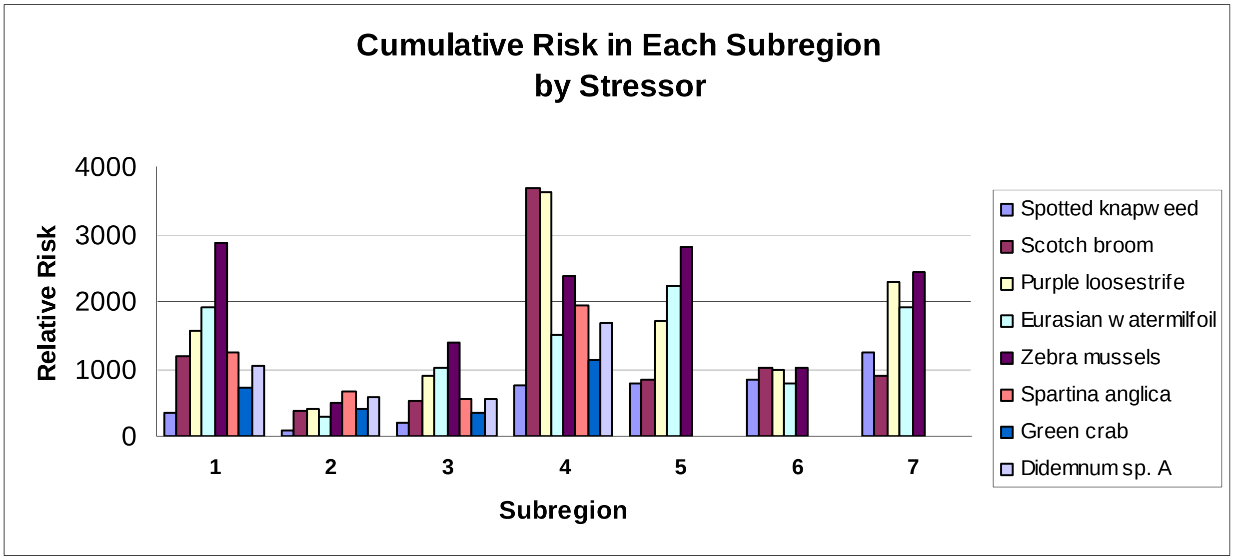

Figure 15. Individual contribution of risk by each stressor to the overall risk in each subregion.

The three habitats with high associated risk from stressors were lakes, urban and rivers (**Figure 16**). Habitats with moderate associated risk were riparian and intertidal habitats. Low risk habitats were; agricultural, shrub steppe, forest, grassland, wetland, estuarine and marine.

Individual stressor contributions to overall risk in each habitat varied widely with zebra mussels, Eurasian watermilfoil, and purple loosestrife contributing the most risk to lakes and rivers (**Figure 17**). Risk to endpoints by all stressors in descending order was: gardens and parks, water quality, Great Blue Heron, Douglas fir, Dungeness crab, hay, cattle, and Taylor's Checkerspot butterfly (**Figure 18**). The contribution of risk to the endpoints by each stressor showed gardens and parks as the only endpoint that was at risk from every stressor; whereas the other endpoints were at risk from multiple (2-6) stressors (**Figure 19**).

