Protecting Our Waters through Integrated Milfoil Research, Education, and Management At the Adirondack Watershed Institute Of Paul Smith’s College

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Abstract
A dedicated community of individuals, agencies, and institutions collaborates to protect the Adirondack region’s unique and relatively intact aquatic resources. The Adirondack Watershed Institute (AWI) of Paul Smith’s College serves as an integral part of this community, accomplishing its mission of water resource protection through the integration of science, education and management. Working with other regional agencies and initiatives, the AWI has played a central role in aquatic invasive species spread prevention and management. This article describes the AWI’s science and management outcomes and its process of integrating these two components with public education through the Watershed Stewardship Program to understand and help prevent the spread of Eurasian water-milfoil in the Adirondack Park. By monitoring plant communities after management, we have confirmed that early detection of aquatic invasive species is critical for milfoil control and the protection of our current ecological communities. Our laboratory research suggests that even very dry fragments of Eurasian water milfoil have a small probability of being viable when re-introduced to water, underlining the need for boater education and spread prevention actions on the part of watercraft users and management agencies. Ongoing research on growth rates and patterns in Eurasian water-milfoil, northern water-milfoil and variable-leaf milfoil and their response to environmental conditions will eventually help us predict outcomes of competition among species, both native and invasive. The AWI integrates science and public education by involving our boat launch stewards in both research and aquatic invasive species field management and by incorporating research outcomes into boat inspector training and public messaging. This promotes engagement on the part of Stewards and broadly disseminates information to the public. In collaboration with other local/regional agencies who share an attachment to this ‘place’, we integrate science, education, and management to protect our native aquatic and human communities.

Biological communities change constantly across evolutionary time scales. The communities we see today are a function of the environmental conditions for establishment and growth in local habitats, and the ability of species to disperse on a regional scale (Caspers et al. 2009). It is the rapid rate of change wrought by successful, often human-introduced invasive species that creates unwanted and potentially unsustainable change in our ecosystems.

Luckily, few introduced species actually become invasive. The ‘rule of tens’ is often invoked to describe the proportion of introduced species that are likely to become invasive: only roughly 10% of introduced species establish and only 10% of those are likely to become invasive (Williams and Fitter, 1996). Yet those species that succeed can quickly spread and often alter our ‘native’ communities in a compressed time frame (e.g. Madsen et al. 1991). Successful invasive plants are typically spectacular dispersers and/or excellent competitors. When we introduce them into environments with amenable environmental conditions and no natural enemies, they do what they do best at the expense of communities that have evolved over long time periods.

There are over 3,000 lakes and ponds in the Adirondack Park (the Park). As of 2012, only 88 of these waters are known to be infested with invasive species (APIPP 2012). Given the ‘rule of tens’, the relatively few invaded lakes, and the strong sense of place in the Park, we have a great opportunity to successfully fight the spread of aquatic invasives.

Aquatic invasive species may decrease the value of recreational experiences both socially and economically. Tourists and visitors spend over 1.2 billion dollars annually in the Park, employing roughly 26,000 people in the recreation and hospitality industries that serve these visitors (Kelting et al. 2006). Seventy percent of visitors report coming to the Adirondacks for water-based recreation including swimming, fishing, or boating, and 85% report a desire to have lodging on or near water. Adirondack

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lakefront residences fronting littoral zones with dense beds of invasive milfoil may experience significant decreases in property value as the milfoil proliferates, as was shown for lakefront property in neighboring Vermont (Zhang and Boyle 2010).

We live in, visit, use, and protect a unique area. While the Adirondack Park is not pristine, it does have a comparatively large area with terrestrial and aquatic ecosystems that have been left to persist with as little interference as we can afford them. With the pressures of global climate change, air pollution, and the need to sustain human communities within the Park, we are also obligated to conduct research on, educate about, and manage to protect this spectacular region from the added pressure of rapid ecological change due to invasive species.

The Adirondack Watershed Institute (AWI) of Paul Smith’s College has the mission to conserve and protect water resources in the Adirondack region. The AWI became involved in aquatic invasive species management in 1990 with the start of the Watershed Stewardship Program (WSP) at the St. Regis Lakes and milfoil management in Upper Saranac Lake. The AWI provides a model for the integration of science, education, and management of Adirondack water quality. Of the 88 waterways that have invasive species, two of the most common are Eurasian water-milfoil (EWM) (Myriophyllum spicatum) and Variable leaf milfoil (VLM) (Myriophyllum heterophyllum). The AWI focuses its research on these two species and their native counterpart, northern water-milfoil (NWM) (Myriophyllum sibiricum).

