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Preventing the Spread of Aquatic Invasive Species into Lake Champlain

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Environmental Studies Program • Middlebury College

Executive Summary

In the Lake Champlain region, aquatic invasive species (AIS) harm native ecosystem biota, negatively affect economic activities, and change how people relate to the lake as a part of their regional identity. Transboundary coordination in AIS prevention and management is a significant determinant of overall success since the Lake Champlain region includes the jurisdictional authority of Vermont, New York, and Québec. We developed our project in coordination with Meg Modley of the Lake Champlain Basin Program to improve aquatic invasive species prevention programs in the Basin. Our analysis focused on preventing the introduction of new species instead of managing current invasives; prevention of introductions is a far more cost-effective and environmentally desirable strategy. In order to address the issue of aquatic invasive species prevention in Lake Champlain, our team focused on four main objectives.

First, we analyzed a subset of 'high-risk' species to address the economic, ecological, and cultural costs of introduction of these species into the Lake Champlain Basin. This subset included the quagga mussel, round goby, hydrilla, and the fishhook waterflea.

Second, we looked at the economic, ecological, and cultural costs of prevention based on vector of transport to provide a more encompassing prevention analysis than species-specific assessments would provide. We identified that the most important vectors for the transportation of AIS into Lake Champlain are canals, overland transport, the aquarium trade, and baitfish.

Third, based on our assessment of the AIS policies in each jurisdiction, we created a set of recommended actions by vector of transport:

- Canals: Implement a physical barrier that closes a short section of the Champlain Canal along with a system to move small boat traffic from one side of the barrier to the other.
- Overland Transport: Dedicate more resources to the Lake Champlain Boat Stewards Program and install power-washing stations at important boat launch locations. Strengthen Vermont policy by prohibiting transportation of AIS on the interior of boats, and implement similar prohibitions in New York and Québec.
- Aquarium Trade: Implement stricter regulations in the U.S. that parallel the new regulatory system recently introduced in Canada.
- Baitfish: Strengthen public outreach efforts to anglers in order to ensure compliance with existing regulations.

Although the study of aquatic invasive species can have a pessimistic outlook, we found that our vector-based approach was unique in providing positive, solutions-oriented conclusions. We believe that this same approach can be applied to studies of AIS prevention in other areas. Emphasizing analysis based on vectors allows for a refocusing of attention from the perceived inevitability of species-specific invasions towards a broader consideration of overall solutions.

About the Project

This project is the result of a semester of work in the Environmental Studies Senior Seminar at Middlebury College under the theme of transboundary issues in sustainability. For this project, we partnered with the Lake Champlain Basin Program (LCBP), a group whose mission is to "restore and protect Lake Champlain and its surrounding watershed." The LCBP collaborates with partners in New York, Vermont, and Québec to address phosphorous pollution, toxic substances, biodiversity, aquatic invasive species, and climate change. Our partner was Meg Modley, the Aquatic Nuisance Species Management Coordinator with the Lake Champlain Basin Program. We developed our project in coordination with Meg to assist in furthering the Lake Champlain Basin Program's aquatic invasive species prevention efforts.

About the Authors

We are a group of six Environmental Studies majors from Middlebury College. Each of us had a different focus within the major and brought a different background to the project. Clockwise from top-left in the photograph: Julia Gulka, Cabot, VT, Conservation Biology focus, African studies minor; Martin Sweeney, Scotch Plains, NJ, Policy focus and Economics double major; Avery Shawler, Cashiers, NC, Conservation Biology focus and Chinese minor; Janet Bering, Houston, TX, Conservation Biology focus and German minor; Abigail Borah, Princeton, NJ, Conservation Biology focus; Charlie Koch, San Francisco, CA, Economics focus. We are all members of the Class of 2013.

Photo Credit: Abigail Borah, 2013

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I. Introduction

Objectives

Understanding the Project Objectives

In order to address the issue of aquatic invasive species (AIS) prevention in Lake Champlain, our team established four main objectives:

1. Develop a subset of high-risk species in different taxonomic groups and analyze the ecological, economic, and cultural costs of introduction of these species into the Lake Champlain Basin.

2. Develop a subset of high-risk vectors that facilitate the transportation of aquatic invasive species into the Lake Champlain Basin and analyze the ecological, economic, and cultural costs of preventing species transport through that vector.

3. Identify the vector-specific policies adopted by each jurisdiction on the state/province (Vermont, New York, and Québec), federal (U.S. and Canada), regional, and international level.

4. Make recommendations to improve the effectiveness of aquatic invasive species prevention in the Lake Champlain Basin.

Stakeholders

Many groups have an interest in preventing the spread of aquatic invasive species into Lake Champlain. In order to review existing prevention measures and make constructive recommendations, we have identified key stakeholders in the Lake Champlain Basin. Our community partner, the Lake Champlain Basin Program, is a key stakeholder due to its involvement with many other organizations and regional governments. These regional governments are also key stakeholders; Vermont, New York and Québec all are within the Lake Champlain Basin and will be affected by the introduction of invasive species. The governments have the power to enact and enforce legislation to prevent the spread of invasives. Boaters, watershed groups, anglers clubs, and their associated industries are also key stakeholders. These organizations and industries have the power to self-regulate and to make local changes. Considering perspectives of all stakeholders helps us navigate the complicated social, economic, political, and ecological issues associated with aquatic invasive species.

Aquatic Invasive Species and their Impacts

Defining Aquatic Invasive Species

As defined by the Aquatic Nuisance Species Task Force, an aquatic invasive species is “any species or other viable biological material (including its seeds, eggs, spores) that is transported into an ecosystem beyond its historic range, either intentionally or accidentally, and reproduces and spreads rapidly into new locations, causing economic or environmental harm or harm to human health." The term "nuisance species" is used synonymously with "invasive species" in this context.

Aquatic invasive species harm native ecosystem biota, affect economic activities in the Lake Champlain region, and change how people relate to Lake Champlain as a part of their regional identity.

Ecological Impacts
The impacts of invasive species are major drivers of global biodiversity loss today (Convention on Biological Diversity 2010). AIS harm native species through competition for food and space, predation, interbreeding, or the introduction of harmful pathogens and parasites. On a more systemic level, AIS have been shown to change entire food web structures, affecting many species interactions and altering the normal functioning of an ecosystem by changing hydrology, nutrient cycling, and productivity (Jaeger 2006).

Other effects of AIS are more species-specific in nature (Strayer 2010). Mollusks like zebra mussels can alter the entire food web structure in an ecosystem, since they are primary consumers at the bottom of the food chain. If a mollusk invasion crowds out native, edible primary producers, the entire ecosystem could collapse. As middle or top consumers, fish species have different effects, generally decreasing the abundance of their prey. Many aquatic plants can reengineer entire ecosystems, changing currents in a body of water as well as air-gas exchanges at the surface. Decreases in invertebrate species diversity and abundance, along with decreased aquatic plant species richness, have been well documented after invasions of aquatic plant species (Stiers et al. 2011). Decapods, small zooplankton, are voracious omnivores that can greatly impact benthic communities (Strayer 2010). Lastly, the effects of introduced pathogens on ecosystems are probably underestimated (Strayer 2010). Even though the exact impacts of any species are impossible to predict, aquatic invasive species have wide-ranging and cascading effects on the ecology of the systems they invade, and understanding how these species have impacted other waterbodies can help in understanding how they might impact Lake Champlain.

Economic Impacts

The direct economic impacts of aquatic invasive species have been well-documented. Damages due to an AIS introduction can be vast, affecting the following types of services: provisional (food, water), regulatory (flood control, water purification), and cultural (recreation, tourism) (Pejchar and Mooney 2009). In terms of provisional services, certain invasives may disrupt fisheries that supply local residents with food and lower revenues for tourism industries. The economic effects of invasives on regulatory ecosystem services are harder to calculate, but examples of harm to regulatory services like flood mitigation and water quality abound.

On a national scale, the economic impact of invasive species amounts to over $120 billion in damages, according to some estimates (Pimentel et al. 2005). This total accounts for some benefits of introduced species, like the impacts on the sportfishing industry.

However, the above valuation of damages does not incorporate certain costs, like damages to property values, which can be complicated to estimate. Horsch and Lewis (2009) developed a model to quantify those damages and found that aquatic invasive weeds can decrease property values by up to 15%.

Cultural Impacts

The cultural impacts of invasive species include effects on aesthetic values, recreation, tourism, spiritual and religious values, educational and scientific values, cultural heritage values, and sense of place. In many cases, the alteration of cultural value is difficult to monitor and assess. The majority of documented cultural impacts concern the economic effects of aquatic invasives to recreation and the tourism industry. For example, invasions of the zebra mussel have increased the concentration of heavy metals dangerous to divers, as well as cuts on swimmers' feet. In Lake Tahoe, the introduction of the Eurasian water milfoil poses a threat to water-based tourism.

Importance of Prevention

There are two strategies that may be used to address aquatic invasives: prevention of introduction (before the introduction of a species) and management or control (after the introduction has occurred). While both strategies are important, prevention strategies are rarely coordinated across jurisdictions, whereas management strategies for invasive species in the Lake Champlain Basin are generally well-coordinated. There are rapid response plans and task forces that are currently set up to respond to species introductions into Lake Champlain, and management strategies are in place for the 49 invasive species already present in the lake. However, the hundreds of invasive species that inhabit neighboring waterbodies pose a threat to the Basin.

To quote Benjamin Franklin, "an ounce of prevention is worth a pound of cure." While Mr. Franklin was not referring to aquatic invasive species, the saying holds true for our topic of study. The damages from aquatic invasive species differ from those associated with conventional pollutants in that AIS will not eventually leave an ecosystem once sources of introduction are contained. Biological invasions require only a single introduction event for a species to wreak havoc on the ecosystem. Once introduced, eradication is often an impossible task (Vander Zanden and Olden 2008). An invasive species will alter the ecosystem in perpetuity after it is introduced, requiring a great deal of time and resources for management. Because of this, the prevention of introductions may be a far more cost-effective and environmentally desirable strategy than actions undertaken after the species has been established (Leung et al. 2002).

Prevention Measures Analysis Framework

To emphasize the benefits of preventing the invasion of aquatic invasive species in Lake Champlain, we created a framework to compare the potential impacts of an invasion to the costs of prevention measures. This framework is the beginnings of a cost-benefit analysis that could make aquatic invasive species prevention measures more salient for policy makers (Figure 1). In our framework, the benefits of aquatic invasive species prevention measures are measured as the damages from a species introduction that are avoided through the prevention measure. The costs of prevention measures are not only the actual costs of regulations to enforcement agencies, but also how these regulations affect various stakeholders in the Lake Champlain region. The effectiveness of a preventative policy measure is virtually impossible to measure. However, that should not stop policy makers from implementing prevention measures, considering how great the potential benefits are. Our analysis constitutes a qualitative comparison, as many of the data we need to conduct a quantitative analysis are unavailable. The framework we have developed for comparison could, however, be used in a more rigorous analysis.

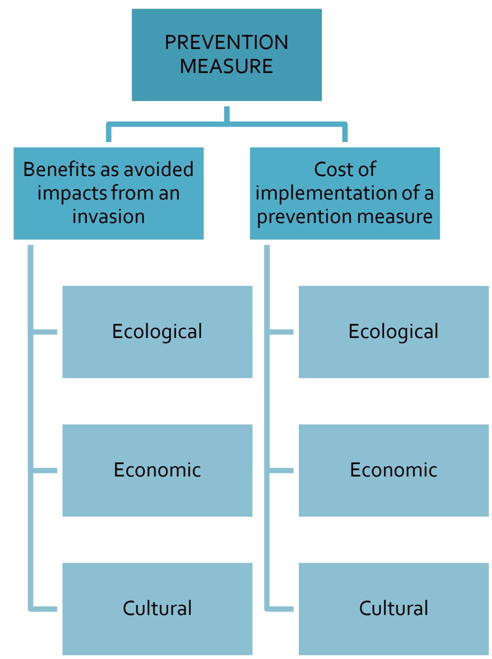

Figure 1. Our framework for a cost-benefit analysis of prevention measures for aquatic invasive species.

II. Background

Background on the Lake Champlain Basin

Limnology of Lake Champlain

Lake Champlain is one of the largest freshwater lakes in the U.S., covering 435 square miles (LCBP 2004). It is roughly 400 feet deep at its deepest point, but the average depth is only 60 feet, as many areas of the lake are shallow. Many waterbodies, including Otter Creek, the Missisquoi River and the Winooski River in Vermont and Lake George in New York, drain into the lake.

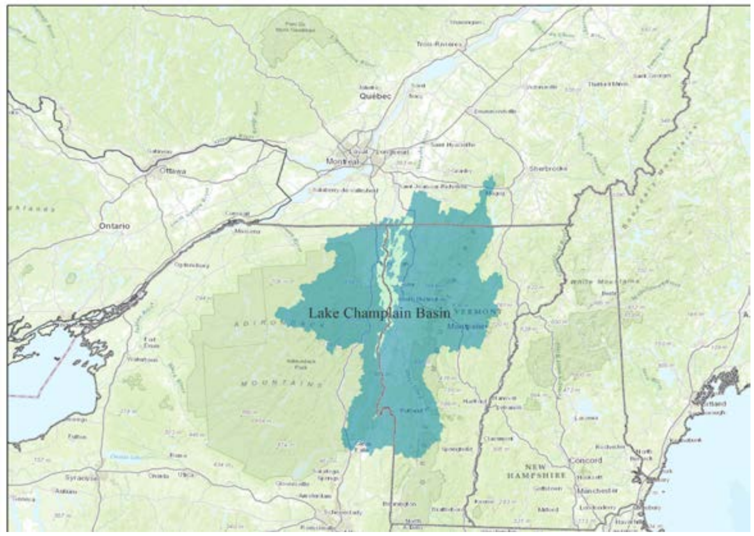

Figure 2. Map of the Lake Champlain Region.
Source: ESRI, USGS

The lake is divided into five distinct regions. The South Lake is very narrow and shallow, and it behaves much like a river. The Main Lake is the deepest, coldest, and largest section of the lake. In the northeastern arm of the lake, there are three distinct bays. The first, Mallet's Bay, is a shallow section of water between Grand Isle and Burlington. Circulation in this bay is restricted due to causeways on either end. The Missisquoi Bay is the most northerly section of the lake and it is located primarily in Canada. This section flows southward into the Inland Sea, another one of the bays. Water then moves west through the islands, meets up with the Main Lake, and flows northward into the Richelieu River. Due to their physical differences, these five sections all support distinct aquatic communities.

During the summer, the lake becomes stratified. The epilimnion, a warm layer of water, forms on the surface of the lake and is, on average, 33 feet deep. Underneath this depth, the water quickly changes through the thermocline to the hypolimnion, the colder water at depth. Wind forcing on the lake during the summer also starts an internal seiche, or giant wave, moving through the lake. This circulation and stratification disappears in the winter.

Ecology of Lake Champlain

Lake Champlain supports a wide array of aquatic ecosystems due to the variations in lake conditions from north to south. Over 80 fish species are found in the lake, along with 14 mussel species and a wide variety of water and shore birds (LCBP 2005). Several of these fish species are important commercial sport fish and are therefore actively stocked.

There are over 300,000 acres of wetland in the Lake Champlain Basin. Several of these wetland areas directly border the lake, which house rare plant communities and support migratory bird species.

History of Lake Champlain and the Canal System

For more than 10,000 years before the arrival of human settlers, Lake Champlain played a vital role in the lives of Native Americans who lived in the valley (Lake Champlain Maritime Museum). In 1609, Samuel de Champlain became the first European to explore the lake, and he discovered an almost complete waterway from the Hudson River to the St. Lawrence. Throughout the colonial period, the French and the British fought almost continuously for control of the lake. Lake Champlain was the site of many important battles during the Revolutionary War. After independence, the population of the Lake Champlain valley rose dramatically and the natural resources of the area, like timber and marble, began to be harvested. Trade with Canada via the Richelieu River was often interrupted due to conflicts with the British, which prompted the construction of a canal south to the Hudson River.

Construction of the Champlain Canal, which connects the Hudson to Lake Champlain, began in 1817, and the canal was opened in 1823. The canal is 60 miles long and connects Whitehall, NY, to Waterford, NY through a system of locks (Lake Champlain Maritime Museum). The canal was a huge success commercially for almost a century, but commercial use began to decline with the expansion of the railway system in the mid- to late-19th century. Currently the canal is primarily used by recreational boaters.

The Champlain Canal's northern counterpart, the Chambly Canal, opened in 1843. The canal was constructed to bypass rapids on the Richelieu River and runs along the west bank of the river for 12 miles. Today, the Chambly Canal is managed by the Canadian National Parks Department for recreational boaters as a part of Canada's historic canal system.

The lake has remained an important asset to the area. Over 500,000 people live in the basin, and approximately one third of these people rely on the lake for clean drinking water (LCBP 2005). On a typical summer day, the lake's 45 marinas support over 10,000 boats and thousands of other recreationists. Every year, thousands of fishing licenses are issued for Lake Champlain. Tourism is a great source of revenue for the Lake Champlain basin.

Species Present in Lake Champlain

In order to understand the threat of new aquatic invasive species entering Lake Champlain, it is important to first understand the effects and the histories of established AIS in the lake. By investigating how these species were introduced to the lake, we may be able to determine which vectors are most prone to enabling the future spread of AIS into Lake Champlain. And by identifying the impacts that established AIS have had in Lake Champlain, we may have a better idea of how new invasive species would affect the lake.

Aquatic invasive species in Lake Champlain have inflicted significant damages and have altered the lake ecosystem. Currently, 49 aquatic invasive species are established in the Lake Champlain Basin (Marsden and Hauser 2009). Established species are categorized as those that are "reproducing and self-sustaining." A majority of these species entered the basin through the canal system that connects Lake Champlain to the Hudson River, as well as the Great Lakes and the St. Lawrence River.

Some of these species are considered high priorities for management because of their extensive damages. These species, taken from the list of priority invasive species in the 2005 LCBP Aquatic Nuisance Species Regional Management Plan, are purple loosestrife (*Lythrum salicaria*), water chestnut (*Trapa natans*), Eurasian watermilfoil (*Myriophyllum spicatum*), zebra mussels (*Dreissena polymorpha*), and the alewife (*Alosa pseudoharengus*).

Figure 3. Purple Loosestrife. Image Source: Wikimedia

The first three of these species are plants. Purple loosestrife is a wetland plant that was first introduced into North America in the early 19th century (Thompson et al. 1987). It likely established itself in Lake Champlain via the Champlain Canal. Purple loosestrife grows rampantly in wetland habitats, displacing many native plant species and providing unsuitable habitat for wildlife species. Currently, the Vermont Department of Environmental Conservation (VTDEC) and the U.S. Fish and Wildlife Service (USFWS) have released leaf-eating beetles throughout the basin in an attempt to control purple loosestrife (LCBP 2005). These efforts have cost the state approximately $200,000 and have largely been ineffective.

Eurasian watermilfoil is another aquatic plant that has been highly damaging to the Lake Champlain Basin. Occupying still areas of lakes and ponds, the plant begins to grow early in the spring, outcompeting and shading over native plants (Jacono and Richerson 2003b). These species also impair travel over the water, reducing opportunities for boating, fishing, and swimming (LCBP 2005). Eurasian watermilfoil has been spread through the aquarium trade and by the overland transport of trailered boats. Successful watermilfoil control programs cost in the millions of dollars, and as of 2005, have cost government agencies within the basin upwards of $5 million (LCBP 2005).

Figure 4. Eurasian Watermilfoil. Image Source: Wisconsin Department of Natural Resources

Figure 5. Water Chestnut
Image Source: Illinois Department of Natural Resources

Water chestnut is another high priority AIS. First introduced to North America from Eurasia in the late 19th century, it was first found in Lake Champlain by the early 1940s (Marsden and Hauser 2009). Water chestnut, like other aquatic plants, grows quickly and can dominate an entire area. In Lake Champlain, water chestnut has restricted boat activity in the southern lake and displaced native plant species (LCBP 2005). The plant can be effectively controlled if the adults are killed before they release seeds. Such control programs cost state and federal agencies more than $5.2 million between 1982 and 2003 (LCBP 2005).

Figure 6. Zebra Mussel
Image Source: USGS

Zebra mussels are famous for being a highly damaging invasive mussel species. They were first seen in Lake Champlain in 1993 and likely entered the lake via the Champlain Canal (Marsden and Hauser 2009). Zebra mussels attach to hard surfaces and feed by filtering up to 1 liter of water per day (Benson et al. 2013a). Since they are also prolific breeders, they have damaged thousands of man-made structures in lakes and rivers. Their capacity to filter water also leads to massive changes in ecosystem structures by reducing plankton populations. They spread via their floating larvae or via overland transport on and in contaminated boats (Benson et al. 2013a). Zebra mussel control and clean up has cost federal, state, and municipal agencies upwards of $5 million in Vermont (LCBP 2005). This figure does not include the damages caused by zebra mussels to historic shipwrecks in Lake Champlain, swimmers, or ecosystem services provided by Lake Champlain.

Figure 7. Alewife
Image Source: New York Department of Environmental Conservation

The alewife is a small herring at a relatively low trophic level, meaning that it is often considered a baitfish for larger sportfish. It was first introduced to Vermont as a large population in 1997, most likely as a result of illegal stocking activities (Marsden and Hauser 2009). It has since spread to Lake Champlain and a population has established itself there. The Vermont Department of Fish and Wildlife (VTDFW) experimented with using piscicides as a control measure, but these efforts were largely unsuccessful (LCBP 2005). The introduction of alewife changes food web structures and displaces native species in lake ecosystems (Fuller et al. 2013a). Alewife also experience periodic die-offs in Lake Champlain, disrupting boat traffic and creating a public health hazard.

Using the dollar figures from just these examples, we can estimate that over the past several decades, aquatic invasive species have cost federal, state, and local agencies within the Lake Champlain Basin at least $15 million. This figure only accounts for costs to these agencies through 2005 and does not include a variety of other costs, including decreased ecosystem services, disrupted recreation, cultural losses, and damages to industry and businesses. If an effective scheme to prevent new AIS introductions is not developed, we will only see these damages increase.