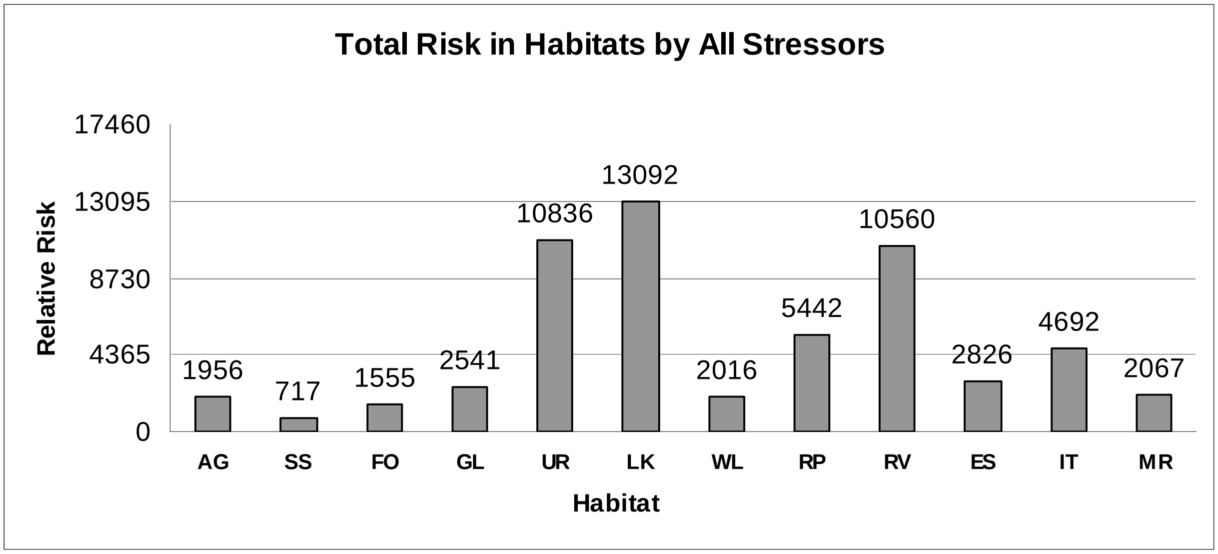

Figure 16. Overall risk associated with each habitat. Abbreviations: AG, agriculture; SS, shrub steppe; FO, forest; GL, grassland; UR, urban; LK, lake; WL, wetland; RP, riparian; RV, river; ES, estuary; IT, intertidal; MR, marine.

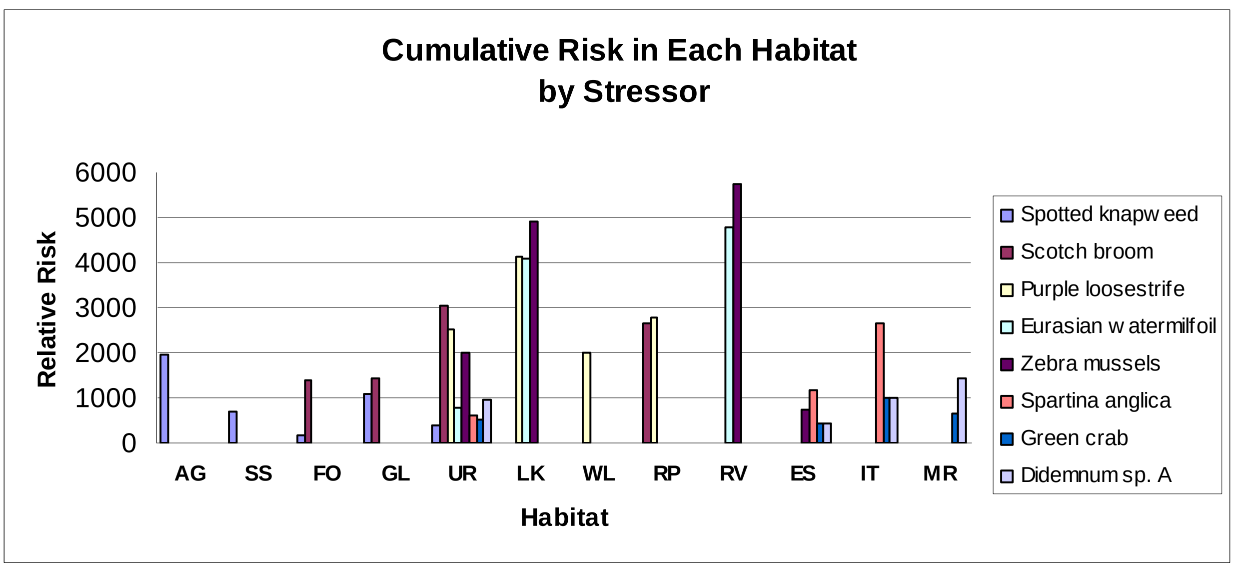

Figure 17. Individual contribution of risk by each stressor to the overall risk to subregions. Abbreviations: AG, agriculture; SS, shrub steppe; FO, forest; GL, grassland; UR, urban; LK, lake; WL, wetland; RP, riparian; RV, river; ES, estuary; IT, intertidal; MR, marine.