This article highlights the AWI’s work over the past decade on water milfoil science, education and management in the Adirondack Park. Our goal is to share our current understanding of milfoil invasion biology and the value of outreach and early detection efforts for management and prevention, based on the work of AWI and others. Ultimately we showcase our process and the value of integrating science, education and management in protecting the aquatic resources of this unique place.

**Linking Research, Education and Management for Protection of a Place**

Here in the Adirondack Park, we have a real opportunity to make research, education and management come together in a powerful protective circle. Researchers are beginning to identify important relationships among the concepts of place, community and natural resource management. There are many published definitions of ‘place’ but Gieryn (2000) suggests that a ‘place’ has three critical components: geographic, physical/material, and ascribed meaning and value. Building from this definition of place, the concept of community-based resource management relies upon the premise that local populations care more about sustainable use of local resources than larger political or industrial entities; and that local communities are more familiar with local ecological processes and are therefore more likely to manage local natural resources more effectively (Brosius et al. 1998). At the AWI, the success of our integrated program has benefitted from shared meanings, values, and Adirondack experiences among community groups, lake associations, visitors, our researchers and our watershed stewards.

Public awareness of invasive species (particularly milfoil) has dramatically changed in recent years. Awareness in the Park has grown thanks in large part to local organizations such as the Adirondack Park Invasive Plant Program, Adirondack Watershed Institute, Lake Champlain Basin Program, Lake George Park Commission and many others. Awareness and concern on the part of our watershed communities and the boating public is critical for making early detection and management possible. Once a management plan is in place, research can verify its effectiveness.

**Community Awareness, Early Detection, and Action: A Case Study**

The importance of public awareness and rapid response can be seen by comparing two large Adirondack Lakes, both with a milfoil problem: Chateaugay Lake and Upper Saranac Lake. It is very likely that Chateaugay Lake was one of the first Adirondack Lakes to be invaded by Eurasian water-milfoil. The species was first identified in 1979 by a Cornell University professor, based on a site visit conducted at the request of a property owner (John Peverly, personal communication). It is easy to understand why the arrival and subsequent establishment of milfoil would be largely ignored. At that time little was known about milfoil, and the science and public awareness of invasion ecology was still in its infancy (Ricciardi and Maclissac 2008).

Nearly two decades later, Eurasian water-milfoil was first in detected in Upper Saranac Lake in 1996. By this time, milfoil was a common problem in many Adirondack Lakes. Coordinated control, initiated by a concerned group of property owners, began with a limited effort two years after initial discovery, followed by intensive whole lake control beginning in 2004. Hand harvesting removed over 25 tons of milfoil between 2004 and 2008 (Keltling and Laxson 2010). In August 2012, the milfoil density across the underwater study transects averaged 65 stems/acre (n = 49), down from as high as 660 stems/acre in 2004 (Keltling 2013). Milfoil is currently a rare member of the plant community in Upper Saranac Lake, existing across less than 2% of the study area (Figure 1).

Although users of Chateaugay Lake began to take notice of the milfoil problem in the early 2000s, coordinated control and detailed monitoring efforts did not begin until 2008, after the species had over 30 years to become established. Hand harvesting from problematic areas around the NYSDNDEC boat launch removed 71 tons of milfoil between 2009 and 2012 (Keltling 2009; Adirondack Invasive Management LLC. 2013). In August 2012, after five years of management, the milfoil density across our underwater study transects averaged 9,900 stems/acre (n = 19), down from as high as 38,000 stems/acre (n = 3) in
2008, before harvesting began (Kelting 2012). Despite the substantial reduction in biomass, milfoil continues to be one of the dominant members of the plant community, existing across 69% of the study area (Figure 2).

It is striking that even though approximately three times the amount of EWM was harvested in Chateaugay Lake over a similar period of time as compared to Upper Saranac Lake, EWM is still a dominant component of that lakes flora while it is rare in Upper Saranac Lake. There are likely many unidentified factors that contributed to the different milfoil densities observed in these two lakes, ranging from limnological condition to boat use patterns. It is, however, rather clear that one of the most important factors is the amount of time from detection to management. Awareness, early detection, and a rapid management response appear to be critical to controlling invasive milfoil.