III. Connected Waters

Humans are responsible for the spread of AIS by enabling species to overcome prior spatial limitations. International shipping, canals and the aquarium trade are some of the main vectors of transport that have allowed species to invade foreign bodies of water. Due to these vectors, previously distinct ecosystems are now highly interconnected systems. This is especially the case for Lake Champlain. The lake is connected to the Hudson River, the Great Lakes and the St. Lawrence River through a network of canals, posing a high risk for the increased spread of invasive species (see Figure 8).

DATA SOURCE: UVM, Lake Champlain Sea Grant, Great Lakes Environmental Research Laboratory, Lafontaine and Costan 2002, and Strayer 2012.

Figure 8. Number of invasive species in connected waterways. Source: LCBP

Great Lakes

Researchers estimate that a total of 184 aquatic invasive species have established themselves in the Great Lakes (Ricciardi 2006). Roughly half of all invasions have occurred within the past 50 years, and while the vectors of transport for invasive species have varied throughout history, the vast majority of recent invasives have reached the Great Lakes region through the ballast water of incoming ships.

The Great Lakes are home to some of North America's most active ports and receive ships from many international ports. As Notre Dame Professor of Biological Sciences David Lodge told The New York Times in 2011, "The Great Lakes are connected by only a few

Figure 9. The Great Lakes area
Image Source: http://www.glerl.noaa.gov/

degrees of separation from every other port on the planet," meaning that the lakes are susceptible to invasions from all regions of the world (Lyderson 2011).

Professor Lodge has been one of many advocates for the regulation of ballast water. Ships take on ballast water to maintain stability during travel, and current regulations require all ships to release their ballast water at least 200 miles away from the U.S. shoreline (Flesher 2013). When they release their ballast water as they approach U.S. ports, surviving organisms in the ballast water are likewise released into new ecosystems.

Nationally, regulations to prevent the spread of aquatic invasive species via ballast water do exist. In 2007, both the House and Senate drafted various pieces of legislation that proposed more stringent ballast water regulations, but none of the bills were voted on (Costello et al. 2007). However, the EPA, which has the authority to regulate ballast water through the Clean Water Act, has taken steps to limit future invasions via ballast water. On March 28, 2013, the EPA announced a new Vessel General Permit, which will go into effect in December 2013 (Flesher 2013). This regulation sets numeric ballast discharge limits for most vessels. Furthermore, it will require high-risk vessels entering the Great Lakes to take additional management measures to reduce the risk of introducing invasive species into the region, including the use of ultraviolet light or chemical agents known to kill at least some organisms.

Figure 10. Boat exchanging ballast water
Image Source: http://www.dnv.com/

These new regulations have several limitations. They will not apply to vessels that travel within the Great Lakes, and they will also take time to become fully effective. While vessels built after December 2013 will need to comply with all the new regulations, requirements will be phased in over time for existing vessels. As existing vessels undergo regular maintenance, they will be required to install adequate treatment technologies. In other words, there is no "hard deadline" that these vessels must adhere to. This means the new regulation could take years to come fully into effect.

Ballast water is a primary vector of transport for new invasives in the Great Lakes. Approximately 10% of Lake Champlain's invasive species — including the zebra mussel — originally invaded the Great Lakes via solid ballast or ballast water (Marsden and Hauser 2009; Mills et al. 1996c).

Pimentel (2005) suggests that the Great Lakes region faces $5.7 billion annually in costs associated with aquatic invasive species. Approximately $4.5 billion of these annual losses are associated with commercial and sport fishing. The West Nile virus is associated with $620 million in annual public health damages in the Great Lakes region. Furthermore, the region's power plants and water supply facilities face an estimated $500 million in damages annually due to zebra and quagga mussels.

Saint Lawrence and Richelieu Rivers

The St. Lawrence River is the primary drainage waterway from the Great Lakes into the Atlantic Ocean and serves as the primary means of transportation for boat traffic going between the Atlantic Ocean and the Great Lakes. As a result, the river's ecological status is deeply intertwined with that of the Great Lakes; any invasive species that gains a foothold in the Lakes has a direct link to the river. The Richelieu River drains from Lake Champlain into the St. Lawrence River, creating another pathway through which Lake Champlain is vulnerable to aquatic invasive species from the Great Lakes.

Figure 11. St. Lawrence River.
Image Source: Environment Canada Weather Service

Built in 1959, the St. Lawrence Seaway modified the St. Lawrence River to allow ocean-going vessels to travel from the Atlantic Ocean into the Great Lakes. This waterway has served as a vital pathway for shipping and transportation. With the introduction of heavy commercial traffic in the waterway came greater environmental management challenges. Flows and water levels along the seaway have been regulated since 1960. The Seaway essentially created a new managed hydrodynamic system that removed the Galop and Long Sault Rapids sections through flooding and other alterations. Changes in water levels have decreased fish abundance, diversity, and health significantly (SOLEC 2005).

Invasive species in the St. Lawrence River have modified the food web, resulting in decreased macroinvertebrate species richness and losses in food diversity. The invasive diatom *Didymosphenia geminata* changes the lower food web, fouls fish spawning grounds, and ultimately reduces fish populations that have high human-use value (such as the Atlantic Salmon of Eastern Québec) (Marty et al. 2010b, Gillis et al. 2010). The bloody red shrimp, *Hemimysis anomala,* also poses a threat to the lower food web in the

Great Lakes Basin, by grazing heavily on algae and zooplankton (Marty et al. 2010a). This species also disproportionately affects nearshore food webs, which are of particular concern due to the higher levels of human use and impact.

Like in the Great Lakes, ballast water from oceangoing ships is of serious concern for the prevention of new aquatic invasive species and is widely considered to be the most important vector for the invasion of new aquatic invasive species into the St. Lawrence River.

The Hudson River

The LCBP estimates that 122 invasive species are present in the Hudson River (LCBP 2012). The earliest transport vectors for species invading the Hudson River include solid ballast and fouling organisms on ship hulls. The construction of canals in the 19th century, however, linked the river basin to other drainage systems and opened new ways into the Hudson River (Mills et al. 1996b). Canals with linkages to the river include the Champlain Canal (Lake Champlain Basin, 1819), the Erie Canal (Lakes Erie Basin and Ontario Basin, 1825), the Delaware and Hudson Canal (Delaware River Basin, 1829), and the Chenango Canal (Susquehanna River Basin, 1837).

Frequent commercial traffic traveling across the network of canals caused a marked increase in the number of new invasions in the Hudson River. While the Great Lakes region is home to far more invasive species than the Hudson River Basin today, the Hudson possessed greater numbers of invasive species historically. As Figure 12 demonstrates, the Hudson River was associated with more frequent invasions throughout the 19th century. It was not until the turn of the 20th century that the trend began to shift and the Great Lakes region began to see higher rates of new invasions than the Hudson. Mills et al. (1996b) suggest that this dynamic is a product of two factors. First, it reflects the historical differences in commerce and agricultural activity in the two regions. Second, the freshwater biota conditions are better in the Great Lakes region than the Hudson Basin, which explains why more invasive species have traveled from the Great Lakes to the Hudson than from the Hudson to the Great Lakes.

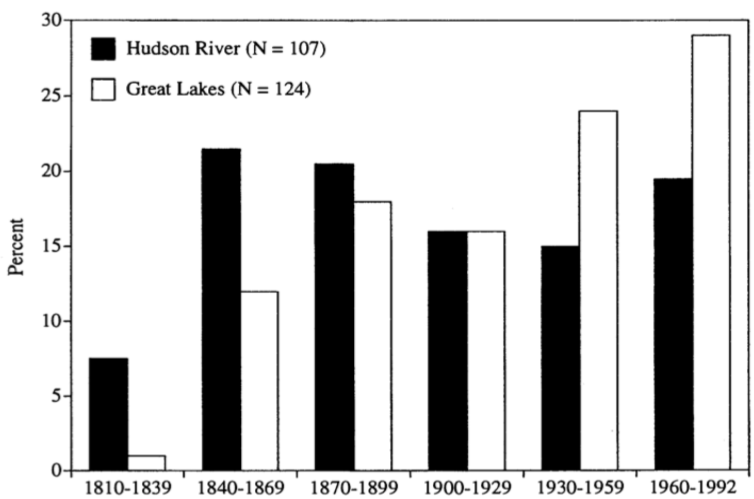

Figure 12. Time course of the entry of established exotic freshwater species into the Hudson River Basin and the Laurentian Great Lakes (Mills et al. 1996b).

Since 1930, the main vectors of transport for all new AIS in the Hudson River Basin have been canals and unintentional releases (Mills et al. 1996b). The canal system has remained a primary vector of transport for new AIS, even despite the decrease in shipping traffic along canals.

Historically, invasive plants arrived in the Hudson typically via unintentional releases and solid ballast, while invasive fish came to the basin via canals and intentional release (Mills et al. 1996b). Invertebrates have traveled into the basin through a variety of vectors, including water ballast. Researchers note that when ships switched from carrying solid ballast to fresh water ballast, plants became less likely to invade and aquatic invertebrates became more likely to invade.

Pimentel (2005) suggests that the total environmental and economic impacts to the Hudson River and the New York State Canal System are nearly $500 million per year. Eighty percent of those damages are associated with commercial and sport fishing. Sport fishermen cut back on their activities due to poorer fishing, and commercial fisheries have a lower number of fishers due to reduced fish production.

Public health is also affected by invasive species in New York: pathogens and parasites, the most prominent of which is the West Nile virus, cost the public an estimated $40 million per year. Finally, industrial facilities face combined costs of approximately $20 million per year due to zebra and quagga mussels; power plants and water supply facilities bear half of these costs.

IV. Overarching AIS Policy and Management

To understand the management of aquatic invasive species in the Lake Champlain Basin, it is important to understand legal statutes, rules, and regulations through which different jurisdictions on different levels deal with this issue. In order to do this, we examined U.S. policy on both the federal and state level (see Table 1). For Canada, we focused on federal policies as these largely influence provincial policy (see Table 2). We also looked beyond policy to committees and task forces that are working on AIS on international and regional levels.

U.S. National and State Policy

U.S. Federal Policies

On a national scale, invasive species authority lies in the U.S. Fish and Wildlife Service (USFWS), the U.S. Army Corps of Engineers (USACE), and the Environmental Protection Agency (EPA). Historically, the most significant national policy on aquatic invasive species was the Non-indigenous Aquatic Nuisance Prevention and Control Act implemented in 1990 and amended in 1996 (USDA 2012). This policy established the Aquatic Nuisance Species Task Force (ANSTF), which focused largely on ballast water as a vector for introduction. This policy expired in 2002 and any revisions have yet to be enacted by Congress, though there are multiple proposals currently on the table to address the issue of aquatic invasive species (NECIS 2013).

There are currently a few policies that work to address invasive species. The Lacey Act of 1900, the Federal Noxious Weed Act of 1990, the Noxious Weed Control and Eradication Act of 2004, and the Clean Boating Act of 2008 all address aquatic invasive species to some extent, but there is overall a lack of national policy specifically addressing aquatic invasions (USDA 2012). The Lacey Act prohibits the import of species that are injurious to humans, to the interest of agriculture, horticulture, forestry, or to wildlife resources in the U.S. (Doelle 2003). The two noxious weed policies give the Secretary of Agriculture the authority to regulate the movement and commerce of weeds and the responsibility of creating an assistance program for weed management. The latter is an amendment to the Clean Water Act, giving the EPA authority to develop management practices for recreational vessels. To date, no regulations have been proposed under this act (EPA 2012).

Vermont Policies

In Vermont, the main authority regarding aquatic invasive species lies with both the Department of Fish & Wildlife and the Water Quality Division of the Department of Environmental Conservation (DEC) (ANMP 2005). These agencies coordinate with the Agency of Agriculture for the management of aquatic invasive plants.

The transport, possession, sale, and distribution of any known aquatic nuisance species, aquatic weeds, or fish is punishable by fines upwards of $1,000 in VT (Aquatic Nuisance Control Program, 1978; Vermont Agency of Agriculture, Food and Markets;

Policy	Authority	Content
U.S. Federal Policies		
Clean Boating Act	EPA[1]	No regulations to date. Aimed at management of discharge, performance standards, and management practices for boats
Lacey Act	USDA[2], DOI[3]	Prohibits the import of a blacklist of species into the U.S.
Noxious Weed Act	USDA	Authority to define, regulate, inspect, seize, destroy, quarantine and control noxious weed species
Noxious Weed Control and Eradication Act	USDA	Provides assistance for eligible weed management entities to control or eradicate noxious weeds
Vermont State Policies		
Baitfish Rule	VT F&W[4]	Regulates what species can be used as baitfish and who can harvest and sell baitfish
Aquatic Weeds Quarantine Rule	VAAFM[5]	Controls the movement, sale, possession and cultivation of noxious weeks
Felt-soled Wader Ban	VT F&W	Bans use of external felt-soled boots and waders in Vermont water bodies
Aquatic Species Transport Law	VT DEC[6]	Prohibits the transport of all invasives on the outside of boats, trailers, and equipment
Fish Propagation	VT F&W	Prohibits the rearing of fish for sale or distribution without a permit
Placing Fish in Waters	VT F&W	Prohibits the importation of live fish for introduction without a permit
Pest Survey, Permits	VAAFM	Prohibits the selling, transport, shipment, or movement of plant pests without a permit
Prohibited, Restricted, and Unrestricted Fish Species	VT F&W	Gives FWS authority to regulate which species are prohibited and restricted for use
New York State Policies		
Taking and Sale of Bait Fish	NY DEC[7]	List of species that are prohibited to take for sale or to sell as bait without a permit
Water Chestnut	NY F&W[8]	Prohibits the transport and introduction of water chestnut
Invasive Species Prevention Act	NY DEC, NYSDAM[9]	No regulations to date. Aimed at the prevention of invasive species
Fish Dangerous to Indigenous Fish Populations	NY DEC	Regulates the buying, selling, and transport of fish species harmful to indigenous species
Prevention of intro. of Injurious insects, Noxious Weeds, and Plant Diseases	NYSDAM	Gives Dept. Agriculture and Markets authority to prevent introduction of insects, weeds, and disease
Taking for propagation and stocking	NY DEC	Authority to regulate propagation and stocking of fish and shellfish
Liberation of Fish, Shellfish and Wildlife	NY DEC	Regulates the release of species without a permit. Specifically addresses zebra mussels
Shipping of Live Pests	NYSDAM	Prohibits sale, and transport of insects, noxious weeds, fungi, bacteria, viruses and other parasites without a permit
Possession and Transportation of Wildlife	NY DEC	Prohibits possession, transport, import, or export of species without a permit

Table 1. U.S. rules and statutes relevant to the regulation of aquatic invasive species on the federal and state levels. See Appendix A for full policy descriptions.

1.Environmental Protection Agency
2.U.S. Department of Agriculture
3.U.S. Department of the Interior
4.Vermont Department of Fish & Wildlife
5.Vermont Department of Environmental Conservation
6.New York Department of Environmental Conservation
7.New York State Department of Agriculture and Markets

Rule establishing a list of prohibited, restricted and unrestricted fish species, 2010). The Aquatic Species Transport Law states that "no person shall transport an aquatic plant or aquatic plant part, zebra mussels, quagga mussels or other aquatic nuisance species… to or from any Vermont waters on the outside of a vehicle, boat, personal watercraft, trailer, or other equipment" (Transport of aquatic plants and aquatic nuisance species 2010). This statute was updated in 2010 to include all aquatic nuisance species and also changed to apply only to organisms on the outside of water vehicles. There are also regulations on fish species that can be used as baitfish, as well as a prohibition on the use of felt-soled waders or boots (Fish Regulation, 2008; Felt-soled boots and waders, 2011). Current policies focus on transportation, specifically on the level of known transport (i.e., people consciously taking fish, bait, weeds, or other species between bodies of water or across state lines). Policies addressing unintentional transfer include the Aquatic Species Transport Law and the recent ban on felt-soled waders, which are known to contribute to the spread of invasive species such as whirling disease in fish and didymo (Ryan 2009; Root and O'Reilly 2012). Beyond these policies, there is a lack of regulation addressing the unintentional transport of species, through activities like recreational boating and through vectors like canals (Marsden and Hauser 2009; Johnson et al. 2001; Malcoff et al. 2005).

New York Policies

The Office of Invasive Species Coordination within the Department of Environmental Conservation is the authority on invasive species in NY, but there does not seem to be a specific group focusing on aquatic invasive species. An Invasive Species Task Force was created in 2003 to explore the invasive species issue in the state (The New York Invasive Species Clearinghouse).

In August 2007, the NYS Invasive Species Council Act was passed, establishing the New York Invasive Species Council and an Invasive Species Advisory Committee to assess "the nature, scope and magnitude of the environmental, ecological, agricultural, economic, recreational, and social impacts caused by invasive species in the state" (NY DEC and NY DAM, 2005). The council was also tasked to identify and coordinate actions to prevent, control, and manage invasive species.

In July 2012, the Invasive Species Prevention Act was created, giving the Department of Environmental Conservation and the Department of Agriculture and Markets the authority to regulate the sale, purchase, introduction, importation, and transport of invasive species and establish penalties for those who violate these regulations. This new law is taking a comprehensive and proactive approach to educating the public and holding those who are negligible accountable.

New York also has regulations that address baitfish, noxious weeds, injurious insects, and plant diseases, in addition to some regulations that target individual species, like water chestnut (ANSMP 2005).

Canadian Federal and Provincial Policy

Policy	Authority	Content
Canadian Federal Policy		
Fisheries Act	FOC[1]	Conservation and protection of fisheries resources. Under this law, Quebec controls the transportation, possession, and use of baitfish
Health of Animals Act	CFIA[2]	Controls the buying, selling, importation, transport and stocking of all fish species, including for aquaculture.
The Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act (WAPPRIITA)	EC[3]	Regulates importation of plant and animal species that are listed by the Wild Animal and Plant Trade Regulations.
Species at Risk Act (SARA)	EC	To prevent wildlife extirpation, endangerment, or threat due to human activity

Table 2. Canadian Federal policy relevant to the regulation of aquatic invasive species. See Appendix A for full policy descriptions.

1. Fisheries and Oceans Canada
2. Canadian Food Inspection Agency
3. Environment Canada

Canadian Federal Policies

Within the Canadian federal government, primary responsibility and authority with regard to AIS rests with Fisheries and Oceans Canada and Environment Canada but, depending on the species and its pathway into Canadian waters, management actions can also involve Transport Canada, Industry Canada, the Canadian Food Inspection Agency (CFIA), the Department of National Defense, the Canadian Border Services Agency (CBSA), Health Canada, and other agencies. Provincial and territorial governments share the responsibility of management, as do bilateral organizations such as the International Joint Commission and the Great Lakes Fishery Commission.

In 2001, federal, provincial, and territorial ministers of forests, fisheries and aquaculture, endangered species, and wildlife agreed to develop a Canadian plan to deal with the threat of invasive species. In 2002, the Canadian Council of Fisheries and Aquaculture Ministers created the Aquatic Invasive Species Task Group to develop an action plan to address the threat of aquatic invasive species. The AIS Task Group directed the National Code on Introductions and Transfers of Aquatic Organisms, which sets standards and provides a risk assessment process that can be applied to introductions and transfers of new aquatic organisms between and within regions. This policy does not address individual species but rather the pathways or vectors through which AIS enter Canadian waters, including shipping, recreational and commercial boating, live bait, aquarium trade, live food fish, unauthorized transfers, canals, and water diversions.

The Canadian Fisheries Act regulates the transport, possession, and use of baitfish. A by-law under the Health of Animals Regulations requires a permit for the importation of breeding fish and wild eggs to reduce the risk of disease introduction, and a 2012 amendment to this bylaw now includes requirements for importing aquatic animals including finfish, mollusks, and crustaceans into Canada (Canadian Food Inspection Agency 2012). Additionally, a bylaw of the Conservation and Development of Wildlife controls the purchase, sale, importation, transport, and stocking of all fish species, alive or dead, except non-indigenous species for use in aquariums. Additionally, Canada's Species at Risk Act (SARA) prevents Canadian indigenous species, subspecies, and distinct populations from becoming extirpated or extinct, provides for the recovery of endangered or threatened species, and encourages the management of other species to prevent them from becoming at risk.

Québec Policies

The Government of Québec enforces Canadian federal policy. In addition, each province has its own environmental statutes based on provincial constitutional powers over property rights, public lands, and private activity. For example, Québec's 2009 Water Resources Preservation Act regulates the transfer of water taken in Québec to outside the province. To the best of our knowledge, Québec has no specific policies of merit that are different from Canadian federal policy.

International Efforts at Cooperative Management

World leaders adopted the U.N. Convention on Biodiversity in 1992, formally recognizing that invasive alien species are one of the main direct drivers to the loss of biodiversity. In 2004, the International Maritime Organization adopted the Convention for the Control and Management of Ships' Ballast Water and Sediments, which establishes standards for the acceptable number of organisms to be present in ballast water. Globally, CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) is an international agreement between governments to ensure that international trade in specimens of wild animals and plants does not threaten their survival. Additionally, the Global Strategy on Invasive Species report prepared by the Global Invasive Species Program sets goals to prevent the spread of aquatic invasives across international borders. The International Joint Commission was formed by the Boundary Waters Treaty in 1909 between Canada and the U.S. to coordinate transboundary water activities. However, their activity has not included the prevention of aquatic invasive species in the Lake Champlain Basin.

International agreements also occur at state and provincal levels. In February 2013, Governor Shumlin of Vermont and Premier Pauline Marois of Québec signed an agreement to work towards greater regional, transboundary cooperation (Ring, 2013). This agreement is focused on economic development between the two regions, primarily through rail and electricity. However, a section of the agreement is dedicated to the environment and the management of Lake Champlain. This section could be used to further aquatic invasive species prevention policy.

Beyond Policy

While formal regulations and legislation are valid approaches for the prevention and management of AIS, it is important to recognize that other alternatives exist. Both Vermont and New York have programs aimed at invasive species management through citizen volunteers, education and outreach, and early detection. Regionally, the Lake Champlain Basin Program, the Lake Champlain Steering Committee, the Northeast Aquatic Nuisance Species Panel, and others are working on the issue in a cross-jurisdictional manner.