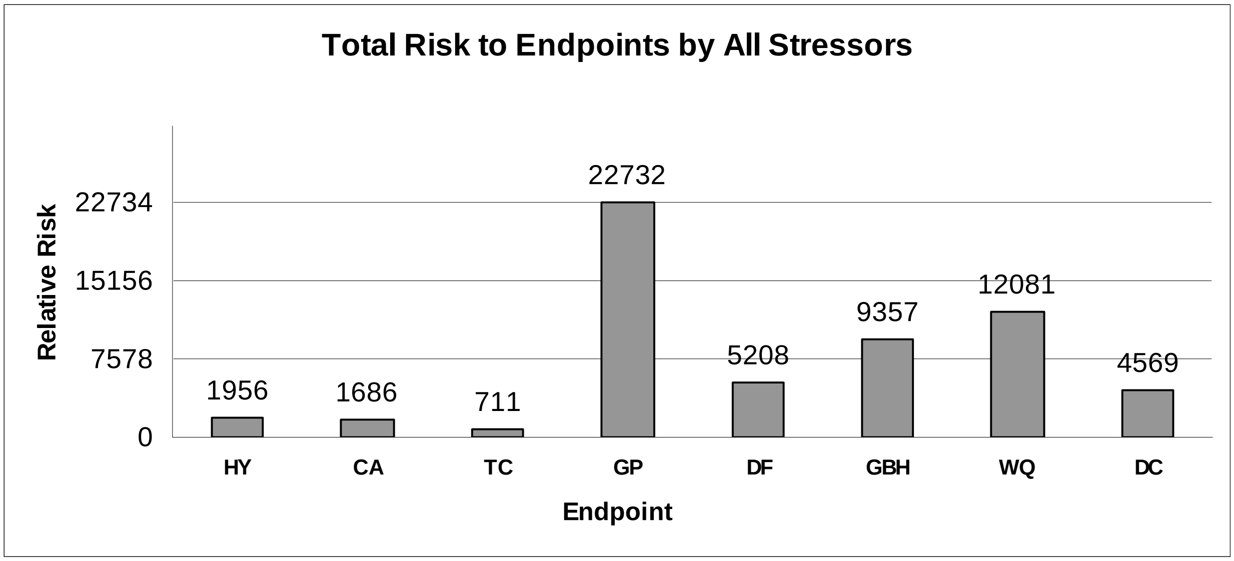

Figure 18. Total risk to endpoints. Abbreviations: HY, hay; CA, cattle; TC, Taylor's Checkerspot; GP, gardens and parks; DF, Douglas-fir; GBH, Great Blue heron; WQ, water quality; DC, Dungeness crab.

