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**Research Article**

## Economically viable strategy for prevention of invasive species introduction: Case study of Otsego Lake, New York\*

Thomas Horvath

Biology Department, State University New York College at Oneonta, Oneonta New York 13820, USA  
E-mail: [horvattg@oneonta.edu](mailto:horvattg@oneonta.edu)

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### Abstract

The literature is full of examples detailing ecological impacts of invasive species and predictions of which and where species will invade next. Many fewer examples of effective prevention strategies are known. Prevention of aquatic invasive species (AIS) to inland lakes should be easily established because most AIS are initially introduced into watersheds by recreational boating activities, especially in North America. The Watershed Management Plan for Otsego Lake, a central New York glacial lake, provides for prevention of AIS via a stringent boat inspection and washing program (BIP). All boats entering Otsego Lake at the public launch are visually inspected and those deemed likely to harbor AIS are required to power wash before launching. However, other sites are available to launch boats. BIP expenses average \$30,000 per year, much of which has been covered by collecting a launch fee. After implementation of the BIP, only one boat was refused access, and less than 1% required washing before allowed access, however, zebra mussels (*Dreissena polymorpha*) and water chestnut (*Trapa natans*) have since been found in the lake. The BIP continues to be supported because other AIS may have been prevented or may be prevented in the future.

**Key words:** aquatic invasive species, prevention, recreational boating, Otsego Lake

### Introduction

By definition, invasive species cause some harm to the environment, economy or human health. Serious impacts on the function of recipient ecosystems are heavily documented. For example, the Laurentian Great Lakes have over 145 recorded invasive species, many of which cause significant ecological impacts (Ricciardi and MacIsaac 2000). Economically, an oft-quoted value of over \$120 billion is spent annually on control and prevention measures in the United States alone (Pimentel et al. 2000). The economy of New Zealand contends with the impacts of invasive species by spending, directly and indirectly, about 1% of its gross domestic product (Bertram 1999). In Australia, the costs

of invasive plants alone amount to over 4 billion Australian dollars annually (Sinden et al. 2004).

The Convention on Biological Diversity lists potential measures to combat invasive species as prevention, eradication and control (as cited in Born et al. 2005). Prevention measures are enacted before invasion occurs, whereas eradication and control are enacted after an invasion has occurred. Approaches to dealing with invasive species have occurred mostly in the control phase. The process of a successful invasion event is described as a series of steps consisting of introduction, establishment, naturalization, and invasion. Each step of this pathway further reduces the total number of potentially invasive individuals (Kolar and Lodge 2001). Williamson's 10% rule also applies; only 10% of the introduced species become established, and

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**Table 1.** A relative assessment of management options for dealing with invasive species.

	Prevention	Control	Elimination
Difficulty of implementation	Low	high	very high
Apparent impact/visibility of success	very low	moderate	high
Likely relative cost	very low*	High-very high	very high
Likely benefit	very high*	high	high

\* - if successful

**Table 2.** Physiochemical characteristics of Otsego Lake (data from Harman et al. 1996).

Limnological Parameters	Value
Maximum length (km)	13.3
Maximum width (km)	2.5
Maximum depth (m)	50.6
Mean depth (m)	22.6
Surface area (ha)	1,710
Volume (m <sup>3</sup> )	386, 500,000
Soluble reactive phosphorus( $\mu\text{g L}^{-1}$ )	>1
Total phosphorus ( $\mu\text{g L}^{-1}$ )	approx. 5
Soluble nitrate-nitrogen (mg L <sup>-1</sup> )	>1
Epilimnetic chlorophyll-a ( $\mu\text{g L}^{-1}$ )	>1

10% of those established become naturalized, etc. (Williamson 1996) (although see (Jeschke and Strayer 2005) for discussion of non-supporting data). Thus, Leung et al. (2002, 2005) suggest that most effort should be applied in preventing species from being introduced in the first place because this is where the greatest return on resources will be realized. However, they and others have pointed out that very few data are available to analyze whether this is a valid strategy.

Depending on the goal, dealing with some invasive species means thinking only in terms of prevention. For example, if the goal is to preserve the natural community and function of a lake, once zebra mussels establish in the lake, no logistically feasible means to eradicate the population exist. We have no methods to manage the population. However, if the only goal is to minimize costs to industry, then prevention is

beneficial, but not if its costs exceed viable strategies for dealing with the impacts of zebra mussels. The ecology of the lake must change and human interests must pay a price. Then it makes sense to consider a cost effectiveness evaluation from the stand point of the cost of prevention, versus the cost of loss of use or direct costs (Table 1).