Lake Champlain Basin Aquatic Nuisance Species Management Plan

The Lake Champlain Basin Aquatic Nuisance Species Management Plan facilitates the coordination of invasives management efforts throughout the Lake Champlain Basin. The Plan implements a key section of "Opportunities for Action," which was originally completed and signed by the governors of Vermont and New York and representatives of the EPA in 1996 and was revised in 2003 and 2010. The Opportunities for Action plan identifies the development and implementation of a comprehensive management program for nuisance aquatic species as one of the highest priority actions required to address the long-term health of the Lake Champlain Basin.

The goals of the Lake Champlain Basin ANS Management Plan are to (1) prevent new introductions into waters of the Lake Champlain Basin; (2) limit the spread of established populations into uninfested waters of the Lake Champlain Basin; and (3) abate harmful ecological, socioeconomic, and public health and safety impacts resulting from infestations of AIS within the Lake Champlain Basin, largely through education and outreach. This plan focuses both on prevention and management of AIS.

Lake Champlain Steering Committee

In 1988, the governors of Vermont and New York signed a Memorandum of Understanding on Environmental Cooperation on the Management of Lake Champlain, which was later signed in 1996 by the Premier of Québec. This memorandum created the Lake Champlain Steering Committee aimed at coordinating across jurisdictions for the management of the lake (ANMP 2005).

Northeast Aquatic Nuisance Species Panel

The Northeast Aquatic Nuisance Species Panel was established in 2001 under the Federal Aquatic Nuisance Species Task Force. Panel members include state, federal, and provincial governments; researchers; commercial and recreational fishing interests; recreational boaters; commercial shipping; power and water utilities; environmental organizations; aquaculture, nursery, and aquarium trades; tribal concerns; lake associations; and the bait industry, among others (ANMP 2005).

V. Impacts of Aquatic Invasive Species Introductions

High-risk Species Analysis

We have identified four species not currently present in Lake Champlain but that are located in connected waters and pose a serious threat to the ecosystem. This is partially based off of the 2005 LCBP list of high priority species for management, but it has been altered to represent how the threats have changed over time. We selected species that represent a variety of taxonomic groups and vectors of transport. These species are hydrilla (*Hydrilla verticillata*), quagga mussel (*Dreissena bugensis*), round goby (*Neogobius melanstomus*), and fishhook waterflea (*Cercopagis pengoi*) (Table 3). Each species has been found to be highly disruptive in nearby ecosystems and, in the absence of interventions, will likely arrive in Lake Champlain. While we focus on these 'high-risk' species, they are by no means the only species at risk of entering and impacting the Lake Champlain Basin.

Species	Vector of Transport	Environmental Impacts	Economic Impacts	Cultural Impacts	Control and Management
Hydrilla (*Hydrilla verticillata*)	aquarium trade, overland transport	displaces native vegetation, kills native fish, alters water chemistry	expensive to manage and control, decreases real estate values, impacts tourism	obstructs recreational activities	mechanical harvest, lake draw-downs, herbicides, biological control, public outreach, education
Quagga Mussel (*Dreissenia bugensis*)	canals, overland transport	alters water chemistry, alters food web, displaces native mussels, releases pseudofeces, contaminates the water	colonizes manmade surfaces, impacts tourism and recreation	decreases sportfish populations, beach closures, colonize historic shipwrecks	Chlorinate water, raise water temperature, public outreach, education
Round Goby (*Neogobius melanostomus*)	canals, baitfish	outcompetes native species by altering the food web and displacing them from their spawning grounds, a link in the bioaccumulation of contaminant	negatively impacts recreational and commercial fisheries,	nuisance to fisherman by removing bait from hooks, threat to human health because of bioaccumulation	electronic barriers, piscicides, pheromone treatment, public outreach, education
Fishhook Waterflea (*Cercopagis pengoi*)	overland transport, canals	alters food web, alters water chemistry	attaches to fishing equipment that has to be replaced	nuisance to fisherman who have to replace their equipment	treat ballast water, clean ship hulls, clean fishing gear and boat equipment, public outreach, education

Table 3. "High-risk" aquatic invasive species, their vectors of transport, impacts, and control and management.

To focus this impact analysis, we have developed a conceptual model based on the work of Doren et al. (2009). This conceptual model highlights the impacts of these invasive species on an ecosystem level (Figure 13). For our purposes, we added human-use impacts to the model in order to better include human interaction with invasive species into the framework. While this framework is not explicitly presented for each species, it informed the way we outline the information.

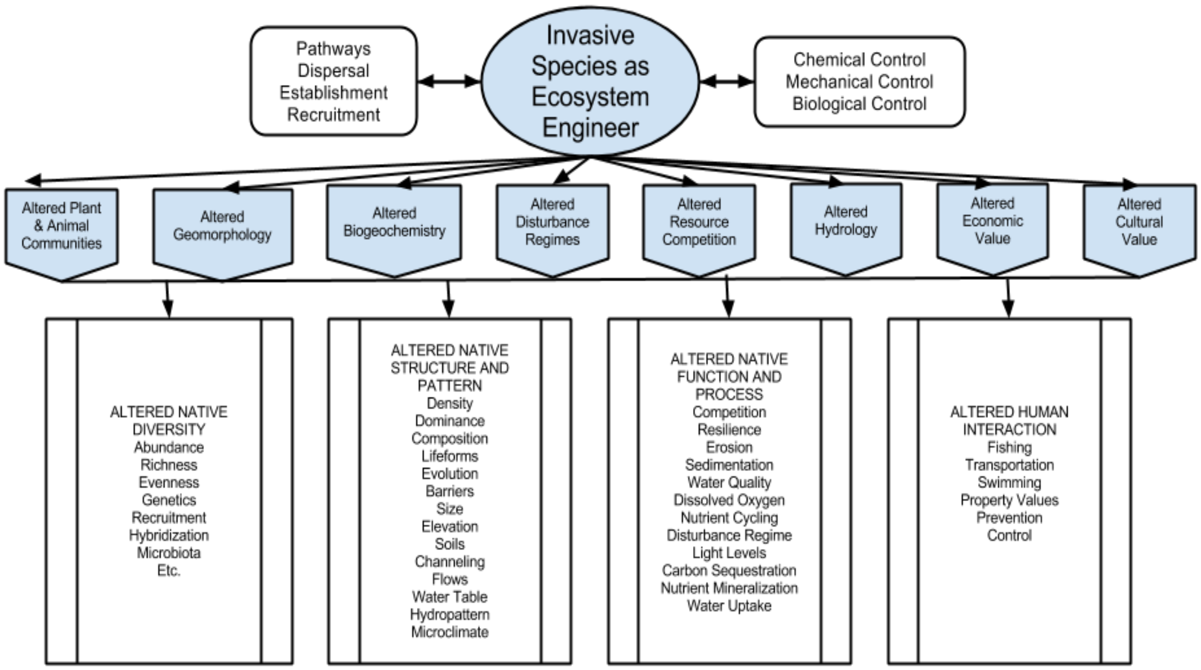

Figure 13. Framework for the impact of invasive species. Adapted from Doren et al. (2009).

Hydrilla (*Hydrilla verticillata*)

Figure 14. Image of *Hydrila verticillata*.
Image Source: USGS

Hydrilla is a flowering aquatic plant that forms dense stands of long stems with leaves arranged in whorls around the stem (Figure 14). Hydrilla is very prolific: a single tuber can grow to reproduce more than 6,000 new tubers per square meter (Ramney and Peichel 2001).

Habitat

Hydrilla is an obligate aquatic species, meaning that it requires a wet habitat to live and grow. Hydrilla can survive and reproduce in a variety of aquatic habitats, making the species particularly adept at invasion. Hydrilla thrives in almost any freshwater habitat including lakes, ponds, rivers, marshes, ditches, tidal zones, impoundments, and canals (Jacono and Richerson 2003a). It can grow in water as shallow as a few inches and in water over 20 feet deep in both low nutrient and high nutrient conditions. Hydrilla also has high resistance to salinity relative to other freshwater aquatic plants. It could spread in the Lake Champlain Basin because hydrilla is somewhat winter-tolerant, however its optimal growth temperature is 20-27 degrees Celsius. Northern populations overwinter and regrow from subterranean tubers.

Invasion History

Hydrilla verticillata is native to the Indian subcontinent. It was introduced to the U.S. as a popular aquarium plant and was subsequently accidentally released into the wild in Florida. It has since rapidly spread north to Connecticut, Massachusetts, and Maine.

Vector

Hydrilla is sold through aquarium supply dealers and over the Internet (Ramney and Peichel 2001). However, hydrilla mainly spreads as castaway fragments on recreational boats. It has spread to over 690 waterbodies in 21 states (Jacono and Richerson 2003a). Hydrilla grows as far north as the U.S./Canada border (Ramney and Peichel 2001).

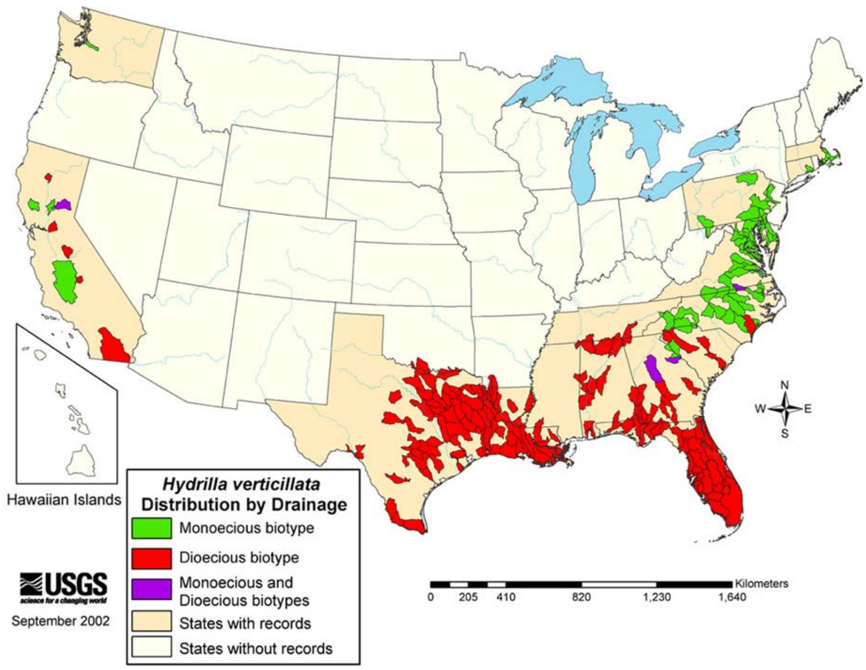

Figure 15. Map of current hydrilla populations in the United States. Image Source: USGS

Impacts of Invasion

<u>Environmental</u>

Hydrilla has numerous ecological impacts. It displaces native vegetation, decreases oxygen availability, and kills native fish populations. Hydrilla can grow one inch per day and forms thick mats that shade out native submersed plants. Dense hydrilla infestations can alter water chemistry and oxygen levels (Ramney and Peichel 2001). This can cause fish kills and zooplankton and phytoplankton declines (Jacono and Richerson 2003a). It can also reduce the foraging efficiency of native fish as open water space and natural vegetation gradients are lost.

Figure 16. Hydrilla on a propeller. Image Source: Florida Department of Environmental Protection

<u>Economic and Cultural</u>

Hydrilla's economic impacts include both the costs of management and control as well as their effects on aquatic ecosystems. For example, in Florida, millions of dollars are spent annually on herbicides and mechanical harvests. An estimated $10 million was necessary to manage hydrilla from 1994 to 1995, and $14.5 million from 1995 to 1996 (Langeland 1996). Control costs aside, hydrilla also affects real estate values, tourism activities, and recreational user groups. There were an estimated $11 million in damages associated with the species in Orange Lake in North Central Florida (Langeland 1996).

Culturally, the heavy growth of the hydrilla can obstruct recreational boating, swimming, and fishing in lakes and rivers. Hydrilla can also clog pipes that draw water for agricultural irrigation and power generation (Lake Champlain Basin Program; Jacono and Richerson 2003a). Major infestations of hydrilla (coverage that exceeds 30%) may also limit sportfish weight and size (Langeland 1996).

Control and Management

There are four common management and control methods employed to reduce the impact of the hydrilla on aquatic ecosystems. Mechanical harvesters and chopping machines remove hydrilla from the water and dispose of it on shore. In many cases, however, the fragmentation of the hydrilla may increase its distribution. Lake drawdowns lower the water level of a lake and increase hydrilla mortality. Stocked fish and insects, specifically the herbivorous Chinese grass carp and leaf-eating flies, have been used to control hydrilla. Finally, temporary control of hydrilla can be achieved through the use of registered aquatic herbicides, but their long term use is not advised (Langeland 1996).

Quagga Mussel *(Dreissenia bugensis)*

Figure 17. Quagga mussel individual.
Image Source: USGS

The quagga mussel is a member of the dreissenid mussel group, comprised of freshwater bivalve mussels, and is a close relative of the zebra mussel (Figure 17, Benson et al. 2013b). It reproduces through external fertilization, which means millions of larvae can be produced in a single breeding event and can float for weeks before finding adequate substrate. The quagga mussel is a filter feeder, feeding on plankton in the water. It can filter up to 1 liter of water per day and can remove large amounts of plankton and particulate matter from the surrounding environment.

Habitat

The quagga mussel is able to colonize more extensively than the zebra mussel (Claxton and Mackie). It can spawn in the hypolimnion, the dense, bottom layer of water, and has been shown to spawn at temperatures as low as 9 degrees Celsius, but is possibly less heat tolerant than the zebra mussel (Mills et al. 1996a). The quagga mussel has been found at depths deeper than 100 meters in Lake Ontario (Mills et al. 1996a). Temperature could explain the quagga mussel's absence or slow colonization of the Erie Canal, as the canal is shallower and therefore warmer than the nearby Great Lakes.

Beyond temperature, the quagga mussel has several other environmental requirements. It cannot survive in highly saline environments (Mills et al. 1996a). Due to the shape of their shell, the quagga mussel can colonize many different substrates and are often found on soft and sandy substrates, as well as harder surfaces (Mills et al. 1996a). The quagga mussel does not stick to substrates as well as the zebra mussel, which may inhibit its ability to colonize in areas with quick moving water (Nalepa 2010). Furthermore, the quagga mussel has a decreased feeding ability in waters with high turbidity (Nalepa 2010). Lastly, the quagga mussel is calcium limited, due to its need to build a shell. In the St. Lawrence River, the quagga mussel is not found in water with a calcium concentration below 12 mg/L (Jones and Riccardi 2005).

Once introduced into a waterway, the quagga mussel can rapidly colonize the ecosystem (Benson et al. 2013b). Since the zebra and quagga mussels occupy similar ecological niches, they compete with one another. Evidence from the Ukraine and the Great Lakes suggests that the quagga mussel may ultimately displace the zebra mussel (Mills et al. 1996a). This means that the zebra mussel population in Lake Champlain could one day be replaced with another equally if not more damaging dreissenid mussel species.

Invasion History

The quagga mussel is native to Eastern Europe and was introduced to North America from the Ukraine (Brown and Stepien 2010). The first quagga mussel was identified in Lake Erie in August 1991 (Benson et al. 2013b).

By 1993 its range extended from the central basin of Lake Erie to the St. Lawrence River at Québec City (Mills et al. 1996a). To date, it has not been reported in either the Hudson or Richelieu Rivers, but quagga mussels have been reported in the Mohawk River (Benson 2011).

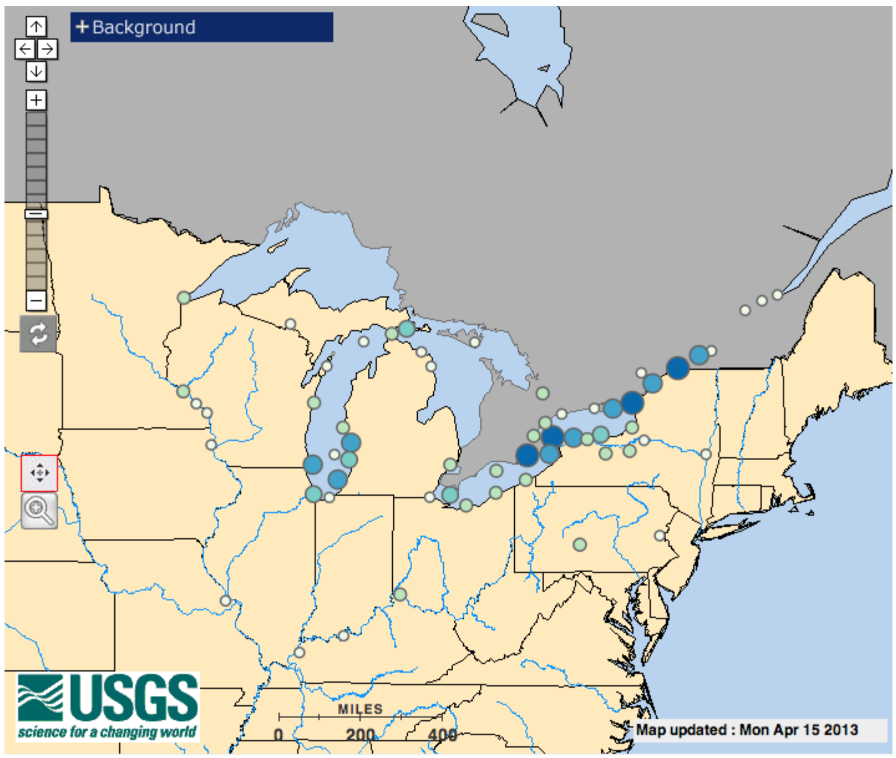

Figure 18. Quagga mussel occurrences in waterways connected to Lake Champlain. Dot size represents size of established population. Image Source: USGS

Vector

The introduction of the quagga mussel to North America is most likely due to ballast water discharges of transoceanic ships in the Great Lakes. Larval drift and boating activities can aid transport of these species (Benson et al. 2013b). Larval drift would likely occur through the Champlain Canal, which introduces new water into the basin, while the Richelieu River flows away from Lake Champlain. Boats are also frequently transported over land, and a contaminated boat could easily transport the quagga mussel into Lake Champlain from another waterway.

Impacts of Invasion

Environmental

The quagga mussel has had impacts similar to the zebra mussel in the Great Lakes and adjacent waterways. Their impacts on the ecosystem and surrounding environments are substantial and wide-ranging. As filter feeders, they alter the water chemistry, increase water clarity, and decrease the phytoplankton content of the water that surrounds them (Benson et al. 2013b). The quagga mussel is arguably more damaging than the zebra mussel to ecosystems. Since the species is not confined to shore ecosystems where hard substrate is located, their impacts can spread throughout an entire lake ecosystem (Mills et al. 1996a). The invasion of quagga mussel in a lake already impacted by zebra mussel effectively doubles the biomass of invasive dreissenid mussel species, further magnifying their negative impacts (Nalepa 2010).

The quagga mussel has several effects on the structure of lake ecosystems. It alters water clarity, which can lead to a proliferation of aquatic plants, changing the basis of the food system and food availability (Benson et al. 2013b). Through filter feeding, quagga mussels remove plankton and many of the nutrients plankton need to survive, moving the energy of the system towards the bacteria, macrophytes, and other invertebrates that live in lake beds (Higgins and Vander Zanden 2010). These effects spread throughout the ecosystem, as planktivore fish species are deprived of their food source, and benthivore fish species thrive. Eventually, the entire lake ecosystem structure is radically different. Quagga mussels also release a pseudofeces, which can foul water quality (Claxton et al. 1998). Furthermore, the pseudofeces also contains the same levels of toxins that bioaccumulate in the quagga mussel tissue. This leads to the creation of a toxic environment for wildlife that consume the mussels.

If it were to be introduced into the Main Lake, the middle and deepest section of Lake Champlain, then the quagga mussel would likely quickly become established. Since the quagga mussel can grow just as well or better than the zebra mussel, especially under low food conditions, it could be expected to take hold in the same areas as the zebra mussel (Baldwin et al. 2002). A potential barrier could be the warm, shallow areas at either end of the lake, as the quagga mussel may be less temperature tolerant than the zebra mussel. Serious changes could occur in the coldwater aquatic ecosystem in the Main Lake if the quagga mussel was established there. The toxic bioaccumulation could also threaten many of the species in the basin that feed on mussels.

Economic and Cultural

Generally, the economic effects of dreissenid mussels are studied together. Dreissinid mussel species degrade water quality due to long-term algal blooms caused by the increased water clarity. They colonize any hard surface, damaging structures like water intake pipes, docks, breakwalls, buoys, and boats (Benson et al. 2013b). The colonization of mussels on or near beaches may also lead to beach closures or injuries, which affect tourism and recreation. Attempts to control the proliferation of these mussels are direct costs to governments and other groups charged with controlling the mussels.

The cultural impacts of invasive species can only be speculated upon without detailed surveys of stakeholders. However, that does not mean that they do not exist and are not broad. A decrease in popular sportfish populations or decreased access to beaches could damage the way many people use a lake ecosystem for recreation. Damage to boats from quagga mussels could also change regional boating cultures. Further study should be completed in this area.

Figure 19. A beach fouled by quagga mussels. Image Source: USDA Aquatic Invasive Species Clearinghouse

Quagga mussels could colonize the historic shipwrecks located in deep parts of Lake Champlain. These wrecks have been largely spared the invasion of zebra mussel, but they are an ideal quagga mussel habitat. Damage to these ships could be irreparable.

Control and Management

There is no known method of eradicating the quagga mussel once it enters a large waterbody. This is because larvae float throughout the waterbody and are well-dispersed. Chlorinating water and raising water temperatures have been shown to cause high mortality levels in quagga mussels (Brady et al. 1996). Both of these methods would harm native ecosystems and are therefore not viable in large waterbodies. However, these methods could be used in a boat lift or when rinsing boats after transport between waterbodies (Beyer et al. 2011).

Round Goby (*Neogobius melanostomus*)

The round goby (*Neogobius melanostomus*) is a small, benthic fish that lives in fresh and brackish water (Figure 20). The round goby has a large head, soft body, spineless dorsal fins, and average three to six inches in length, but can reach 10 inches (LCBP Baitfish Guide 2005). The zebra mussel is a main food source for the round goby, so the goby could potentially thrive if introduced in the Lake Champlain Basin (Fuller et al. 2013b).