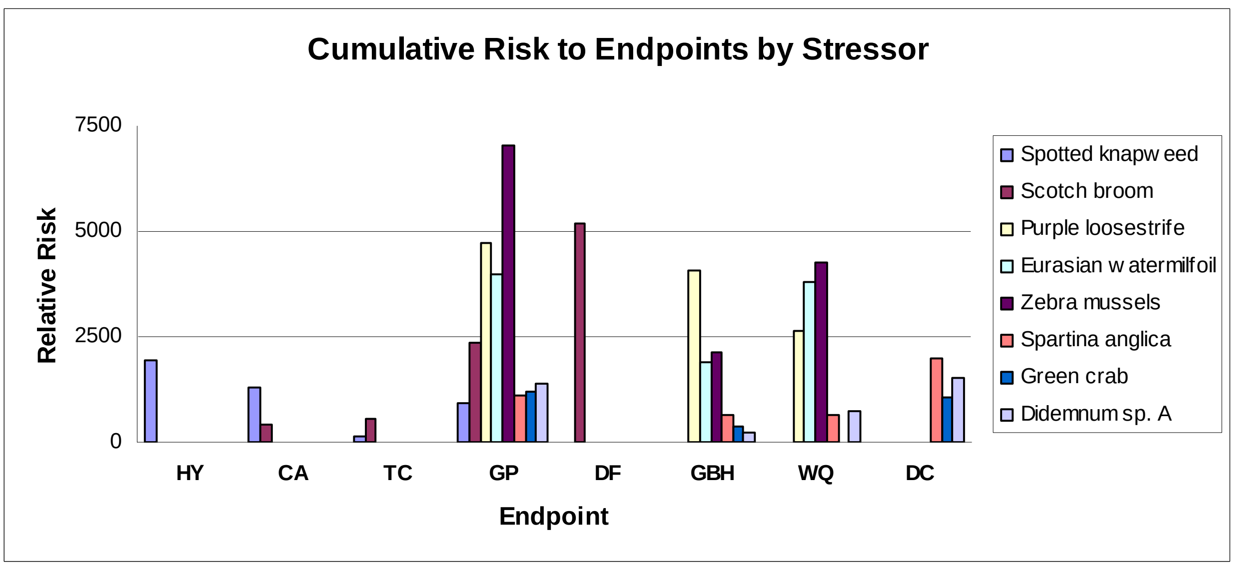

Figure 19. Individual contribution of risk by each stressor to the overall risk to endpoints. Abbreviations: HY, hay; CA, cattle; TC, Taylor's Checkerspot; GP, gardens and parks; DF, Douglas-fir; GBH, Great Blue Heron; WQ, water quality; DC, Dungeness crab.

Uncertainty Analysis

Uncertainty distributions were created for cumulative risk posed by the modes of transportation by stressor, habitat, endpoint, and subregion. However since they were simply different ways of summing the risk scores in the risk calculation, the uncertainty analyses used the same input resulting in identical distributions. There was a very broad distribution of possible values for risk scores given the associated uncertainty **(Figure 20**).

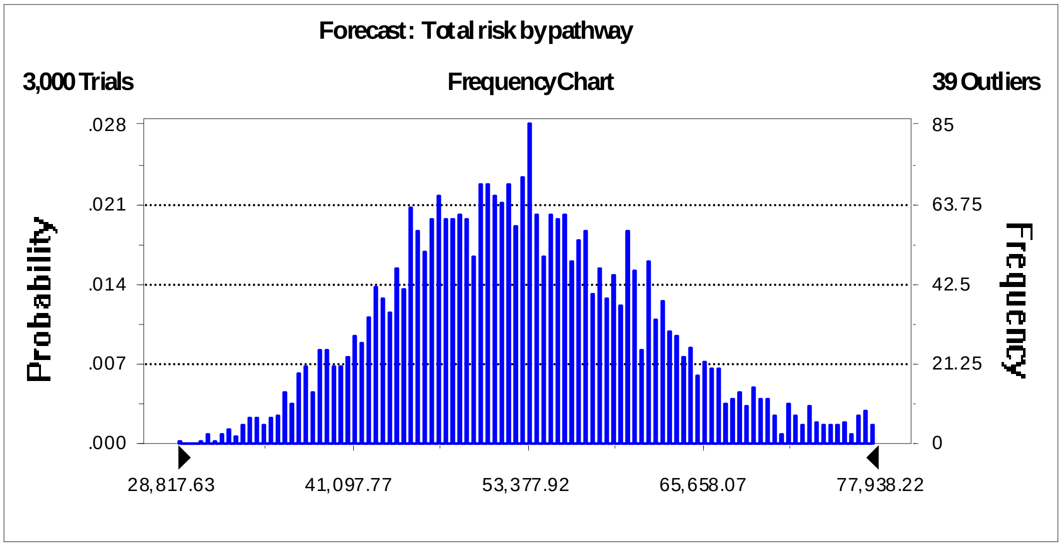

Figure 20. Uncertainty analysis output. The distribution shows the range of possible values for the risk scores of cumulative risk by transport pathways, given the uncertainty in the data.

Sensitivity Analysis

One component in the risk calculations made a large contribution to the overall uncertainty; the effect of *Didemnum* on the European Green crab. This component contributed 27.3% of the uncertainty in the RRM results. All other components made contributions of less than one percent (**Figure 21**). The Sensitivity Analysis output shows the top ten contributors to the uncertainty. The summed contributions to uncertainty for each exposure and effect filter show the highest uncertainty (28.4%) for Effect filter 3, followed closely by Exposure filter B, the viable transport distance of NIS at 27%, and then by the habitat rank and Exposure filter C at18.8% and 16%, respectively.