The inland lakes of the northeast United States often receive invasive species extending their range from the Great Lakes. Examples include such species as dreissenid mussels (*Dreissena polymorpha* (Pallas, 1771) and *Dreissena bugensis* (Andrusov, 1897)), water chestnut (*Trapa natans* L.), and Eurasian water milfoil (*Myriophyllum spicatum* L.). For these species, and others not mentioned, recreational boating is by far the most probable vector of initial introductions into watersheds (Johnson and Carlton 1996; Padilla et al. 1996; Les and Mehrhoff 1999). Once introduced, other vectors do become important, especially natural dispersal through connected water bodies (Horvath and Lamberti 1997 and 1999). Thus, according to Leung et al. (2002, 2005) preventing boats from serving as vectors to inland lakes makes economic sense.

In this study, I evaluate the effectiveness of a prevention program in Otsego Lake in central New York (USA). As the prevention program is already implemented, I am employing Born et al.'s (2005) category (ii) "Evaluation of an implemented measure". Thus the analysis consists of a cost effectiveness evaluation approach.

### Otsego Lake description

Otsego Lake is located in central New York (42°40'N, 74°55'W) and forms the headwaters of the Susquehanna River, which is the major tributary to the Chesapeake Bay along eastern North America. The lake is of glacial origins and supports a sports fishery composed of lake and brown trout [*Salvelinus namaycush* (Walbaum in Artedi, 1792) and *Salmo trutta* L.], Atlantic salmon (*Salmo salar* L.), bass [*Micropterus salmoides* (Lacepède, 1802) and *Micropterus dolomieu* (Lacepède, 1802)], and, recently, walleye [*Sander vitreus* (Mitchill, 1818)]. Of these, only the lake trout is considered native, although its population is augmented by stockings of various strains from nearby

hatcheries. The introduction of alewife [*Alosa pseudoharengus* (Wilson, 1811)] in the 1980s and anthropogenic pressures have caused the lake to shift from oligotrophic to moderately mesotrophic. It is a dimictic lake that stratifies from May to November. See Table 2 for detailed limnological descriptions.

The shoreline is populated with private residences, commercial establishments, and a state park. On any given day, the lake is used by recreational boaters, especially by anglers. Annual boat counts reveal about 1300 resident boats, and a conservative estimate of annual public launches is 1300-1400. Its use is moderate, relative to other highly populated lakes in the area.

Four communities surround the lake: Cooperstown, Springfield, Middlefield and Otego. The only publicly accessible boat launch capable of accepting powered boats is in Cooperstown. Springfield also has a launch, but it is available only to its residents. The state park allows car-top boats (e.g., canoes, inflatables and kayaks). Additionally, a private marina and 2 hotels have launches used by their customers.)

### Invasive species in Otsego Lake

The history of invasive species in Otsego Lake is partially documented. The macrophytes *Myriophyllum spicatum* and *Potamogeton crispus* L. were in the lake prior to the 1970s and 1980s, respectively. It is not known if their introductions were natural or human-mediated. A few individuals of *Trapa natans* were found in the lake prior to 1999 and again in 1999, but they were quickly eradicated. Smelt [*Osmerus mordax* (Mitchill, 1814)], alewife and the game fishes mentioned above were intentional introductions. Smelt and alewife were illegal introductions in the late 1970s and mid 1980s respectively (Harman et al. 1996). These all occurred prior to the BIP.

Summer 2007 proved to be a disappointing period. A few adult zebra mussels were confirmed from Otsego Lake in July. Although no larvae were detected in numerous plankton surveys (cross-polarized light techniques (Johnson 1995) were used in the examinations), their spatial distribution and shell-size frequency indicate that the population was established and reproducing. Also, a few individuals of *T. natans* were found again, and again subsequently

eradicated. It is difficult to say if the *T. natans* were reintroductions or dormant seeds from previous introductions, but it was clear that zebra mussels arrived via recreational boating. Hence, the boat inspection program was unable to prevent this introduction.

### Description and history of BIP

In 2002, zebra mussels (*D. polymorpha*) were discovered in Canadarago Lake, which is about 5 km west of Otsego Lake. At that time, a task force was formed within the local government of Cooperstown, NY to begin a boat inspection program (BIP) with the goal of decreasing the risk of zebra mussels entering Otsego Lake. The plan consists of having an inspector present at the main public launch site in Cooperstown beginning in mid-May through October; this covers the months when zebra mussels reproduce and boat traffic is highest. The launch is manned daily from 05:00 to 19:00. These times were chosen for logistic and practical reasons; most launches occur between these times, however, it is realized that some early-morning anglers will be missed. All boats launching from this site would be visually inspected. Inspectors would be looking for signs on the boat of recent use such as existing water in the hull or wells, wet gear, or presence of macrophytes on trailers, boats and motors. Boats considered low risk would be allowed to launch. Some boats with noticeable water in the hull or in wells would be voluntarily rinsed with a weak (10%) bleach solution. Any boat considered to be a high risk would be asked to be cleaned with a nearby high-pressure power washer. The boat would be refused launching rights until proof of washing was presented. Boats considered extreme risks, those with invasive species noticeable, would be refused entrance all together.