Figure 20. Round goby individual from the Great Lakes. Image Source: USGS

Habitat

The round goby perches on rocks and other substrates in shallow areas but has been known to thrive in other habitats. In its native range the benthic round goby occupies a variety of habitat types including coarse gravel, as well as shell and sandy inshore areas (Ray and Corkum 2001). In the St. Clair River of the Laurentian Great Lakes, the round goby can be found in cobble, riprap, and vegetation by the shore where substrates provide large interstices for refuge and spawning (Jude and Deboe 1996). According to a study by Ray and Corkum (2001), the round goby is more abundant in rocky substrates than in sandy substrates.

Invasion History

The round goby is native to the Caspian, Black, and Azov Sea regions and their tributaries, and it was first found in the Great Lakes in 1990 in the St. Clair River in Michigan (Sea Grant Pennsylvania). There is strong evidence that it was most likely introduced from the ballast water of an ocean freighter. Its rapid spread since 1990 indicates either multiple introductions or continued spread through lake freighters (Kostel 2001).

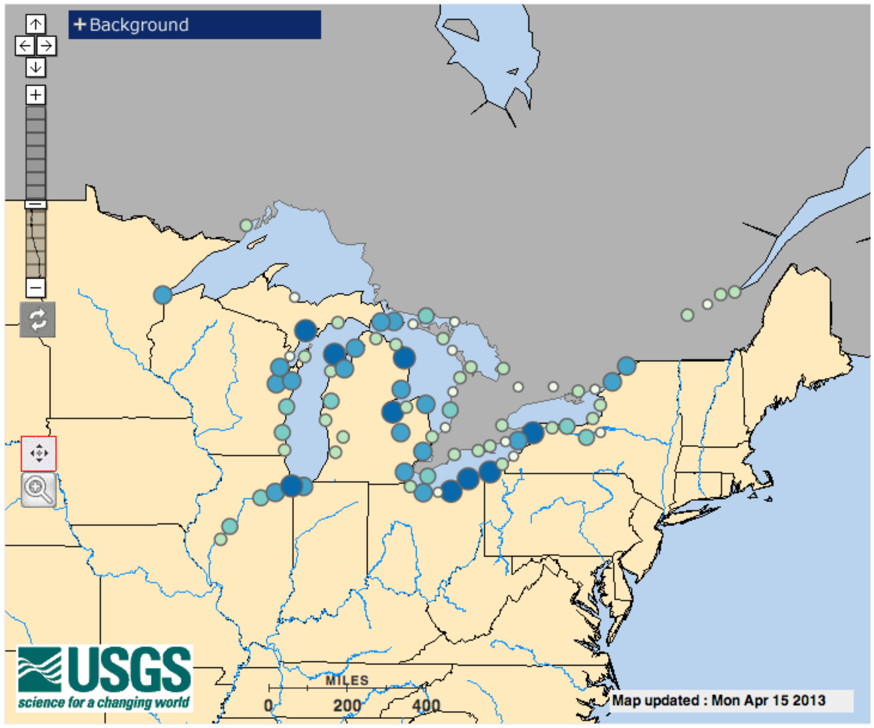

Figure 21. Distribution of round goby in waterways surrounding Lake Champlain. Dot size is the established population size.
Image Source: USGS

It has since spread to all of the Great Lakes and is working its way inland through rivers and canal systems. Some studies have predicted that it could spread to North American coastal marshes and estuaries, where salinities are similar to Eurasian habitats (Kornis et al. 2012).

Vectors

Because the round goby can feed at night, nocturnal ballasting could easily result in the transport of thousands of juveniles at a time, and night-time foraging suggests that the round goby would be able to survive in dark ballast tanks for extended periods (Kornis et al. 2011). The young round goby often resembles small baitfish and can be accidentally spread by boaters and fisherman who carry it from one body of water to another in bait buckets, bilge water, and on plant debris (Sea Grant Pennsylvania). Several studies have shown that because there is high intraspecific competition between the round goby at high densities in streams, it has expanded its range (Kornis et al. 2011).

Impacts of Invasion

Environmental

The round goby has affected native species through competition, predation, and providing forage. While they do feed on the zebra mussel, their ecological benefits are outpaced by the harm they impose (Bello 2011).

The round goby is a fierce competitor for a number of reasons. Because of its well-developed sensory system that enhances its ability to detect water movement, it can feed at night. This gives it a huge competitive advantage over other fish in the same habitat (Kornis et al. 2011). The round goby also has a suctorial disk located on its pelvic fin which allows it to attach to rocks/substrates and remain fixed on the bottom in fast currents. It also can thrive in poor water conditions, including areas of high salinity and low oxygen levels (Kornis et al. 2011). The round goby is a voracious predator and feeds on many taxa including zooplankton (as juveniles), benthic invertebrates, small fish, and the eggs and larvae of large fish. Its adaptability to locally abundant food sources facilitates its species invasion potential.

The round goby is also a repeat spawner and aggressively defends its nest, driving away native fish from prime spawning areas. It has been known to aggressively attack native intruders by killing and even eating them. Its aggressive behavior reduces the reproductive success of native species (Sea Grant Pennsylvania). Studies in the Great Lakes have found that females will spawn every three to four weeks from April through September, whereas other native benthic fish will only spawn once. Their spawning is cued by water temperature, and their spawning period has been prolonged due to warmer water temperatures associated with climate change (Kornis et al. 2011).

Due to its widespread abundance in both the Great Lakes and the Baltic Sea, the round goby has become an important forage item for many species (Kornis et al. 2011). Species that depend on the round goby include the burbot, double-crested cormorants, watersnakes, and yellow perch. There is some evidence that the predation levels help control the round goby population (Kornis et al. 2011).

Whether or not the round goby has played a role as a contaminant vector has been a subject of much debate. Several studies have suggested that round goby increase bioaccumulation of sediment-related toxins in predatory fish (Kornis et al. 2011). Because the round goby feeds heavily on bivalves, which are filter feeders, and because they are important forage to many larger fish, they provide a link where contaminants can be transferred. Other studies have found that the round goby does not always contribute to the biomagnification of toxins in the Great Lakes food web, as bioaccumulation is more dependent on ambient levels of sediment contamination (Kornis et al. 2011).

The round goby is also believed to have contributed to higher rates of avian botulism. The species is a probable vector because it spends almost all of its time on the lake bottom, where *C. botulinum* is more likely to be present. An infected round goby exhibits hyperpigmentation and erratic swimming right before it dies, which makes it an easy target for the birds. This suggests that the round goby is the main vector for the transfer of the botulism neurotoxin to fish-eating birds (Kornis et al. 2011).

Economic and Cultural

The round goby has already had negative effects on recreational and commercial fisheries in the Great Lakes. The depletion of native species affects the angling industry and recreational sport fishers. The round goby interferes with angler activities because it will remove the bait from the hooks, causing the anglers to catch the round goby instead of the sport fish. There is no definitive study on the economic costs of the round goby in the Great Lakes, mainly because this species degrades indirect-use values that are difficult to measure (Kornis et al. 2011).

The round goby is also a threat to human health. Because it heavily feeds on zebra mussels and quagga mussels, which are filter feeders, it can accumulate contaminants such as heavy metals, PCBs, harmful bacteria, and toxins in their fatty tissues (Sea Grant Pennsylvania). Because many sport fish are found to prey on the round goby, the bioaccumulation of these contaminants moves up the food chain, leading to more restrictive fish consumption advisories.

Control and Management

Given its abundance the Laurentian Great Lakes, eradication of the round goby would be impractical. Management efforts have focused on prevention and control measures.

Currently the most common control methods for the round goby in the Great Lakes are electronic barriers (fences and mats) and piscicides, sometimes in combination. According to Steingraeber and Thiel (2000), electric barriers effectively prevent the passage of the round goby. Corkum et al. (2008) found that pheromones also have potential for use in selectively trapping and controlling round gobies. Although pheromone traps have not been field-tested and would probably require greater effort than chemical treatments, they would be highly specific to round gobies and not pose risks to human health.

Public education and outreach has been another method employed in the Great Lakes region. Boaters are reminded to empty their bait buckets on land before moving from one watershed to another and are reminded that it is illegal to use round gobies as bait (or to even possess live gobies). Making sure that anglers know how to identify the round goby is extremely important because they are normally the first to know of a round goby infestation. Another control mechanism could be commercial exploitation and canning for human consumption, which occurs in their native range (Jude et al. 1992).

Fishhook Waterflea (*Cercopagis pengoi*)

Figure 22. Fishhook waterflea individual.
Image Source: USGS

The fishhook waterflea (*Cercopagis pengoi*) is in an order of small cladoceran crustaceans that are generally found in inland aquatic habitats. This zooplankton shares many morphological features with the spiny waterflea, another invasive zooplankton (MacIsaac et al. 1999). The fishhook waterflea has a large caudal appendage that is five to eight times its body length. The appendage has a distinct terminal loop, serving as protection against fish and other aquatic predators (Figure 22, Benoît et al. 2002; Jacobs and MacIsaac 2007). The fishhook waterflea is a predatory zooplankton. In capturing its prey, it tears and punctures it with mandibles and sucks out the body contents. It is a generalist and opportunistic feeder, preying primarily on other zooplankton including copepods, rotifers, and podonids (Birnbaum 2011; Laxon et al. 2003; Kane et al. 2003).

The fishhook waterflea reproduces both sexually and asexually depending on its environment, meaning that a single individual can result in an introduction (Kane et al. 2003). Along with reproductive versatility, this invasive waterflea also has the ability to produce diapausing eggs, which remain viable for a period of dormancy, allowing the species to resist adverse environmental conditions like desiccation, exposure to salt water, and passage through fish digestive tracts (Jacobs and MacIsaac 2007). The combination of asexual reproduction, production of resting eggs, and a “sticky” hooked caudal appendage promote rapid population growth, viability during unfavorable periods, and widespread dispersal (MacIsaac et al. 1999).

Habitat

The fishhook waterflea is found both in brackish waters and freshwaters (Birnbaum 2011). It exhibits a great deal of environmental tolerance to salinity and temperature, as the species can persist in waters as cold as 8 degrees Celsius and as high as 30 degrees Celsius and salinities ranging from 0.1 to 14% (Kane et al. 2003). Although present throughout the water column, the greatest abundance of the fishhook waterflea is found in the upper 20 meters of the water column (Benoît et al. 2002; Krylov et al. 1999). Studies have found peak abundance of the fishhook waterflea to be between mid-July and mid-August, the period with the highest water temperatures (Krylov et al. 1999). Its short generation time, rapid growth, early sexual maturity, and rapid dispersal all contribute to the spread and success of this invasive species.

Invasion History

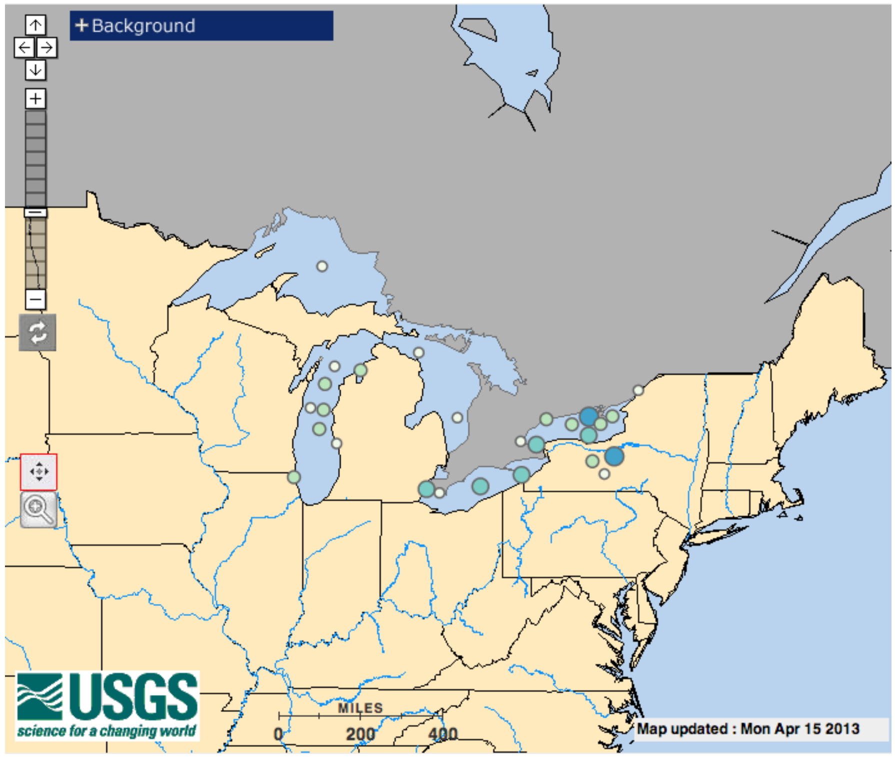

Figure 23. Map of the current distribution of fishhook waterflea in waterways near Lake Champlain. Size of dot represents size of established population. Image Source: USGS

The fishhook waterflea is native to Eurasia including the Caspian and Aral Seas and coastal lakes and estuaries of the Black Sea (Kane et al. 2003). It was first recorded in the Baltic Sea in 1992 and by 1995 reached high densities in the eastern Gulf of Finland (Krylov et al. 1999). The first North American introduction was recorded in Lake Ontario in 1998. It has since spread to Lake Michigan and the New York State Finger Lakes (Benoît et al. 2002; Laxson et al. 2003; Brown and Balk 2008; Kane et al. 2003).

Vectors

It is thought that the fishhook waterflea was introduced into North America through the transport of diapausing eggs in ballast water of vessels traveling from the Baltic Sea to Lake Ontario (Kane et al. 2003; Jacobs and MacIsaac 2007; Brown and Balk 2008). Because of their salinity tolerance, it is possible for the fishhook waterflea to survive in ballast tanks even if they are flushed with seawater before entering a freshwater region (Jacobs and MacIsaac 2007). Once established in Lake Ontario, transfer to Lake Michigan, Lake Erie, and the New York State Finger Lakes was almost certainly through ballast water as well (Jacobs and MacIsaac 2007). Despite this homogeneity of introduction, vectors of transport for the fishhook waterflea are not restricted to ballast water. The small crustaceans or resting eggs can easily be transferred on fishing gear and plankton nets, on trailered boats, in bait buckets, and even in the plumage or digestive tracts of waterfowl and fish (MacIsaac et al. 1999).

Impacts of Invasion

<u>Environmental</u>

The fishhook waterflea, once introduced, has the propensity for population growth and the ability to have considerable impacts both on higher and lower trophic levels in the food chain (Benoît et al. 2002). It is difficult to predict the effect that the fishhook waterflea will have on the food web in Lake Champlain, as it has direct impacts on zooplankton populations and indirect impacts on zooplankton, phytoplankton, and planktivorous fish populations. The fishhook waterflea has the potential to alter trophic food webs and energy fluxes throughout the ecosystem, causing changes in populations and water quality (McPhedran 2001; Telesh et al. 2001).

The fishhook waterflea is a voracious predator and it has been found to prey on native zooplankton, including other species of waterflea, copepods, and rotifers (Laxson et al. 2003; MacIsaac et al. 1999). The abundance of native zooplankton species pre- and post-invasion of the fishhook waterflea in Lake Ontario indicates that in August, when the fishhook waterflea is at its highest seasonal abundance, dominant native species have declined significantly in their abundance since the invasion (Benoît et al. 2002). This can directly affect zooplankton populations and indirectly impact phytoplankton, which may be released from predation pressure. The addition of the fishhook waterflea to the food web can also affect planktivorous fish, especially if the caudal appendage of the waterflea hinders the ability of fish to feed on the waterflea.

Economic and Cultural

Figure 24. Fishhook waterfleas on a fishing line. Image Source: MN Sea Grant

The greatest economic and cultural impact of introduction of the fishhook waterflea is on the fisheries and angling communities. Many waterfleas attach to fishing lines, making it difficult for lines to fit through the eyelets of fishing rods (Figure 24). Waterfleas also clog nets and trawls of large-scale fishing operations (Birnbaum 2011; Jacobs and MacIsaac 2007). In the Baltic Sea, for example, the mass abundance of fishhook waterfleas was accompanied by the formation of a "paste" that fouled fishing nets and trawls (Birnbaum 2011). For an individual this might mean having to cut and replace lines, and for larger-scale operations, this might mean replacement of expensive fishing gear.

There are no studies that estimate the economic impacts of the fishhook waterflea specifically, though it is possible to get a sense of potential costs of introduction. While large-scale commercial fisheries are not present in Lake Champlain, the basin is home to an active angling community. Fish harvested commercially in the basin are caught by anglers or by licensed bait dealers. Few records of catch and sale exist, though an estimate from 1991 suggests that between 91 and 388 metric tons of fish were sold (Marsden et al. 2010). The introduction of the fishhook waterflea into Lake Champlain could therefore affect anglers by lowering their catch yields and requiring more replacement equipment.

An economic study estimated that between 1998-99 the Lake Champlain Basin portion of the tourism economy of Vermont was valued at $2.7 billion and the New York portion of the basin was valued at approximately $1.1 billion; additionally, it was estimated that there was an annual expenditure of $228 million spent on Lake Champlain related activities including boating, camping, fishing, and lodging (Lake Champlain Steering Committee 2003). It is difficult to predict the extent to which introduction of the fishhook waterflea would impact these numbers, but evidence suggests that the local economy will experience adverse economic effects.

Control and Management

There are currently no known specific eradication or control efforts for the introduction of the fishhook waterflea, making prevention of transfer the only option. Specific prevention measures include treating ballast water, cleaning ship hulls, and cleaning fishing gear and boat equipment prior to relocation and overland transport. Using a chemical disinfecting agent in these processes could help reduce the risk of spread by killing nesting eggs (Birnbaum 2011; MacIsaac et al. 1999). Additionally, public education campaigns can help to ensure that anglers do not unwittingly introduce waterfleas into neighboring waterbodies (Jacobs and MacIsaac 2007).

VI. Impacts of Preventative Control Measures

Invasive species management often takes a species-specific approach, and while it can be beneficial to assess risk of introduction at the species level, a vector-based approach to prevention is more comprehensive, as many aquatic species are introduced into new waterbodies through the same pathways. A vector is a mechanism through which transfer or transport occurs. So even if high-risk species change through time, prevention by vector provides a greater safeguard against invasions. In this section, we outline the impacts of preventative control measures by vector: canals, overland transport, the aquarium trade, and baitfish. These four vectors are considered the most likely pathways through which a new aquatic invasive species could be introduced into Lake Champlain (Ellen Marsden 2013, pers. comm.). Historically, most AIS have been introduced to Lake Champlain through these vectors, and all four of our high-risk species are transported through at least one of these mechanisms. For each vector, we identify the risk of introduction, the different types of associated prevention measures, and the economic, cultural, and ecological costs associated with each, if known.

Canals

There are two main canals that connect the Lake Champlain Basin to regional waterbodies. The Champlain Canal connects the southern end of Lake Champlain directly to the Hudson River system and indirectly to the Great Lakes via the Erie Canal, while the Chambly Canal improves the linkages between Lake Champlain and the St. Lawrence Seaway and Atlantic Ocean (Figure 25). Marsden and Hauser (2009) consider the Champlain Canal to be the more important vector for aquatic invasives because, unlike the Chambly Canal, it creates a pathway from Lake Champlain to previously unconnected waterways.

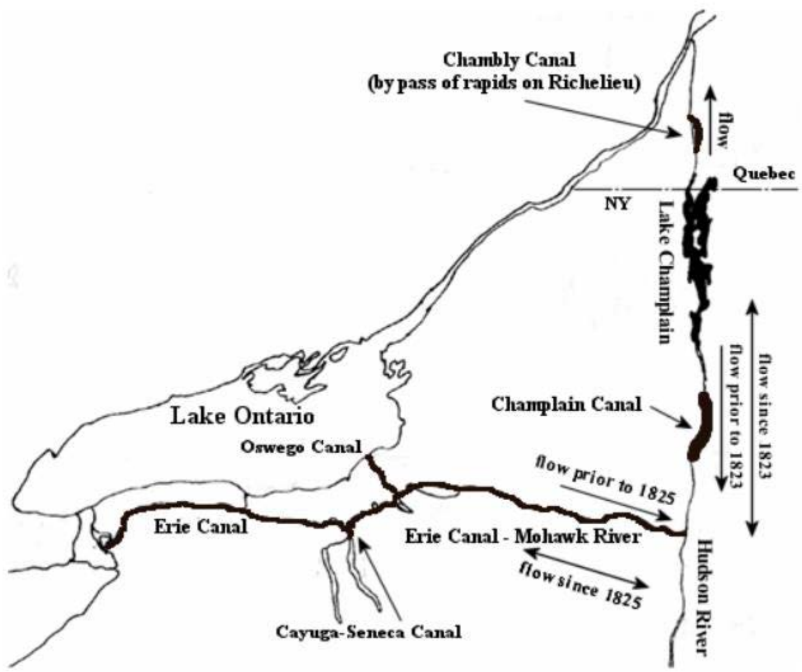

Figure 25. Map of the canal system connecting Lake Champlain to other waterbodies. Image Source: Malchoff et al. (2005)

Risk of Transport

Canals are considered the most common vector of transport for aquatic invasive species into Lake Champlain. Marsden and Hauser (2009) estimate that 20 of the 49 aquatic invasive species in Lake Champlain have invaded the basin via canals. The vectors of introduction for 11 species is unknown, which means that over 60% of aquatic invasive species in Lake Champlain whose origin of introduction is known entered the basin via canals, and of those 20 species, 12 are thought to have arrived via the Champlain Canal. These species include water chestnut, zebra mussels, and white perch. In terms of our high-risk species, Marsden and Hauser (2009) suggest that the quagga mussel, the fishhook waterflea and the round goby have the potential to reach the Lake Champlain basin via the Champlain Canal.