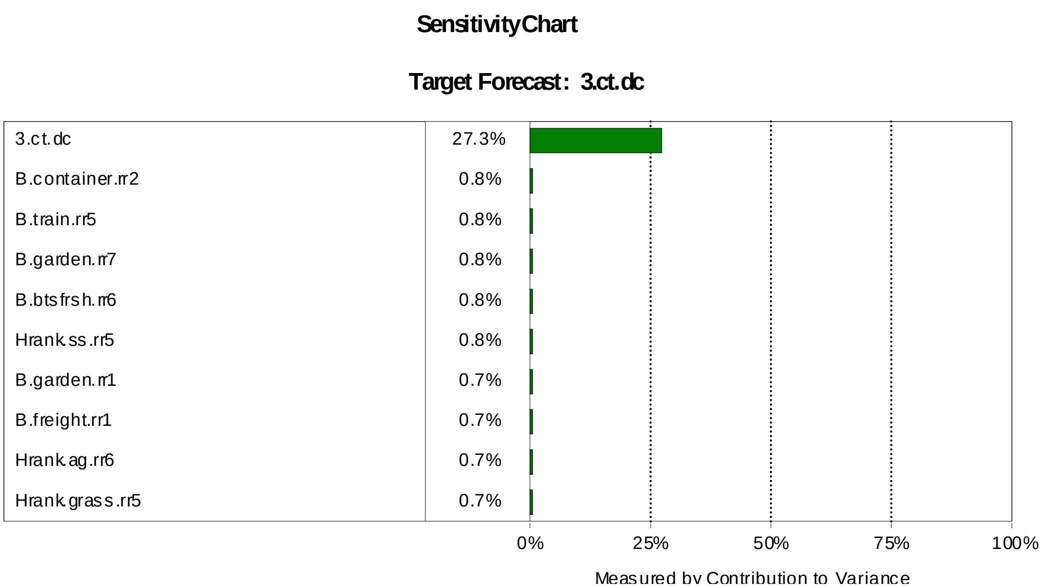

Figure 21. Sensitivity Analysis output. Chart shows the top ten contributors to model uncertainty and the percentage of uncertainty each component contributes.

Table 6. Percentage of overall model uncertainty contributed by each rank and filter in the model.

Component	Uncertainty
Source	0
Transportation Rank	2.8
Exposure Filter A	2.6
Exposure Filter B	27
Exposure Filter C	16
Exposure Filter D	0.4
Exposure Filter E	1.8
Exposure Filter F	0
Habitat Rank	18.8
Effect Filter 1	0.9
Effect Filter 2	0
Effect Filter 3	28.4
Impact Rank	0.8
Total	**99.5**

DISCUSSION

The Conceptual Model created for this risk assessment is notably biased toward terrestrial modes of transport. Trucks, trains and garden escapes are all terrestrial pathways. Freight and freight containers had terrestrial components as well. Compared with the freshwater and marine pathways, which each represent only two pathways (boats and freight or ships and freight), it is not surprising that the terrestrial pathways had the highest combined risk scores. The significance of the freshwater boat pathway having the highest risk score of all modes of transport is therefore more apparent given the obvious bias towards terrestrial modes. The boat pathway had the highest risk score due to the high risk score contributions of the zebra mussel, Eurasian watermilfoil and purple loosestrife stressors. These three stressors had high risk scores because they all have high potential to be transported, are not easily prevented or controlled, and have great economic, ecological, and/or cultural impacts to the endpoints included in the risk assessment. The influence of these three stressors is seen throughout the results. The habitats at highest risk, besides urban areas, were lakes and riparian habitats. Individual stressor contributions to risk in each habitat and to the endpoints within them were largely driven by the risk associated specifically to these same three species.

Subregion 3, the Whatcom-Skagit subregion, was considered low risk relative to the rest of the subregions in the study area, however, this too can be explained when one considers the importance of the freshwater boat risk score. Compared to the other subregions this subregion does not have as many access points for freshwater boating as in the others and therefore limits access to this mode of transport.