Despite the efforts of the BIP, some holes remain. The town of Springfield refused to implement an equivalent inspection system. Instead, it had an employee who checks residence stickers and looks for gross warning signs of high-risk boats. These would be asked, but not required, to wash at a public car wash station. No data were available from this site, but observations suggest that the launch is not as heavily used as Cooperstown. The Springfield marina agreed to thoroughly inspect all boats and wash those deemed risks at their facility prior to

**Table 3.** Generalized expenses and income from the boat inspection program (BIP) in Cooperstown, New York for the first four years since implementation. All values are in US dollars.

	Years			
	2003	2004	2005	2006
Miscellaneous materials	\$2057	\$153	\$683	\$531
Labor	\$35,556	\$26,900	\$16,975	\$16,175
In-kind services	\$5000	\$5000	\$5000	\$5000
Total expenses	\$42,613	\$32,053	22658	\$21,706
Donations	\$10,750	\$10,750	\$10,750	\$10,000
Grants	\$950	\$0	\$0	\$0
Launch fees	\$14,420	11985	11960	\$10,790
Total Revenues	\$26,120	\$22,735	\$22,710	\$20,790

launching. It is uncertain if the hotels have any regulations enforcing preventative inspections, although they do make available an information pamphlet outlining the risks of invasive species introduction posed by recreational boating. No data were available from the hotels.

### Direct Costs of BIP

Economic data were provided by the Zebra Mussel Committee of Cooperstown, New York and are reported in US Dollars throughout. At the initiation of the inspection program, some direct costs were incurred. Two high-pressure power washers were required, signage alerting boaters of the inspections prior to them entering the launch area, and labor. For successive years, only miscellaneous expenses, labor and in-kind services expenses were incurred. The bulk of the program costs were associated with labor (Table 3).

A fee schedule for launches was initiated at the start of the BIP to help cover expenses. Prior to the inspections, launches were free of any charges. Boaters were charged \$10 for each

launch (bulk rates were available), all of which went to fund the inspection program. Various grants and donations from state and private organizations were received to fund the remainder of the program expenses (Table 3). The power washers were donated. The government of Cooperstown agreed to cover remaining costs (values calculated as difference between revenues and expenses).

The overall costs of the program decreased over time. Available estimated costs for 2007 indicate that the cost of the program has leveled off to a steady value around \$23,000. The costs incurred by Cooperstown also declined over time. The program cost Cooperstown about \$16,000 the first year, but quickly declined in following years. The program was self-sufficient in 2005, but ran a deficit of about \$1000 for 2006. It is estimated that Cooperstown will have costs around \$1000 in coming years.

Revenue from boat launch fees also declined from the start of the program as the number of launches declined. The low value of \$10,790 in 2006 may be related to weather conditions. Estimated 2007 revenue is \$11,900, which is likely to stay somewhat stable.

### Indirect Costs of BIP

It is difficult to quantify the costs associated with invasive species that have not arrived. However, given that zebra mussels are now present, but have not reached nuisance levels, it seems appropriate to estimate costs associated with them.

Although 4 communities surround the lake, Cooperstown stands to be most impacted by invasive species in Otsego Lake. The community gets its drinking water directly from Otsego Lake and any number of invasive species could impact that resource. For example, dreissenids could clog the intake (Mackie et al. 1989) or change the algal dynamics to favor Cyanobacteria species (Juhel et al. 2006). Prior to the BIP, the cost effectiveness evaluation indicated that the low costs incurred by Cooperstown associated with maintaining the BIP made sense. A retrofit system installed on the existing infrastructure, for example, could cost hundreds of thousands of dollars to control zebra mussels in the water intake of Otsego Lake (exact values are not available). Leung et al. (2002) used a value of \$1.6 million to control zebra mussels in a power plant's water intake. Thus, Cooperstown had

**Table 4.** Statistics from the boat inspection program (BIP) at Otsego Lake, New York. Boats requiring washing had noticeable biofouling of the hull and/or had been recently in a lake with known populations of invasive species. Launch refusals were due to excessive fouling by invasive species.