While the Champlain Canal was designed and used as a commercial cargo shipping route, it is now largely a recreational and historical resource: from 1996 to 2004, recreational lockings were eight to ten times more frequent than commercial lockings in the Champlain Canal (Malchoff et al. 2005). Commercial shipping volumes declined from about 250,000 tons in 1988 to a mere 800 tons in 2004 (Malchoff et al. 2005). More recently there has been a slight increase with 6,000 tons of commercial shipping travelling along the Champlain Canal in 2011 and 40,000 tons travelling along the canal in 2012 (Post-Standard 2013; Toscano 2013). This increase is possibly due to the environmental and economic benefits of waterborne freight logistics. According to a study by the New York Department of Energy and New York Department of Tranportation, barges are 300% more energy-efficient than trucks and are therefore less vulnerable to volatility in oil prices (Goodban Belt, LLC 2010).

Despite this increasing trend, today the Champlain Canal is primarily used for recreational boating. According to the most recent data from 2004, 89% of all vessel lockings were associated with recreational boating. In the past five years, the average number of lockings in the Champlain Canal has been 20,573 per year (Toscano 2013). The five-year minimum was 18,068 lockings in 2008, while the five-year maximum was 23,842 lockings in 2009.

To gauge how frequently the canal is actually used, we can divide the total number of vessel lockings in the past five years (102,863) by the number of locks in the Champlain Canal (11) and by the approximate number of days that the Champlain Canal was operational in the past five years (950) (New York State Canal Corp 2011). Typically, the canal is open from May 1 to November 15 each year, a period of 199 days. Occasionally, however, the entire canal is closed due to weather events or repairs. For instance, in 2011, the canal's opening was delayed by roughly three weeks due to weather events and high waters (New York State Canal Corp 2011). On the other hand, the canal has opened a few days early in years past, as in 2012 when it opened on April 29. Instead of using 995 days (199 possible days x 5), we chose to use 950 days as an estimate for the canal's total operating days in order to account for closures or delayed openings.

According to this calculation, there was an average of approximately 108 lockings per day of operation. That means that the equivalent of 9.84 vessels per day traveled the equivalent of the full length of the Champlain Canal in the past five years, on average. Our daily vessel estimate is a rough measure, it could be that there were slightly more vessels, each traveling shorter distances across the canal and thus, there may be some portions that are less frequently used than these estimated. Overall, our lockings data reveals that the canal waters are, in fact, utilized somewhat infrequently.

Prevention Measures

Malchoff et al. (2005) provide an excellent summary of the potential benefits and costs of various prevention measures along the Champlain Canal. They propose five potential plans for the canal and assess the feasibility of each option.

Alternative One: Close the Champlain Canal entirely
Alternative Two: Physical/mechanical modification
Alternative Three: Behavioral fish barriers
Alternative Four: Chemical/water quality barriers
Alternative Five: Biological barriers

Impacts of Prevention Measures

Alternative One: Close the Champlain Canal entirely

If the Champlain Canal is closed, no new invasions into Lake Champlain would occur through the canal. However, closing the Champlain Canal would come with significant costs and many objections. The closure of the canal would prohibit recreational boating, resulting in a loss of more than 20,000 passages through the system annually. The closure would reduce the tourism activities of the region and there would also be some impacts on shipping, albeit limited impacts, as the annual volume of shipping traffic across the canal is small.

The closed canal could be used in a variety of ways. It could be used for water storage or could be dewatered and recovered for alternate uses. There are no ecological impacts associated with the closure of the Champlain Canal, as the canal represents a waterway that would not exist without human intervention, and therefore such interventions would have negligible effects on native species and the aquatic ecosystem. There could even be economic benefits associated with recreational use of bike paths and fishing sites.

According to the Canal System Annual Traffic Report of 2004, the New York State Canal System as a whole contributes $384 million annually in economic benefits to New York. The Champlain Canal is just one part of the system, however its 60-mile length makes up roughly 11% of the canal system's length.

If we make the assumption that the economic benefits of canals are evenly distributed—in other words, if a one-mile stretch of the Erie Canal brings about equal benefits as a one-mile stretch of the Champlain Canal -- we can estimate an annual economic benefit at nearly $44 million for the Champlain Canal. This estimate appears somewhat problematic. It suggests that for every vessel that traverses the equivalent of the entire length of the canal, more than $23,600 is added to the economy.

Upon inspection, this per vessel benefit estimate sounds like a significant overestimate of the true economic benefits associated with the canal. We recognize that the economic benefits of canals are not limited to their direct use, of course: canal visitors may not board a vessel traveling along the canal, but they may still spend money on lodging and food, among other things. Furthermore, we recognize that many passengers can travel on one vessel at a time: up to 60 passengers for some touring company vessels (Champlain Canal Tours). But since as much as 90% of Champlain Canal traffic is comprised of recreational boaters with relatively few passengers, we believe the economic benefits cited by the Canal Corporation to be an overestimation.

Of course, it could be that the economic benefits associated with the Champlain Canal are lower than the economic benefits of other canals in the canal system, like the Erie Canal, most notably. In that case, the per vessel economic benefit estimate would be less, but even if it were reduced by a large factor, it would still be orders of magnitude away from a reasonable estimate.

Although our analysis suggests that the canal is utilized somewhat infrequently, and that the economic benefits that the Canal Corporation repeatedly emphasizes are an exaggeration, multiple stakeholders would likely object to the decision to close the canal. The Canal Corporation is required by law to operate for commercial traffic. Unless the law is amended, closing the canal would violate New York state law.

The canal also has aesthetic and historic value to those who live on or near it as well as to those who travel vial the canal, meaning that closing the canal could affect its unique cultural value.

Alternative Two: Physical/mechanical modification

Physical or mechanical modifications to the Champlain Canal to prevent the spread of AIS would consist of limited hydrologic separation with provisions for overland transport of recreational vessels, and use of graving (dry) dock or seasonal lockage restrictions for commercial vessels. Filling or dewatering a very short stretch of the canal may serve as an effective barrier against aquatic invasives. Malchoff et al. (2005) suggest that recreational vessel passage could be enabled through the dewatered portion by short-distance transport vehicles and systems. This would require engineering or operational solutions in order to allow for both recreational and commercial passage. Three methods have already been developed to transport recreational boats short distances overland:

1. A forklift system, which is already used in many dry-stack boat storage yards and marinas.
2. A sling-type lift in which a boat is lifted, transported a short distance, and placed back into the water.
3. A marine railway, which is typically used to clean, paint, or apply anti-fouling protection to the hull.

The marine railway could transport larger vessels that the other lift systems could accommodate. Large vessels could also use specialized locks built adjacent to the separation barrier. The Lake Champlain Transportation Company suggested commercial vessels in the Champlain Canal could theoretically be locked into a dry dock that could serve as a physical AIS barrier when the lock area is dewatered. Also, existing locks could be used but remain closed except for by permit, and transits limited to spring-fall periods when low water temperatures and AIS life history patterns (i.e., few eggs and larvae) combine to minimize the risk of unwanted AIS passage.

Malchoff et al. (2005) suggest that a physical barrier located between locks 8 and 9, at the junction of Glenn Falls Feeder Canal would be ideal because they are the highest point of the Champlain Canal and that way both northerly and southerly bound AIS would be blocked before heading down the elevational gradient (Figure 26). The effectiveness implementing physical barriers is contingent upon the inspection and cleaning of boat hulls and the emptying of live wells and bait buckets.

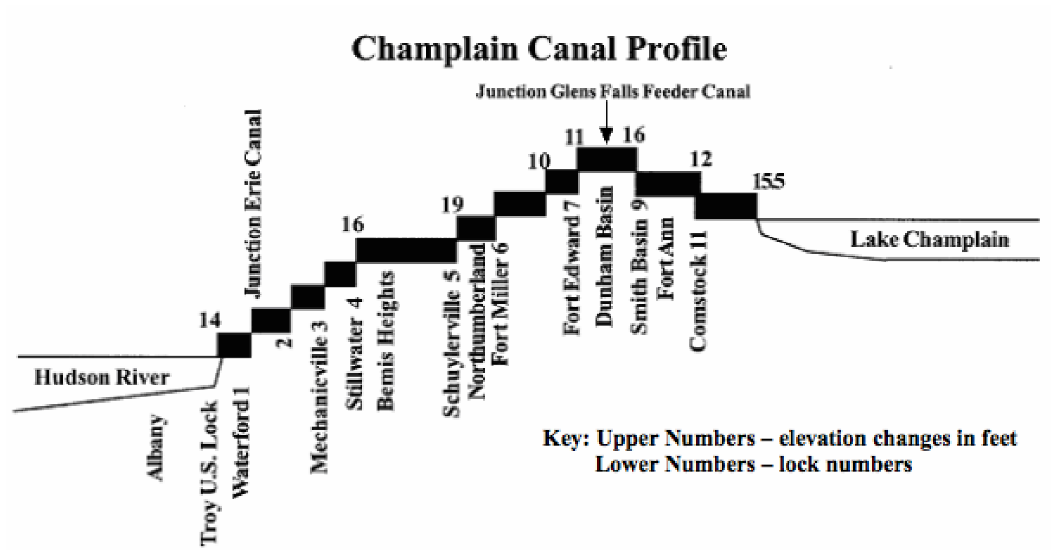

Figure 26. Malchoff et al. (2005) suggest putting a physical barrier between Locks 8 and 9, as indicated by the arrow.

The benefits of hydrologic separation have already been documented in the Chicago Sanitary Ship Canal Barrier II, and it seems to offer the best insurance against invasives via canal (Wisconsin Sea Grant Program 2001).This method is especially effective in addressing nearly all taxa and life history stages of the most threatening invasive species. The delay that recreational boaters will face when waiting for their boat to be transported provides educational and economic opportunities. Boaters will be forced to recognize the direct impact invasive species have on their lives and will be more willing to learn about the reason for the barrier. Boaters can also engage in activities that may help the economy such as buying food or shopping at local businesses. Tourism opportunities may be developed at this physical barrier. Additionally, pumping, collection, and treatment of dirty bilge water at the barrier site would contribute to improved water quality.

As with closing the canal, there are no ecological costs to this alternative; however, the associated economic costs of implementing these boat lift and transportation systems are mostly unknown. Transporting boats across a barrier could carry a per-boat cost, which could be paid by either the boater as a tax for use of the canal system, by the state(s) that are protected by the barrier, or by the businesses that benefit from the canal.

In looking at cultural impacts, the use of a mechanical barrier could cause a more significant impediment and impact on boaters if they have to pay for passing through the canal and there would also be a time-cost associated, both of which could impact the willingness of recreational boaters to utilize this route, therefore affecting how they view the canal and Lake Champlain.

Alternative Three: Behavioral fish barriers

Behavioral barriers include electrical, sound, bubble curtain, and strobe-light technologies, or various combinations of the above. These technologies have been used successfully to deter fish from power plant intakes, irrigation canals, and other engineered conduits and waterways.

The idea of an electrical barrier for the Champlain Canal was first investigated in 1989 by Smith-Root, Inc. at the request of NYSDEC in response to the threat of the invasion of alewife. But this plan wasn't pursued because of concerns about safety and liability. One of the problems of the electrical barrier is that it is only effective against vertebrate aquatic species (fish), some macroinvertebrates (crayfish), and large insect larvae. It would not affect plants and bacteria and would have a negligible effect on plankton or mollusks.

Boating traffic would be unimpeded by behavior barriers, and the effect of installation on the canal landscape would be relatively minor and would have a negligible ecological impact. Costs of certain barriers can be estimated by comparing the cost of the Chicago Canal electrical barrier. The total cost of design and installation is estimated at $8.4 million. Annual costs are not included in the estimate above, and would include maintenance and power use.

Opportunities for public education at the site are less ideal than the physical barrier because boaters wouldn't need to stop at the behavioral barrier. Looking back at why the electrical barrier wasn't pursued in 1989, public concerns about safety would also have to be addressed. The costs associated with these concerns include site investigation, construction, electrodes, annual operation and maintenance, annual electricity, monitoring, and hydro-acoustic array.

Alternative Four: Chemical/water quality barriers

Another alternative is to treat the water entering the specialized locks in the vicinity of the Glen Falls Feeder Canal and make it inhospitable to most aquatic life. These treatments could include chemically reducing dissolved oxygen (e.g., adding sodium thiosulfate), adding nitrogen, bubbling to purge oxygen from the water, increasing or decreasing pH, heating of the water, or adding a toxin. Piscicides such as Rotenone, can also be employed, which work by interfering with oxygen intake across gill membranes. Concerns with these chemical barriers include human health hazards, costs, implementation, liability, and impacts to native species.

The benefit of using chemical controls is that they are generally very effective in preventing invasive species. A study by Keppner and Theriot (1997) compared chemical and physical methods of preventing AIS in the Illinois Waterway system in terms of effectiveness, cost, and regulatory restriction. They found that chemical treatments are more desirable than electrical barriers, but the costs of the chemicals are higher. Chemical barriers represent possible ecological costs, as such chemicals could have negative impacts on non-target species and other unanticipated impacts to the ecosystem.

Economic costs can be broken down into at least three types. The first costs that need to be considered are the resource requirements of the chemical treatment such as the specific chemical, labor, and equipment for application. These all tend to be expensive because of the relatively small market for invasive species control products. The second costs are the permit requirements and maintenance or supervision of application. The permitting process requires careful review of scientific and legal records, and involves a substantial investment in time, state personnel, and fees. The third type of cost is environmental costs transformed into economic costs. The technical application costs can be expected to cost from tens to hundreds of thousands of dollars.

Alternative Five: Biological barriers

The use of biological control for invasive species has historically involved introducing a predator to limit the numbers of an already established exotic. Throughout the U.S., mosquitofish have been stocked to control disease-bearing mosquitoes, and Pacific salmon were stocked in the Great Lakes to control alewives (Fuller et al. 1999). Aquatic weevils and moths have also been introduced to waterbodies to control Eurasian watermilfoil (Creed 1998).

But there are several complicating factors when stocking predators and grazers in a canal. First the target species that the predators will go after are (1) often unknown, (2) not predictable in the timing of their arrival, (3) may involve several taxa, and (4) may present a mismatch with available predators. Secondly, exotic species in the canal are likely to be in small numbers and fairly dispersed, which limits predator efficiency. Third, the stocking effort must be focused on species that are native to all of the connected ecosystems, because any species introduced to the canal will disperse. Lastly a predator may not be effective at controlling the target species.

Other examples of biological control include the use of sterilization techniques and pheromones. Sterilization involves swapping fertile males with sterile males that mate with females, thus producing no offspring for the next generation. Chemical pheromone traps have been used to disrupt mating by target species. But these techniques are targeted toward exotic species that are already established and offer little advantage in prevention of invasions.

Using biological control requires a lot of research before any implementation, and is also subject to great variability in cost. Because of the variability of biological barriers, it is difficult to assess their ecological impact.

It is hard to estimate what the real impacts of these prevention measures would be, but to help, a survey should be conducted to gauge the canal's usage and importance in order to help make decisions on what kind of barrier, if any, could be implemented in the Champlain Canal. Also engineering studies are needed to predict the physical viability and costs associated with these alternatives. The costs of this new infrastructure need to be detailed before any serious deliberation on the problem of canal/AIS vector could begin. But based on current knowledge and options, we think that a mechanical barrier is the best option for AIS prevention in the Champlain Canal. It is effective at preventing spread of invasives while still allowing use of the canal by boaters.

Overland Transport

Ever since humans first set sail on the open sea, aquatic organisms have been hitching rides attached to the hulls of boats (Hulme 2009). However, attachment to hulls represents only one of many mechanisms in which aquatic species can be transported by boats, including entanglement of fragments or individuals in fishing gear and anchor chains, attachment to trailers, and through the transport of standing water including livewells, bilge water, and bait buckets (Figure 27) (Kelly et al. 2013; Rothlisberger et al. 2008). Overland transport and transient recreational boating is perceived as the primary vector of species transport between unconnected bodies of water, a mechanism through which species would not naturally travel (Johnson et al. 2001). Targets for this vector are recreational boaters and the vessels they are using. Recreational boaters comprise a diverse group including anglers, water skiers, charter boat operators, fishing guides, cruisers, sailors, small-boat commercial fisherman, personal watercraft users, and hunters (Rothlisberger et al. 2008). The boats of interest include powerboats, small commercial and recreational fishing boats, sailboats, personal watercraft, canoes, kayaks, and pontoon boats (Rothlisberger 2009).

Risk of Transport

Overland transport represents a risk in transfer of species between unconnected waterbodies. Of the species already present in Lake Champlain, the Asian clam (*Corbicula fluminea*), didymo or "rock snot" (*Didymosphenia geminata*), variable-leaved watermilfoil (*Myriophyllum heterophyllum*), and the zebra mussel (*Dreissena polymorpha*) entered through overland transport. In looking beyond Lake Champlain, nuisance species including spiny waterflea, rusty crayfish, and Eurasian milfoil have been transferred via hitchhiking throughout the Great Lakes region.

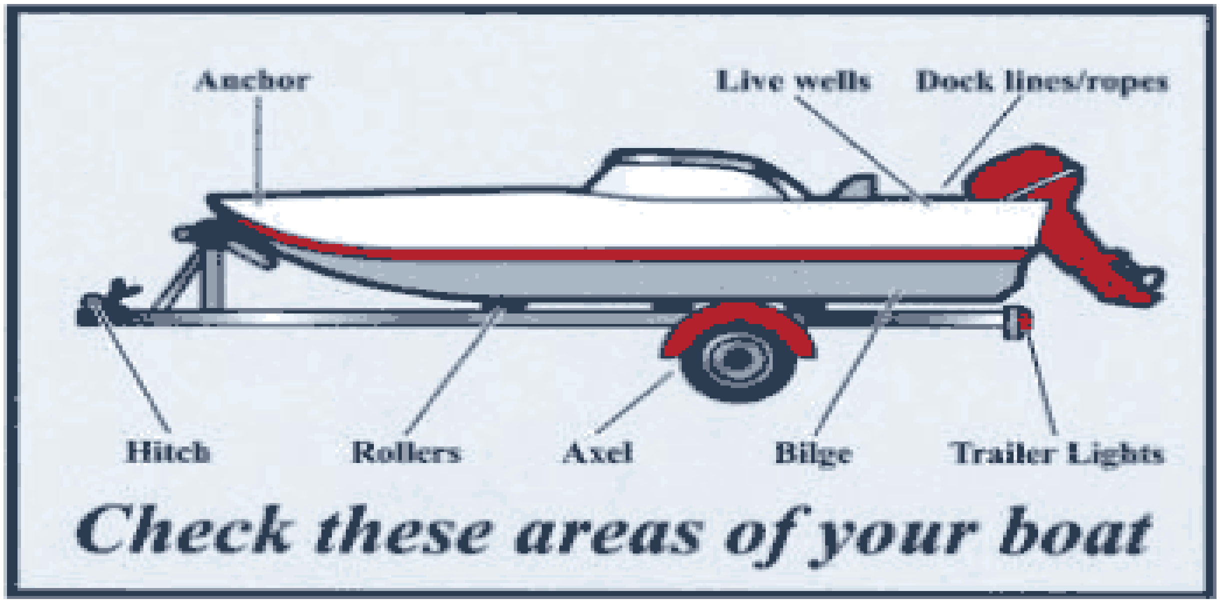

Figure 27. Areas on a boat that can carry AIS. Source: http://www.fish.state.pa.us/

Even more recently, Viral Hemorrhagic Septicemia (VHS) has spread in other regions through contaminated bait buckets, livewells, and bilge water (Rothlisberger et al. 2008). Generally, overland transport of plants occurs when they get tangled in propellers, anchors, and other outer parts of boats, while invertebrates could attach to the hull of boats and could also be transported via water in live wells, bilges, bait buckets, and engines, as could juvenile and larval fish (Johnson et al. 2001). Risk is especially high of transporting species that possess planktonic life stages (Johnson et al. 2001).

Understanding high-risk species and boating practices can help to understand the risk of introduction by overland transport (Hulme 2009). In looking at species, it is necessary to understand not just environmental suitability, but the surrounding waterbodies that have greater numbers of invasive species that can be transported on recreational boats. The more invasive species in a lake, the more likely it is to 'donate' organisms to another nearby lake (Rothlisberger et al. 2008). Factors of boating also affect the risk of transfer, including recreational boating populations that move between waterbodies in a season, the amount of traffic between different waterbodies (more boats mean more options for a hitchhiker), and the boat hygiene behaviors of different subgroups of boaters (Buchan and Padilla 1999; Rothlisberger et al. 2008; Rothlisberger 2009). To slow the spread of boat-dispersed aquatic hitchhikers, management efforts should target high frequency boater movements and regions with the greatest volume of source and destination boater movement (Buchan and Padilla 1999).

Prevention Measures

There are programs to facilitate the removal of hitchhikers through both hand removal and boat and trailer washing. Visual inspection and hand removal can effectively remove invasive aquatic plants such as Eurasian watermilfoil and hydrilla from boat propellers and other areas where plants are visible. However, this method is ineffective for other types of aquatic invasive species including small-bodied organisms that are difficult to see with the naked eye, including fish larvae and zooplankton like the fishhook waterflea (Rothlisberger et al. 2008). Due to the nature of these invaders, to date, boat washing has been a focus in prevention via overland transport, with treatments varying from pressure washing and chemical treatments to other emerging technologies, each with the goal of removing possible invaders before a boat is transferred from one waterbody to another. There are several ways to remove AIS from boats and trailers, and each has varying costs and benefits (Table 4).

Boat washing Technology	**Advantages**	**Disadvantages**
Pressure Washing	No chemicals, effective (especially with hot water)	Large amount of water, pests in runoff/stormwater
Chemical Application	Less water use, very effective	Chemical reservoir/runoff, chemical exposure, effect of chemicals on watercraft
Chemical Dipping	Immerse entire boat, quick turnover, very effective, less chemical runoff, less chemical exposure	Chemical use, high construction and maintenance costs, residual chemicals on boats, effects of chemicals on watercrafts
High Temperature Steam Cleaning	Very little water, can displace pooled water on boats	Risk to operators, potential damage to watercraft

Table 4. Summary of boat washing techniques and their advantages and disadvantages (from Miller et al. 2006).