The risk scores for the other subregions in the model appear to be driven by a combination of freshwater boat access and the amount of urban area, which was the highest risk habitat in the model. While no other subregion besides Subregion 4 was considered high risk, medium risk subregions either had large urban areas (such as Spokane, Subregion 7) or many freshwater boat access points into large areas of freshwater habitat.

It is not surprising that urban areas were the highest risk habitat. Since urban areas are the primary destinations for receiving shipped goods, as well as sending areas from which goods are shipped to other urban are via all modes of transportation, they have the highest overall traffic volume and exposure to potential NIS stressors. Urban areas are also the most likely places for transfer of freight from one transport pathway to the other, e.g., from marine shipping to trucks or trains. In addition, urban areas had high associated risk because urban "habitat" is actually a land use practice that is characteristically different from less managed habitats. They can, however can contain any and all habitats, from grasslands to rivers to intertidal zones. For example, Subregion 4, the King-Snohomish-Pierce area, is the only subregion in the study area where the Taylor's Checkerspot butterfly is known to exist, yet it is highly urbanized. Thus the risk of NIS to endpoints in urban areas is very high.

The gardens and parks endpoint had the highest risk score, due primarily to its general designation as both an endpoint and potentially as a habitat. There are many different kinds of gardens and parks, ranging from manicured lawns to huge National Parks. While gardens are more limited to urbanized or built-up areas, parks can be rural or urban and may contain any habitat type. Therefore, many other endpoints can be found in them, contributing to the higher risk score. The effects to those other endpoints may range from a mere nuisance of finding a "weed" in a lawn to major ecological affects from NIS establishment.

It is to be expected that a risk assessment such as this would have high associated uncertainty, even though many of the NIS stressors in the model have been well studied. In this project detailed data were required for very specific categories that have not yet been well studied. For example, although much work has been done to identify transport pathways for NIS, documentation of the viable distance of transport was identified as a significant data gap for many of the NIS stressors, accounting for 27% of the assessment's uncertainty. This part of the risk calculation was based on the assumption that NIS were able to be carried via these transport pathways at least throughout the study area. However, many of the NIS were probably introduced to the west coast of North America from greater distances than those in the study area using one of the transport pathways identified so the assumption could be accurate.

Another large source of model uncertainty was the effects NIS have on endpoints. This was largely due to the uncertainty surrounding the specific effects of *Didemnum* sp. A on selected endpoints, which accounts for 27.3% out of 28.4% of the uncertainty associated with this component. *Didemnum* is such a relatively new NIS that it has yet to be properly identified and named to species level. As a result, insufficient time has passed for the scientific community to thoroughly study and understand its impacts, even on the east coast where it has been established longer.

The third large source of uncertainty was the habitat ranks. The sources of uncertainty in this category are related to the GIS datasets used to rank habitat area. Many of the habitat ranks were derived from the Washington GAP Project dataset (Cassidy, 1997), which was derived from Landsat imagery dating from 1991. The data have not been fully evaluated for accuracy with little ground-truthing conducted to verify the land cover data layers and characterizations. The scale of this risk assessment was large enough to minimize the uncertainty associated with data accuracy; however, in acknowledgement of the amount of development that has occurred in Washington since 1991, medium uncertainty was assigned to habitat ranks because of the age of the dataset used.

Other datasets used in ranking habitats had similar issues. The bathymetry and elevation datasets used for ranking marine habitat were only completed for Puget Sound, excluding the west coast of the Olympic Peninsula which necessitated making an estimate of a significant portion of the marine habitat in Subregion 1. The National Wetlands Inventory dataset was very completed but outdated; the information used to compile the dataset was gathered from 1977 to 2006, and no mention was given in the metadata as to the present-day accuracy.

Uncertainty from GIS datasets was, overall, a major component of model uncertainty. Taken together, all components derived from GIS datasets comprised 38.5% of model uncertainty. However, this is an overestimate since other assumptions imbedded in some GIS-related components also contributed to the uncertainty.