**Milfoil Research**

When we started to investigate this question back in 2009, surprisingly little was known about the way plant fragment transport on boats and trailers influenced the viability and growth of Eurasian water-milfoil (EWM). However, knowledge of modes of growth and dispersal within a lake was quite well established. Dispersal of Eurasian water milfoil within lakes is mostly due to stolon growth and fragmentation; seeds are thought to be a relatively unimportant means of dispersal (Madsen and Smith 1997, C. Laxon unpublished data). Fragments naturally break apart in mid-late summer when biomass is greatest, and these fragments may form rootlets and can be carried by currents to surrounding areas to settle and establish. Disturbances such as boat motors, paddles, and wind, break fragments free from rooted stems and allow establishment of new colonies within a lake as well.

Fragmentation has been shown to be responsible for 26% to 46% of the spread of Eurasian water-milfoil in different study locations (Madsen and Smith 1997). Dispersal of invasive aquatic species from one water body to another appears to be caused mainly by the transfer of fragments on watercraft and trailers. In a New Zealand study, nearly 20% of the aquatic wetland flora were introduced species, transferred...
almost exclusively by the lake-to-lake movement of boats (Johnstone et al. 1985). These researchers reported that none of the 5 invasive species they were studying were found in lakes without boating or fishing activity.

At the AWI, our work on milfoils since 2009 has included the effects of drying on viability of transported fragments, the physiology and growth of invasive milfoil fragments as compared to the native northern water-milfoil, and the response of invasive and native milfoil fragments to water temperature changes that are predicted to occur due to climate change. Environmental conditions and dispersal factors appear to be equally responsible for the impact of invasive species at the regional scale (Capers et al. 2009), thus, knowing as much as possible about response to local conditions and the mechanisms of dispersal will allow us to better understand the threats to our native aquatic ecosystems in the Adirondacks and to tailor management efforts to address these threats.

**EWM Desiccation Research**

The most obvious environmental change encountered by fragments being dispersed over land is drying. Plants have different levels of tolerance for desiccation, so we asked how quickly do milfoil fragments dry? What effect does different degrees of drying have on viability of those fragments once they are rehydrated? Fragments dry very quickly even in a laboratory setting (Evans et al. 2011); after 13 hours, fragments sitting at room temperature were 100% dry. Drying reduced the probability of new growth from 98% (fresh) to 2% in samples that were considered completely dry. Even though this is a very large reduction, transported fragments are introduced into new lakes all the time and one successful establishment could mean a new infestation (Evans et al. 2011).

This outcome reinforces the importance of boat inspection and removal of all plant matter regardless of whether it looks dry or ‘dead’. While many factors will determine whether a dry fragment that produces new growth will in fact establish a new community of EWM, under the ‘right’ conditions it will only take one successful propagule. It is not worth the risk.

**Boat Launch Fragment Study**

Starting in 2012, our Watershed Stewards collect all the incoming milfoil fragments on boats and trailers that are inspected at launches. Samples taken from watercraft by stewards during watercraft inspections are processed in the AWI lab, where they are made part of an ongoing project to identify risk factors for invasion. Information on the dryness, morphology, and location of fragments found on watercraft entering all the boat launches at which we are stationed (as mentioned above) are collected. We will continue to field test some of what we learned about drying in the lab using samples that have actually been transported on boats and trailers and have dried in the process. Our preliminary analysis of EWM fragments collected from boat launches during the summers of 2012 and 2013 corroborate the work of Jerde et al. (2012), who showed that coiled fragments tend to stay more wet than uncoiled fragments. Our laboratory studies have also examined the role of the apical or growing tip of fragments in retaining moisture. These studies/models do not yet take into account the distance traveled from the previous lake, which likely interacts strongly with fragment moisture levels. As we continue to collect more of these fragments and focus in on the factors that influence desiccation during transport we can begin to develop models that rank the likelihood of invasion at various boat launches. Data on the number of fragments transported to each lake and the most recent lakes those boats traveled, have been collected by our Stewards for 12 years. Gathering this new information on the moisture status and morphology of fragments integrates the geographic pattern data with the EWM physiology data to give us a better understanding of potential risk to lakes.