	2003	2004	2005	2006
Launches	1635	1380	1391	1132
Required power washing	3	12	3	2
Refused launch	0	0	0	1

only to spend a few thousands of dollars on prevention to potentially save millions on the cost of control.

Lakeside residents outside of Cooperstown also draw raw water from the lake for use in homes. These people experience almost no inconveniences or direct expenses from the BIP, but receive some benefit. For example, in addition to drawing water, many of them store boats in the lake throughout the year, so they are not subject to boat inspections. Their recreational use of the lake could be impacted if certain invasive species colonized the lake. Their main direct cost would be a retrofit filtration system that costs each of them about \$120 one time, with occasional replacements over time.

The ecological economics literature offers examples of placing economic values on goods and services derived from ecosystems (Farber et al. 2006; Root et al. 2003). Although such valuation was not quantified, the recreational value of Otsego Lake should be considered. Presence of zebra mussels will affect the use of the public and private beaches and may impact total revenue to the state park, where visitors often come to swim. Nearby Canadarago Lake closed its public swimming area within a few years of zebra mussel colonization because of liability issues related to cuts from the mussel shells.

## Results from BIP

The total number of boats launching from the BIP site went from a high of 1635 in 2003 to a low of 1132 in 2006 (Table 4). The number of launches averaged 1385 in the between years. The decline in launches immediately after the BIP began was probably a direct result of the inconvenience of the BIP process. The low

number of launches in 2006 was likely due to weather. The Otsego Lake watershed experienced high waters that flooded most of the lake shore area, including the launch area. Water recession and area repairs lasted through July so access to the lake was somewhat restricted. Initial numbers from 2007 suggest that the number of launches will again be near 1300. Only a few boats required washing with the power washer in any year (Table 4). On one occasion, a boat was refused launching rights because the inspector noted excessive biofouling on the hull of the boat. The inspector decided that power washing alone would not be enough to reduce the risk of contaminating the lake. It could not be confirmed where the boat had been previously nor the species that had fouled the hull. It may have been marine organisms on the hull, which would not have been a threat to Otsego Lake. It is encouraging that the BIP is serious enough to refuse launching rights to individuals deemed too risky.

Some resistance to the program was expected. For example, boaters would be inconvenienced by inspections, incurring the \$10 launch fee, and the possibility of having their boat washed (approximately an additional hour). Initially, some resentment was experienced (as observed at the launch and in local newspapers); however, within a short period of time, boaters started arriving at the launch with boats in much better condition. Thus a social change took place within the boating community. Additionally, many boaters appreciated the use of equipment now present at the launch (e.g., boat hooks, waste receptacles), which were not present prior to the inspection.

At this time, the Otsego Lake community appears to continue to support the BIP, despite the recent arrival of zebra mussels. The committees formed to look into options for prevention of this event realized that prevention programs such as the BIP are never 100% certain of protection. Even if no invasive species colonized the lake, one could never be sure that the lack of colonization was due to the preventative actions. For this reason, it is inherently difficult to mobilize people to spend money or be inconvenienced for an action whose success is invisible. Supporters of the BIP did inform the public that the overall costs would be minimal because of the fee schedule.

Although not formally discussed, other options were available to the lake community. For example, one option was doing nothing. The

advantage of this strategy is the absence of upfront costs. The risks for future costs do increase, however. If a successful colonization were to occur, costs for control could be significant. Control programs are designed to eradicate or reduce the influence/impacts of an invasive species. When a control measure is enacted, we are much more certain that the outcomes (i.e., reduction or elimination) are the direct result of the control measure. The benefit of doing nothing for prevention, which is uncertain in terms of success, and risking the cost of control is that the need for control is obvious.

In the long run, prevention as a policy may provide unforeseen benefits. For example, with aquatic invasive species, recreational boating has been identified as a major vector. Thus, prevention programs may be well served by addressing this vector, because the cost associated with it could prevent additional species invasions. In the case of Otsego Lake, the BIP was implemented to reduce the risk of zebra mussel colonization. At the same time, the program could be effective in preventing equally harmful species such as *Cercopagis pengoi* (Ostroumov, 1891) or the virus causing viral hemorrhagic septicemia, both of which are found in nearby lakes.

## Conclusions

The BIP initiated by the Otsego Lake community, primarily by Cooperstown, is a minimal cost program. Although some of the more notorious aquatic invasive species have been introduced since the BIP's inception, the potential benefit of keeping out other invasive species that are on the horizon suggests that the program should be continued. In general, policymakers should be informed of the benefits of prevention programs from the standpoint of both reducing species invasions other than the target species, as well as the economic benefits associated with avoiding potential future direct and indirect costs of unchecked invasion, control, or elimination.

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## Strategy for prevention of invasive species introduction

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