The most widespread technique for boat cleaning is high-pressure washing to remove aquatic invasive species from the exterior of boats, trailers, and equipment (Jensen 2009). This is done either through a handheld wand or an automatic system similar to an automatic car wash that power washes either with hot or cold water (Figure 28). Hot water is more effective at killing and removing hitchhikers than cold water but requires increased capital (Miller et al. 2006). When combined with visual inspection and hand removal, this system proves generally effective, as long as pests in the washdown water are disposed of properly and do not enter the waterbody or stormwater drains (Miller et al. 2006).

Figure 28. High-pressure washing. Source: http://www.jhunderground.com

Chemical cleaning is another approach and comes in two forms: chemical application and dipping. Chemical application involves washing down the boat with one of many chemicals, including simple organic compounds, oxidizing agents, and organic biocides, and it has the advantages of less water use and a higher efficacy in eliminating pest organisms. However, the chemicals may be harmful to people and possibly to boating equipment (Miller et al. 2006). These chemicals would also have to be stored in a reservoir after use, where there is risk of leakage into the surrounding environment. The other chemical method is referred to as decontamination dipping, where boats are towed into a low-lying bounded area filled with a chemical, with benefits including the ability to immerse the entire boat or trailer and quick turnover as operators can simply drive through the system; there is also less human exposure to chemicals as no aerosol is created during this process as is the case with chemical application (Miller et al. 2006). One downside is that residual chemicals on the boats may enter the waterbody when the boats are launched (Miller et al. 2006).

High-temperature steam cleaning uses very little water to remove AIS from boating equipment and can displace pooled water that might collect in trailers or boat structures. However, using the technique poses a safety hazard to operators and may harm boats (Miller et al. 2006). A promising future technology is ultrasonic irradiation, as ultrasonic sound has the ability to disrupt cell microstructure and to collapse or implode gas vacuoles in cells, and has been shown to kill and control cyanobacterial blooms under some conditions. The technology for this methodology is still in test stages, but it warrants further investigation as it could provide an alternative to water-intensive power washing and environmentally risky chemical treatment (Miller et al. 2006).

Boat-washing is currently the only widespread method used for AIS prevention through overland transport. However, this does not necessarily mean that it is the only method of prevention, as more extreme measures might include banning recreational boating altogether, only allowing boats to be used in one waterbody, or preventing transport between certain waterbodies that have large numbers of aquatic invasives. These methods are unlikely to be feasible due to cultural resistance by anglers and recreational boaters as a whole.

In looking at the current options, it seems that pressure washing with water is the most environmentally friendly and effective option. Visual inspection and hand removal, while cheap and easy, is not very effective at removing all species. Rothlisberger et al. (2008) estimates that hand removal is only about 70% effective at removing small-bodied organisms while manned power washing stations can be over 90% effective (see Table 5). While cost and effectiveness are proportional, a 20% increase in effectiveness is substantial.

Impact of prevention measures

Ecological Impacts

Ecological costs of boat-washing systems depend on the system and whether it is water-based or chemical-based. Pressure washing has minor ecological costs, the main one being the use of a large amount of water. Depending on where this water is drawn from, it could impact surrounding ecosystems, though if drawn from town or city water systems it is likely coming from groundwater with no significant impact on the ecology of the area. Chemical washing systems have a much higher potential for ecological costs, as any use of chemicals creates the risk of those chemicals entering both terrestrial and aquatic systems, which could have negative impacts on species. It is hard to quantify these costs as they represent a cost that exists only if chemicals are not properly disposed of after use and if residual chemicals remain on the boats when launched into the water. Though difficult to quantify, these costs still exist.

Economic Impacts

In looking at economic costs of prevention, the largest amount of data exists for power washing stations, as this is currently the most widespread approach. But even in looking at boat-washing alone, there is a great deal of variation, both in terms of initial capital investment and annual labor costs depending on the sophistication of the system, the portable or permanent nature, whether there is a containment system for wash water, and whether it is self-serve or a manned station (Rothlisberger et al. 2008). Table 5 represents estimates for start-up costs for inspection and hand-removal, low-pressure wash, and both self-serve and manned power wash stations, ranging from \$25 to \$35,000 in initial capital expense and annual labor costs for stations ranging from \$0 to \$12,800 per year. The table also outlines the estimated efficacy of each treatment method, recognizing that the most expensive systems are also the most effective at removing aquatic invasive species, as you get what you pay for. High-pressure washing is the most effective technique for removal of AIS and a manned station offers the benefit of higher compliance.

Figure 29. Overland Transport Outreach
Source: www.crescentlakewi.org

	Capital Expense	Annual Labor Costs	Efficacy (% reduction in AIS)	
			For vegetation	For small-bodied organisms
Inspection and hand-removal	$25 (training by Clean Waters)	[3]$0- [4]$12,800	87%	70%
Low pressure wash (unmanned)[7]	$50-$200	$0	63%	73%
Power wash station (self serve)	[1]$300-[2]$35,000	$0	85%	90%
Manned Power wash station	[1]$300-[2]$35,000	$0-[5]$12,800	>85%	>90%

1. For a portable high pressure washer with no containment system--for use on outgoing boats at source (i.e., already invaded) lakes.
2. For a portable high pressure washer with filter and containment system to prevent incoming species..
3. Volunteers can be trained as boat inspectors
4. Assumes two paid inspectors 40 hrs/wk for 20 weeks (the same time period as Clean Boats/Clean Waters)
5. Manned power wash station with containment system would need at least two people to run. With training and experience we would expect on average a higher standard of cleaning and compliance
6. Garden hose with normal pressure without hand removal

Table 5. Cost per boat landing and efficacy for different intervention options. From Rothlisberger et al. 2008

Economic costs to the Lake Champlain region depend not just on cost per unit, but also on the number of stations necessary to cover all access areas to the lake. Figure 30 shows all documented boat ramps and fishing access points in Vermont, boat ramps in New York, and points (mostly car washes) in nearby areas that the Lake Champlain Basin Program have identified as boat-washing stations. In order for fully understand the need for boat-washing stations, data are needed for all boat ramps and fishing access areas in all jurisdictions. It is unnecessary to install stations at each boat launch area, but rather target those most heavily used and at key transit points (e.g., gas stations), thus understanding boater traffic is an important part of understanding the best location placement for stations and the number of stations needed (Rothlisberger et al. 2008). Additionally, high rates of overland transport often occur for fishing tournaments, representing additional high traffic for short periods of time. The placement of stations should factor this in and could also warrant the use of portable washing stations for these tournaments. In order to achieve high compliance rates, the stations themselves are only part of the solution: education efforts and disincentives for non-compliance are also necessary components (Rothlisberger 2009).

The LCBP currently has a boat stewards program working on the issues of overland transport with highly trained staff working at between seven and eight boat launches from Memorial Day through Labor Day with public outreach and visual inspections. The annual cost of this program is estimated at $50,000 (Eric Howe and Mike Winslow, pers.

comm.). This cost of public outreach could be incorporated into boat-washing strategies. Other forms of public outreach such as pamphlets and signs can and are also used (Figure 29).

Cultural Impacts

The biggest cultural cost associated with boat-washing stations is the time cost to users. While different boat washing strategies require different amounts of time, each requires boaters to stop and wash their boats before launching into the lake, which may make them less likely to comply or less likely to come to Lake Champlain if boat-washing is a hassle.

To fully understand how Lake Champlain recreational boaters will be impacted by these prevention measures, it would be beneficial to create a survey to gauge their views on the subject. Recreational boaters represent a diverse group, so likely there would also be differing opinions and differing impacts. Understanding these could help in decision-making on whether the cost of this prevention method is worthwhile and how policy could be implemented to help with this prevention.

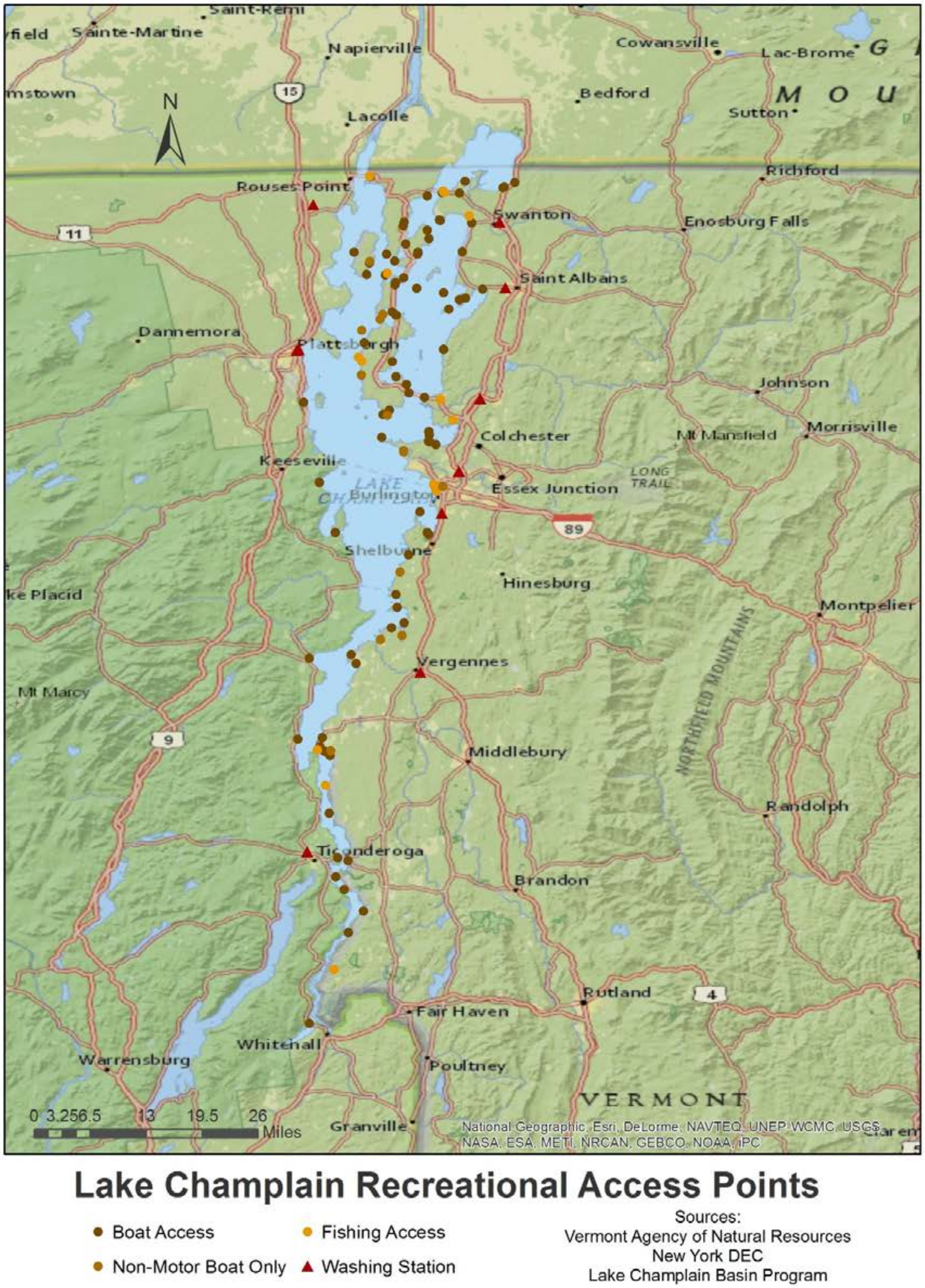

Figure 30. Map of Lake Champlain Recreational Access Points. Sources: Vermont Agency of Natural Resources, New York Department of Environmental Conservation and the Lake Champlain Basin Program.

Aquarium Trade

Risk of Introduction

Only 2% of introduced aquatic invasive species in Lake Champlain have come through the release of aquarium species or pets (Marsden and Hauser 2009). Despite this small percentage, the aquarium trade poses a great risk, one of the most damaging species in the Lake Champlain Basin to date, the Eurasian watermilfoil, can be spread through the aquarium trade. Hydrilla, one of our high-risk species, is also spread through the aquarium trade and could be introduced into Lake Champlain through this vector. Though few species have become established in the past after aquarium introductions, risk of release of a new aquatic invasive species through aquaria remains significant for a number of reasons: the many opportunities for species introduction throughout any given trade route, the wide area into which a species may be released, the unpredictability and uncertainty of species used in aquaria, and the lack of enforcement and education surrounding existing regulations.

A traded aquatic species passes through several hands before reaching consumers (Figure 31) (Cohen et al. 2007). From distributors to store owners, there is a potential for accidental release from each one of these steps. Constumers may also release their purchases through improper disposal methods, like releasing the individual directly into waterways or storm sewers (Figure 32). When a species is released directly into the waterway, it may not survive. If the individual is carrying a pathogen, it could spread even if the species does not survive, posing a greater threat to the ecosystem than just the species itself.

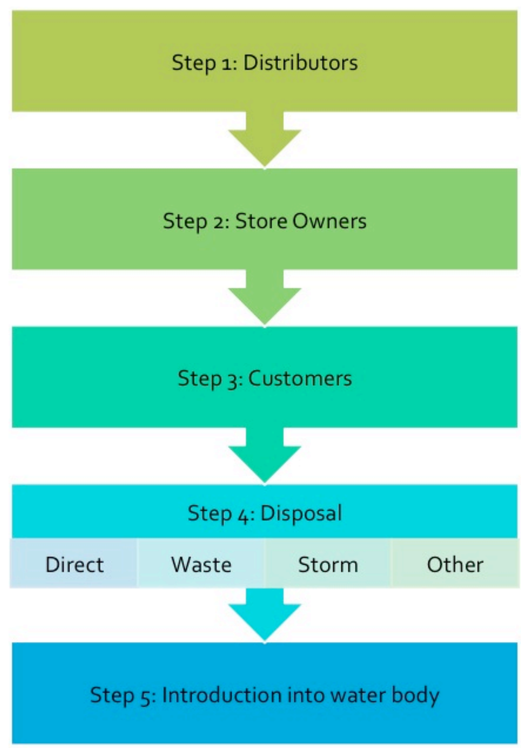

Figure 31. Flow of aquarium trade before release. Adopted from Cohen et al. (2007).

Once a species has been released into any of the waterways connected to Lake Champlain, it may eventually reach the lake itself. In the region surrounding the lake, studies on aquarium release have mainly focused on the Saint Lawrence Seaway and the Great Lakes. In the Saint Lawrence Seaway, Cohen et al. (2007) identified several invasive plant species that are currently sold in Montreal by aquarium shops. By analyzing the pathways through which an invader could be released, they estimated the propagule pressure for these species indirectly. This study found that there is a fairly high probability that one of these species could be released either directly or indirectly into the Saint Lawrence. Within the Great Lakes, Rixon (2004) identified a group of potential invaders that are sold in aquarium shops around the Great Lakes. After surveying aquarium shops and performing a risk analysis on the species sold, Rixon found a group that included several fish, several plant, and one crustacean species, several of which have been shown to be invasive in other parts of the world. New introductions of aquatic invasives via aquarium dumping into waterbodies adjacent to Lake Champlain is a persistent threat.

Since freshwater aquatic species comprise 96% of the international aquarium trade, the risk to freshwater ecosystems is great (Rixon 2004). Aquarium hobbyists have easy access to potentially invasive aquatic species through internet trade (Padilla and Williams 2004). The international sales of aquatic species on the internet is currently unregulated, allowing Americans to easily avoid federal regulations regarding potential invasive species (Ellen Marsden 2013, pers. comm.). Beyond illicit trade, the pool of invaders is always expanding (Rixon 2004). Aquarium stores and distributors are always looking for a new popular species to sell, and these species could be potentially invasive.

Even if aquatic species are regulated, many problems and shortcomings exist within the regulations, increasing the risk of invasion. Misidentification of closely related aquatic plant species could lead to the accidental sale of prohibited, dangerous invasive species instead of its safe relative. For example, species of watermilfoil were found to be often mislabeled in aquarium shops across the country (Thum et al. 2012). These species of watermilfoil can be identified through genetic markers. Unfortunately, this process is expensive and not well developed for every taxonomic group.

Trade bans may be ineffective for aquatic plant species because they are often not enforced. For example, an aquarium trade ban in California on *Caulerpa* species was found to be largely ineffective in part due to lack of enforcement (Diaz et a. 2012). This case underscores the necessity of thorough, well-funded enforcement in making regulations against this threat effective.

Prevention Measures

Many potential prevention measures address the threat of invasive species introduction via aquarium trade. These measures are organized in this section by the successive steps in the aquarium trade supply chain.

To prevent the introduction of AIS through the aquarium trade at the distributor and store-owner level, controls on the sale of invasive species must be implemented. One way to do this is to blacklist species. Currently in Vermont, certain species designated as prohibited or restricted cannot be sold without a permit from the state (VT statute). Federal and internationally binding structures need to support theses blacklists for them to be effective. Including provisions to stop the trade of aquatic invasive species in internationally binding treaties such the North American Agreement on Environmental Cooperation (NAAEC) and the Convention on International Trade in Endangered Species (CITES) has been proposed (Padilla and Williams 2004). Beyond blacklisting species, businesses could be deterred from buying dangerous species by requiring them to pay a fee that would represent the predicted costs of a release (Padilla and Williams 2004). To prevent risk of pathogen introduction, requiring any imported species to have a certification from a veterinarian before importation is a potential mechanism (Brent Niel, pers. comm.).

Whatever the mechanism, the regulation needs to be widely enforced for it to be effective. Currently, most invasive species trade bans are loosely enforced, if at all (Diaz et al. 2012). Requiring store owners to improve the labeling and identification of the species in their shops could also improve compliance with any blacklist of species (Chang et al. 2009; Thum et al. 2012). This effort could ensure that unknown yet harmful species are removed from the shelves.

For consumers, education is paramount to decreasing the spread of AIS through aquarium dumping. Customers buying species for an aquarium should be informed about which species to buy and proper disposal methods to decrease the risk of an introduction (Chang et al. 2009). Furthermore, better options for the release of fish could be developed.

Figure 32. Aquarium Dumping. Image Source: Univ. Florida

Impacts of prevention measures

Ecological Impacts

It is not likely that there are any ecological costs to these preventative measures because they are mostly comprised of prohibitions on specific species and they do not involve alterations to ecosystems.

Economic Impacts

We were unable to find formal, published academic literature evaluating the economic costs of aquarium trade regulations. Some of the potential impacts could be cost of enforcement, cost of educational programs, costs to businesses in terms of compliance, and decreased trade. Additional data is necessary for this quantitative assessment.

Cultural Impacts

The cultural impacts of aquarium trade regulations are difficult to characterize. Perhaps the prohibition of certain species has restricted aquarium owners from acquiring any species that they find interesting. A survey of aquariums in the San Francisco Bay Area concluded that many aquarium store employees seem to be willing to change their policies in order to prevent the spread of dangerous invasive species (Chang et al. 2009).

To assess some of these questions, we conducted interviews with a handful of local aquarium shop owners and managers to begin to informally assess the impacts to businesses and aquarium hobbyists in the region. See Appendix B for a transcript of the interview questions and locations for shops called.

Throughout the interview process, we got limited responses. One of the shops, All Bright Aquariums in New York, responded that they primarily sell tropical species that they don't think would survive in northern latitudes. Therefore, they didn't have anything to say about invasive species. Since there seem to be few aquarium shops directly in the basin, it is reasonable to assume that there are also not very many aquarists in the region. This means that the cultural impacts of aquarium trade regulation in the Lake Champlain Basin could probably be limited.

In nearby connected basins, more people and therefore more aquarium shops are present. The impacts of trade regulations are more likely to be greater in these areas than in other places. This became apparent in the interview with Brent Neil, the species buyer for Aquatica Aquarium Supplies in Montreal. Not only did he outline the new Canadian regulations on the aquarium trade, but also he described the impacts on his business and his customers in great detail.

The impacts of regulations on the business of Aquatica Aquarium Supplies occur primarily in terms of employee time. It now takes three hours for Brent to process new orders, when it used to take ten minutes. The cost of the permit is $60 for the whole year, but considering the number of orders the shop processes, this cost is incredibly minimal per order. Aquatica Aquarium Supplies has had to change suppliers a bit, causing a moderate cost to the store. For example, they now cannot order any fish from Israel because the shop cannot get the proper medical permits from anywhere in Israel. There are also certain distributors in the United States that Neil can no longer order from because they serve as middlemen between foreign nations and Canada. However, this has not been a large imposition on their business, as they have been able to source the fish and plants they need from other places.

The impacts of these regulations on his customers have been negligible. There are only one to two species that are no longer available, and similar species are also available. Occasionally a customer will ask for a snakehead (a highly invasive fish species) but those interactions are rare. In terms of outreach, there are no formal education programs about the proper disposal of aquarium species. Regulations are completely focused on blocking entry of species into store shelves and not on customer behavior change. In Neil's opinion, this is the best option, as he has not seen any behavior changes in his customers.

Baitfish

Risk of Transport

The risk of introduction through baitfish is similar to that of the aquarium trade, in the release of non-native fish into waterbodies (Figure 33). To date, 8% of aquatic invasive species introduced into Lake Champlain were introduced to the system as baitfish (Marsden and Hauser 2009). One of our high-risk species, the round goby, is transported via baitfish. Young gobies and other species may be accidentally picked up as bait by fishermen and boaters (Sea Grant Pennsylvania). Viral hemorrhagic septicemia (VHS), a deadly fish virus, is likely transported through the movement of baitfish as well (Ellen

Marsden 2013, pers. comm.). VHS has caused large declines in the rainbow trout populations as well as large economic losses in Europe (Goodwin 2004).

Figure 33. Baitfish
Image Source: New York Department of Environmental Conservation

Ludwig and Leitch (1996), in a study of the probability of the inter-basin transfer of aquatic biota via anglers' bait buckets, found that the overall probability of accidental live baitfish transfer is almost 100%. Although the probability of any individual angler releasing a live baitfish in one day is very low (1.2/100), the cumulative number of instances of anglers' fishing days makes this overall probability very likely.

This risk of baitfish also extends to disease introduction. Baitfish that are caught and used in the same waterbody pose no threat of disease movement, but in commercial markets, sellers frequently transport wild fish long distances from one watershed to another and anglers may transport their purchases even farther. The domestic freshwater baitfish industry is a significant market, with total sales exceeding $1 billion per year in Canada and the U.S. (Litvak & Mandrak 1993). More than 80% of baitfish are farmed, and the vast majority are bought live (not frozen) by fishermen and anglers. Significant disease testing and control programs exist in the farmed baitfish industry that make disease transport unlikely. However, the wild baitfish industry is much harder to regulate (Goodwin et al. 2004). In part, this is due to the fact that most baitfish harvesters and dealers are small-scale and have easy access to technology that makes baitfish transportation over long distances relatively simple (Litvak & Mandrak 1993).