CONCLUSIONS

In this study it was demonstrated that the methodology used in the Relative Risk Model assessment process can be used to assess risk of NIS transport by various modes of transportation across international and multi-jurisdictional boundaries. While many transport pathways may convey NIS across international boundaries, these results indicate that freshwater boats represent the highest risk in transporting NIS stressors in this study area. The risk posed by the freshwater boat pathway was heavily influenced by the high ease of transport, aggressive ability to invade freshwater habitats and become well-established, and impact caused by these freshwater NIS species (zebra mussel, Eurasian watermilfoil, and purple loosestrife).

Management of NIS in terrestrial, freshwater and marine systems is largely segregated in the United States. Local, state, and federal agencies are given authority to make decisions and manage one or a few natural resources in any given environment. They rarely work together to manage a system in a comprehensive, integrative manner using an ecosystem-level approach. Too often natural resources are managed by the separate agencies on a species by species level instead. As a result, studies and assessment of NIS often reflect this segregation. Moreover, like other species, studies and risk assessments of the potential effects NIS are typically focused on one species at a time. This project puts enables the analysis of these three ecosystems and eight biotic stressors in an integrated, holistic context that allows comparisons and promotes management strategies using an ecosystem-level approach. This comparative strategy should prove useful to decision-makers and resource managers, especially where an understanding of large scale interactions is crucial to protecting valued cultural, economic, ecological, and social resources for future generations.

As this is the first phase in conducting this ecological risk assessment of this type, there was high uncertainty associated with several of the parameters selected for inclusion in the assessment. Data gaps and sources of uncertainty were identified to help guide future research so uncertainty may be reduced in subsequent assessments. Essential data gaps to be reduced in future assessments include documentation of the mechanisms and viable distance of NIS transport via the various modes of transportation. Moreover, the effects of NIS on endpoints, e.g., *Didemnum* sp. A on Dungeness crab, also need to be researched more fully. If, in the future, GIS technology such as interpretation of Landsat imagery improves and datasets become more quickly updated, uncertainty from GIS datasets may be reduced.

Finally, it is important to include a note about interpretation of these risk scores. A risk assessment is used to estimate the risk of an effect occurring given various conditional inputs. Although the Conceptual Model was developed based on stakeholder input, there was no value judgment placed on a risk score. Value judgments are reserved for decision-makers. For instance, in this risk assessment the Taylor's Checkerspot butterfly, a species threatened by 99% of its habitat being developed or modified (Vaughan and Black, 2002), had the lowest risk score of all the endpoints in the final assessment. This was due to the small habitat it occupies, the small amount of traffic (modes of transportation) volume likely to intersect with its habitat, and the fact that only one NIS stressor directly affects it. However, the effect of that one stressor, Scotch broom, has been shown to severely displace critical forage and nectar plants (Vaughan and Black, 2002). This study attempted to assess the potential magnitude of impacts NIS have on valued endpoints in the study area, however it remains a value judgment to decide whether an endpoint with minor associated risk may be more important to stakeholders than the risk associated with, for example, the gardens and parks endpoint that received the highest risk score in the assessment.

RECOMMENDATIONS

The results of this study are in alignment with the concerns of the stakeholders that were consulted at the beginning of this project. In general, there was high stakeholder concern over aquatic NIS such as zebra mussel, purple loosestrife and Eurasian watermilfoil. These concerns are reflected in the Washington State laws regarding NIS, which specifically name zebra mussel and purple loosestrife as NIS of concern.

These risk findings indicate that stricter monitoring and prevention of freshwater boats crossing the Canada - U.S. border into Washington State would reduce the risk of NIS introduction, establishment, and proliferation to new areas. Commercially owned boats that are transported via trailer, truck, etc are inspected at weigh stations in Washington State, therefore it is more likely that NIS carried in this manner will be detected and controlled using appropriate measures. It is recommended that privately owned boats being transported across land should be especially targeted for inspection for NIS at border crossings. This is particularly important because NIS like zebra mussels, purple loosestrife, and Eurasian watermilfoil are hardy, resistant to physical stresses, and able to proliferate rapidly in new environments to the detriment of native species. In addition, public education about aquatic NIS and the risk associated with boats should specifically target the boating community, including anglers and recreational boaters.

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