**Milfoil and Climate Change**

Researchers at Paul Smith’s College have been studying the effects of warming water temperature on viability and growth of milfoil fragments since the fall of 2011. Professor David Patrick and his students found that warmer water temperatures in the later part of the growing season may extend growth into the fall for EWM but not NWM (Patrick et al. 2012). At the AWI we have studied growth and viability of invasive and native milfoil under two scenarios of summer water temperature across a range of 5 temperatures (ranging from 14°C to 33°C). Results from these studies will allow us to predict relative growth rates of our two most troublesome invasive species in a ‘warm water’ future, which will help us to better understand their competitive interactions with the native milfoil. We will put this science into action by using our results to prioritize management and education on the invasive species that are most likely to succeed in a warming Adirondack climate.

**Stewardship and Education at the AWI**

Paul Smith’s College’s Watershed Stewardship Program was initiated at the AWI in 2000 as a localized effort to protect a single ecologically intact waterway: the St. Regis Lakes chain in the northern Adirondack Park. The program’s primary activity is to place watercraft inspectors at boat launches...
to educate resource users about aquatic invasive species and to perform careful watercraft inspections to remove visible plants and animals. The program has grown each year as lake associations across the Adirondacks become interested in protecting their own waterways, and with funding from the U.S. Environmental Protection Agency and U.S. Fish and Wildlife Service through the Great Lakes Restoration Initiative (see Figure 3). Depending on funding, each year the program has approximately 25 employees educating the public and inspecting watercraft at approximately 20 boat launches across the Adirondack Park. The WSP works closely as a mentor and collaborator with other boat launch steward programs in the region to coordinate educational messages, data collection protocols, educational materials, and training. These programs all gather and share data on invasive species found on boats, in order to develop a body of information to address spread prevention at the landscape level.

The seasonal staff of WSP, whose main responsibility is to educate and monitor transport of invasives at boat launches, are also involved in invasive control and ecological research. Just as all components of the watershed interact ecologically, we have found that stewardship efforts reach their highest potential when education, management and scientific investigations are linked. By involving the watercraft inspectors themselves as research assistants, the stewards 'own' the information and become energized about the ecology and management of aquatic invasive species. This knowledge and enthusiasm allows them to inform watercraft operators regarding the intent, design, and findings of laboratory investigations being conducted at the Adirondack Watershed Institute. In addition, stewards that participate as researchers may be more credible in their interactions with the public. Stewards share research findings learned from their training as well as their personal experience with interested boaters. The telling of stories and 'lived experiences' among stakeholders can shape the way we value place (Barkley 2013). The sharing of experiences between stewards and boaters helps to establish a common ground between them, and therefore may strengthen the disposition of users to act responsibly in the future (Vaske and Cobrin 2001).

Between 2000 and 2014 just over 289,000 boaters were engaged by Watershed Stewardship Program stewards in educational discussions about the prevention of invasive species (Figure 3). Over time, steward outreach has become a valuable mechanism for the dissemination of research, as well as a providing feedback from those using the resource to the research program. The ultimate goal of public education is to encourage boaters to adopt spread prevention measures even when stewards are not present. In sum, the WSP works as part of the AWI to help create the integrated cycle of research, education, and management. Each of the three potentially separate elements is linked through the undergraduate summer staff and their mentors.

**Conclusion**

In the Adirondacks we have a strong network of community organizations committed to invasive species awareness. Within this community, and in this place, the Adirondack Watershed Institute of Paul Smith's College plays an important role in the research, education, and management concerning aquatic invasives such as milfoil. Our work demonstrates the synergy of these three components for the protection of our local waterways. Research informs management and management outcomes inspire new directions for research. Being involved in research empowers our educators, improves their credibility, and increases the dissemination of information both scientific and social. Invasive species initiatives at the Watershed Institute are integrated through positive feedback loops that keep us moving forward, together, for the protection of our treasured, local water resources.

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**Figure 3.** Number of boats contacted by Watershed Stewards each year, showing the growth and dissemination of the Watershed Stewardship Program from 2001 to 2014 (E. Holmlund, pers.com., 2014)


Adirondack Watershed Institute of Paul Smith's College. 12p.