Prevention Measures

Both Vermont and New York have existing baitfish regulations outlining which species can be sold as baitfish. These statutes do not include the full range of possible alternatives to prevent the transport of aquatic invasive species through baitfish trade. Litvak and Mandrak (1993) give an overview of potential measures that could be taken to limit harm from baitfish trade to ecosystems generally. Many of these recommendations, however, apply to aquatic invasive species prevention. Beyond prohibiting release and transport of baitfish, sales of baitfish should be restricted to disease-free, sterilized, cultured fish (Litvak and Mandrak 1993). An additional possibility would be banning the use of live baitfish outright. This measure would be the most drastic.

Impacts of Prevention Measures

<u>Ecological Impacts</u>

The ecological impacts of the prevention measures proposed are probably only positive. Restricting the introduction of new species and diseases into a lake ecosystem would not disrupt any natural processes, and it would only stop actions that have damaged ecosystems elsewhere. The one possible ecological cost, if baitfish regulations require fishermen to use wild baitfish from the local region where they are fishing, could be that populations of those species could be depressed if the waterbody is heavily fished. This negative impact would be alleviated if the regulation either required fishermen to use cultured baitfish or banned the use of live bait all together. An unanticipated effect could also be the increased use of plastic bait, which could lead to increased plastic levels in the lake due to improper disposal.

Economic Impacts

We were unable to find any published studies on the economic impacts of baitfish regulations. We can hypothesize impacts for a suite of regulations restricting the trade of baitfish. To state and federal agencies, the impacts may include the cost of enforcement measures and education campaign for anglers. To businesses, there could be costs associated with changing their practices to meet new regulations and a possible loss of business across state borders.

Cultural Impacts

Again, there are few studies published about the societal impacts of baitfish regulations, though we found some examples of reactions to regulations in news sources. In 2007, Vermont fishermen felt very unprepared to deal with the emergency baitfish regulations released to help prevent the spread of VHS (Garafalo 2008). This regulation was not well received by the angling community because it was considered too restrictive. However, the next year, the Department of Fish and Wildlife held a series of public hearings and the rules were revised to meet the needs of the angling community and to prevent the spread of VHS into Lake Champlain. These revisions included the allowance of personal baitfish harvest if used in the same waterbody, the redefinition of the term 'waterbody' to include all tributaries of lakes and ponds up to the first barrier impassable by fish to allow anglers to freely move up and down connecting streams and rivers to fish with live bait, as well as other revisions based on input received from anglers and baitfish dealers (Vermont State Government 2008). This case illustrates the need for regulations to be adaptive to the needs of baitfish shops and fisherman without losing their strength, as well as the need for public outreach (Figure 34).

Figure 34. Baitfish awareness sticker. Image Source: Great Lakes Sea Grant

To assess some of these questions about the cultural and economic impacts, we conducted interviews with a handful of bait shop owners and managers whose businesses are approved to sell bait for Lake Champlain in order to informally assess the impacts to businesses and anglers in the region. See Appendix B for a transcript of the interview questions and locations for shops called. We were only able to interview a few shops, and the results of those interviews are found below.

1. Ray's Seafood, Burlington, Vermont

Ray's Seafood used to sell live minnows, but stopped because of low sales levels. Now they do not sell live fish, so they do not experience interference from regulations.

2. Holiday Harbor Shop, North Hero, Vermont

In speaking with owner Bruce Batchelder, he showed little concern in regard to the effect of regulations on business on a day-to-day basis, in that he now has to fill out transportation slips for every customer transaction, but he found this to be an easy task.

While Mr. Batchelder has seen an increase in bait costs, he did not attribute most of that increase to regulations, but instead to fluctuations of supply, demand, and the increasing costs of transportation of baitfish from rising oil prices. However, he did say that regulations on imports of baitfish from other states do increase prices. The shop is only able to purchase imported bait from a supplier in Arkansas, an industry that represents over half of the entire U.S. baitfish market (Adhikari et al., 2012). Mr. Batchelder believes that this supplier has some control over the prices and supply of baitfish.

In gauging the customer response to these regulations, where Vermont has stricter regulations than surrounding states, Mr. Batchelder stated that customers generally understand the reasons behind the regulations and comply with them because they want to protect and support a healthy fishery.

3. Norm's Bait and Tackle, Crown Point, New York

Owner Norman St. Pierre was overall very critical of baitfish regulations. For baitfish to be used in Lake Champlain, his shop is only allowed to sell regulated and certified bait from one producer in Arkansas, which goes through one distributer in Vermont. Mr. St. Pierre believes that this producer has a monopoly on the supply of baitfish and that therefore they can raise prices. Not being able to trap his own bait has been tough on his business. Since he is not making good profit on the sale of baitfish, he has to raise the prices on other goods in his shop. He stated that the new regulations were not difficult to comply with as they were rather straightforward, but they were costly.

The complex and uncoordinated regulations across boundaries make things much more complicated for Mr. St. Pierre's business. According to Mr. St. Pierre, the federal regulations were "bad enough," but additional regulations from the state of Vermont made things more complicated and compliance more difficult. Furthermore, customers in his shop can only use his bait on Lake Champlain and in New York. They cannot take the bait into Vermont, as all Vermont bait must stay in Vermont. This causes a great inconvenience to many of his customers that live in Addison County, because there are few bait shops on the other side of the lake in this region. It is also bad for his business, as some of his customers must go other places to buy bait. He feels that a baitfish policy for the whole Champlain Valley on both sides of the lake would be most beneficial.

Most generally, Mr. St. Pierre thinks that the baitfish regulations should be stopped. “People have been catching their own bait here for over 100 years and we haven’t had any problems.” Baitfish regulations have greatly altered his way of life and a long-standing culture. He doesn’t understand the necessity of regulations, considering that VHS hasn’t been found in Lake Champlain, and if they don’t find it there soon, he thinks they should stop the regulations and let things go back to the way they were.

It is apparent from just these few interviews that a wide range of opinions exist on baitfish regulations among baitfish shop owners. These prevention measures have both economic and cultural costs. To further understand the issue, it would be beneficial to gauge the opinions of anglers who are using the baitfish to understand how they are impacted. In considering baitfish prevention measures, there are a wide range of opinions that should be taken into account when creating new rules to ensure that undue harm is not being done to baitfish shops and traditional methods of fishing around the basin.

VII. Recommendations

Vector Based Approach

We recommend first and foremost the use of a vector-based approach when developing AIS prevention policies and measures. This method is much more adaptive and inclusive than focusing on preventing the spread of a specific species, as many potentially invasive species travel through the same pathways. Considering prevention measures that stop the movement of all invasive species through a specific vector reduce the likelihood that a particular unknown species may slip through the cracks. Furthermore, focusing on vectors provides protection against species that have not even yet been identified as invasive, making the policies inherently adaptive to changing conditions. We also believe a vector-based approach is hopeful and solution-oriented. Instead of becoming frustrated by the perceived inevitability of the arrival of a specific species, policy makers and other leaders can take concrete steps to reduce the general probability of aquatic invasive species introduction through different vectors. This approach is also applicable to any basin, even though many of our recommendations are specific to Lake Champlain.

Prevention Measures

For each vector, we identify gaps in existing policies for preventing an AIS introduction through a specific vector and then recommend ways that these gaps can be addressed. The recommendations come in two forms. Either they describe broad policy options that could be implemented in each jurisdiction or the recommendations highlight successful policies in one jurisdiction and how they could be implemented in the others. Beyond policy components, this section provides preventative measures that go beyond legal frameworks. These recommendations are largely for public outreach measures, which can spread a similar message in each jurisdiction and be promoted by organizations like the LCBP.

Canals

Policy

New York State law requires the canal system to remain open during its operating season. Closing the canal violates state law. There are no regulations that prohibit the transport of AIS in the New York State Canal System. Even if such regulations were created, enforcement poses many logistical challenges. A full and thorough boat inspection requires vessels to be out of the canal waters and on land. If such regulations were to be properly enforced, significant capital expenditures and additional labor would be required.

Beyond Policy

A Champlain Canal engineering study should be conducted to determine the feasibility of installing a physical barrier to obstruct the spread of AIS. There are number of existing funding sources available to finance both the engineering study and the initial design and construction of a physical barrier. As of July 2012, there was $4.5 million in a U.S. Army Corps of Engineers fund dedicated to Lake Champlain. A large portion of these funds could be used to fund the barrier's design and construction. Currently, the LCBP and U.S. Army Corps of Engineers has $500,000 set aside to conduct an engineering study of the feasibility of a Champlain Canal physical barrier. We recommend that these funds be put to use immediately for the purposes stated above.

Overland Transport

Policy

Currently, Vermont is the only jurisdiction with policy regarding overland transport. The Vermont Aquatic Species Transport Law prohibits the transport of any aquatic plant or dreissenid mussel species on the outside of recreational boats. The issue with the policy is that this policy does not regulate other invertebrate or mussel species, and that AIS can also be transported on the *inside* of boats, as mentioned earlier, via bait buckets, livewells, bilge water, or any other standing water. Therefore, this statute could be improved by prohibiting transport of any AIS on any part of a recreational boat. With such an improvement, this represents an important policy in addressing overland transport and the Lake Champlain Basin could benefit if the other jurisdictions were to adopt a similar policy.

Beyond this prohibited transport, there is no policy requiring the washing of boats and trailers during overland transport. The Lake Champlain Basin Program, through their Boat Stewards Program have been working hard through public engagement to encourage boaters to prevent the spread of AIS. While no current studies exist in our jurisdictions as to the proportion of boaters who voluntarily wash their boats, in Michigan and Wisconsin (both of which have similar aquatic transport laws to Vermont), states where educational efforts have been among the most vigorous in the U.S., two-thirds of the boaters who responded to surveys do not always clean their boat when moving between waterways, and more than a quarter do not always remove aquatic weeds when they see them attached to their boat or trailer (Rothlisberger 2009). This suggests both further regulation and further enforcement are needed. Policy could require all boats to be washed at a boat-washing station when moving between waterbodies.

Lake George currently has a petition to implement a mandatory boat inspection and decontamination program. The proposed plan is modeled after one implemented at Lake Tahoe, which is in its third year of regulation with a flexible program for different boat users on the lakes, with separate inspections based on permanent and transient boating habits (Bauer et al. 2012). Lake Tahoe has regulations that make it illegal for a boater to launch a boat on Lake Tahoe that has not been inspected or for a launch operator to launch a boat that has not passed inspection. Additionally, boat launches that were publicly or commercially accessible are closed if no personnel are available to verify a boat has been inspected (Bauer et al. 2012). There are three types of inspection stickers and fees based on "Tahoe Only" boats, "Tahoe In and Out" Boats, and a 7-Day Launch

Pass (Figure 35). While this is a very stringent approach, it is also effective at ensuring that transient boaters are washing their boats if they are travelling between waterbodies.

Figure 35. 2012 Lake Tahoe Boat Inspection Fees. From Bauer et al. 2012

Overland transport of invasive species is not restricted to boats and trailers, but they can also be transported in bait buckets and on fishing gear. While the felt-soled wader ban in Vermont makes transport on some gear less likely, an overarching policy for all fishing equipment, such as that requiring the cleaning of equipment when going between waterbodies could help decrease the likelihood of introduction through this mechanism.

Beyond Policy

Looking beyond the policies themselves, an increase in infrastructure is needed for boat washing policy to be effective. According to the Lake Champlain Basin Program, there are currently only ten boat washing stations within New York and Vermont, and they are all car washes that are working in cooperation with the LCBP. However, the number of boat washing stations should be increased and should be targeted towards high-risk and high-traffic areas. A study should be conducted in order to understand the flow of boat traffic, where boats are coming from, going to, and when, so that resources can be allocated appropriately. It could also include talking to the boat washing stations currently in place to better understand compliance and use.

While regulation such as mandatory inspection and decontamination could prove very effective at preventing AIS through overland transport, such a program is expensive. Another possibility would be a ‘self-certification and random inspection program’ where boaters are responsible for pledging that their boats are clean, drained and dry. This would be cheaper than a mandatory crackdown, though the comparable effectiveness must be questioned (Alexander 2012).

Public outreach is also an important aspect of successful prevention of aquatic hitchhikers. People need to understand not only regulations in place but also the importance of boat washing and prevention of AIS. In order for recreational boaters to comply with policy—or in the absence of policy care about prevention—they must understand the impacts of AIS. The LCBP plays a large role in this and has done a lot of work towards this end, and increased funding for public outreach is an important part of the process.

Aquarium Trade

Policy

In Vermont, while the quarantine rule has restrictions on possession, sale, cultivation, movement, and distribution of invasive plant species, there is no such rule that applies to all aquatic invasives. So while the VTDEC can monitor compliance of pet stores and nurseries for the sale of potentially invasive aquatic plants, there is no such authority for other types of invasives (Misha Cetner, pers. comm.). Similarly, in New York, the regulation pertaining to the prevention of noxious weeds only gives regulatory authority to regulate plants, not other types of invasive species. Regulations extending to the sale and release of all aquatic invasive species would give authority to state government to prevent the distribution and sale of invasives. Furthermore, expanding resources for enforcement could further increase the efficacy of these regulations.

Beyond specific species being sold in pet stores, there are several other aspects of the aquarium trade that are unregulated. When buying from a pet store, people may not be aware of the risk or threat these species pose to natural systems. A law requiring retail stores to label where species cannot legally be released could help raise this awareness and prevent subsequent release of species into waterbodies. Aquatic species, especially fish, purchased in pet stores may also be infected with unknown pathogens. A veterinary certification program for species being imported could help limit the spread of diseases through aquarium dumping. The rise of internet trade, coupled with lowering costs of transportation, has enabled the trade of aquatic species over large spans of geographic space with relative ease. This extends the reach of the aquarium trade far beyond local pet stores. There are currently no regulations with regards to invasive species in this type of trade.

These are all issues that need to be addressed, and they would be best addressed in the United States on the federal level. Several of these regulations already exist on the national level in Canada. While this type of policy is beyond the purview of the LCBP, the organization could show their support for this through lobbying and other efforts.

Beyond Policy

Beyond regulating the aquarium shops themselves, public outreach programs are important for decreasing the risk of aquarium dumping. Outreach may not prevent each aquarist from improperly disposing of their baitfish, but it would lead to some behavioral changes. The newly created website www.habitattitude.net, created by the Aquatic Nuisance Species Task Force, is a great part of this effort. Furthermore, initiatives like the labeling of proper release locations, veterinary certification, and even the blacklisting of specific species could be undertaken on a store by store basis. A voluntary “invasive-free” certification program for shops and suppliers could be implemented. This would allow aquarium shops to market themselves as “green” and potentially increase their customer base. While this program would require time and effort on the part of shops, and resources to monitor the participating shops, it would be in many ways easier to implement than passing new national or even state legislation. It could also be specific to the Lake Champlain Basin.

Baitfish

Policy

Preexisting baitfish policies in jurisdictions surrounding Lake Champlain appear to be largely effective in regulating the use of baitfish bought in certified shops. In sum, this policy requires commercial baitfish shops to be permitted and to sell state-approved baitfish (Appendix A). This law also requires anglers fishing in Lake Champlain to carry a receipt that shows that their bait is approved for use in Lake Champlain or Vermont. By regulating the types of baitfish that can be sold and used in Lake Champlain, these laws prevent diseased fish or an invasive species from entering the lake.

Beyond Policy

Effectively regulating and enforcing baitfish regulations on all anglers is difficult. Anglers may capture wild baitfish and transport them with relative ease. For this reason, effective public outreach that clearly explains to anglers the dangers of AIS transmitted as baitfish is necessary. This outreach should focus on aspects of AIS damages and prevention that are relevant directly to the sportfish populations that anglers value. Outreach may not prevent each angler from improperly disposing of their baitfish, but it could lead to some behavioral changes.

Challenges

Cross-Jurisdictional Coordination

Currently, AIS prevention policy in the Lake Champlain Basin is fragmented across jurisdictions. If a policy addressing a vector exists in a particular jurisdiction, it is most likely different from the neighboring jurisdictions. The most coordinated efforts are generally outreach and education programs, as they can be repeated and spread by non-governmental organizations (Meg Modley 2013, pers. comm.). These policies are fragmented and different for several reasons. Differences arise through different cultural associations with water, different structures for protection, and differing levels of acceptance of regulation and enforcement. These differences make cross-cultural coordination difficult. However, these differences do not inherently mean that there are gaps in prevention measures, especially through a vector-based approach. Through a vector-based approach, each jurisdiction can address each vector based on what is culturally and politically possible. There are many different policy options for each vector, meaning that this is an option for coordination between the jurisdictions, without each jurisdiction having the same exact policy.

Measuring Efficacy

For the different prevention measures, there is also a gap in measuring the effectiveness of each policy that enforces the prevention measure. Right now, there is no way of measuring effectiveness. Many of the existing measures are believed to be effective but state authorities haven't been able to measure it (Ann Bove 2013, pers. comm.). Surveys can give an indication of behavioral changes and the effects of outreach measures, but they do not necessarily measure the effectiveness of policy (Meg Modley 2013, pers. comm.). Developing a system to measure the efficacy of prevention measures could add more evidence in support of their implementation.

Enforcement

Each prevention policy must also be enforced. Most policies are not effective without consistent and well-designed enforcement policies. The level of enforcement depends on whether the resources exist: are enough enforcement officers patrolling and can they feasibly achieve their responsibilities (Ann Bove 2013, pers. comm.). For the existing policies, the responsibility for enforcement is spread out among many types of officials (Meg Modley 2013, pers. comm.) It is therefore hard to measure how much time and energy is spent on enforcement of existing AIS policies.

Gaps in Data

Currently, there is little quantitative data on the ecological, economic, and cultural costs of AIS prevention policy within the Lake Champlain Basin or anywhere. This lack of data makes it difficult to compare the differences between the different policies. There is also a lack of reporting of the activities at the municipal level. We know what policies are instituted at the state level, but further investigation of municipal actions is necessary to fully address AIS prevention measures.

Appendices

Appendix A: Federal, State and Provincial AIS Policies

U.S. Federal Policies

Clean Boating Act of 2008
Authority: Environmental Protection Agency

Congress passed the Clean Boating Act (CBA) in 2008 as an amendment to the Clean Water Act. This law provides that recreational vessels shall not be subject to the requirement to obtain a CWA permit to authorize discharges incidental to their normal operation. It instead directs EPA to evaluate recreational vessel discharges, to develop appropriate management practices for the discharges, and to promulgate performance standards for those management practices. The CBA then directs the USCG to promulgate regulations for the use of the management practices developed by EPA; finally, the law requires recreational boater compliance with such practices.

The CBA has three phases of implementation:
Phase 1: EPA will determine the discharges incidental to the normal operation of recreational vessels for which it is "reasonable and practicable" to develop management practices and develop these practices.
Phase 2: EPA will enact regulations establishing performance standards for each management practice.
Phase 3: USCG will enact regulations that specify the design, construction, installation, or use of management practices to meet EPA's performance standards.

EPA anticipates proposing the Phase 1 regulation in 2013. While it is difficult to project implementation timelines, the EPA anticipates that the Phase 2 regulations will take 18-24 months to complete, following finalization of Phase 1. After finalization of Phase 2, the USCG will develop the Phase 3 regulation.
From water.epa.gov

Lacey Act of 1900
Authority: U.S. Department of Agriculture, U.S. Department of the Interior

The *Lacey Act of 1900* prohibits the “importation into the United States… of such other species of wild mammals, wild birds, fish (including mollusks and crustaceans), amphibians, reptiles, brown tree snakes, or the offspring or eggs of any of the foregoing which the Secretary of the Interior may prescribe by regulation to be injurious to human beings, to the interest of agriculture, horticulture, forestry, or to the wildlife resources of the United States.” Title 16 makes it illegal to import, export, transport, sell, receive, acquire, or purchase in interstate or foreign commerce any fish or wildlife taken, possessed, transported, or sold in violation of any law or regulation of any State or in violation of any foreign law. This policy uses a blacklist approach of species (Doelle 2003).

Federal Noxious Weed Act of 1990 and the Noxious Weed Control and Eradication Act of 2004
Authority: U.S. Department of Agriculture

The *Federal Noxious Weed Act* of 1990 gave the Secretary of Agriculture the authority to designate plants as noxious weeds by regulation, and the movement of all such weeds in interstate or foreign commerce was prohibited except under permit. The Secretary was also given authority to inspect, seize and destroy products, and to quarantine areas, if necessary to prevent the spread of such weeds. He was also authorized to cooperate with other Federal, State and local agencies, farmers associations and private individuals in measures to control, eradicate, or prevent or retard the spread of such weeds. The *Noxious Weed Control and Eradication Act* of 2004 requires the Secretary of Agriculture to establish a program to provide assistance to eligible weed management entities to control or eradicate noxious weeds on public and private land.
From fws.gov

Vermont Policy

Fish Regulation: The taking, possessing, transporting, use and selling of baitfish (Baitfish Rule)
Title 10 V.S.A. App., Chapter 2 § 122
Authority: Vermont Department of Fish & Wildlife

This statute regulates personal harvesting, commercial purchasing and dealing, and use of baitfish.
Personal Baitfish Harvest - personally harvested baitfish may be used only on the same waterbody from which they were collected. A person may harvest for baitfish only those fish species listed under paragraphs 5.6. and 5.6.1.
Commercially Purchased Baitfish - It is unlawful to import baitfish into the State of Vermont without a Fish Importation Permit. Anglers may purchase baitfish from a New York baitshop for use on Lake Champlain only, provided the baitshop is Vermont-licensed, and the baitfish are accompanied by a Vermont-issued baitfish transportation receipt. Anglers shall not transport baitfish away from waters of the state by motorized vehicle.
Commercial Bait Dealers - Any person who buys bait for resale or sells baitfish is required to obtain a Commercial Bait Dealers Permit from the commissioner. Commercial Bait Dealers may sell as bait only those species of fish listed under section 5.6 and 5.6.1. Commercial Bait Dealers may also sell rainbow smelt as bait, provided they are obtained from a fish hatchery approved by the commissioner as per paragraph 5.5.4 and its subsections below, or harvested and sold for use on the same waterbody on which the Bait Dealer is located as per paragraph 5.5.5 and its subsections below.
Approved Species of Fish for use as Bait – provides a list of species approved for use as bait.

Aquatic Weeds Quarantine Rule
AAFM #3
Authority: Agency of Agriculture, Food and Markets

The movement, sale, possession, cultivation, and / or distribution of Class A Noxious Weeds designated in Appendix A of this rule is prohibited. The sale, movement, and / or distribution of Class B Noxious Weeds designated in Appendix A of this rule is prohibited. Violation of any of these prohibitions may result in:
1. The issuance of cease and desist orders; and / or,
2. Temporary or permanent injunctions; and / or,
3. Administrative penalties as specified in 6 V.S.A., Chapter 1, Section 15, and Chapter 84, Sections 1037 and 1038.
From http://www.vermontagriculture.com

Felt-soled Wader Ban
Title 10 § 4616
Authority: Vermont Department of Fish & Wildlife

It is unlawful to use external felt-soled boots or external felt-soled waders in the waters of Vermont, except that a state or federal employee or emergency personnel, including fire, law enforcement, and EMT personnel, may use external felt-soled boots or external felt-soled waders in the discharge of official duties. From http://www.leg.state.vt.us/

Aquatic Species Transport Law (Transport of aquatic plants and aquatic nuisance species)
Title 10 V.S.A § 1454
Authority: Vermont Agency of Natural Resources

(a) No person shall transport an aquatic plant or aquatic plant part, zebra mussels (*Dreissena polymorpha*), quagga mussels (*Dreissena bugensis*), or other aquatic nuisance species identified by the secretary by rule to or from any Vermont waters on the outside of a vehicle, boat, personal watercraft, trailer, or other equipment. This section shall not restrict proper harvesting or other control activities undertaken for the purpose of eliminating or controlling the growth or propagation of aquatic plants, zebra mussels, quagga mussels, or other aquatic nuisance species.

(b) The secretary may grant exceptions to persons to allow the transport of aquatic plants, zebra mussels, quagga mussels, or other aquatic nuisance species for scientific or educational purposes. When granting exceptions, the secretary shall take into consideration both the value of the scientific or educational purpose and the risk to Vermont surface waters posed by the transport and ultimate use of the specimens. A letter from the secretary authorizing the transport must accompany the specimens during transport. From http://www.leg.state.vt.us/

Fish Propagation
10 App., Chapter 2 § 117A
Authority: Vermont Department of Fish & Wildlife

A person shall not rear for sale or distribution any species of live fish within this state without first procuring a permit from the Commissioner to do so (10 V.S.A. chapter 119, §§ 5207-5209). Persons maintaining fish in a closed rearing aquarium (no water discharge) may request exemptions (on the fish propagation application form) from the Annual Fish Health Inspection and/or the Breeders License. From http://www.leg.state.vt.us/

Placing Fish in Waters; Fish Importation Permits
Title 10 Chapter 111 § 4605A
Authority: Vermont Department of Fish & Wildlife

1. A person shall not introduce or attempt to introduce: (a) pickerel or northern pike into any waters; or (b) any fish, except trout or salmon, into any waters except private ponds lacking access to other waters of the state.

2. A person shall not bring into the state for the purpose of planting or introducing, or to plant or introduce, into any of the inland or outlying waters of the state any live fish or the live spawn thereof, unless, upon application in writing therefore, the person obtains from the commissioner a permit so to do. The permit may include conditions, which the commissioner finds necessary to guard the health of Vermont's fish population.

3. The commissioner may, by rule, adopt a list of fish, which if introduced into Vermont waters, have the potential to cause harm to the fish population of the state. A person shall not possess or bring into the state any fish on the list unless the person has received a permit issued pursuant to this subsection. The commissioner may issue a permit allowing importation and possession of a fish on the list, provided the fish is to be kept in a controlled situation and used for a public purpose such as research or education. A permit issued under this subsection shall include conditions that ensure the health and safety of Vermont's fish population.

4. Applicants shall pay a permit fee of $50.00. The commissioner or duly authorized agents, shall make such investigation and inspection of the fish as they may deem necessary and then the importation permit may be granted pursuant to regulations which the board shall prescribe. The commissioner or duly authorized agents shall make a determination on the permit within 10 days of receiving the application. The department may dispose of unlawfully imported fish as it may judge best, and the state may collect damages from the violator of this subsection for all expenses incurred.

5. Nothing in this section shall prohibit the board, the commissioner or their duly authorized agents from bringing into the state for the purpose of planting, introducing, or stocking, or from planting, introducing, or stocking any fish in the state. From: http://www.leg.vt.us/

Pest Survey, Detection and Management, Permits
Title 6 Chapter 84 § 1035
Authority: Vermont Agency of Agriculture, Food and Markets

No person may sell, offer for sale, barter, expose, move, transport, deliver, ship, or offer for shipment into or within this state any plant pest or biological control agent in any living stage without first obtaining either a federal permit, where applicable, and a state permit from the secretary. A state permit may only be issued after it has been determined by the secretary that the plant pests or biological control agents are not injurious, are generally present already, or are for scientific purposes subject to specified safeguards. From http://www.leg.vt.us/

Prohibited, Restricted, and Unrestricted Fish Species
Title 10 § 4081
Authority: Vermont Department of Fish & Wildlife

This rule is adopted pursuant to 10 V.S.A § 4081 (a) which provides that the protection, propagation, control, management, and conservation of fish, wildlife, and furbearing animals in this state is in the interest of the public welfare and that the safeguarding of these valuable resources for the people of the state requires a constant and continual vigilance, and in accordance with 10 V.S.A. § 4605 (c) provides that the commissioner may, by rule, adopt a list of fish which, if introduced into Vermont waters, have the potential to cause harm to the fish population of the state.

It is the purpose of this regulation to carry out the mandate of the Vermont General Assembly to control through a permit program the importation and possession of fish species as provided in 10 V.S.A. § 4605 (c) to guard the health of Vermont's fish populations by preventing the introduction of fish species that could have the potential to cause harm to fish populations of the state.
From http://www.leg.state.vt.us/

New York Policies

Taking and Sale of Bait Fish
Chapter 43-B Article 11 § 11-1315 (partial)
Authority: New York Department of Environmental Conservation

No person, without first obtaining the appropriate license from the department [Environmental Conservation], shall take for sale as bait, nor sell as bait the following fish: minnows (family Cyprinidae), except carp or goldfish; top minnows or killifish (family Cyprinodontidae); mudminnows (family Umbridae); darters (family Estheostomidae); sticklebacks (genus *Eucalia*); tadpole stone cats (genera *Noturus* and *Schilbeodes*); smelt or ice fish (*Osmerus mordax*); alewives, saw bellies or blueback herring (family Clupeidae); suckers (family Catostomidae).

Fish taken pursuant to such license shall be used only for bait in hook and line fishing. All carp, goldfish, and lamprey larvae (family Petromyzontidae) taken in nets operated pursuant to such license shall be destroyed immediately.
From: http://www.dec.ny.gov/

Water Chestnut
Chapter 43-B, Article 11 § 11-0509
Authority: New York Department of Fish and Wildlife

No person shall plant, transport, transplant or traffic in plants of the water chestnut or the seeds or nuts thereof nor in any manner cause the spread or growth of such plants.
From: http://public.leginfo.state.ny.us/

Invasive Species Prevention Act
Amendment to Environmental Conservation Law § 9-1709
Authority: New York Department of Environmental Conservation, New York State Department of Agriculture and Markets

While the regulations have yet to be put into effect, the aim of this amendment is for the Department of Environmental Conservation and the Department of Agriculture and Markets to produce the following:
1. a permit for prohibited species disposal, control, research and education;

2. a list of prohibited species, which shall be unlawful to knowingly possess with the intent to sell, import, purchase, transport or introduce;

3. a list of prohibited species which shall be unlawful to import, sell, purchase, propagate, transport, or introduce except under a permit for disposal, control, research, or education; and

4. a list of regulated species which shall be legal to possess, sell, buy, propagate and transport but may not be knowingly introduced into a free-living state or introduced by a means that one knew or should have known would lead to the introduction into a free-living state. From: http://pelr.blogs.law.pace.edu/

Fish Dangerous to Indigenous Fish Populations
6 NYCRR § 180.9
Authority: New York Department of Environmental Conservation

Prohibitions-
1. Except as provided in subdivisions c and d of this section, no person shall buy, sell or offer for sale, possess, transport, import or export, or cause to be transported, imported or exported live individuals or viable eggs of a list of species of fish, which the department has determined present a danger to indigenous fish populations:

2. No person shall liberate to the wild any species listed in this section, cause such species to be liberated to the wild or allow such species to exist in a state or condition where it is likely to escape into the wild.

Exceptions - Notwithstanding the prohibitions contained in this section, Bighead carp may be sold, possessed, transported, imported and exported in the five boroughs of the City of New York (Manhattan, Bronx, Queens, Brooklyn, and Staten Island) and the Westchester County Towns of Rye, Harrison, and Mamaronek and all the incorporated cities or villages located therein. Bighead carp offered for sale in any retail establishment shall be killed by the seller before the purchaser takes possession of said fish.

Permits- The department may issue permits, the term of which shall not exceed one year, to possess, transport, import or export species of live fish listed in this section only for educational, exhibition or scientific purposes, as defined in section 175.2 of this chapter. Permits issued pursuant to this section may contain terms, conditions and standards designed to prevent escapement while fish species listed in the permit are held in captivity, and to ensure safe disposition of those species following expiration of the permit or cessation of the permitted activity. The permit fee shall be $500, except that the fee may be waived for bona fide employees, representatives or affiliates of accredited colleges or universities, research institutions, government agencies, or public museums or aquariums.

Seizure - Environmental conservation officers, forest rangers and members of the state police may seize species of fish listed in this section that are possessed without a permit. No action for damages shall lie for such seizure, and disposition of seized animals shall be at the discretion of the department.
From: http://www.dec.ny.gov/

Prevention of Introduction of Injurious Insects, Noxious Weeds, and Plant Diseases
Chapter 69, Article 14 § 163
Authority: New York State Department of Agriculture and Markets

1. The commissioner shall take such action as he may deem necessary to prevent the introduction into this state of injurious insects, noxious weeds, and plant diseases, provided that he shall consult with the commissioner of environmental conservation

prior to the commencement of any action to eradicate noxious weeds.

2. All nursery stock shipped into this state shall bear or carry on the container thereof an unexpired certificate, or copy thereof, to the effect that (a) the contents of such container have been inspected by a duly authorized official and that the contents appear to be free from all injurious insects or plant diseases, or (b) that the nursery stock of the grower of such contents had been examined by a duly authorized official and had been found to be apparently free from all injurious insects or plant diseases. Such certificate shall be the certificate of the chief horticultural inspector, by whatever name known, of the country, province or state in which such shipment originated. There shall be shown in the certificate or by a separate tag attached hereto the name and address of the consignor or shipper, the name and address of the consignee or person to whom the nursery stock is shipped, and the general nature of the contents together with labels upon each variety of nursery stock declaring the name thereof and a statement by the consignor or shipper that such nursery stock is in a live and vigorous condition.

3. Any person within the state receiving nursery stock from without the state not accompanied by the certificate described in subdivision two of this section, shall immediately notify the commissioner of the receipt of such nursery stock and shall not unpack the same unless permitted by the commissioner so to do, and shall not allow such nursery stock to leave his possession until it has been inspected and released by the commissioner.

4. It shall be unlawful for any person to offer for sale or to sell dead nursery stock.
From: hppp://www.agriculture.ny.gov/

Taking for propagation and stocking; fish hindering
Chapter 43-B, Article 11 § 11-0511 (partial)
Authority: New York Department of Environmental Conservation

1. The department may take, or it may permit any person to take wildlife for propagation or stocking purposes, or fish or shellfish for propagation purposes.

2. It may also remove, or permit to be removed, in any manner it may prescribe, from either public or private waters, fish or shellfish which hinder the propagation of food fish or shellfish, or which are in imminent danger of being killed by pollution or otherwise. Such fish or shellfish shall be disposed of as the department may direct.
From: http://www.dec.ny.gov/

Liberation of Fish, Shellfish and Wildlife
Chapter 43-B, Article 11 § 11-0507
Authority: New York Department of Environmental Conservation

1. Fish or fish eggs shall not be placed in any waters of the state unless a permit is first obtained from the department; but no permit shall be required to place fish or fish eggs in an aquarium.

2. No person shall liberate or import or cause to be imported for the purpose of liberation within the state any European hare (*Lepus europaeus*), European or San Juan rabbit (*Oryctolagus cuniculus*), Texas or jack rabbit (*Lepus californicus*), gray fox (*Urocyon cinereoargenteus*), including captive bred gray fox, red fox (*Vulpes vulpes*), including captive bred red fox or nutria (*Myocastor coypus*), whether taken from within or without the state. Nutria may be imported only by permit of the department for scientific, exhibition or for breeding purposes.

3. No person shall willfully liberate within the state any wildlife except under permit from the department. The department may issue such permit in its discretion, fix the terms thereof and revoke it at pleasure. These provisions do not apply to migratory game birds, importation of which is governed by regulation of the department.

4. No person shall intentionally liberate zebra mussels (*Dreissena polymorpha*) into any waters of the state. No person shall buy, sell, or offer to buy or sell, or intentionally possess or transport zebra mussels except under a license or permit issued pursuant to section 11-0515. Zebra mussels, except those lawfully held pursuant to a license or permit, may be destroyed by any person at any time.
From: http://www.dec.ny.gov/

Shipment of Live Pests
Chapter 69, Article 14 § 164-a
Authority: New York State Department of Agriculture and Markets

No person, shall sell, barter, offer for sale, or move, transport, deliver, ship, or offer for shipment, into or within this state any living insects in any state of their development, or noxious weeds, living fungi, bacteria, nematodes, viruses or other living plant parasitic organisms without first obtaining a permit from the commissioner. Such permit shall be issued only after the commissioner has determined that the insects, noxious weeds or living bacteria, fungi, nematodes, viruses or other plant parasitic organisms in question are not injurious to plants or plant products, if not already present in the state, or have not been found to be seriously injurious to warrant their being refused entrance or movement, if known to be already established within the borders of the state; provided, that the commissioner may at his discretion exempt the sale and transportation of specific insects, noxious weeds, fungi, bacteria, and other plant parasitic organisms from the provisions of this section if such sale and transportation is not considered harmful to the health and welfare of the people of the state, or for scientific purposes under specified safeguards determined by the commissioner.
From: http://www.agriculture.ny.gov

Possession and Transportation of Wildlife
Chapter 43-B Article 11 § 11-0511
Authority: New York Department of Environmental Conservation

No person shall, except under a license or permit first obtained from the department the prominent warning notice specified in subdivision nine of section 11-0917 of this article, possess, transport or cause to be transported, imported or exported any live wolf, wolfdog, coyote, coydog, fox, skunk, venomous reptile or raccoon, endangered species designated pursuant to section 11-0535 hereof, species named in section 11-0536 or other species of native or non-native live wildlife or fish where the department finds that possession, transportation, importation or exportation of such species of wildlife or fish would present a danger to the health or welfare of the people of the state, an individual resident or indigenous fish or wildlife population. Environmental conservation officers, forest rangers and members of the state police may seize every such animal possessed without such license or permit. No action for damages shall lie for such seizure, and disposition of seized animals shall be at the discretion of the department.
From: http://www.dec.ny.gov

Canadian Federal Policies

Fisheries Act
Authority: Fisheries and Oceans Canada

This legislation, which deals with the conservation and protection of fisheries resources, provides the mandate to prepare this Code on Introductions and Transfers of Aquatic Organisms. The Governor in Council may make regulations for carrying out the purposes and provisions of this Act and in particular, but without restricting the generality of the foregoing, may make regulations for the proper management and control of the sea-coast and inland fisheries, in respect to the protection and conservation of fish, and in respect to the taking or carrying of fish or any part thereof from one province to any other province. The Government of Québec enforces the federal fishing regulations under the Fisheries Act, which controls the transportation, possession, and use of baitfish.
From: http://www.dfo-mpo.gc.ca

Health of Animals Act
Authority: Canadian Food Inspection Agency

This legislation is primarily aimed at the protection of livestock from infectious diseases that could be imported from the international community. A recent amendment to this act addresses the importation of aquatic animals (finfish, mollusks, and crustaceans) and requires that aquatic animals that are brought into Canada must be declared and in the case of aquatic animals on the susceptible species list, must have an import permit. This bylaw went into effect in 2013 and helps control the buying, selling, importation,

transport, and stocking of all fish species, alive or dead including aquaculture and the sale of fish.
From: http://laws-lois.justice.gc.ca/

The *Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act (WAPPRIITA)*
Authority: Environment Canada

Under the *Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act* (WAPPRIITA) any importation of plant and animal species that are listed in schedules to the Wild Animal and Plant Trade Regulations requires a permit. The schedules include all species regulated by the Convention on International Trade in Endangered Species (CITES) of Wild Flora and Fauna and alien species considered invasive in and potentially harmful to Canadian ecosystems. Provincial governments may also request that a species be listed if they are of the opinion that transport into their jurisdiction would be harmful to its environment. The federal Department of Environment's Canadian Wildlife Service administers the Act and is currently considering different approaches to augment the list of species regulated. The Act protects certain species of animals and plants by implementing CITES and regulates international and interprovincial trade in these animals and plants. In addition, it permits provinces to make regulations that prohibit the import of animals and plants that may be harmful to the environment.
From http://www.dfo-mpo.gc.ca

Species at Risk Act (SARA)
Authority: Environment Canada

The purposes of the *Species at Risk Act* (SARA) are to prevent wildlife species in Canada from disappearing, to provide for the recovery of wildlife species that are extirpated (no longer exist in the wild in Canada), endangered, or threatened as a result of human activity, and to manage species of special concern to prevent them from becoming endangered or threatened. A series of measures applicable across Canada provides the means to accomplish these goals. Some of these measures establish how governments, organizations, and individuals in Canada work together, while others implement a species assessment process to ensure the protection and recovery of species. Some measures provide for sanctions for offenses under SARA.
From: http://www.ec.gc.ca/

Appendix B: Interview Questions for Baitfish and Aquarium Shops

Baitfish Shop Interview Script

Hello, my name is Janet/Charlie and I am a student at Middlebury College. I'm working on a research project about aquatic invasive species in Lake Champlain. As part of this project, I'm conducting short, informal interviews with baitfish shops about their experience with baitfish regulations. Is there someone in your shop that would be willing to speak with me about baitfish? Would you mind taking a few minutes to talk with me now about how these regulations have affected your shop? If not, is there some other time that I should call your shop?

1. Have baitfish regulations affected your business?
   a. Have they caused any additional costs to your shop?
   b. If so, how would you characterize the types and extent of those costs?
2. How much time does your shop spend on efforts to comply with baitfish regulations?
3. In what ways do you see the enforcement of baitfish regulations?
4. Do your customers ever mention the regulations? If so, what do they say?
5. How have baitfish regulations affected fishermen?

Baitfish Stores in the Lake Champlain Basin in Vermont:

ALBURG VILLAGE STORE CLIFFORD PARAH	13 SOUTH MAIN STREET ALBURG VT 05440	(802) 309-5730	Lake Champlain
BAYSIDE BAIT & TACKLE CAROL PION	135 CHUBB STREET ST ALBANS BAY VT 05481	(802) 524-2222	Lake Champlain
BILL'S SPORT SHOP WILLIAM CHAMPAGNE	193 U.S. RTE 2 GRAND ISLE VT 05458	(802) 372-4531	Lake Champlain
HOLIDAY HARBOR BRUCE BATCHELDER	8369 RTE 2 NORTH HERO VT 05474	(802) 372-4077	Lake Champlain
ISLAND BAIT MICHAEL LARROW	71 HYDE ROAD GRAND ISLE VT 05458	(802) 372-9116	Lake Champlain
MARTIN'S GENERAL STORE GILBERT GAGNER	2934 U.S. RTE 7 HIGHGATE SPRINGS VT 05460	(802) 868-4459	Lake Champlain
NORM'S BAIT & TACKLE NORMAN ST.PIERRE	286 BRIDGE ROAD CROWN POINT NY 12928	(518) 597-3645	Lake Champlain

RAY'S SEAFOOD PAUL DUNKLING	49 NORTH STREET BURLINGTON VT 05401	(802) 658-7928	Lake Champlain
TORREY'S BAIT JEFFREY TORREY	5555 LAKE STREET BRIDPORT VT 05734	(802) 758-2408	Lake Champlain

Aquarium Shops Interview Script

Hello, my name is Janet/Charlie and I am a student at Middlebury College. I'm working on a research project about aquatic invasive species in Lake Champlain. As part of this project, I'm conducting short, informal interviews with aquarium shops about their experience with regulations for the trade of fish and aquatic plants. Is there someone in your shop that would be willing to speak with me about this? Would you mind taking a few minutes to talk with me now about how these regulations have affected your shop? If not, is there some other time that I should call your shop?

1. How have regulations for restricted or prohibited fish affected your business?
    a. Have you had to change your inventory or selection of species based on prohibited fish or plant regulations?
    b. Have these regulations caused any additional costs to your shop?
    c. If so, how would you characterize the types and extent of those costs?
2. How much time does your shop spend on efforts to comply with aquatic species trade regulations?
3. In what ways do you see the enforcement of regulations on prohibited or restricted species?
4. Do your customers ever mention the regulations? If so, what do they say?
5. How have aquatic species trade regulations affected aquarium enthusiasts?

Aquarium Shops in the Basin, according to Google:

- Bridge Street Aquarium - Plattsburgh, NY - (518) 561-7387
- Green Mountain Aquarium - Winooski, VT - (802) 985-4160
- All Bright Aquariums - New York - (518) 307- 9291
- Tri Lakes Aquarium Pets - Mineville, NY - (518) 481-5537
- Aquatica Aquarium Supplies - Montreal, QC - (514) 428-0099

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